Anxiety, Stress, & Coping,
April 2008; 21(2): 173–184

Routledge
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Effects of warned and unwarned demand transitions on vigilance performance and stress

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Abstract
The present study was designed to explore the effects of warned and unwarned demand transitions in vigilance on performance and self-reported stress. Twenty observers (10 women and 10 men) were assigned at random to each of six conditions resulting from the factorial combination of signal salience (high and low salience signals) and switching (no switch, switch with warning, and switch without warning). Performance metrics and self-reported stress state (Task Engagement, Distress, and Worry) were collected. While demand transitions did destabilize subsequent performance, increasing intra-individual variability, overall performance efficiency was uninfluenced by either switching or warning. Demand transitions, whether warned or not, increased self-reported distress. A dynamic model of performance stress may be necessary and research employing vigilance tasks in the future may be useful for developing this performance-stress model.

Keywords: *attention, demand transitions, stress, warnings, vigilance*

During vigilance or sustained attention tasks participants monitor displays for prolonged periods of time and are required to execute overt detection responses to infrequently occurring critical signals (Davies & Parasuraman, 1982; Warm, 1984; Warm & Jerison, 1984). Vigilance tasks have proven useful for understanding the control of attention and the nature of attentional deficits (Broadbent, 1971; Manly, Robertson, Galloway, & Hawkins, 1999; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997) and vigilance plays a critical role in many applied settings, such as process and quality control, and medical and security screening (Hancock & Hart, 2002; Wickens & Hollands, 2000). In addition, vigilance tasks are stress inducing, and the stress of vigilance tasks is closely tied to the psychophysical demands of the tasks (Galinsky, Rosa, Warm, & Dember, 1993; Hancock & Warm, 1989; Temple et al., 2000). Vigilance tasks have provided a useful test-bed for investigating stress responses to task performance (Helton, Dember, Warm, & Matthews, 2000; Matthews, Campbell, et al., 2002; Matthews, Emo, et al., 2006; Matthews, Joyner, Gilliland, Huggins, & Falconer, 1999; Szalma, Hancock, Dember, & Warm, 2006). Indeed, the workload imposed by the task may drive both objective performance and appraisals of task demands that in turn influence subjective stress response (Matthews, 2001; Matthews et al., 2002).

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ISSN 1061-5806 print/ISSN 1477-2205 online © 2008 Taylor & Francis
DOI: 10.1080/10615800801911305

Laboratory studies of vigilance or sustained attention traditionally maintain a constant information-processing load throughout the experimental session (Davies & Parasuraman, 1982). The vigilance tasks encountered in many operational settings, however, such as air-traffic control, security screening, and medical system monitoring, can contain abrupt changes in the demands placed upon operators during a duty cycle. Consequently, the National Research Council (Huey & Wickens, 1993) identified transitions in task demand as an important dimension for study in future vigilance research. Some researchers have proposed that workload transitions tend to be generally damaging to performance (Cox-Fuenzalida & Angie, 2005; Cox-Fuenzalida, Beeler, & Sohl, 2006). However, there have only been a few studies investigating the impact of demand transitions on vigilance performance and these studies have mixed results (Gluckman, Warm, Dember, & Rosa, 1993; Helton et al., 2004; Krulewitz, Warm, & Wohl, 1975).

In only one of these studies (Helton et al., 2004) were the stress effects of demand transition explored. Helton et al. (2004) made use of the Dundee Stress State Questionnaire (DSSQ; Matthews et al., 2002; Matthews et al., 1999). The DSSQ samples 10 state constructs within the domains of affect, motivation and cognition. Matthews et al. (2002) present psychometric and experimental evidence based on studies with the DSSQ that identify three broad higher-order state factors, *Task Engagement, Distress,* and *Worry,* through factor analysis of the 10, correlated first-order state dimensions. *Task Engagement* integrates state constructs that relate to task interest and focus: energetic arousal, motivation, and concentration. Low task engagement corresponds to feelings of fatigue (Matthews & Desmond, 1998). *Distress* appears to integrate unpleasant mood and tension with lack of confidence and perceived control. *Worry* is primarily composed of self-focused attention, self-esteem, and cognitive interference resulting from both task-related and personal concerns. Matthews et al. (2002) and Matthews et al. (1999) validated this three-dimensional taxonomy by showing that the state factors were differentially related to task stressors, personality factors and situational cognitions (appraisals and coping strategies). These three dimensions may represent the three key aspects of conscious experience in person–environment transactions in performance settings: commitment of effort, overload and self-evaluation, respectively (see Matthews et al., 2002). The DSSQ has been used previously to measure task-induced stress in vigilance and prior research has shown a vigilance "signature" in regard to the DSSQ – observers feel less task engaged and more distressed after a vigil than prior to its start (Helton et al., 2000; Matthews et al., 2002; Matthews et al., 2006; Matthews et al., 1999; Temple et al., 2000). Furthermore, these responses may be linked to workload. Higher workload tasks appear to elicit greater loss of engagement, and greater increase in distress (Temple et al., 2000).

Prior to Helton et al. (2004) no one had specifically studied the effect of demand transitions in vigilance on self-reported stress. Helton and his colleagues reported two primary findings regarding the stress effects of demand transition: first, regardless of the direction of the switch (from easy to hard or vice versa), a demand transition increased distress in comparison to constant demand controls, and second, a switch from an easy high signal salience task to hard low signal salience task elevated task engagement, an atypical finding in vigilance. Unpredictable environmental changes have been hypothesized to be stress inducing (Cox-Fuenzalida, Swickert, & Hittner, 2004; Selye, 1956); therefore, unwarned workload transitions may also be stress inducing, regardless of the direction of the change. Fluctuations of task engagement in response to task demands would fit proposed models of effort regulation (Hockey, 1997), where effort is actively regulated in response to task demands. The emerging transactional model of vigilance-induced stress entails an active role for the individual observer (Helton et al., 2000; Helton, Hollander, et al., 2005; Helton, Shaw, et al., 2004; Matthews et al., 2002). The observer's resulting stress state does not only depend on objective, psychophysical features of the vigilance task, but also on the observer's appraisals and strategies (Lazarus & Folkman, 1984; Miceli & Castelfranchi, 2005).

The primary aim of the present study was to conduct a further test of demand transition effects on stress state response and performance, controlling for possible alerting effects of the transition. As in Helton et al. (2004) demand transitions in signal salience were investigated; performance efficiency in vigilance varies directly with signal salience (Warm & Jerison, 1984). In the Helton et al. (2004) study, the observers were not, however, given any warning of a possible demand transition. Observers warned of a possible demand transition may have different stress responses than observers taken by surprise, where the demand transition is completely unwarned. As Miceli and Castelfranchi (2005, p. 293) indicate, "a central component of anxiety is often considered to be the anticipation of an indefinite threat, and the consequent uncertainty and wait." In the present study a pre-warned demand transition group was added to the conditions of Helton et al. (2004). Warning the observers of the demand transition may reduce uncertainty following the transition and subsequently reduce subjective distress.

An additional aim was to test the effects of stress responses induced by the transition on performance. Previous studies (e.g., Matthews & Davies, 2001; Matthews, Davies & Lees, 1990; Matthews, Warm, Dember, Mizoguchi, & Smith, 2001) have shown that task engagement (or its energetic arousal component) correlates with superior performance on vigilance and other demanding attentional tasks. Task engagement may serve as a marker for attentional resource availability (Matthews & Davies, 2001). Changes in task engagement may thus produce concomitant changes in performance. Helton and his colleagues (2004) did not directly investigate possible relationships between stress states and vigilance performance, whereas, we examined these relationships in this investigation.

Method

Participants

One hundred and twenty undergraduates (60 women and 60 men) served as observers in this experiment. All were enrolled in introduction to psychology courses at a Midwestern United States university and participated to fulfill a class requirement. They ranged in age from 18 to 37 years ($M = 19.94$, $SD = 3.79$). All observers had normal hearing, and normal or corrected-to-normal vision based on self-report responses to sensory interview questions given prior to the experimental session.

Procedure

Twenty observers (10 women and 10 men) were assigned at random to each of six conditions resulting from the factorial combination of signal salience (high and low salience signals) and switching (no switch, switch with warning, and switch without warning). All observers participated in a 12-min vigil divided into six continuous 2-min periods. They inspected the repetitive presentation on a video display terminal (VDT) of light gray capital letters consisting of an "O," a "D," and a "backwards D." The letters were exposed for 40 msec at a rate of 57.5 events/min against a visual mask consisting of unfilled circles on a white background. Critical signals for detection ($p = 0.20$/period of watch) were the appearance of the letter "O." Observers signified their detection of critical signals by pressing the key on a response pad. Prior to the main vigil, all participants were given a 2-min period of practice to familiarize themselves with the vigilance task. In the high salience condition, the contrast between the letter stimuli and the background was 59%, as indexed by the Michaelson contrast ratio ([maximum luminance − minimum luminance/maximum luminance + minimum luminance] × 100; Coren, Ward, & Enns, 1999). In the low salience condition, the contrast between the letter stimuli and the background was 45%. This abbreviated vigilance task has been found to duplicate the general effects of signal salience and task-induced stress noted with more traditional long-duration tasks (Helton et al., 2000; Helton et al., 2004; Temple et al., 2000). In addition, this abbreviated task also demonstrates right cerebral dominance as is the case in longer-duration vigilance tasks (Helton et al., 2007).

Switch participants performed for 6 min at one salience level and then for 6 min at the other. In the switch with warning condition, participants were informed prior to the start of the vigilance session that the salience of the signal would change at some point during the session. Participants in the switch without warning condition were not informed of a change in signal salience. The vigil was conducted in a small featureless room. Ambient illumination in the testing room was 7.54 cd/m^2. It was provided by a 15-Watt light bulb housed in a covered ceiling fixture located above and behind the observer and angled to reduce glare on the VDT. The VDT was mounted on a table at eye level approximately 40 cm from the seated observer. Stimulus presentation and response recording were orchestrated by a Power Macintosh computer. Observers surrendered their wristwatches, pagers, and/or cell phones at the outset of the experimental session and had no knowledge of its duration other than it would not exceed 60 min.

Perceived stress was assessed by means of the DSSQ (Matthews et al., 1999), which provides factor-analytically differentiated scales of Task Engagement, Distress, and Worry. The DSSQ was administered in two sessions: a pre-vigil questionnaire completed prior to the practice period and a post-vigil questionnaire completed after the vigil.

Results

Vigilance performance

Performance. Mean percentages of correct detections for the six groups over the six periods of watch are displayed in Figure 1. Prior to analysis the detection scores were arcsin transformed as recommended (Kirk, 1995; Maxwell & Delaney, 2004). Within each block (periods 1–3, pre-switch Block 1, and periods 4–6, post-switch Block 2), lines of best fit using least squares estimation were calculated for each observer. The three periods of watch within the block were centered before calculating the lines of best fit. Hence, the intercept of the line was equivalent to the mean of detections for the entire block and the slope indicated the overall linear trend of signal detections for the observer over the block (Keppel & Zedeck, 2001). Although this departs from the approach of analyzing vigilance performance most commonly employed in the literature, repeated measures analysis of variance, this strategy enabled us to make specific tests regarding average block performance (the intercept), linear change in performance over the block (the slope), and deviation from the linear fit or intra-individual variability (residual error).

Separate regression analyses were conducted for intercepts, slopes, and residual errors for both blocks (pre- and post-switch). The signal salience condition for the block being examined was coded, low signal salience as 1 and high signal salience as −1. The switch groups were orthogonally coded with two vectors: first, a switching versus no switching

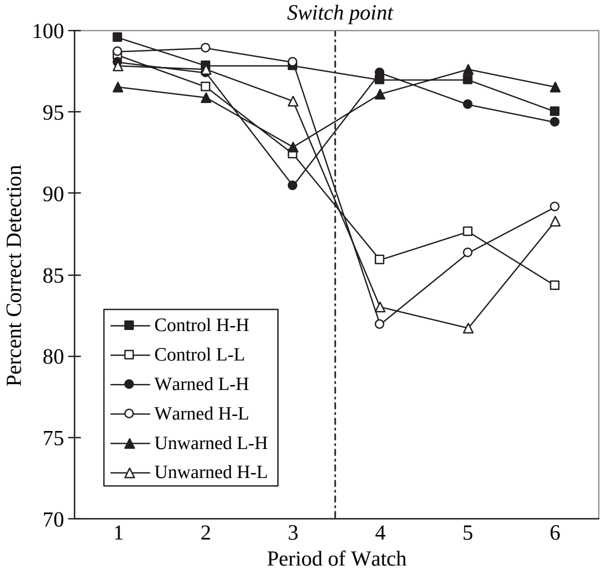

Figure 1. Mean percent of correct detections for the six groups over the six 2-min periods of watch (H represents high signal salience and L represents low signal salience).

vector, where both switching groups were coded as .5 and the non-switching control group was coded as −1, and second, a warning versus no-warning vector, where the control group was coded as 0, the switch with warning group coded as −1, and the switch without warning group was coded as 1. Interactions between salience level and switch groups were also examined by including two interaction vectors in the models.

Our primary focus was on what occurred after the demand transition, e.g. Block 2; however, Block 1 was also examined. In the case of Block 1, signal salience was the only significant factor in the intercept, slope, and residual error models, $p < .01$ in all cases; all other factors were non-significant, $p > .15$. In Block 1, the low signal salience condition had a lower average intercept (mean detection rate), a steeper negative slope (more vigilance decrement), and more residual error (intra-individual variability or departure from linear fit). These results are presented in Table I. The overall regression model results were for intercept, $F(5,114) = 1.85$, $p = .11$, $R^2 = .08$, for slope, $F(5,114) = 2.67$, $p = .03$, $R^2 = .11$ and for residual error, $F(5,114) = 2.42$, $p = .04$, $R^2 = .10$. The lack of a significant effect for the switching or warning factors in these models merely indicated that there were no significant initial differences among these groups in performance for Block 1. The significant signal salience results found in this analysis match those previously observed with the abbreviated vigilance task (Temple et al., 2000).

The results of the three regression models for Block 2 are presented in Table II, Model 1. In Block 2, the low signal salience condition had a lower average intercept (mean detection rate), and more residual error (intra-individual variability or departure from linear fit), but did not differ in slope. These results are presented in Table I. Switching or being warned of the switch did not appear to influence performance, except for residual errors, where switching (regardless of warning or not) approached significance, $p = .07$. As will be discussed in a subsequent section, when changes in stress state were included in the model, this relationship was significant, $p = .03$. The overall regression model results were for

Table I. Means and SDs (italics) for the three performance metrics.

		Block 1			Block 2		
Group	Salience	Intercept	Slope	Error	Intercept	Slope	Error
Control	High–high	98.41	−0.87	1.95	96.30	−0.98	2.40
		1.93	*2.27*	*2.93*	*5.49*	*3.96*	*3.61*
	Low–low	95.80	−3.04	2.66	85.94	−0.76	5.06
		4.46	*3.55*	*2.34*	*14.82*	*7.93*	*3.74*
Switched	Low–high	95.29	−3.80	3.28	95.72	−1.52	3.73
Warned		*6.24*	*6.02*	*3.22*	*5.81*	*5.28*	*2.76*
	High–low	98.55	−0.33	1.33	85.80	3.59	6.48
		2.10	*1.28*	*1.62*	*15.43*	*9.78*	*4.90*
Switched	Low–high	95.07	−1.85	4.53	96.74	0.22	2.66
Not warned		*7.09*	*3.40*	*5.20*	*3.61*	*3.45*	*3.23*
	High–low	97.03	−1.09	1.42	84.35	2.61	6.03
		9.27	*2.49*	*2.20*	*19.67*	*14.50*	*6.29*

intercept, $F(5,114) = 5.92$, $p < .001$, $R^2 = .21$, for slope, $F(5,114) = 1.14$, $p = .34$, $R^2 = .05$ and for residual error, $F(5,114) = 2.03$, $p = .08$, $R^2 = .08$.

False alarms. The overall mean false alarm rate was less than 1%. Consequently, false alarm data were not examined further.

Dundee Stress State Questionnaire

Stress state. The DSSQ scale scores were standardized against normative data secured from a large sample (Matthews et al., 2002; Matthews et al., 1999), using the formula (Raw score − Norm Group Factor Mean)/Norm Group Factor Standard Deviation. Factor scores for Task Engagement, Distress and Worry were calculated using regression weights from the

Table II. Two-step regression models for the Block 2 performance metrics.

	Intercept		Slope		Residual error	
Factor	*B*	*p*	*B*	*p*	*B*	*p*
Model 1						
Salience	**−0.177**	**<.01**	0.036	0.10	**0.027**	**0.05**
Switching	−0.003	0.95	0.030	0.33	0.036	0.07
Warning	−0.008	0.84	0.002	0.93	0.026	0.12
Salience × Switching	0.008	0.87	0.031	0.31	−0.006	0.76
Salience × Warning	0.014	0.73	0.026	0.33	−0.008	0.75
Model 2						
Salience	**−0.183**	**<.01**	0.039	0.08	**0.030**	**0.03**
Switching	−0.013	0.79	0.044	0.17	**0.045**	**0.03**
Warning	−0.004	0.92	0.006	0.81	0.028	0.10
Salience × Switching	−0.014	0.77	0.030	0.34	−0.005	0.79
Salience × Warning	−0.006	0.89	0.024	0.37	−0.007	0.67
Engagement	**0.115**	**0.01**	−0.005	0.86	−0.015	0.43
Distress	−0.012	0.77	−0.052	0.07	−0.030	0.10
Worry	−0.060	0.15	−0.033	0.24	−0.005	0.79

Note. Statistically significant ($p < .05$) predictors are bold.

normative sample. Factor scores are distributed with a mean of 0 and a SD of 1, so that values calculated for a sample represent a deviation from normative values in standard deviation units. We tested for initial pre-task differences between our six experimental groups using ANOVAs and there were no significant differences between the groups ($p > .15$ in all cases). Therefore, change scores were determined for each participant using the formula, *d*-Score = Normalized Post-Factor Score–Normalized Pre-Factor Score, as previously performed with the DSSQ (Szalma et al., 2006). These change scores served as the units of analysis as recommended by Rogosa (1995) for examining individual change in state over time.

Separate regression analyses were conducted for each of the three state factor changes scores: Engagement, Distress, and Worry. The ending block signal salience condition was coded low signal salience as 1 and high signal salience as −1. As in the case of the overall performance analysis, the switch groups were orthogonally coded with two vectors: first, a switching versus no switching vector, where both switching groups were coded as .5 and the non-switching control group was coded as −1, and second, a warning versus no-warning vector, where the control group was coded as 0, the switch with warning group coded as −1, and the switch without warning group was coded as 1. Interactions between salience level and switch groups were also examined by including two interaction vectors in the models.

The results of these analyses are presented in Table III. The overall regression model results were for Engagement, $F(5,114) = 2.35$, $p = .04$, $R^2 = .09$, for Distress, $F(5,114) = 2.12$, $p = .06$, $R^2 = .09$ and for Worry, $F(5,114) = .36$, $p = .88$, $R^2 = .02$. The change scores for the three factors are illustrated in Figure 2. Mean standardized change scores are displayed as departing from a standard score of 0 (i.e., no change). Error bars are *standard errors*. The profile of state change exhibited by the observers indicates that they were more distressed when switched than when task demands remained constant; being warned did not appear to make much of a difference in this regard. It is also evident that the observers were more engaged when switched from an easy to a hard task, than when switched from a hard to an easy task in the switched without warning condition. The participants' level of worry did not seem to be affected by the task conditions.

Relationship between stress state and performance. In order to test the relationship between the experimental conditions (switch groups and salience level), stress state, and performance, regression analyses were employed. Models using both the experimental conditions and stress state changes to predict Block 2 performance (intercepts, slopes and residual errors) were conducted. Table II includes two-step regression models. Model 2 in Table II employs

Table III. Regression models for the DSSQ factors.

	Engagement		Distress		Worry	
Factor	*B*	*p*	*B*	*p*	*B*	*p*
Salience	0.047	0.50	0.066	0.36	−0.024	0.74
Switching	0.097	0.32	0.273	**0.01**	−0.031	0.76
Warning	−0.009	0.91	0.043	0.62	0.050	0.58
Salience × Switching	0.228	**0.02**	−0.112	0.27	0.101	0.33
Salience × Warning	0.184	**0.02**	−0.086	0.33	0.050	0.58

Note. Statistically significant ($p < .05$) predictors are bold.

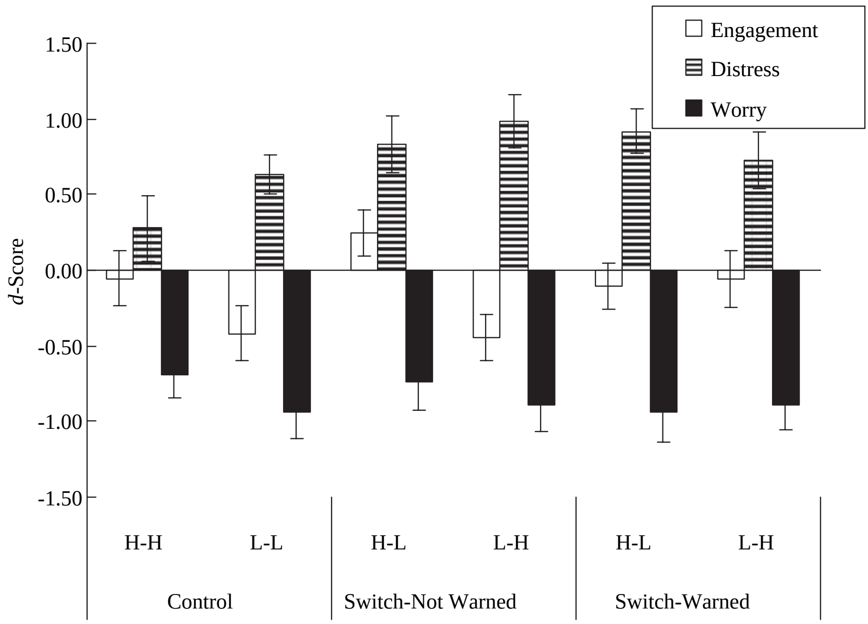

Figure 2. Standardized pre-post vigil change scores (*d-Score*) for the factors of the DSSQ for both switched and non-switched participants (H represents high signal salience and L represents low signal salience; error bars are standard errors of the mean).

both the experimental conditions and stress state change scores to predict the performance metrics. Aside from signal salience which was significant in the intercept and error models, Engagement was a significant factor in the intercept model, $p = .01$, and switching was a significant factor in the error model, $p = .03$. The overall regression Model 2 results were for intercept, $F(8,111) = 5.26$, $p < .001$, $R^2 = .28$, for slope, $F(8,111) = 1.41$, $p = .20$, $R^2 = .09$ and for residual error, $F(8,111) = 1.71$, $p = .10$, $R^2 = .11$. In addition, the Pearson correlation coefficients between Engagement change scores and average Block 2 performance ($r = .18$, $p = .04$), and absolute post-task Engagement scores and average Block 2 performance ($r = .20$, $p = .02$) were both significant.

Discussion

The average signal detection post-shift performance of shifted observers in this study simply equaled that of their non-shifted controls similar to earlier findings by Gluckman et al. (1993). The stress responses, however, of shifted observers were not the same as their non-shifted controls: demand transitions affected both task engagement and distress. Self-reported stress states may be more sensitive indicators of cognitive and emotional responses than standard performance metrics (overall average performance level and decrement over time) during workload transitions in tasks requiring sustained attention or self-reports may be indicative of different underlying processes.

Shifts in demand levels had a notable effect upon observers' self-reports of stress. Regardless of the direction of shift in task demand or warning status, shifted observers were significantly more distressed at the end of the vigil than non-shifted controls. Interestingly, even in the case of the task becoming objectively easier (a low to high signal salience transition), switched participants reported greater distress than their non-switched controls.

This is a potentially counter-intuitive finding, as being switched to an easier task could be thought to be relieving. The finding fits more closely with a transactional view of task stress, where distress is the outcome of an appraisal of whether available cognitive resources match task demands (see Matthews, 2001). This appraisal is difficult to make when the task demands are changing and unpredictable. As Miceli and Castelfranchi (2005, p. 294) indicate, "according to our definition the object of anxiety is not a danger, but an event which implies a possible and uncertain danger." Distress should occur when an observer is unable to predict or appraise how many cognitive resources will be required by the task, as when demand transitions shift abruptly. An early warning of a demand transition did not appear to alleviate this distress response. The early warning may not have been specific enough to eliminate the observers' uncertainty and subsequently their distress.

Changes in distress did not appear to have any direct impact on performance, in line with previous studies showing that vigilance is generally insensitive to distress (e.g., Matthews et al., 2001). However, distress may be predictive of impairment on multiple task performance (Matthews et al., 1999). It is thus interesting that detrimental effects on performance of both high-to-low and low-to-high transitions have been obtained using dual-task paradigms (Cox-Fuenzalida & Angie, 2005; Cox-Fuenzalida et al., 2006).

Switching did have an effect on one aspect of Block 2 (post-shift) performance; it increased Block 2 individual residual error from a linear fit. One interpretation of this finding is that the demand transition destabilized the observers' performance, even if it did not significantly affect average performance (intercept) or the overall linear performance trend (slope). Essentially, the transitioned observers' performance in Block 2 became more unpredictable or erratic than their non-transitioned controls. In a metaphoric sense, the observers' performance wobbled after experiencing an abrupt demand transition. This finding may have consequences for the development of predictive human performance models and fits a compensatory model of effort regulation (Hockey, 1997). The observers when switched may have had to work to maintain or self-regulate their performance. This performance response when combined with the increased distress reported in the switch conditions provides support for a dynamic model of human performance in which cognitive resource theory (Hirst & Kalmar, 1987; Kahneman, 1973) is combined with a transactional theory of stress (Lazarus, 1966, 1999; Lazarus & Folkman, 1984; Matthews, 2001). Future researchers should explore the relationship between task predictability, stress responses, and performance more closely.

The left-most panel of Figure 2 shows that, in unswitched conditions, task-induced changes in task engagement corresponded to those found in previous studies (e.g., Temple et al., 2000). In the high salience condition (lower workload), engagement showed little change, reflecting the modest demands of the task. In the low salience condition (higher workload), engagement declined markedly. The middle panel of the figure shows transition effects. The group shifted to high salience (L–H) show lower engagement than the control group (H–H), despite experiencing the same workload. By contrast, the group shifted to low salience (H–L) showed higher engagement than the appropriate controls (L–L). Providing a warning (right-most panel) appeared to eliminate (L–H shift) or attenuate these effects (H–L shift). Thus, engagement does not depend simply on absolute level of workload. A key factor may be the level of challenge afforded by the task, given that challenge appraisals relate to task engagement responses to performance (Matthews & Falconer, 2002). For example, upward shifts in workload may provide a challenge that maintains task engagement, although a prior warning may reduce the challenge appraisal following the transition.

The data also show that the distress and task engagement dimensions of the DSSQ did not show similar results in regard to task switching. In line with Cox-Fuenzalida et al.'s (2004) analysis, distress is sensitive to change alone, whereas engagement reflects the direction of the change. The presence of a distress – engagement dissociation in the present data provides further evidence for the utility of the multidimensional view of stress advocated by Matthews et al. (2002) and Matthews et al. (1999). The dissociation between Engagement and Distress found in this study corresponds to the multidimensional conceptualization of the arousal construct originally advocated by Thayer (1989); energetic arousal corresponds to engagement and tense arousal to distress (Matthews et al., 2002).

The present findings also suggest that Engagement is a critical predictor of overall signal detections. Theoretically, self-reported task engagement reflects the amount of cognitive resources available for or properly allocated to task performance (Matthews et al., 1990). The significant correlation between changes in task engagement and overall performance (Block 2 intercept scores) in the present study lends general support to the resource theory of vigilance (Helton et al., 2005; Warm, 1993) and to previous research indicating that task engagement correlates consistently with perceptual sensitivity on resource demanding tasks, such as high event-rate vigilance tasks, and controlled visual and semantic category search (Matthews & Davies, 1998; Matthews et al., 1990; Matthews et al., 1999; Matthews et al., 2001). These findings are, moreover, consistent with the hypothesis advanced by Humphreys and Revelle (1984) that energetic arousal (engagement) increases the availability of resources for sustained information processing.

The findings that transitions in task demand can produce increased feelings of distress regardless of warning may have long-term implications for employee well-being in operational settings (cf. Cox-Fuenzalida et al., 2004). It may be difficult to mitigate distress responses to the shifts in task load typical of many jobs. However, unexpected upward shifts in workload may be beneficial for maintaining task engagement on monotonous tasks requiring sustained attention; further work would be necessary to determine how long changes in engagement persist, and to investigate how workload shifts might be optimally scheduled. The performance data also confirm previous findings (e.g., Matthews et al., 1990) indicating that loss of task engagement is detrimental to sustained monitoring. We have also suggested that, while changes in distress may be harmful to multitasking (cf. Cox-Fuenzalida et al., 2006), they have little observed impact on vigilance. In addition, the finding that demand transitions make human performance more unpredictable may have implications for human performance modelers (see Wickens, Gordon, & Liu, 1998). Accordingly, the results of this study underscore the National Research Council's view (Huey & Wickens, 1993) that workload transition is an important factor to be considered in future vigilance research. Moreover, vigilance tasks may be useful tools for researchers investigating general theories of human stress.

Acknowledgements

Supported by the Department of Defense's Multidisciplinary University Research Initiative (MURI) program administered by the Army Research Office under grant DAAD19-01-10621 to Dr. P.A. Hancock, principal investigator. The views expressed in this work are those of the authors and do not necessarily reflect Army policy. We thank Drs. Mike Drillings, Elmer Schmeisser, and Sherry Tove for providing administrative and technical direction for the grant.

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