British Journal of Psychology (2006), 97, 115–135
The British Psychological Society
www.bpsjournals.co.uk

Training for vigilance: The effect of knowledge of results format and dispositional optimism and pessimism on performance and stress

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This study investigated the impact of knowledge of results (KR) format on the performance and stress associated with a vigilance task. Also examined was the effect of the interaction of KR-format (Hit-KR, False Alarm-KR, Miss-KR, and a composite of all three formats) with dispositional optimism and pessimism on performance outcome and reported stress state. Hypotheses based upon a theory of feedback intervention were tested. KR regarding correct detections and the composite-KR (KR regarding correct detections, false alarms, and missed signals) enhanced perceptual sensitivity. However, False Alarm-KR and Miss-KR did not. Contrary to expectations based on the theory, performance was unrelated to the traits across all KR conditions. However, the effects of KR-format on self-reports of stress depended on the individual's level of pessimism and optimism. In addition, KR format and personality affected the multiple dimensions of stress state in different ways.

Tasks demanding vigilance or sustained attention require observers to monitor displays for the appearance of infrequent signals for action over prolonged periods of time. The central issue, in almost 60 years of vigilance research, has been the decline in performance with time on watch termed the vigilance decrement (See, Howe, Warm, & Dember, 1995). Although vigilance has been and remains an important part of many contemporary work environments, it has assumed significantly greater importance with the introduction of many 9/11-mandated security systems such as by the Transportation Security Administration's (TSA) need to screen 100% of all baggage at all US airports (Harris, 2002 see also Hancock & Hart, 2002). The advent of these, and many similar, security requirements has increased the need for effective training procedures for system operators. In vigilance, training has traditionally employed feedback in the form of knowledge of results (KR) regarding an operator's accuracy expressed in terms of

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DOI:10.1348/000712605X62768

correct detections, false alarms, or missed signals. KR has been shown to improve performance on sustained attention tasks (for a review, see Warm & Jerison, 1984). However, there is experimental evidence that the form of KR can impact its effectiveness. For example, Dittmar, Warm, and Dember (1985) asked participants to monitor increments in a vertical line presented on a video display terminal (VDT) and provided observers with feedback, in the form of a 1,000 Hz tone, regarding their correct detections, false alarms or missed signals. They observed that hit- and false alarm-KR enhanced perceptual sensitivity (A′) and attenuated the vigilance decrement, but miss-KR had no such effects. They explained these findings in terms of the information provided by each KR format. Hit- and false alarm-KR provide information regarding responses to specific stimuli but miss-KR is not linked to the observer's noticing of any particular characteristic of a signal event or to the observer's subsequent response.

Although Dittmar and her colleagues (1985) reported performance effects of KR format, they did not examine the stress effects associated with the use of KR. Several experiments have reported that vigilance tasks are stressful. Observers report feeling more boredom, strain, irritation, distress and less task engaged after the task than prior to its start (e.g. see Szalma *et al.*, 2004; Warm, 1993). In addition, research has indicated that manipulations of task characteristics that influence performance also influence individual subjective state (e.g. Szalma *et al.*, 2004; Temple *et al.*, 2000; see also Warm, Dember, & Hancock, 1996). Therefore, it is feasible that the format in which KR is provided to observers can influence their stress state in addition to influencing their performance. Given that Dittmar *et al.* observed performance differences as a function of KR format, and the associations between performance and subjective state (Warm *et al.*, 1996), one might expect that hit- and false alarm-KR would be associated with reduced stress symptoms and that miss-KR would be associated with greater stress, relative to a no-KR control condition. That is, the effect of KR format on stress should mirror the effects previously reported by Dittmar and her colleagues with regard to performance. Previous studies using a composite format have shown that used together the three forms of KR enhance performance (e.g. Szalma, Hancock, Warm, Dember, & Parsons, in press; Szalma, Miller, Hitchcock, Warm, & Dember, 1998), but these studies did not examine the effects of composite KR on observers' stress states. It may be that providing all three forms of KR will show the greatest performance enhancement and reduction in stress, since all information regarding detection accuracy is explicitly provided. One goal for the current experiment was to test these propositions.

Individual differences in performance and stress response: Feedback intervention theory (FIT)

From existing evidence, it appears highly likely that the effects of KR format on performance and stress associated with vigilance will depend upon the characteristics of the individual. Indeed, it has been long recognized that general individual differences among observers can influence performance in vigilance (see Berch & Kanter, 1984; Davies & Parasuraman, 1982). Recent evidence has confirmed that responses to the stress of sustained attention also depend on characteristics of the individual observers (e.g. Helton, Dember, Warm, & Matthews, 1999; Szalma, 2002a). Such findings are consistent with transactional models of stress that emphasize the importance of appraisal processes in stress response (Lazarus & Folkman, 1984; Matthews, 2001).

An individual differences variable that has recently emerged as an influential factor on stress responses to sustained attention is dispositional pessimism/optimism.

Helton *et al.* (1999) investigated the effect of false failure feedback on the performance and stress of both pessimists and optimists in a vigilance task. Although false failure feedback did not significantly impact performance, individuals high in pessimism and low in optimism exhibited steeper vigilance decrements across conditions relative to individuals low in pessimism and high in optimism. Helton and his colleagues also observed that pessimistic individuals reported changes in stress-related parameters such as greater tension, lower hedonic tone (i.e. a more negative mood state) and less confidence relative to optimists. These findings suggest that the high stress associated with vigilance may be moderated by an observer's relative level of pessimism/optimism. Further evidence for the influence of pessimism and optimism on observers' subjective stress states was reported by Szalma (2002a) who found that higher degrees of pessimism were associated with greater *distress* and lower *task engagement* after a vigilance task. Szalma also reported that pessimism predicted greater reliance on emotion-focused coping, consistent with prior research indicating use of this coping strategy by pessimistic individuals. Optimism, in contrast, was less predictive of stress and coping.

With regard to individual differences in the effectiveness of KR for vigilance, predictions can be made based upon a theory of feedback intervention (FIT), derived from a meta-analytic study of the feedback intervention literature (Kluger & DeNisi, 1996). FIT serves as a general framework for understanding the processes that influence feedback effectiveness. Drawing on control theory (see Carver & Scheier, 1981, 1998), FIT assumes that behaviour is regulated by comparison of feedback to goals or standards that are hierarchically organized. Two further assumptions of this theory are that (1) only those feedback interventions that receive attention can influence performance, and (2) feedback interventions have the capacity to alter the locus of attention within the goal hierarchy. Although hierarchies can vary in complexity, Kluger and DeNisi describe three general levels relevant for feedback effects. At the lowest level are *task-learning processes* consisting of 'hypotheses' for improving performance that individuals test by utilizing feedback. Attention to this level of the hierarchy constitutes attention to the details of focal task performance. These processes are regulated by the next highest level in the hierarchy, *task-motivation processes*, which serve as standards or comparators for the task-learning processes. At the highest level are *meta-task processes* involving the self and general but highly salient goals. Specifically, *meta-task processes* relate task outcomes to higher-level goals that are important to the individual. Kluger and DeNisi argued that most affective reactions to feedback interventions, when they occur, result from evaluation of feedback with respect to salient self-goals specified at the meta-task level.

According to FIT, feedback is effective in improving performance only to the extent that it serves to focus attention on the task (i.e. *task-motivation* and *task-learning processes*). Thus, an FIT interpretation of the results of Dittmar and her colleagues (1985) would be that the hit- and false alarm-KR directed attention to task-learning processes (e.g. learning the nature of a signal/non-signal) and perhaps task-motivational processes (e.g. see Warm, Kanfer, Kuwada, & Clark, 1972; Warm, Epps, & Ferguson, 1974), while miss-KR failed to adequately direct attention to relevant task characteristics. Miss-KR may fail to direct attention appropriately because it is not linked to a specific, overt response from the observer, so that observers are unable to use the feedback to associate their response to the stimulus characteristics (see Szalma *et al.*, in press). Moreover, one of the propositions of FIT (see Proposition 5, Kluger & DeNisi, 1996, p. 269) is that feedback cues that match salient personal goals associated with a given personality trait will direct attention to meta-task processes and thereby debilitate performance. This may subsequently induce stress effects in such individuals.

Kluger and DeNisi suggested a general mechanism for these effects whereby individuals' traits influence their ability to redirect their attention to the details of the task in response to feedback. They proposed that this occurs via an inhibition mechanism that protects working memory space from competing demands imposed by the goal hierarchy, and that traits such as the tendency to blame oneself for failures may exert debilitative effects on feedback by interfering with this inhibition mechanism. Hence, individual differences relevant to an observer's response to feedback may influence the effectiveness of training with feedback interventions such as KR.

Given the propositions of Kluger and DeNisi (1996), traits such as pessimism and optimism, which affect general expectancies regarding performance and affective responses to performance success and failure (see Chang, 2002), should influence the effectiveness of KR in improving vigilance. Specifically, the negative outcome expectancies associated with pessimism may serve to interfere with these inhibitory processes and thereby reduce KR effectiveness, particularly for 'negative' KR (i.e. false alarm-KR and miss-KR), since individuals high in pessimism tend to appraise events more negatively than those low in pessimism. Such feedback may, in Kluger and DeNisi's terms, 'release' the pressure on the regulatory system to eliminate the feedback-standard discrepancy at the task level. Attention is then redirected towards the self and managing the negative affect associated with pessimistic appraisals of the task. In contrast, the more positive expectations of individuals high in optimism would result in feedback directing their attention towards more task-based processes, thereby improving performance and reducing stress symptoms. These effects may be weak, however, since optimism has been shown to be a weaker absolute predictor of other measures than pessimism (Szalma, 2002a; see also Hummer, Dember, Melton, & Schefft, 1992). The results of Helton *et al.* (1999) concerning false failure feedback sit contrary to these hypotheses, as failure feedback would be expected to impair performance of pessimists by inducing negative appraisals and directing their attention towards dealing with their subsequent negative affect. However, the absence of significant KR effects in their study may be due to the fact that feedback was not veridical and was provided at the end of a block of trials (i.e. summary KR). Veridical feedback provided after each response (or failure to respond when appropriate) provides many more opportunities for the personality traits to differentially exert their influence on performance and stress state across feedback conditions.

The present study was thus also designed to test these propositions by examining the impact of individual differences in optimism and pessimism on performance and stress in vigilance, and the effectiveness of KR in facilitating performance and reducing stress. Specifically, individuals higher in pessimism should exhibit greater performance impairment and report higher levels of stress symptoms after the vigil. Based on FIT, it is hypothesized that veridical feedback emphasizing failure immediately following an error (i.e. miss- or false alarm-KR) should debilitate performance and increase stress for observers higher in pessimism (due to a shift in focus from the task towards the self) relative to a no-KR control condition. In the composite condition, the effects of negative KR may be offset by the provision of hit-KR. Thus, participant disposition should interact with feedback type, such that performance and stress effects associated with high pessimism should manifest themselves primarily in the context of false alarm- and miss-KR. In contrast, individuals high in optimism may respond positively to hit-KR, although the findings of Szalma (2002a) and previous research on optimism and pessimism (Hummer *et al.*, 1992) indicate that these effects may be weaker than those associated with pessimism.

Experimental method

Experimental participants

Participants were 55 male and 55 female undergraduates from the University of Cincinnati who took part in this experiment in exchange for course credit. Participants ranged from 18 to 30 years old, with a mean of 20.0 years. All participants had normal or corrected-to-normal vision and were free of any known hearing impairments.

Feedback conditions and task characteristics

Of the participants, 22 were assigned at random to each of the following five groups, with the only restriction being that the groups were equated for gender: hit-KR – observers received feedback regarding correct detections; false alarm-KR – observers received feedback when they made errors of commission; miss-KR – observers received feedback when a signal appeared on the screen and they failed to respond to it; composite-KR – observers received all three forms of feedback; no-KR – observers received no feedback regarding performance quality and acted as the comparison control group. The task required monitoring a simulated chemical process display presented on a VDT for patterns of deviation that would lead to an uncontrolled reaction (see Fig. 1). The display consisted of Cartesian coordinates (formed by 3.2 cm green line segments) representing

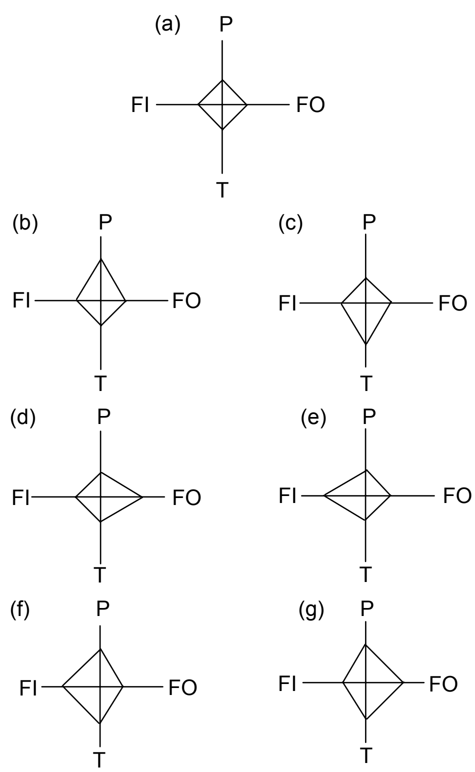

Figure 1. Stimuli employed in the current experiment. Displays (a) through (e) are 'neutral events', requiring no overt response from the observer. Displays (f) and (g) are 'critical signals', defined by simultaneous changes on both axes.
Note. P = pressure; *T* = temperature; FI = flow rate in; FO = flow rate out.

the state of four system variables, each of which was represented as a point on one of the axes. These points were connected via green line segments, which formed a polygon that changed shape according to changes in system variables. Representative stimuli are displayed in Fig. 1. The variables to be monitored were the pressure, temperature and the flow rates in and out of the 'vat' of chemicals. Neutral events, which required no overt response from the observer, were cases in which these variables were in balance (see Display (a) in Fig. 1) or when their levels varied along one axis (e.g. pressure/temperature; see Displays (b) and (c) in Fig. 1) but not the other (e.g. flow rate; see Displays (d) and (e) in Fig. 1). There were five such events. Under one of these conditions, the four vertices along the axes (each representing the level of a system variable) were 0.8 cm from the origin, resulting in a square-shaped polygon. For the other four neutral events, one of the points moved to 1.2 cm from the origin, resulting in four different orientations of a 'kite' shape. Critical signals for detection were cases in which the flow rate-in did not equal the flow rate-out and *both* temperature and pressure increased. Specifically, critical signals consisted of cases in which (1) the temperature, pressure and flow rate-in points were moved from 0.8 cm from the origin to 1.2 cm from the origin; or (2) the temperature, pressure and flow rate-out points were moved from the origin to 1.2 cm from the origin. Since critical and non-critical events were defined in terms of combinations of variable levels, the state of the overall system was conveyed via the shape of the polygon. Thus, neutral events were cases in which the figure displayed was either 'square-' or 'kite-' shaped, while critical signals were cases in which the quadrangle was not diamond- or kite- shaped.

Displays of this type are referred to as 'object' or 'volumetric' displays, and have been successfully employed by human factors researchers in the design of displays in the workplace (see Bennett & Flach, 1992, for a review; see also Hancock & Szalma, 2003). An advantage of these displays is that they allow observers to assess the state of a multidimensional system by inspection of a geometric shape rather than by inspection of several separate gauges, and recent evidence indicates that such displays can attenuate performance decrement, but that they do not reduce the stress of sustained attention (Szalma, 2002b). Note that the display employed in this study was not intended to simulate a specific real-world process, but rather to simulate the kind of displays that have been used to simplify the inspection of complex, multidimensional systems (Bennett, Nagy, & Flach, 1997).

Questionnaires

Observers' stress states were assessed with the Dundee Stress State Questionnaire (DSSQ, version 2.0; Matthews *et al.*, 1999; see also Matthews *et al.*, 2002), which is a multidimensional, self-report instrument for assessing transient mood states. Specifically, this version of the DSSQ comprised 10 factor-analytically determined scales. These scales have been subjected to a secondary factor analysis, yielding three dimensions associated with stress state, *distress*, *task engagement* and *worry*. Thus, increases in stress are associated with increased scores on the *distress* and *worry* scales and/or a decrease on the *task engagement* scale. Example items for *distress* include ratings of the degree to which adjectives such as 'tense', 'relaxed', 'happy' or 'contented' describe the individual's current subjective state. Examples of items associated with *task engagement* include subjective state ratings of adjectives such as 'energetic'. 'alert' or 'vigorous', as well as ratings of statements such as 'I expect the content of the task will be interesting' and 'I am committed to attaining my performance goals'. Example items associated with the *worry* scale include ratings of statements such as 'I'm reflecting about myself' and 'I thought about the difficulty of the problems'.

Optimism and pessimism were assessed using the optimism/pessimism instrument (OPI) developed by Dember, Martin, Hummer, Howe, and Melton (1989). This instrument consists of a 56-item (18 items indicating optimism, 18 indicating pessimism and 20 filler items) regarding the individual's attitudes and expectations. Scores on the OPI range from 18 to 72. Several studies using the OPI have indicated that optimism and pessimism are not simply polar opposites, but are partially independent (for a review, see Dember, 2002). The OPI was administered pre-vigil, and the DSSQ was administered both pre- and post-vigil.

Procedure

Observers participated in a 30-minute vigil divided into six continuous 5-minute periods on watch. The display was presented for 500 ms every 1.5 seconds (30 events per minute), and critical signals for detection occurred twice/min (signal probability = .066) within each period of watch. KR was provided by a computer using a pre-recorded female voice to announce correct detections ('correct'), missed signals ('miss'), and errors of commission ('false alarm'). In the no-KR condition, the voice announced 'saved' after each response in order to control for added auditory stimulation in the KR-conditions. Previous experiments using the female voice to deliver feedback found that this form of KR effectively enhanced performance (Szalma *et al.*, 1998, 2004).

Upon entering the laboratory, participants surrendered their wristwatches and cell phones, read a brief description of the experiment and signed a consent form. Participants completed the OPI, followed by the pre-task version of the DSSQ. The experimenter then read the instructions for the sustained attention task, which were simultaneously presented on the VDT. Observers had no prior knowledge of the length of the vigil, other than that it would not exceed 90 minutes. At the end of the vigil, participants completed the post-task version of the DSSQ and were then debriefed.

Experimental results

Performance measures

Vigilance performance data are usually analysed using signal detection theory (SDT) indices or their base component measures, hit and false-alarm rates. However, in the present experiment, as in many other vigilance experiments, a substantial proportion (37%) of the false alarm scores were zero across participants, periods and KR group (e.g. Szalma *et al.*, 2004, in press; see also Davies & Parasuraman, 1982). Computation of parametric SDT parameters from zero false alarm scores requires adjustments to the data that can introduce error into the estimates (Craig, 1977; Davies & Parasuraman, 1982; Macmillan & Creelman, 2005). The difficulty in interpreting parametric SDT indices under these conditions led Craig (1979) to argue against the uncritical application of these measures to vigilance data. He suggested that nonparametric sensitivity indices (specifically, A') be used when parametric measures are inappropriate. Subsequent research established that among the available, non-parametric indices of response bias, β''_d (Donaldson, 1992) was the most effective for vigilance, as this measure remained sensitive to non-perceptual manipulations and it is effective in estimating response bias at chance performance levels (See, Warm, Dember, & Howe, 1997). One advantage of non-parametric indices is that they are defined for cases in which there are many instances of zero false-alarm rates, as in the present experiment. Correct detections and false alarms for each observer were therefore used to compute SDT measures A′ and β''_d for each period of watch. A 5 (group) by 6 (period) ANOVA was computed for each of these respective performance measure. Mean sensitivity scores for observers in each KR condition are plotted as a function of period of watch in Fig. 2.

Performance remained relatively stable across the watch period, and observers who received any form of KR achieved higher A′ scores than those who did not receive KR. The ANOVA confirmed a significant effect for KR, $F(4, 105) = 3.85, p < .01, \omega^2 = .02$, and a significant effect for period on watch, $F(3, 318) = 7.49, p < .001, \omega^2 = .05$. The latter effect is probably a reflection of the fluctuation in performance over the course of the vigil (*M*s for Periods 1 through 6 were 0.87, 0.88, 0.85, 0.90, 0.86 and 0.88, respectively). The interaction between these factors lacked significance ($p > .05$). For all analyses involving repeated measures, Box's epsilon was used to adjust the degrees of freedom for violations of sphericity (see Maxwell & Delaney, 2004). Tukey HSD tests for the KR conditions revealed that relative to those in the no-KR control group ($M = 0.81$), observers who received composite-KR ($M = 0.92$; Cohen's $d = 0.84$) or hit-KR ($M = 0.89$; Cohen's $d = 0.60$) achieved significantly higher sensitivity scores. The four KR conditions did not differ significantly from one another in perceptual sensitivity ($p > .05$ in each case).

Mean response bias scores for observers in the five KR conditions are plotted as a function of periods of watch in Fig. 3. The ANOVA indicated a significant effect for KR, $F(4, 105) = 2.54, p < .05, \omega^2 = .009$, and for period on watch, $F(3, 291) = 9.58, p < .001, \omega^2 = .06$. The interaction between these factors was not statistically significant ($p > .05$). Tukey HSD tests for the KR conditions revealed that observers receiving composite KR ($M = 0.91$) were significantly more conservative than those who did not receive KR ($M = 0.49$; Cohen's $d = 0.80$). All other comparisons failed to reach statistical significance ($p > .05$ in each case). The significant main effect for periods indicates that conservatism increased with time on watch (*M*s for Periods 1–6 were 0.54, 0.67, 0.71, 0.73, 0.77 and 0.77, respectively). These results are consistent with prior research in vigilance, and are probably due to growing awareness by participants during the vigil that the signals to be detected were relatively rare (Craig, 1978).

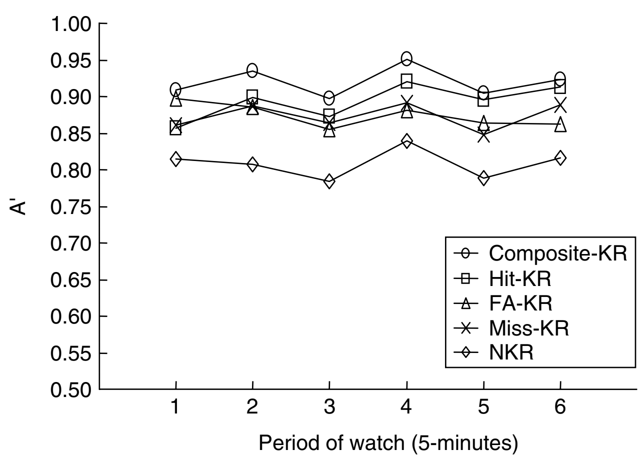

Figure 2. Perceptual sensitivity (A′) as a function of period on watch.
Note. NKR = no KR.

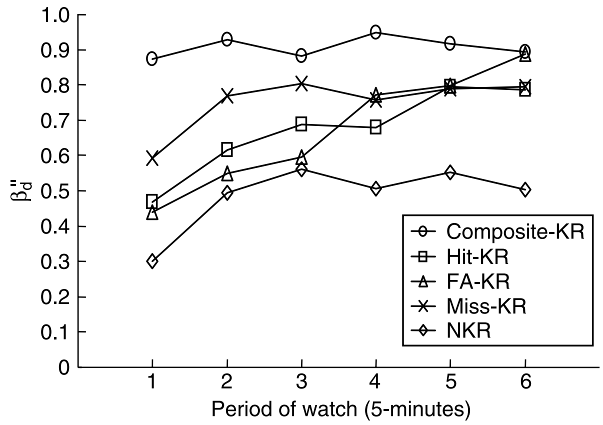

Figure 3. Response bias (β''_d) as a function of period on watch.
Note. NKR = no KR.

Perceived stress

Preliminary ANOVAs confirmed that participants across the KR conditions did not differ significantly in their pre-vigil *distress*, *task engagement* or *worry* scores ($p > .45$ in each case). Pre- and post-DSSQ responses were therefore used to compute pre-post z scores for the three DSSQ factors. One-sample t tests using the Bonferroni correction ($\alpha = .05$) indicated that across all conditions, observers reported significant increase in *distress* ($M = 0.66$), $t(109) = 6.42$, $p < .001$, and significant declines in *task engagement* ($M = -0.86$), $t(109) = -10.05$, $p < .001$, and *worry* ($M = -0.46$), $t(109) = -5.33$, $p < .001$. Thus, for two of the three dimensions of stress, the data indicate that the vigil itself was stressful. To examine KR effects, an ANOVA was computed for each stress scale. These analyses indicated that there were no significant differences among KR conditions for the *distress* and *worry* dimensions ($p > .05$ in each case), but that there was a significant KR effect for *task engagement*, $F(4, 105) = 3.59$, $p < .01$, $\omega^2 = .09$. Tukey HSD tests indicated that participants in the no-KR control condition ($M = -1.25$) reported a greater decline in *task engagement* after the vigil than those in the composite-KR condition ($M = -0.38$; Cohen's $d = 1.02$). No other comparisons reached conventional levels of significance ($p > .05$ in each case).

In sum, only hit- and composite-KR were effective in enhancing perceptual sensitivity relative to a no-KR control, and only composite-KR was effective in reducing the stress associated with the vigil. However, this effect was restricted to the *task engagement* dimension. In subsequent sections, the effects of pessimism and optimism are evaluated to determine whether they moderated these relations between KR, performance and stress state.

Pessimism and optimism

The mean pessimism score across all 110 participants was 36.5 ($SD = 6.6$), and the mean optimism score was 53.56 ($SD = 5.0$). The correlation between these variables was $r = -.40$ ($p < .001$), which is lower than that usually obtained between these two variables (approximately $r = .5$; see Dember, 2002; Dember *et al.*, 1989). However, inspection of the mean, standard deviation and coefficient alpha for each scale ($\alpha = .81$ for optimism; $\alpha = .83$ for pessimism) indicated that these indices did not meaningfully differ from results obtained from prior samples. Preliminary analyses indicated that there were no significant differences among KR conditions in optimism or pessimism ($p > .5$ in each case).

Feedback and dispositional optimism and pessimism

To evaluate the impact of optimism and pessimism, and their interaction with KR format, a hierarchical regression approach was employed using procedures outlined by Pedhazur (1997; see also Hardy, 1993). The KR variable was dummy-coded so that the no-KR condition was assigned a value of zero across all four vectors. Each vector (i.e. hit-KR, false alarm-KR, miss-KR and composite-KR) therefore represented the comparison between a KR condition and the no-KR control. The terms in each regression were trait (optimism or pessimism), KR (the dummy coded vectors) and trait by KR product vector terms ('interaction' terms). Separate regressions were computed with optimism and pessimism to simplify analyses and avoid problems associated with multicollinearity.

When the vector products are included in the model, interpretation of the regression weights for KR and trait terms are meaningless, since the product vectors are correlated with their constituent parts (see Pedhazur, 1997; see also Jaccard & Turrisi, 2003). Thus, the interaction terms are interpreted according to the increment in the proportion of variance accounted for (i.e. ΔR^2) after the variance accounted for by pessimism and the KR vectors (the 'main effects') has been entered into the model. Step 1 of the hierarchical regression procedure consisted of entry of the trait variable (optimism or pessimism), Step 2 consisted of entry of the trait variable and the dummy coded KR variable, and Step 3 consisted of the main effects and the 'interaction' terms. A non-significant increment in ΔR^2 for the full model (Step 3) resulted in evaluating the models at Step 1 (trait only) or Step 2 (trait and KR). Cases in which a significant product vector was obtained indicated that the slope of the regression of the dependent variable on the trait variable was significantly different between the corresponding KR conditions. That is, the test for the regression weight for each product vector (e.g. hit-KR by pessimism, false alarm-KR by pessimism) constitutes a test of the difference between the regression weights for the no-KR group and the particular KR condition. Following Pedhazur, such product vectors were tested using the Johnson-Neyman procedure for determination of simultaneous regions of significance (see also Huitema, 1980; Jaccard & Turrisi, 2003). This procedure, analogous to a test of simple effects in ANOVA, involves determining over which regions of the continuous predictor variable (e.g. pessimism) differences between the categorical variables (e.g. no-KR vs. FA-KR) are significant. In this framework, the trait variable is considered a moderating variable for the relation between KR and the dependent variable (i.e. performance, stress; see Jaccard & Turrisi, 2003). To control for Type I error, the Bonferroni F statistic was used in the computation of regions of significance (see Huitema, 1980). To simplify performance analyses, regressions of performance on the trait variable (pessimism, optimism), KR and the associated product vectors were performed for sensitivity and response bias in two ways: (1) an overall index of sensitivity and bias based on the total number of correct detections and false alarms over the entire vigil; and (2) a difference score for these indices between the first and last periods on watch.

Pessimism

Performance

Regressions of overall A' and the difference score between Periods 1 and 6 revealed no impact of pessimism on performance, nor did pessimism interact with KR in influencing performance ($p > .05$ in each case). Similar analyses with overall β''_d and the difference score for Periods 1 and 6 indicated that pessimism did not impact response bias, nor did it interact with KR to influence overall response bias or change in bias between the beginning and end of the session ($p > .05$ in each case).

Perceived stress

Stress state was analysed via separate hierarchical regressions of the pre-post difference scores of each scale (*distress*, *task engagement* and *worry*) on pessimism, KR group and the interaction between these factors.

Distress

The regression of pre-post *distress* on pessimism, KR, and the product vectors (i.e. KR × pessimism) was significant, $F(9, 100) = 2.41, p < .05, R^2 = .18$. The increment in variance accounted for by the product vector terms was significant, $F(4, 100) = 2.59$, $p < .05\ \Delta R^2 = .09$. Significant regression weights were observed for the dummy coded false alarm vector ($b = -5.35, SE_b = 2.06, \beta = -2.00, t(34) = -2.00, p < .05$) and the product vector for pessimism and false alarm-KR ($b = 0.14$, $SE_b = 0.06$, $\beta = 1.92$, $t(34) = 2.46, p < .05$). The significant effect for the regression weight associated with the product vector for pessimism and false alarm-KR indicates that the regression weights for the no-KR and false alarm-KR conditions were significantly different from one another. The relation between pre-post task *distress* and pessimism is shown in Fig. 4 for the false alarm-KR and no-KR conditions. Application of the Johnson-Neyman procedure revealed that for pessimism scores less than 31.7, observers who received false alarm-KR reported significantly less *distress* than those in the no-KR group. Hence,

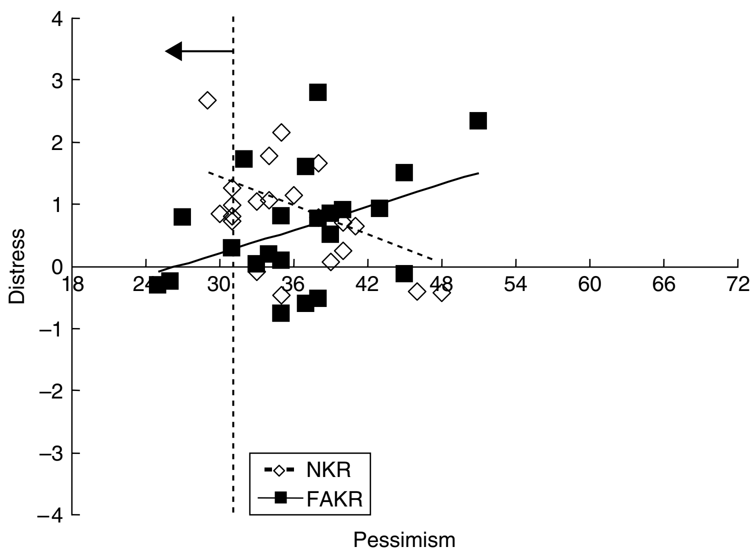

Figure 4. Pre-post task *distress* as a function of pessimism for the false alarm-KR and no-KR groups. *Note.* Dotted line with arrow represents the region of significant differences between the regression lines. Separate regression equations: false alarm-KR group: D = .06P − 1.64, $R^2 = .17$; no-KR group: D = −.08P + 3.71, $R^2 = .13$; intersection point of regression lines: P = 38.8. NKR = no-KR; FAKR = false alarm-KR; D = distress; P = pessimism.

false alarm-KR was effective in reducing *distress*, but only for participants low in pessimism. This effect was attenuated for individuals high in pessimism.

Task engagement

The regression of pre-post *task engagement* on pessimism, KR and the product vectors was significant, $F(9, 100) = 3.57$, $p < .01$, $R^2 = .24$. The increment in variance accounted for by the product vector terms was significant, $F(4, 100) = 3.33$, $p < .05$ $\Delta R^2 = .11$. Significant regression weights were observed for the dummy coded false alarm vector ($b = 4.64$, $SE_b = 1.64$, $\beta = 2.08$, $t(34) = 2.82$, $p < .01$) and the product vector for pessimism and false alarm KR ($b = -0.11$, $SE_b = 0.04$, $\beta = -1.85$, $t(34) = -2.47$, $p < .05$). Pre-post *task engagement z* scores are plotted as a function of pessimism for the false alarm-KR and no-KR conditions in Fig. 5. The Johnson-Neyman procedure was applied to investigate the significant false alarm-KR/pessimism product vector. This analysis revealed that for pessimism scores below 35.6, observers who received false alarm-KR reported significantly higher *task engagement* than observers who did not receive feedback. That is, false alarm-KR was more effective in increasing *task engagement* for participants relatively low in pessimism, but the effectiveness of this KR format was reduced for individuals higher in pessimism.

Worry

Analyses indicated non-significant regressions for pessimism and KR ($p > .05$ in each case), but a significant regression for the full model (Step 3), $F(9, 100) = 2.23$, $p < .05$, $R^2 = .18$. The increment in variance accounted for by the product vector terms was significant, $F(4, 100) = 3.79$, $p < .01$ $\Delta R^2 = .13$. This outcome is analogous to non-significant main effects in an ANOVA but a significant interaction. However, tests of the

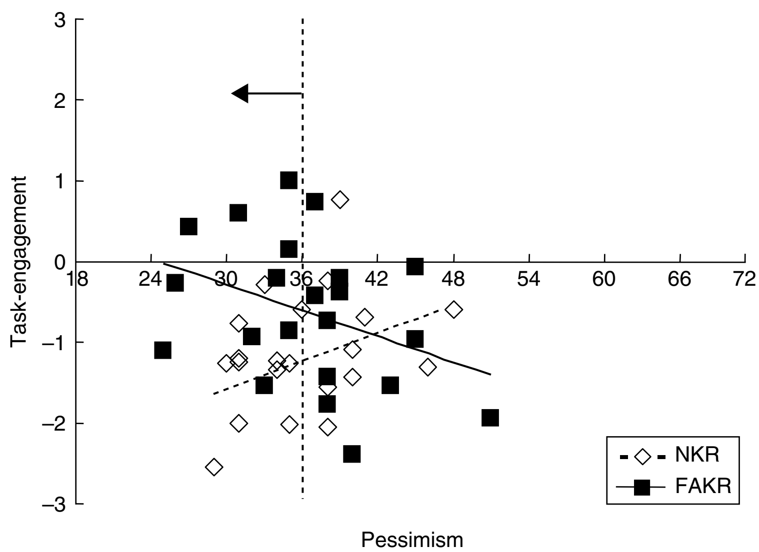

Figure 5. Pre-post *task engagement* as a function of pessimism for the false alarm-KR and no-KR groups. *Note.* Dotted line with arrow represents the region of significant differences between the regression lines. Separate regression equations: false alarm-KR group: $TE = -.05P + 1.32$, $R^2 = .14$; no-KR group: $TE = .06P - 3.32$, $R^2 = .11$; intersection point of regression lines: $P = 41.8$. NKR = no-KR; FAKR = false alarm-KR; TE = task engagement; P = pessimism.

regression weights revealed no significant *b*s, although the coefficient for the product vector for Miss-KR/pessimism was marginally significant ($b = -0.08$, $SE_b = 0.05$, $\beta = -1.41$, $t(34) = -1.87$, $p = .06$). Pre-post *worry* scores are plotted as a function of pessimism for the miss-KR and no-KR conditions in Fig. 6. Application of the Johnson-Neyman procedure was unsuccessful, probably due to high within-groups variability, which can cause failures in solutions for regions of significance (see Pedhazur, 1997). Separate regressions of *worry* on pessimism for the no-KR and miss-KR conditions revealed a non-significant regression for the former and a significant regression for the latter, $F(1, 20) = 9.11$, $p < .01$, $R^2 = .31$ ($b = -0.06$, $SE_b = 0.02$, $\beta = -56$, $t(34) = -3.09$, $p < .01$). Contrary to prediction, increased pessimism was related to decreased *worry* for participants in the miss-KR condition.

Optimism

Performance

Regressions of overall A′ on optimism, KR and their product vectors revealed a significant regression for the full model, $F(9, 100) = 2.73$, $p < .01$. However, inspection of the data indicated that these effects were primarily due to two outlier scores in the false alarm-KR condition. When these were omitted from the analysis, no significant effects were observed. Inspection of the DSSQ and OPI scores of these two individuals indicated that they did not differ from their group mean (the false alarm-KR condition) on the OPI or DSSQ scales by more than 1.5 standard deviations. Similar analyses on A′ difference scores, β''_d and β''_d difference scores indicated that optimism did not significantly influence change in performance between the beginning and end of the vigil, nor did optimism interact with KR format in influencing overall response bias or changes or response bias ($p > .05$ in each case).

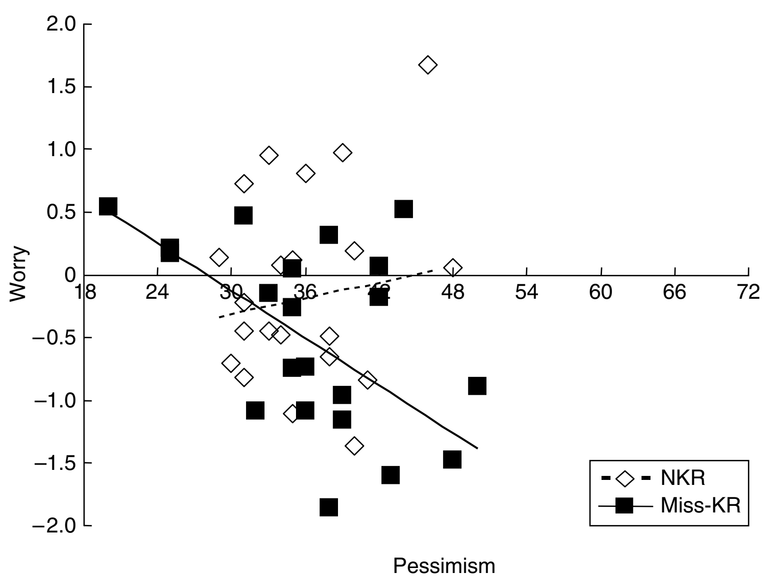

Figure 6. Pre-post task *worry* as a function of pessimism for the miss-KR and no-KR groups. *Note.* Separate regression equations: miss-KR group: $W = -.06P + 1.76$, $R^2 = .31$; no-KR group: $W = .02P - .96$, $R^2 = .01$; intersection point of regression lines: $P = 32.3$. NKR = no-KR; W = worry; P = pessimism.

Perceived stress

As with the analyses involving pessimism, stress state was analysed via separate hierarchical regressions of each scale (*distress*, *task engagement* and *worry*) on optimism, KR and the interaction between these factors.

Distress and task engagement

Regression analysis indicated that optimism, KR, and the product vectors did not significantly predict *distress* ($p > .05$). Optimism predicted pre-post *task engagement*, $F(1, 108) = 6.50$, $p < .05$, $R^2 = .06$, and the model including optimism and KR conditions was significant, $F(5, 104) = 3.84$, $p < .05$, $R^2 = .16$, although the product terms for these variables did not significantly add to the variance accounted for by the regression ($p > .05$). Significant regression weights were observed for optimism, ($b = -0.03$, $SE_b = 0.02$, $\beta = -0.19$, $t(38) = -2.08$, $p < .05$), the false alarm-KR vector ($b = 0.56$, $SE_b = 0.26$, $\beta = 0.25$, $t(38) = 2.18$, $p < .05$) and the composite-KR vector ($b = 0.79$, $SE_b = 0.26$, $\beta = 0.36$, $t(38) = 3.09$, $p < .01$).

Worry

For pre-post task *worry*, the full regression model was significant, $F(9, 100) = 2.62$, $p < .01$, $R^2 = .19$, and the product vectors significantly added to the variance accounted for by the regression, $F(4, 100) = 4.83$, $p < .01$, $\Delta R^2 = .16$. Significant regression weights were observed for the false alarm-KR vector ($b = 7.39$, $SE_b = 2.72$, $\beta = 3.26$, $t(34) = 2.72$, $p < .01$), and the false alarm-KR/optimism product vector ($b = -0.14$, $SE_b = 0.05$, $\beta = -3.34$, $t(34) = -2.84$, $p < .01$). Pre-post *worry* scores associated with the false alarm-KR and no-KR conditions are plotted as a function of optimism in Fig. 7.

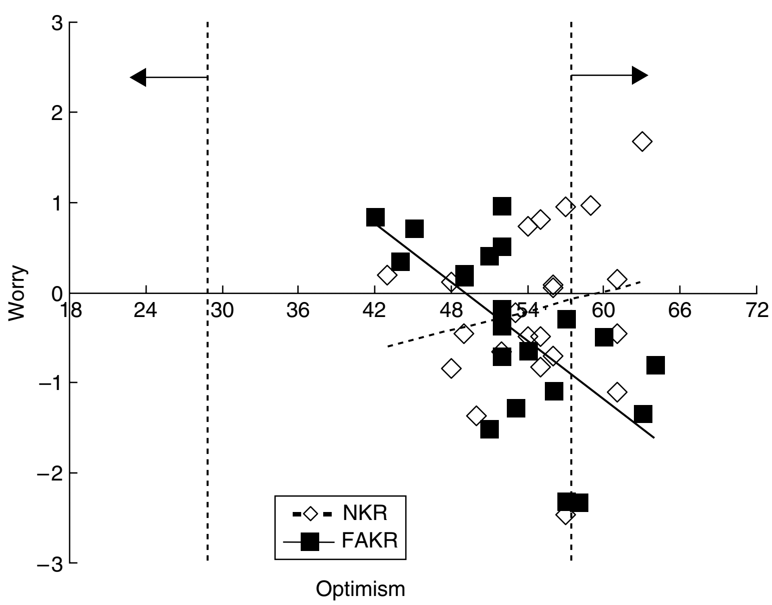

Figure 7. Pre-post task *worry* as a function of optimism for the false alarm-KR and no-KR groups. *Note.* Dotted lines with arrows represent the simultaneous regions of significant differences between the regression lines. Separate regression equations: false alarm-KR group: $W = -.11Opt + 5.26$, $R^2 = .41$; no-KR group: $W = .04Opt - 2.12$, $R^2 = .04$; intersection point of regression lines: Opt = 51.8. NKR = no-KR; FAKR = false alarm-KR; W = worry; Opt = optimism.

Johnson-Neyman analyses revealed that for optimism scores below 28.6, false alarm-KR induced greater *worry* compared with No-KR, but for scores above 57.6, receiving false alarm-KR induced less worry relative to no-KR controls. Note that the results for the low end of the optimism scale must be interpreted with caution since the regions of significance represent an extrapolation to a region in which there are no sample data.

Discussion

A primary purpose of the present study was to investigate whether the performance differences as a function of KR format observed in previous research (Dittmar *et al.*, 1985) were associated with differences in stress state, and whether combining these formats into a single condition is most effective in improving performance and reducing stress. A second goal was to investigate the possibility, based upon hypotheses derived from FIT (Kluger & DeNisi, 1996), that dispositional optimism and pessimism would influence the effectiveness of different KR formats in improving vigilance performance and in reducing the stress associated with prolonged monitoring. Specifically, it was hypothesized that false alarm- and miss-KR should impair performance and increase stress for individuals high in pessimism. By contrast, hit-KR should facilitate performance and reduce stress symptoms for individuals high in optimism, although these effects were expected to be weaker than those associated with pessimism.

The present results obtained with hit-KR were consistent with the findings of Dittmar *et al.* (1985), while the composite-KR was effective at enhancing sensitivity as also observed in prior testing (Szalma *et al.*, 1998, 2004). Also consistent with Dittmar *et al.,* miss-KR was not effective in enhancing perceptual sensitivity. However, in contrast to the results of Dittmar and her colleagues, false alarm-KR was also not effective in enhancing sensitivity relative to a no-KR control. Moreover, a major finding of Dittmar and her colleagues of an interaction between KR format and time on task for both sensitivity and response bias was not confirmed in the present experiment. This is most probably due to the absence here of a sensitivity decrement and large within-groups variability observed in the response bias data. These differences are probably task-specific and confirm that the influence of KR format depends on the information-processing requirements of the particular vigilance task at hand. The task employed by Dittmar *et al.* required discrimination of the length of a vertical line, while in this experiment, participants monitored patterns of change in the shape of an object display. Prior research has shown that use of an object display enhances sensitivity and attenuates the vigilance decrement without the provision of feedback (Szalma, 2002b). It might be that the differential effects of KR format depend on the perceptual and cognitive demands of the specific task, and while several of these factors have been determined (Davies & Parasuraman, 1982; Warm & Dember, 1998), a full exposition has yet to emerge. In comparison with the Dittmar *et al.* results, note that the mode of KR also has varied since their report. Dittmar and her colleagues used a 1,000 Hz tone as feedback, while in the present experiment a female voice controlled by the computer was employed to deliver feedback. Whether such mode differences in KR presentation influences effectiveness for enhancing vigilance is a matter for future research.

Stress

Consistent with previous vigilance experiments, observers in this study found the vigil to be stressful (Hancock & Warm, 1989). A significant increase in *distress* and reduction in *task engagement* was observed across all conditions. However, KR format failed to significantly impact *distress* or *worry*. A significant KR effect was observed for *task engagement*, but *post hoc* tests revealed that this effect was restricted to the composite-KR condition. Taken together with the performance results, these results indicate that although hit-, miss-, and false alarm-KR differ in their effects, combining them has the greatest impact in improving performance and reducing stress. Moreover, these results indicate that regardless of the separate effects of the different KR formats, training regimens for vigilance may benefit from providing feedback regarding all three outcomes. Providing such information may direct attention away from the self and towards task goals to a greater degree than when the formats are presented singly. The different forms of KR in this instance might serve as cues for observers to attend to their respective responses to stimuli, so that the KR serves to strengthen the association between stimulus characteristics and observer response. The different effects across the three stress state dimensions reflect the multidimensional nature of the stress construct (Matthews, 2001), and may represent different appraisals to task demands and different coping responses to those demands. Thus, the 'core relational theme' (Lazarus, 1991) that links to *distress* is 'overload of capacity for successful performance' and *task engagement* relates to 'commitment of effort' (Matthews *et al.*, 2002, 1999). Thus, composite-KR did not relieve the overload associated with vigilance (see Warm *et al.*, 1996), but it did enhance the commitment of effort to perform. The latter result conforms to the exposition concerning the motivational effect that KR has on vigilance (see Warm & Jerison, 1984).

In this experiment, *worry* declined after the vigil across all conditions. According to Matthews *et al.* (1999) the *worry* dimension is associated with self evaluation 'such that the nature of the task provokes re-assessment of personal qualities and goals' (p. 348) and with emotion-focus and avoidant coping (Matthews & Campbell, 1998). Indeed, they noted that self-reflection is most likely to occur in monotonous tasks such as vigilance. Further, Matthews *et al.* (2002) argued that this theme would fall under the *meta-task* process described by Kluger and DeNisi (1996). In this experiment, *worry* declined across all conditions, indicating an overall attenuation of *meta-task* processes. However, these effects depended on the pessimism and optimism of observers, as discussed below.

Performance and stress: The non-reciprocity of hit- and false alarm-KR

Dittmar and her colleagues noted that hit- and false alarm-KR are reciprocals of one another since they provide the same information regarding whether a response was correct. However, their effects in this study were not equivalent in terms of performance and self-report of stress state. Hit-KR, but not false alarm-KR, enhanced sensitivity relative to observers who did not receive KR. False alarm-KR, but not hit-KR, reduced the *distress* and increased *task engagement* relative to no-KR controls, but only for individuals low in pessimism. Although hit-KR observers performed better than controls who did not receive KR, this performance enhancement was not associated with reduced *distress* or increased *task engagement*, suggesting that hit-KR does not alter the coping strategies observers use to deal with task demands. In contrast, false alarm-KR reduced the stress symptoms for individuals low in pessimism, but this benefit was not associated with performance effects. This indicates that false alarm feedback influences appraisals observers make in respond to task demands, that these appraisals occur independent of actual performance, and that these appraisals depend upon the person's level of dispositional pessimism.

Effects of pessimism and optimism: The test of feedback intervention theory (FIT)

Performance

Consistent with prior experimental findings, pessimism and optimism did not significantly affect the performance of observers (see Ganey *et al.*, 2003; Szalma, 2002a; Thropp, Szalma, Ross, & Hancock, 2003). In one exception, Helton *et al.* (1999) observed a steeper decrement in pessimists relative to optimists, but evidence from this and other investigations implies that these effects may be dependent on task characteristics. Specifically, Helton *et al.* employed a rather difficult discrimination at a very high event rate (57.5 per minute), while relatively easier discriminations at lower event rates were used in this and other experimental procedures which did not show this influence.

Helton and his colleagues also observed that pessimism/optimism did not interact with false summary KR to influence performance, a finding that was replicated in this study using veridical feedback after each response (or failure to respond appropriately). This result was inconsistent with the hypotheses based on FIT. One possible explanation is that the nature of the KR and the task was not sufficiently important relative to the individuals' self-goals (i.e. *meta-task* goals). This interpretation is supported by the finding that across all conditions, pre-post *worry* declined, which reflects less self-evaluative processes (Matthews *et al.*, 2002). Stronger effects might be observed if the attention to the levels of the goal hierarchy discussed by Kluger and DeNisi (1996; i.e. *meta-task*, *task-motivational* and *task-learning processes*) were manipulated specifically.

A second explanation can be derived from the processing efficiency theory of Eysenck and Calvo (1992). According to this theory, individuals who have difficulty coping with stress can compensate by exerting more task effort. The effects of stress are therefore manifested as a reduction in the efficiency of information processing rather than in the output of such processing. Thus, two individuals may exhibit equivalent levels of performance, but one individual is maintaining that performance at greater cost. Evidence from the current study indicates that individuals high in pessimism can achieve levels of performance equivalent to those of their less pessimistic cohorts but that maintaining such performance occurs at greater cost, particularly when negative feedback is provided. It may therefore be that negative KR and pessimism interact to influence processing efficiency rather than the absolute level of performance.

Stress

Pessimism

Although the expected interaction between trait and KR was not observed with regard to performance, interactions were observed in stress state and the effect of pessimism on stress depended on the joint effects of KR format and dimension of stress. Thus, the effect of 'negative KR' (i.e. false alarm- and miss-KR) in reducing stress was observed only for individuals low in pessimism. Moreover, false alarm-KR exerted its influence on *distress* and *task engagement*, while miss-KR exerted its influence on *worry*. However, while false alarm-KR reduced *distress* and increased *task engagement* for individuals low in pessimism, miss-KR reduced *worry* for individuals *higher* in that trait. Thus, the two forms of negative KR influenced different stress state dimensions in different ways. It is important to remember that *distress* and *task engagement* dimensions relate to mood, motivation and cognitive states, but the *worry* dimension reflects only the cognitive component of affective states (Matthews *et al.*, 2002, 1999). False alarm-KR may therefore have pervasive effects across the mood, motivation and cognitive components of state, while miss-KR may influence primarily the cognitive component. The latter result does not conform to the original hypotheses, based on the findings of Dittmar *et al.* (1985) and Kluger and DeNisi (1996) that one would expect miss-KR would cause participants to engage in more of the *meta-task* processes associated with the *worry* dimension (Matthews *et al.*, 2002), and that these effects would be more likely for those higher in pessimism. However, individuals higher in pessimism who received miss-KR reported *less worry* after the vigil, indicating that they were engaging in less self-evaluative processes.

The interaction of KR with pessimism may also be influenced by the different coping strategies associated with the three dimensions of stress state. *Distress* and the absence of *task engagement* are associated with emotion-focused coping (Matthews & Campbell, 1998; Matthews *et al.*, 1999), and this form of coping is also typically adopted by pessimists (Helton *et al.*, 1999; Scheier & Carver, 1987). Further, Szalma (2002a) indicated that pessimism is associated with increased reliance on emotion-focused coping strategies. Thus, the differences between false alarm-KR and no-KR on the *distress* and *task engagement* dimensions may be due to less emotion focused coping among those low in pessimism. As pessimism increases, emotion focused coping increases, diverting processing resources to *meta-task processes* (Kluger & DeNisi, 1996), and thereby reduces the effectiveness of KR in reducing these symptoms.

Optimism

As expected, the interaction effects between KR and optimism were weaker than those between KR and pessimism. For participants who received false alarm-KR, higher levels of optimism were associated with decreased *worry* and lower levels of optimism associated with increased *worry*. However, higher optimism predicted lower *task engagement* across all KR conditions. Taken together, these results indicate that individuals high in optimism find false alarm-KR less aversive than those low on that trait, but optimism does not protect against loss of engagement. The reasons for the latter effect are a matter for future research.

Summary and conclusions

It is evident that the stress effects of vigilance are complex and multidimensional and that the effectiveness of KR in reducing stress depends on both the type of KR provided and characteristics of the individual. Taken together with the results of prior research in this area, the current study indicates that these KR effects depend on the perceptual demands of the task. The results of the present study also serve to underscore the importance of examining individual differences in stress responses to vigilance (Berch & Kanter, 1984). KR format did not significantly impact *distress* or *worry* dimensions of stress, but KR effects on these variables did emerge when dispositional pessimism and optimism were taken into account. Further investigation needs to be directed to explore these joint effects of feedback and observer characteristics on performance and stress in vigilance tasks. Such efforts can lead to improved training regimens that are tailored to the individual to maximize performance in crucial operational settings.

The hypotheses based upon FIT received partial support in that negative feedback did not enhance performance, and that false alarm-KR was effective in reducing stress symptoms only for those individuals low in pessimism. However, the predicted interaction effect on performance of feedback type and pessimism was not observed. Future investigations should test for this interaction by systematically manipulating participants' goals according to the hierarchy described in Kluger and DeNisi (1996).

Since 9/11, the world has become much more wary and invested in safety and security systems. Often, these individuals and the technology created to help them perform their tasks are looking for the equivalent of a 'needle in a haystack'. Even with highly sensitive systems and highly motivated observers, such rare signal occurrences lead to an abundance of false alarms (Parasuraman, Hancock, & Olofinboba, 1997) that eventually society in general will not tolerate. From our present experiment, it is clear that the effectiveness and efficiency of vigilance is contingent upon the character of the targets being searched, how that information is presented, and the nature of the individual to whom it is presented. The current findings point to the strong, interactive nature of these factors and begin to chart a course to better systems, better selection and better training for those who perform this vital task.

Acknowledgements

Completion of this work was supported in part by the Department of Defense Multidisciplinary University Research Initiative (MURI) program administered by the Army Research Office under Grant DAAD19-01-1-0621. P. A. Hancock, Principal Investigator. The views expressed in this work are those of the authors and do not necessarily reflect official army policy. The authors wish to thank Dr Sherry Tove, Dr Elmar Schmeisser and Dr Mike Drillings for providing administrative and technical direction for the grant.

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Received 20 April 2005; revised version received 14 July 2005