INTRACLASS AND INTERCLASS TRANSFER IN TRAINING FOR VIGILANCE

A thesis submitted to the

Division of Graduate Education and Research
of the University of Cincinnati

in partial fulfillment of the
requirements for the degree of

MASTER OF ARTS

in the Department of Psychology
of the College of Arts and Sciences

1997

by

James L. Szalma

B.S., University of Michigan, 1990

Committee Chair: Joel S. Warm, Ph.D.

ABSTRACT

The expanded use of automation in our technological society has increased the importance of vigilance or monitoring functions in the workplace. As a result, the problem of training for vigilance is a salient human factors concern (Warm, 1993). In an influential study, Wiener (1967) argued that the problem may not be an especially complex one, since training for vigilance is primarily general in character. Hence, he suggested that training on one vigilance task may transfer to another regardless of the precise requirements of the two tasks.

A challenge to this view comes from a study by Becker, Warm, and Dember (1994) which made use of simultaneous (SIM), or comparative judgment, and successive (SUC), or absolute judgment, vigilance tasks (cf. Parasuraman, Warm, & Dember, 1987). Becker and her associates reported that training in a SIM task with knowledge of results (KR) did not transfer to performance on a SUC task, and that while there was general transfer in the SUC to SIM direction, it was considerably weaker than the specific transfer effects observed in conjunction with the SIM-type vigilance task. Accordingly, they suggested that training for vigilance is task-type specific and that the skills and knowledge that monitors acquire in relation to a particular class of tasks

are paramount in determining transfer of training in vigilance.

Note that Becker et al. made use of the maximum conditions for specific transfer in their study: Monitors trained on one task were tested on the identical task in the specific transfer conditions (Underwood, 1966). Thus, while Becker et al. clearly established a task asymmetry in the transfer of vigilance training, the limits of the specific component of transfer are unknown, since task-specific effects were confounded with potential display-specific effects in their experiment. One goal for this investigation was to disengage the task-specific and display-specific components with regard to training for a SIM-type vigilance task. Toward that end, comparisons were made of transfer effects on a criterion SIM task (featuring vernier discriminations) which result from training on the criterion task itself or a SIM task featuring a different display (discriminations of spatial distance). Transfer of training from a SUC-task (also featuring spatial distance discriminations) to the criterion task was measured as well.

A second goal for the present study was to assess performance differences in the training and transfer phases in terms of signal detection measures of perceptual sensitivity (d') and response bias (the index c; See, Howe, Warm, & Dember, 1995; See, Warm, Dember, & Howe, 1997).

While such measures have been used extensively in vigilance studies involving KR-training (Warm, 1993), they have not been used in examining KR-based transfer effects. Thus, the degree to which such effects are mediated by perceptual and response bias factors is unknown at present.

Participants experienced a 24-min. training vigil divided into three continuous 8-min. periods and a 32-min. test vigil divided into four continuous 8-min. periods. In both phases of the study, participants monitored stimuli presented on a VDT. Sixteen observers (8M, 8F) were assigned at random to one of the following six groups defined by the nature of their training experience. (1) SIM/Criterion/KR--Participants received KR training on the SIM task to be used later in the testing phase of the study; (2) SIM/Alternate/KR--Participants received training on an alternate task that was categorically identical to the criterion task but which featured a different display format, and then tested on the SIM-criterion task; (3) SUC/KR--Participants were trained on a SUC task that featured the same display format as the SIM/Alternate/KR task and then tested on the criterion task. Unlike observers in groups 1-3, those in groups 4-6 did not receive KR training, and were tested on the criterion task after initial experience with either that task itself (4-SIM/Criterion/No-KR), the SIM-alternate task (5-

SIM/Alternate/No-KR), or the SUC-task (6-SUC/No-KR). The last three groups served as controls for the effects of KR as well as for those associated with task exposure and changes in display format per se. During training, observers who received KR were informed of correct detections (hits), commissive errors (false alarms), and omissive errors (misses) by means of a recorded female voice which announced "correct" to indicate correct detections or hits, 'false alarm" to indicate an error of commission or false alarm, and "miss" to indicate a nondetection or miss.

In the SIM/Criterion task, observers monitored 200 msec flashes of a doughnut-like circular display flanked by two horizontal lines for occasional events for which the two lines were not aligned with one another. The SIM/Alternate task consisted of 200 msec flashes of a large centering disk flanked by two smaller dots. Critical signals for detection were cases in which one of the smaller dots (left or right) was farther from the centering dot than the other one. The SUC task consisted of 200 msec flashes of a large centering disk flanked by a smaller dot either on the left or the right. Critical signals for detection were events for which the small dot was farther from the large dot than usual (either to the left or the right).

The presence of KR enhanced d' for all three tasks during training, but the effects of such training only transferred to subsequent performance on the criterion task for observers trained on the SIM/Alternate task. This result supported the conclusion reached by Becker et al. (1994) that perceptual learning in vigilance is not general in character. Rather, it is task-type specific.

Training with KR induced observers in the criterion and SIM/Alternate tasks to adopt a more cautious mode of responding, an effect which also transferred across task boundaries. Unfortunately, the degree to which specific and general factors contributed to such transfer could not be assessed since KR training had no impact upon response bias with the SUC task. The fact that KR affected observers' response strategies on tasks requiring comparative but not absolute judgments suggests that complex interactions may exist between task types and KR formats in training for vigilance. Further research is needed to clarify these interactions.

The dissimilarity in results obtained with the SIM/Alternate and SUC tasks on both signal detection theory measures is dramatic, given the fact that except for the type of discrimination required, these tasks were more alike in terms of general task architecture than either was to the criterion task. Consequently, the present results lend support to Davies and Parasuraman's (1982) assertion that

SIM- and SUC-type vigilance tasks provide observers with singular psychophysical challenges.

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CHAPTER I

Introduction

The Problem of Vigilance

Vigilance or sustained attention refers to the ability of observers to detect transient and infrequent signals over prolonged periods of time (Davies & Parasuraman, 1982; Dember & Warm, 1979; Warm, 1984). The systematic study of this ability originated with Mackworth's (1948;1950/1961) efforts during the Second World War to understand why British airborne radar observers missed U-boat contacts while on antisubmarine patrol. More than half a century later, vigilance remains a significant concern to human factors and ergonomic specialists because of its importance in many automated human-machine systems (Howell, 1993; Proctor & Van Zandt, 1994; Wickens, 1992).

As Sheridan (1970; 1987) has noted, the expanded use of automation in our technological society has altered the role of human operators in many work settings from that of active, hands-on controller to that of a monitor/executive, who must attend to displays and take action only in the event of imminent problems. Hence, operator vigilance is a vital aspect of system function in situations such as air-traffic control, cockpit monitoring, industrial process and quality control, and robotic manufacturing (Parasuraman, 1986; Pigeau, Angus, O'Neill, & Mack, 1995; Satchel, 1993; Warm, 1984; 1993). Vigilance is also a crucial element of performance efficiency in many medical settings, including cytological screening and the inspection of anesthesia gauges during surgery (Daly & Wilson, 1993; Gill, 1996; Paget, Lambert, & Sridhar, 1981; Weinger & Englund, 1990). Failure to notice untoward critical events in venues such as these can have serious consequences for worker productivity and for public health and safety. Thus, knowledge of the factors which influence vigilance and how best to train operators for tasks requiring sustained attention is a salient human factors concern (Warm, 1993).

Training For Vigilance

For the most part, training for vigilance has featured the use of feedback in the form of knowledge of results (KR) regarding the quality of operators' performance (Warm & Jerison, 1984). Such an approach is consistent with the use of KR as a training vehicle for many other perceptual and motor functions (Annett, 1969; Bilodeau, 1969; Gibson, 1969; Newell, 1981; Proctor & Dutta, 1995; Salmoni, Schmidt, & Walter, 1984). While KR has not always been effective as a training method in other areas (Kluger & DeNisi, 1996), vigilance studies have consistently reported that KR enhances the speed and accuracy of signal detections in sustained attention tasks (Becker, Warm, Dember, & Hancock, 1995; Chinn & Alluisi, 1964; Hardesty, Trumbo, & Bevan, 1963; McCormack, 1959; McCormack, Binding, & Chylinski, 1962; Sipowicz, Ware, & Baker, 1962; Warm, Epps, & Ferguson, 1974; Warm, Reichman, Grasha, & Seibel, 1973). In addition, as would be expected of a meaningful training vehicle, the beneficial effects of KR-based instruction transfer to subsequent conditions where KR is withdrawn (Adams & Humes, 1963; Warm et al., 1973; Wiener, 1963; 1968).

A central issue in transfer of training concerns the nature of such transfer, i.e., whether it results from general, nonspecific factors such warm-up or learning-to-learn, or from factors specific to the particular task in question, or some combination thereof (Ellis, 1969; Houston, 1981; Postman, 1971; Underwood, 1966). In an influential study, Wiener (1967) argued that the problem of training for vigilance may not be an especially complex one, since such training is primarily general in character. That is, training on one vigilance task may transfer to another regardless of the precise information-processing requirements of the two tasks.

A challenge to this view comes from Davies and Parasuraman's (1982) claim, based upon their information-processing model, that vigilance tasks can be classified as simultaneous or successive in character. The former are comparative judgment tasks in which all the information needed to distinguish signals from noise is present in the stimuli themselves, and there is no need to consult working memory for the detection of signals. An example might be a case in which observers must determine whether one line in a pair of lines is longer than the other. In contrast, successive tasks are absolute judgment tasks in which observers must consult working memory in order to separate signals from nonsignals. An example is the case in which observers must determine whether a target line is longer than normal. As a result of the memory imperative, Davies and Parasuraman (1982) maintain that simultaneous and successive tasks are singular in nature and that successive tasks are more capacity-demanding than their simultaneous counterparts. A considerable amount of evidence is available to support this view. In a comprehensive review of the validity of Davies and Parasuraman's task taxonomy, Warm and Dember (in press) noted that inter-category task correlations are generally quite low ($r \leq .30$) while correlations among tasks within a category are much higher (r = .60-.80), even when the tasks involved in the correlations crossed sensory boundaries. Moreover, peformance on successive tasks is more likely than that on simultaneous tasks to be degraded by psychophysical challenges, such as increments in event rate (the rate of cascade of stimulus events in which critical signals for detection are embedded) and the spatial uncertainty of signals, which increases the information-processing demands placed upon observers. The simultaneous/successive distinction leads to the possibility that transfer of training in vigilance may be far less general in character than Wiener (1967) believed.

Using the line displays described above and knowledge of results (KR) as the training vehicle, Becker, Warm,and Dember (1994) tested Wiener's generality notion by comparing the relative strengths of general and specific transfer in training with simultaneous and successive vigilance tasks. Specific transfer was assessed by training observers on either the simultaneous or successive versions of the line display and then testing them on the identical display. General transfer was evaluated by training observers on one categorical version of the display and then testing them on the other version -- i.e., training on the simultaneous version and testing on the successive, or vice versa. Becker and her associates found strong evidence for specific transfer in both the simultaneous and successive formats. However, training in a simultaneous format did not transfer to subsequent successive-task performance, and while there was general transfer in the successive-to-simultaneous direction, it was considerably weaker than the specific transfer effects observed in conjunction with the simultaneous-type vigilance task. Accordingly, Becker et al. suggested that training for vigilance is task-type specific and that the skills and knowledge that monitors acquire in relation to a particular class of tasks are paramount in determining transfer of training in vigilance.

The Limits of Specific Transfer

As described by Underwood (1966), the approach adopted by Becker et al. of training observers on one task and testing them on the identical task made use of the maximum conditions for assessing specific transfer. While an approach of this sort can provide strong evidence for such transfer when the training task per se is the primary dimension of interest, it does not necessarily provide compelling evidence for specific transfer when the training task is taken as a representative of a class of tasks (in this case, tasks in the simultaneous or successive categories), since category-specific effects are then confounded with potential display-specific effects. Thus, while Becker and her colleagues clearly established a task asymmetry in the transfer of vigilance training, the limits of the specific component of transfer cannot be determined from their experiment.

Accordingly, one goal for the present investigation was to disengage category-specific and display-specific components in regard to specific transfer in training for vigilance. Toward that end, a SIMULTANEOUS-TYPE TASK featuring vernier discriminations was employed as a criterion task, and comparisons were made of transfer effects which resulted from (a) training on the criterion task itself, (b) training on another SIMULTANEOUS task featuring discriminations of spatial distance, and (c) training on a SUCCESSIVE task which also featured spatial distance discriminations. If, as Becker and her associates (1994) suggest, transfer of training in vigilance is indeed task-type specific, we should expect that transfer to the criterion task in this study will be greater from another simultaneous task than from a successive task.

Sensing and Decision Making Aspects of Vigilance Training

The theory of signal detection (TSD) is a model of perceptual processing which permits the independent characterization of observers as sensors and as decision makers (Green & Swets, 1966; Macmillan & Creelman, 1991). This model has received wide use in regard to many perceptual issues (Commons, Nevin, & Davison, 1991) and has been applied extensively in studies of vigilance (Davies & Parasuraman, 1982; Warm & Jerison, 1984). For example, a TSD analysis of the vigilance decrement, the decline in the frequency of signal detections over time which typifies vigilance performance (Warm, 1984), has shown that the decrement reflects both a decrease in the observer's ability to distinguish signals from noise and a change in response strategy whereby observers become more conservative in responding over the course of a vigil (See, Howe, Warm, & Dember, 1995; See, Warm, Dember, & Howe, 1997).

In addition to the vigilance decrement, TSD measures have also been employed to assess the manner in which KR influences vigilant behavior. Thus, Dittmar, Warm, & Dember (1985) reported that feedback regarding correct detections

(Hit-KR) and its inverse, feedback concerning errors of commission (False alarm-KR), enhanced observers' levels of perceptual sensitivity and eliminated the vigilance decrement, a result which suggests that this type of feedback can augment signal definition. In addition, Dittmar and her associates also reported that KR alters the response strategies that observers adopt in performing a vigilance task. They found that False alarm-KR promotes a conservative response strategy, while Hit-KR and feedback concerning missed signals (Miss-KR) lead observers to be more lenient in emitting detection responses. These findings have essentially been replicated by Becker (1990). It is noteworthy that while KR has been shown to influence both sensitivity and bias in vigilance studies, the transfer properties of these effects have not been addressed. Accordingly, the effort in this study to examine the limits of specific transfer in training for vigilance was conducted within the context of the sensing and decision-making aspects of performance with KR as the training vehicle.

CHAPTER II

Method

Observers. Ninety-six psychology students, 48 men and 48 women, from the University of Cincinnati served as observers to fulfill a course requirement. They ranged in age from 17 to 34 years, with a mean age of 21 years. All participants had normal or corrected-to-normal vision and were free of any known hearing impairment.

Design. Three task conditions (Simultaneous/criterion, Simultaneous/alternate, and Successive) were combined factorially with two levels of KR (KR, No-KR) to produce six experimental groups. Sixteen observers were assigned at random to each group with the restriction that the groups were equated for sex (8 men and 8 women). As shown in figure 1, the groups were defined by the nature of their KR-training/transfer experience:

(1) Simultaneous/Criterion/KR--observers received KR training on the SIMULTANEOUS/criterion task and were then tested on that task; (2) Simultaneous/Alternate/KR--observers received training on the alternate SIMULTANEOUS task and were then tested on the Criterion task; (3) Successive/KR--observers were trained on a SUCCESSIVE task and then were tested on the Criterion task. Unlike observers in groups 1-3, those in groups 4-6 did not receive KR-training. They were tested on the CRITERION task after initial experience with either that task itself, (4) Simultaneous/Criterion/No-KR, the SIMULTANEOUS/alternate task, (5)

Simultaneous/Alternate/No-KR, or the SUCCESSIVE task, (6) Successive/No-KR. The latter three groups served as controls for the effects of KR as well as for any effects associated with task exposure itself, such as warm-up, learning-to-learn, and changes in display format (Ellis, 1965; Hall, 1966; Underwood, 1966).

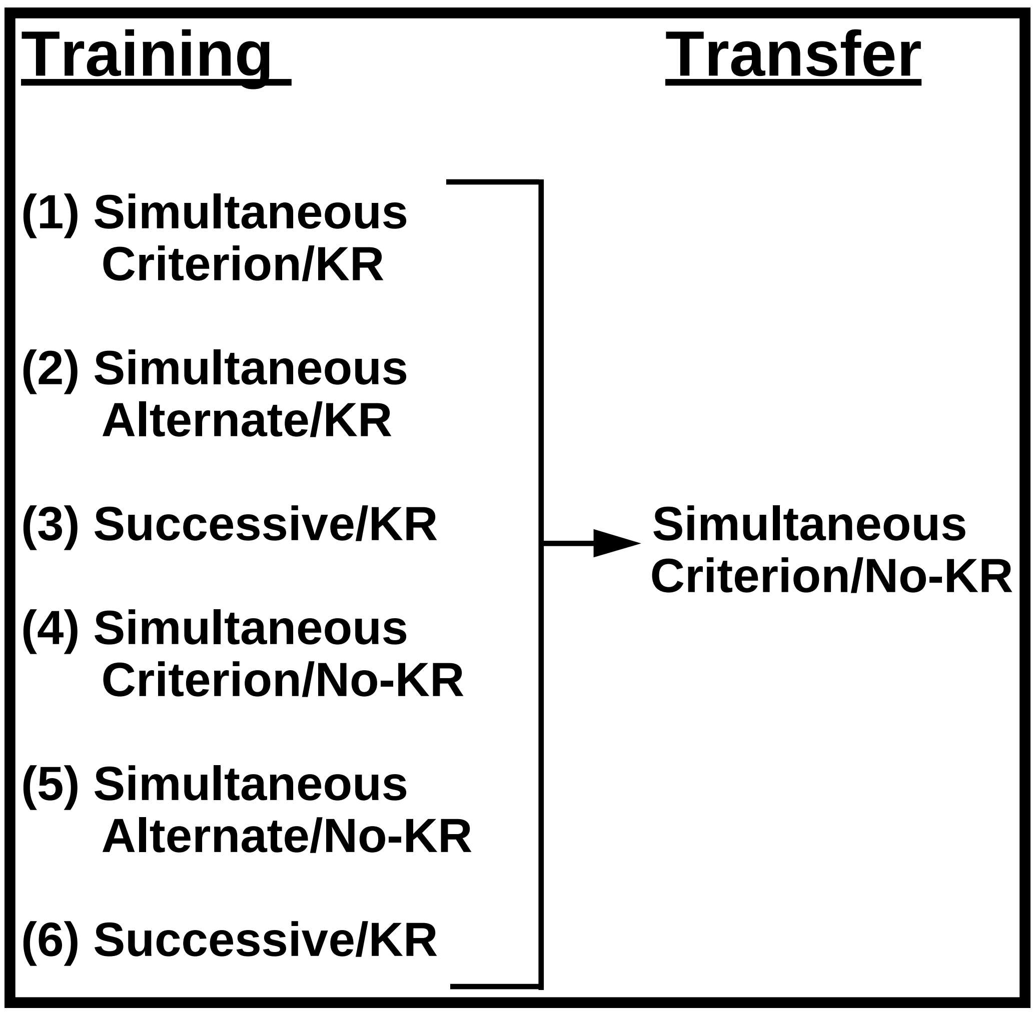

Figure 1: Experimental groups used in the present study. The groups were defined by the nature of their KR training/transfer experience.

Apparatus and Procedure. Observers experienced a 24-min. training vigil divided into three continuous 8-min. periods and a 32-min. test vigil divided into four continuous 8-min. periods. As in the Becker et al.(1994) study, KR was provided during training and withdrawn during the test vigil. In both phases of the study, observers monitored 200 msec presentations of stimuli presented on a VDT.

Figure 2 portrays the three vigilance tasks that were used in the study. All stimuli were green in color and were presented against a gray background. The Criterion task consisted of a doughnut-like circular display. The diameter of the outer border of the “doughnut” was 2 cm, while that of its inner border was 1 cm. The ring of the doughnut was 0.5 cm thick. The circular display was flanked (0.3 cm) on both sides by two 1.1 x 0.1 cm horizontal lines which were normally aligned with each other along the horizontal diameter of the doughnut or along chords 0.2 cm above or below that diameter. Critical signals for detection were cases in which the lines were misaligned (i.e., one line was 0.2 cm above or below the horizontal diameter of the doughnut). The Simultaneous/alternate task consisted of a large centering disk 1.4 cm in diameter flanked by two dots 0.3 cm in diameter arrayed along a horizontal vector which passed through the center of the disk. Normally, the dots were positioned so that they both were either 1.5 cm or 1.0 cm away from the disk. Critical signals were cases in which

one of the dots, left or right, was 1.5 cm away and the other was 1.0 cm from the disk. The Successive task made use of a display identical to that employed in the Simultaneous/alternate task, except that only a single flanking dot was used. The dot appeared either to the left or right of the disk. Normally, it was positioned 0.9 cm away; critical signals were cases in which the dot was 0.3 cm farther away from the disk than usual.

It can be seen in Figure 2 that while the Criterion task and the Simultaneous/alternate task both required comparative judgments, they differed considerably in basic task architecture. The former featured a doughnut-line format in which neutral events could be instantiated in three ways, and critical signals, in terms of vernier misalignments, in four ways. The Simultaneous/alternate task featured a disk-dot format in which neutral events and critical signals, in terms of spatial distance judgments, were each instantiated in only two ways. While the Successive task required a different class of judgment than its cohorts, it shared much of the task architecture of the Simultaneous/alternate task. Like the latter, it featured a disk-dot format with two instantiations of both neutral events and critical signals and discriminations were made in terms of spatial distance. Thus, any differences in transfer characteristics observed with these two tasks cannot be attributed to gross structural differences. Pilot work insured that the three tasks were equated for psychophysical difficulty under alerted conditions using a two-alternative forced choice procedure.

During training, observers who received KR were informed of correct detections (hits), commissive errors (false alarms), and omissive errors (misses) by means of a recorded female voice (50 dBA, at the observer’s ear) which announced "correct" to indicate correct detections or hits, "false alarm" to indicate an error of commission, and “miss” to indicate a failure of detection. Rather than using separate KR formats for Hits, Misses, and False Alarms, as in the case of Becker (1990) and Dittmar, Warm, and Dember (1985), composite KR was employed in this study to duplicate the training procedure employed by Becker et. al. (1994). In order to control for accessory auditory stimulation, observers in the control groups heard the word "save" which was announced in the female voice after each response. A 15-min. interval separated the training and transfer phases of the study.

Observers were tested individually in a 1.95 x 1.90 x 1.88 meter Industrial Acoustics sound-attenuated chamber. They were seated in front of the VDT, which was mounted on a table at eye level with a viewing distance of 70 cm. Ambient illumination in the chamber was 0.74 cd/m^2 and was provided by a 25W soft white incandescent bulb housed in a parabolic reflector positioned above and behind the seated observer so as to minimize glare on the VDT. The VDT was positioned in front of a white wall.

Upon reporting for the experiment, observers completed an informed consent form (Appendix A) and surrendered their watches. They had no knowledge regarding the length of the sessions other than that the entire experiment would not exceed 90 min. Before each session, instructions (Appendix B) were displayed on the VDT and were read aloud by the experimenter.

Stimuli for inspection in all experimental conditions occurred once every 1.9 sec (event rate = 30/min.); critical signal probability was 0.036. Stimulus presentations and the delivery of KR or response acknowledgement ("save") were orchestrated by a Macintosh IIci computer in conjunction with a color monitor and SuperLab(v1.5)software. Observers indicated the detection of critical signals by pressing the spacebar on the computer keyboard. Responses occurring within 1.3 sec after the appearance of a critical signal were recorded automatically by the computer as correct detections. All other responses were tallied as false alarms.

CHAPTER III

Results

For each observer, percentages of correct responses and false alarms during the training and transfer phases of the study were used to compute signal detection theory measures of sensitivity (d') and response bias(c). The index c was used in preference to the more traditional measure β because of recent evidence indicating that c is more sensitive to experimental manipulations than β (See, Warm, Dember, & Howe, 1997).

Perceptual Sensitivity

Mean d' values for the KR and No-KR conditions during <u>training</u> are plotted as a function of periods of watch in Figure 3. Data for the three tasks are presented separately in each panel.

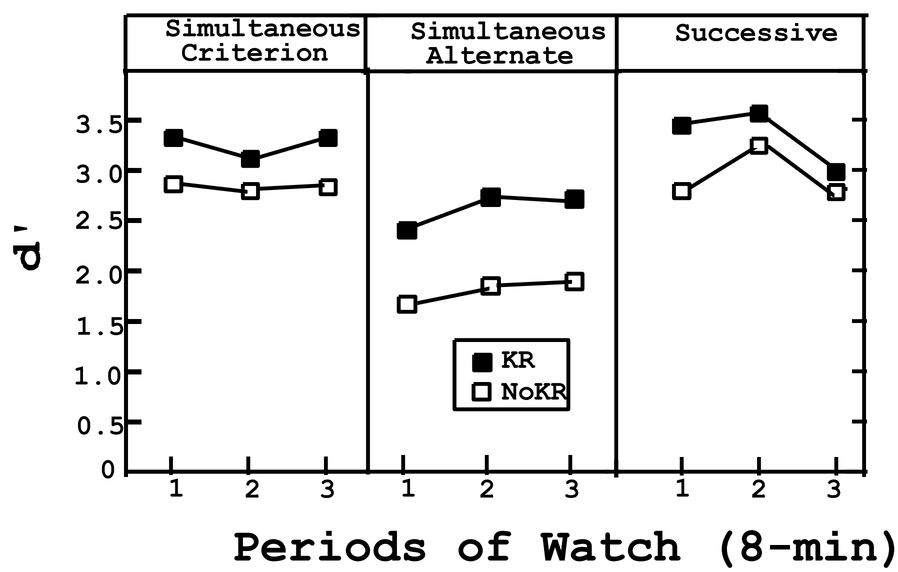

Figure 3: Perceptual sensitivity with and without KR as a function of periods of watch during training. Data for the simultaneous/criterion, simultaneous/alternate,and successive tasks are presented separately in each panel.

It is evident in the figure that KR served to increase perceptual sensitivity within each task. An analysis of variance of these data revealed significant main effects for KR, $F(1,90) = 13.45$, $p < 0.001$, and for task, $F(2,90) = 12.03$, $p < 0.001$.[1] It can be seen in the figure that the training scores in the Simultaneous/alternate task (M = 2.32) were lower than those in the Criterion (M = 3.04) and the Successive (M = 3.08) tasks. The main effect for periods of watch during training was not significant, $F(2,180) = 1.77$, $p > 0.05$. However, there was a significant Periods x Task interaction, $F(4,180) = 4.37$, $p < 0.01$. All other interactions involving KR, Task, and Time were not significant ($p > 0.05$ in each case). Thus, the effects of KR were similar for all three tasks throughout the training session.

Tests for the simple effects for periods within each task revealed that there was a significant change in sensitivity for observers in the Successive task across the three periods of watch, $F(2,180) = 7.60$, $p < 0.001$. As can be seen in Figure 4, sensitivity in the Successive task increased from period 1 to period 2 but then dropped in period 3. No significant differences across periods were found in the Simultaneous/criterion task, $F(2,180) < 1$, $p > 0.05$, or the Simultaneous/alternate task, $F(2,180) = 2.24$,

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[1]ANOVA tables for perceptual sensitivity and response bias scores during both training and transfer sessions are presented in Appendix C.

$\underline{p} > 0.05$, indicating that periods differences were localized within the Successive task.

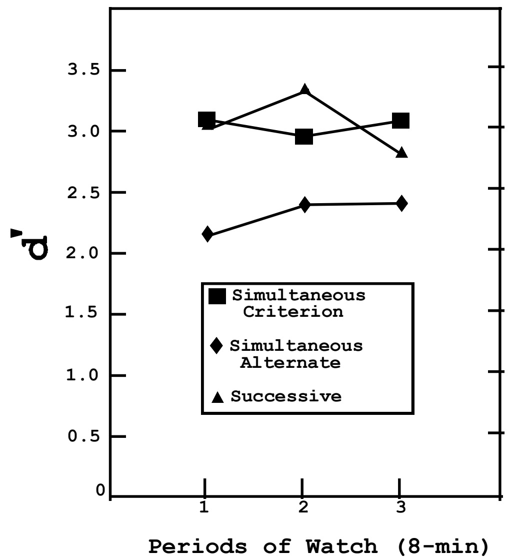

Figure 4: Perceptual sensitivity in three experimental tasks as a function of periods of watch during training.

In order to assess the effects of KR-training on subsequent perceptual sensitivity in the Criterion task, comparisons were first made of the transfer-phase sensitivity scores attained by observers in the three No-KR groups. As shown in Figure 5, these values were quite similar.

An analysis of variance of the transfer data for the three No-KR groups revealed that while perceptual sensitivity declined significantly over time in these groups, $\underline{F}(3,135) = 6.75$, $\underline{p} < 0.001$, there were no significant overall differences among the groups, and there was no significant Groups x Periods interaction ($\underline{p} > 0.05$ in each case). Given the equivalence among the No-KR groups, the data for the Criterion/No-KR group were used as the baseline against which to assess the transfer effects to the

Criterion task of KR-training on that task, the Simultaneous/alternate task, and the Successive task.

Mean d' scores during transfer for the three KR groups and the Criterion/No-KR group are plotted as a function of periods of watch in Figure 6.

It is evident in the figure that during the transfer phase, the scores for observers who received KR-training on the Simultaneous/alternate task were similar to those who were originally trained on the Criterion task itself, and that the scores for both of these groups were consistently higher than those for the Criterion/No-KR control group. The scores for observers originally trained on the Successive task and now tested on the Criterion task fell between those of the control group and the two other groups. The figure also shows that in all cases, sensitivity declined over the course of the watch.

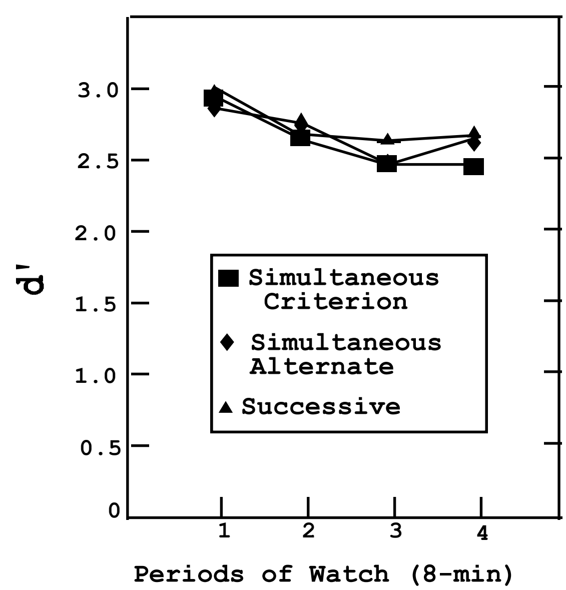

Figure 5: Perceptual sensitivity on the criterion task during transfer for groups not exposed to KR-training. Data are plotted as a function of time on task.

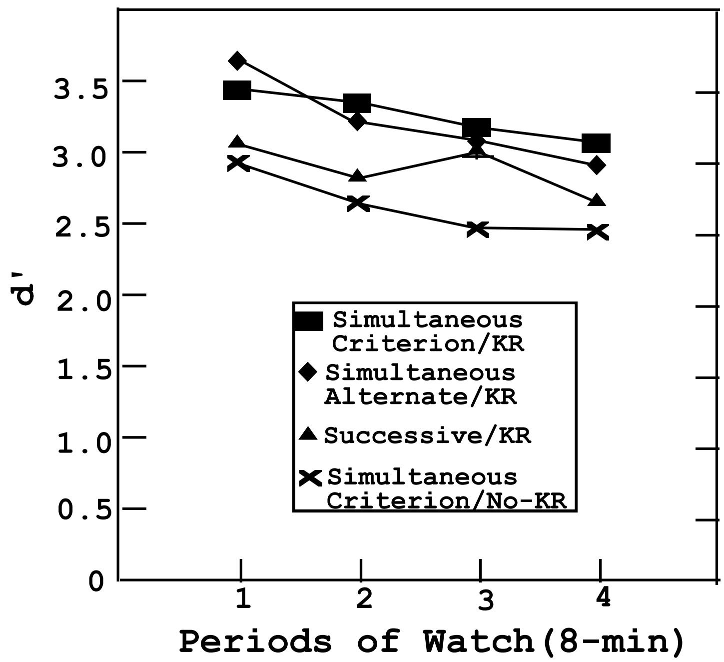

Figure 6: Perceptual sensitivity on the criterion task during transfer for groups receiving KR-training and the No-KR criterion control group. Data are plotted as a function of time on task.

An analysis of variance of the transfer d' data revealed significant main effects for Groups, $F(3,60) = 3.34$, $p < 0.05$, and for Periods, $F(3,180) = 11.12$, $p < 0.001$. The interaction between these factors was not significant. Subsequent Newman-Keuls tests, with alpha set at 0.05 for each comparison, revealed that the Criterion/KR and the Simultaneous/KR groups did not differ significantly from each other and that the d' scores of both of these groups significantly exceeded those of the Criterion/No-KR control group. In contrast, the transfer performance of the Successive/KR group failed to differ significantly from that of the control group. Thus, in terms of perceptual sensitivity, the data provide strong evidence for intra-task or specific transfer but no evidence for inter-task or general transfer.

Response Bias

Mean response bias or “c” values in all experimental conditions are displayed in Figure 7. Once again, data for the three tasks are presented separately in each panel. With the "c" measure, negative values denote leniency and positive values conservatism.

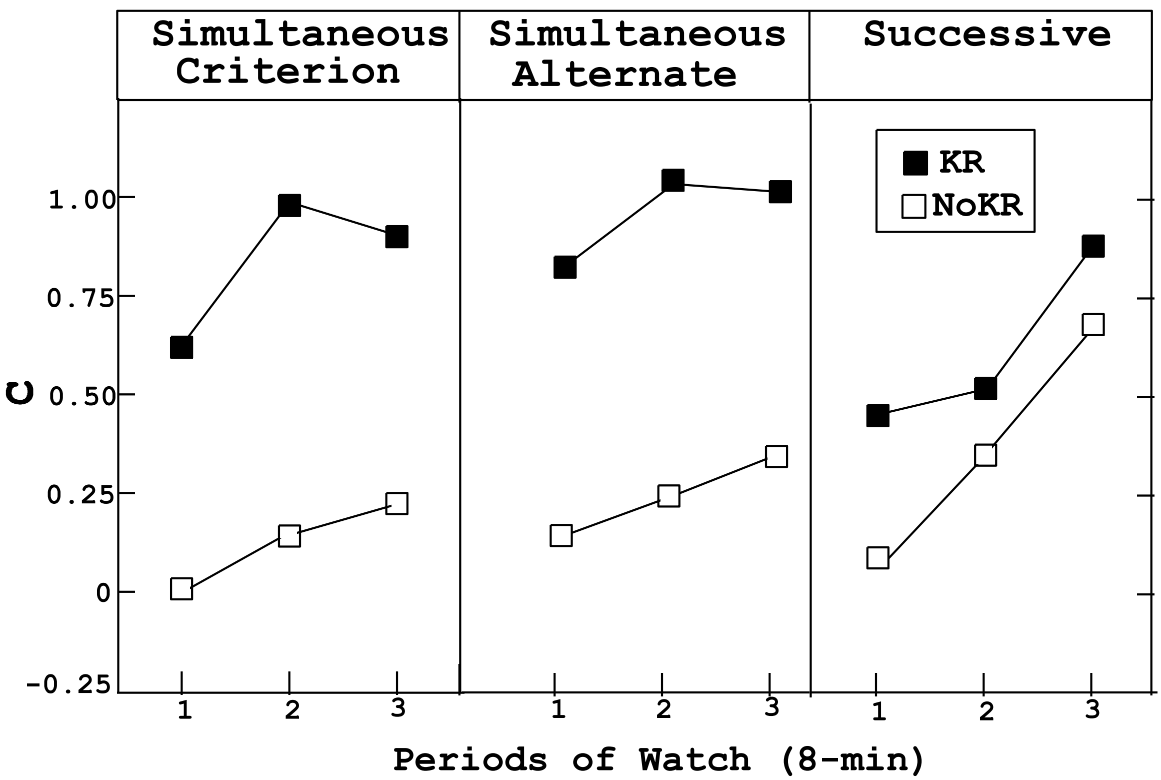

Figure 7: Response bias with and without KR as a function of periods of watch during training. Data for the simultaneous/criterion, simult-aneous/alternate,and successive tasks are presented separately in each panel.

It is evident in the figure that observers in all task conditions became more conservative in responding over time and that KR served to increase the overall level of conservatism, more so in the Criterion and Simultaneous/alternate tasks than in the Successive task.

These effects were confirmed by an analysis of variance which revealed significant main effects for Periods of watch, $F(2,180) = 27.87$, $p < 0.001$, and for KR, $F(1,90) = 54.24$, $p < 0.001$. There was also a significant Task x KR interaction, $F(2,90) = 4.24$, $p < 0.05$, and a significant Task x Periods interaction, $F(4,180) = 3.89$, $p < 0.004$.

Tests for the simple effects of KR within each task indicated that observers in both the Criterion and Simultaneous/alternate tasks who received KR were significantly more conservative than their No-KR controls, $F(1,90) > 29$, $p < 0.001$ in each case. However, the effects of KR were negligible in the case of the Successive task: $F(1,90) = 3.51$, $p > 0.05$.

Tests for the simple effects of periods within each task revealed that there was a significant change in response bias for observers in all three tasks across the three periods of watch: Simultaneous/criterion task, $F(2,180) = 7.22$, $p < 0.01$; Simultaneous/alternate task, $F(2,180) = 3.89$, $p < 0.05$; Successive task, $F(2,180) = 23.78$, $p < 0.01$. As can be seen in Figure 8, response bias in all three tasks increased from period 1 to period 2, but changed little in the Simultaneous/criterion and

Simultaneous/alternate tasks from period 2 to period 3. In contrast, response bias changed considerably in the Successive task from period 2 to period 3.

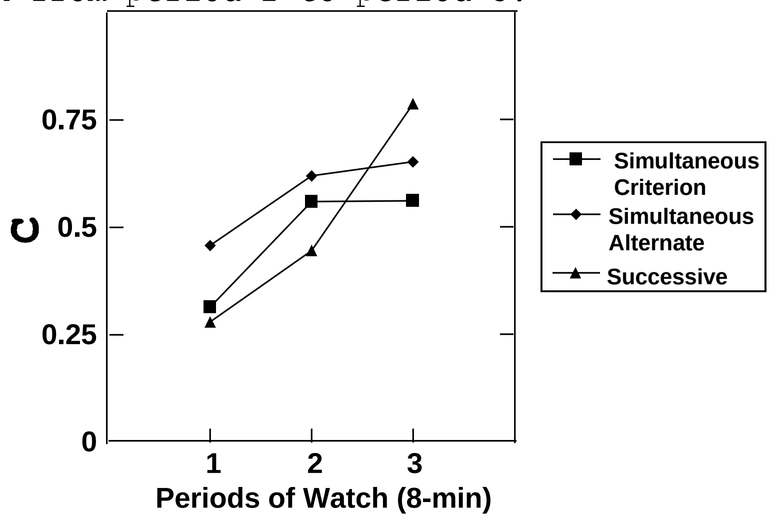

Figure 8: Response bias in three experimental tasks as a function of periods of watch during training.

The absence of a KR effect in the response bias data for the Successive Task during training mandated that the assessment of transfer effects in regard to response bias be restricted to the Criterion and Simultaneous/alternate tasks. As in the case of the d' scores, transfer-phase c-scores for the No-KR groups were first compared in order to establish a baseline for evaluating transfer effects in the groups which received KR-training. As shown in Figure 9, the c-scores during transfer for the two No-KR groups were quite similar and increased consistently over the course of the transfer portion of the experimental session. An analysis of variance of these data revealed a significant main effect for Periods, $F(3,90) = 8.38$, $p < 0.001$, but no significant overall task difference, $F(1,30) = 0.06$, $p > 0.05$, and no significant Periods x Task interaction, $F(3,90) = 0.97$, $p > 0.05$.

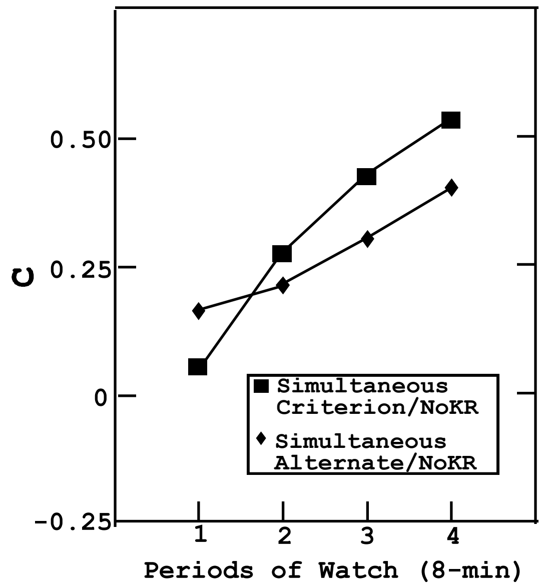

Figure 9: Response bias on the criterion task during transfer for the criterion and simultaneous/alternate No-KR control groups. Data are plotted as a function of periods of watch.

Given the equivalence of the two No-KR control groups during transfer, the data of the Criterion/No-KR group were again employed as the baseline against which to assess transfer effects in the Criterion/KR and Simultaneous/alternate-KR groups. As shown in Figure 10, c-scores on the Criterion task during transfer for observers who received KR-training on the Simultaneous task were similar to those who received KR-training on the Criterion task itself, and in both of these groups, the level of conservatism was consistently greater than that in the control group. In addition, the figure shows that the level of conservatism increased over time in all three groups.

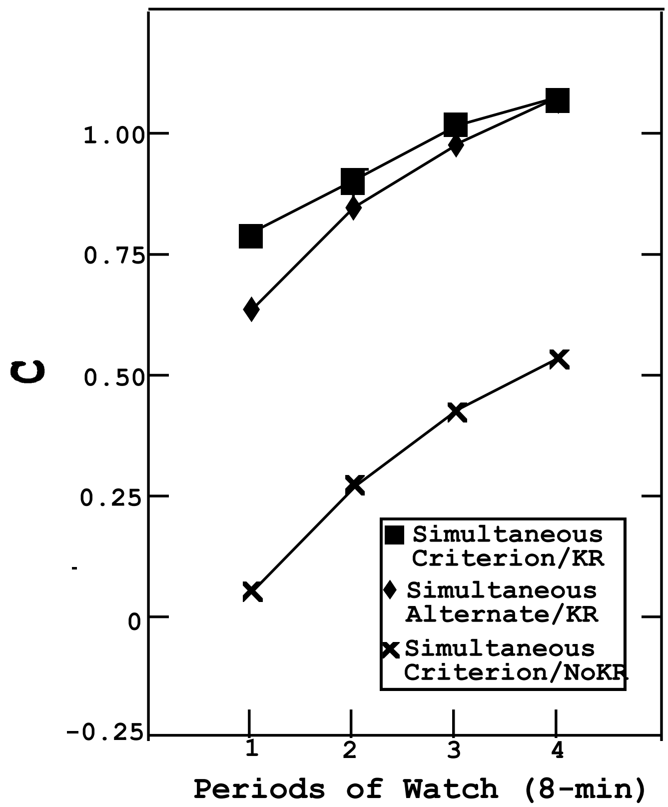

Figure 10: Response bias on the criterion task during transfer for groups receiving KR-training and the criterion No-KR control group. Data are plotted as a function of periods of watch.

These impressions were supported by an analysis of variance which indicated that there were significant differences among the groups, $F(2,45) = 10.94$, $p < 0.001$, and that the overall level of conservatism increased significantly over time, $F(3,135) = 16.51$, $p < 0.001$. The interaction between these factors was not statistically significant, $F(6,135) = 0.37$, $p > 0.05$. Subsequent Newman-Keuls tests ($\alpha = 0.05$ for each comparison) revealed that the Simultaneous/criterion/KR and the Simultaneous/alternate/KR groups did not differ significantly from one another and that the c-scores of both of these groups significantly exceeded those of the Simultaneous/criterion/ No-KR control group.

CHAPTER IV

Discussion

The purpose for the present study was twofold: (1) to disengage potential display-specific from category-specific transfer effects in KR-training for vigilance, and (2) to determine the degree to which such training/transfer effects are reflected in changes in perceptual sensitivity and response bias.

As in several earlier experiments (Becker, 1990; Becker, Warm, Dember, & Hancock, 1995; Dittmar, Warm, & Dember, 1985), KR-training was found to enhance perceptual sensitivity. In addition, the training effects were indeed transferable from one task to another, but successful transfer depended upon the types of tasks involved. During the transfer phase of the study, perceptual sensitivity on the Criterion task was identical for observers trained initially on that task and those trained on another simultaneous task having a different display architecture. Moreover, the scores for both groups significantly exceeded those for the Criterion control group participants, who were not afforded training with information feedback. In contrast to the Simultaneous/alternate group, transfer scores on the Criterion task for observers whose initial training was on the Successive task did not differ significantly from those of controls who experienced the Criterion task without KR-training. Thus, the transfer effects noted in regard to perceptual sensitivity did not support Wiener's (1967) claim that training in vigilance is primarily general in character, nor did they support the argument that such effects might be display-specific. Instead, they sustained the conclusion reached by Becker et al. (1994) that perceptual learning in vigilance is task-type specific. The similarity in the sensitivity scores of the Criterion/KR and Simultaneous/alternate/KR groups during transfer is especially noteworthy, given the fact that the level of perceptual sensitivity associated with the Simultaneous/alternate task during training was lower than that associated with the Criterion task, and the fact that transfer is often weakened by differences in the level of difficulty between training and test tasks (Ellis, 1965; Holding, 1987).

Along with its influence on d', KR-training also affected observers' response strategies, inducing those in the Criterion and Simultaneous/alternate groups to adopt a more cautious mode of responding. This effect also transferred across task boundaries: The level of conservatism evident in the transfer phase of the study was identical for observers trained initially on the Criterion task to that of those trained on the Simultaneous/alternate task. Unfortunately, the degree to which specific and general factors contributed to transfer in this case could not be assessed because KR-training had no impact on response bias with the Successive task.

The absence of KR effects on response bias with a successive-type task is not unique. A similar outcome has also been reported by Becker, Warm, Dember, and Hancock (1995) using the more conventional bias index β. This result contrasts with earlier reports by Becker (1990) and Dittmar et al. (1985) that KR can alter response bias in a successive as well as in a simultaneous task. In those studies, however, observers received KR in terms of only <u>one</u> facet of performance, hits, false alarms, or misses, whereas composite KR was employed in both the present study and the recent investigation by Becker and her associates (1995). Note that the various KR manipulations in the Becker (1990) and Dittmar et al. (1985) experiments did not produce completely uniform results: Feedback about false alarms promoted a conservative response strategy while the other forms of KR encouraged leniency in responding. Perhaps when combined with the uncertainties in comparing stimuli to a remembered standard in successive or absolute judgment tasks (Baird & Noma, 1978), the divergent effects of different forms of information feedback which are blended within a composite format somehow nullify one another.

The above account implies that complex interactions might exist between the types of information feedback given to observers and the types of vigilance tasks they must perform. Along this line, recall that in the Simultaneous/alternate task, where composite KR was effective in moderating observers' response strategies, KR promoted a more conservative mode of responding. In view of the earlier findings of Becker (1990) and Dittmar et al. (1985), in which KR was limited to only one facet of performance, the present result suggests that in the composite format, the false alarm component of information feedback may outweigh information about hits and misses in their influence upon response bias. Clearly, further research is needed to clarify the interrelations among task types and KR formats in training for vigilance.

The dissimilarity in results obtained with the Simultaneous/alternate and Successive tasks on both TSD indices is dramatic, given the fact that except for the type of discrimination required, these tasks were more alike in terms of general task architecture than either was to the Criterion task. Consequently, the present results lend support to Davies and Parasuraman’s (1982) assertion that simultaneous- and successive-type vigilance tasks provide observers with singular psychophysical challenges.

From the present results, one might conclude that training programs for the improvement of monitoring skills cannot be based solely on the expectation of non-specific or generalized transfer effects. Observers may learn to be vigilant, but the nature of what is learned will clearly depend upon the task category, simultaneous or successive, within which their training occurs. For example, memory skills may be of value in aiding observers in making the absolute judgments required in successive tasks, while skills in scanning and shifting attention from one display element to another may be useful in handling the comparative judgments required in simultaneous tasks (Becker, 1990; Siegel & Siegel, 1972). Since such skills may enable observers to gain a more definitive representation of the nature of critical signals, they may, at least in the case of the simultaneous tasks used in this experiment, also lead observers to become more selective in responding.

It should be emphasized that the transfer effects observed in this investigation were limited to overall levels of sensitivity and response bias. Training with KR did not eliminate the decline in sensitivity over time or the rise in conservatism over time that typify vigilance performance (Davies & Parasuraman, 1982; See, Howe, Warm, & Dember, 1995; See, Warm, Dember, & Howe, 1997). The temporal rise in conservatism does not necessarily represent a performance deficit; it most likely reflects a growing awareness on the part of observers of the low signal probability in effect during a vigilance task (Craig, 1978; Williges, 1969). The sensitivity decrement, however, is another matter. It has been linked to several factors, including inappropriate observing and the depletion of information-processing resources (Jerison, 1970; Parasuraman, Warm, & Dember, 1987). The development of training regimens that will attenuate such loss in sensitivity over time and transfer across different vigilance tasks is a major challenge for the future.

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Appendix A: Informed Consent Form

INFORMED CONSENT FORM
AIRCRAFT INSTRUMENT DISPLAY STUDY

The purpose of this investigation is to study observer's ability to monitor video displays that simulate cockpit instrument displays in Navy jet fighters such as the F-14, and to assess the perceived workload associated with such tasks. During the session you will be seated alone in a sound-attenuated chamber. Your job will be to monitor the video screen in front of you and to respond to particular changes that occur(these will be explained to you in the instructions given by the researcher). You will also be asked to complete a short workload inventory.

The task you will be performing is analagous to those which confront not only pilots, but also air-traffic controllers, people engaged in nuclear power plant regulation, and industrial quality control inspectors. By providing information about workload which can influence performance in these types of tasks, the present study may have potentially important implications for worker comfort and performance as well as the safety of the general public.

The entire session will take about one hour and thirty minutes, and you will receive 2 hours of credit (5 points toward the final exam for psych. 381 students) for your participation. You are free to discontinue your participation at any time without forfeiting your participation credit. After the session has ended you should feel free to ask any questions that you might have. Also, if you wish to obtain a summary of the results of the study you may give the researcher a self-addressed stamped envelope and the results will be sent to you upon completion.

Every effort has been made to ensure your safety in the study. In the unlikely event of an unforseen accident or circumstance which may result in physical injury, you should know that:

The University of Cincinnati follows a policy of making all decisions concerning compensation and medical treatment for injuries occurring during, or caused by, participation in biomedical or behavioral research on an individual basis. If you believe that you have been injured as the result of this research you should contact the principle investigator(s) listed on the signup sheet or the department of psychology (556-5529).

I, the undersigned, have understood the above explanations and given consent to my voluntary participation in the study entitled "Aircraft Instument Display Study."

-- ----/----/----
Participant's signature Date

-- ----/----/----
Investigator signature Date

Appendix B: Instructions to Participants

Training Session

Simultaneous Criterion Task

Artificial Horizon Indicator Display

Imagine that you are the pilot of a Navy jet fighter like the F-14. One of your tasks is to be aware of the orientation of your plane with respect to the horizon. To do this you will need to monitor an instrument known as an artificial horizon, which will be simulated on the computer screen in front of you. You will see a green circle flanked by two horizontal lines, which will be flashed on and off at a fairly rapid rate. The circle is your aircraft and the flanking lines indicate your orientation with respect to the horizon. Normally the two lines will be aligned with each other across the green circle. This is called the neutral event, which means yuou are flying straight and level. This is normal flight path and you do not need to respond. Occasionally, however, the lines will be out of alignment--the line(left or right)on one side of the plane (the green circle) is slightly higher than the one on the other side. Your flight path is not straight and level. You are banked (tilted) too much to the left or right. This is a dangerous condition and therefore a critical signal for detection. Whenever you think you've seen a critical signal, you are to respond by pressing the spacebar on the keyboard, but please don't respond indiscriminately because this may lower your score.

Please press the spacebar to view the neutral events and critical signals.

(Exposure to Signals)

Simultaneous Alternate Task

Two Wingman Position Indicator Display

Imagine that you are the pilot of a Navy jet fighter like the F-14. One of your tasks is to be aware of the positions of your two wingmen. To do this you will need to monitor an instrument known as a position indicator, which will be simulated on the computer screen in front of you. You will see a large green dot flanked by two smaller green dots, which will be flashed on and off at a fairly rapid rate. The large dot is your aircraft and the flanking dots indicate how far your wingmen are from you. Normally the two small dots will be an equal distance from the large dot. This is called the neutral event, which means your wingmen are equally far away from you. This is normal formation, and you do not need to respond. Occasionally, however, one of the small dots (left or right) is farther from the large dot than the other one, which means you are not flying in normal formation. One wingman is farther from you than the other one. This is a dangerous condition, and therefore a critical signal for detection.

Whenever you think you've seen a critical signal, you are to respond by pressing the spacebar on the keyboard, but please don’t respond indiscriminately because this may lower your score.

Please press the spacebar to view the neutral events and critical signals.

(Exposure to Signals)

Successive Task

One Wingman Position Indicator Display

Imagine that your are the pilot of a Navy jet fighter like the F-14. One of your tasks is to be aware of the position of your wingman. To do this you will need to monitor an instrument known as a position indicator, which will be simulated on the computer screen in front of you. You will see a large green dot flanked by a smaller green dot either on the left or the right, which will be flashed on and off at a fairly rapid rate. The large dot is your aircraft and the flanking dot indicates how far your wingman is from you. Normally the small dot will be a standard distance, either on the left or the right, from the large dot. This is called a neutral event, which means you and your wingman are flying in normal formation. You do not need to respond. Occasionally, however, the small dot will be farther from the large dot than the standard distance (on the left or the right), which means you are not flying in normal formation. Your wingman is too far away from you. This is a dangerous condition and therefore a critical signal for detection.

Whenever you think you've seen a critical signal, you are to respond by pressing the spacebar on the keyboard, but please don't respond indiscriminately because this may lower your score.

Please press the spacebar to view the neutral events and critical signals.

(Exposure to Signals)

Knowledge of Results

During this part of the experiment, you will be guided by three types of feedback through the earphones regarding the quality of your performance. (1) A female voice controlled by the computer will say "correct" immediately after you make a correct detection. You have pressed the spacebar correctly when a critical signal has appeared on the screen. (2) The voice will say "false alarm" when you have responded inappropriately. You have made an error by responding to a neutral signal rather thatn a critical signal, and (3) The voice will say "miss" when a critical signal has appeared on the screen and you have failed to respond to it. Remember, your task is to press the spacebar whenever you think you've seen a critical signal appear on the screen. Please do not respond indiscriminately. Any questions?

No Knowledge of Results

During this part of the experiment, the computer will say the word “save” immediately after you respond by pressing the spacebar. This indicates that the computer has recorded your response, but contains no evaluative information. Remember, your task is to press the spacebar whenever you think you’ve seen a critical signal appear on the screen. Please do not respond indiscriminately. Any questions?

Transfer Session

Artificial Horizon Indicator Display

Imagine once again that you are the pilot of a Navy jet fighter like the F-14. One of your tasks is to be aware of the orientation of your plane with respect to the horizon. To do this you will need to monitor an instrument known as an artificial horizon, which will be simulated on the computer screen in front of you. You will see a green circle flanked by two horizontal lines, which will be flashed on and off at a fairly rapid rate. The circle is your aircraft and the flanking lines indicate your orientation with respect to the horizon. Normally the two lines will be aligned with each other across the green circle. This is called the neutral event, which means yuou are flying straight and level. This is normal flight path and you do not need to respond. Occasionally, however, the lines will be out of alignment--the line(left or right)on one side of the plane(the green circle)is slightly higher than the one on the other side. Your flight path is not straight and level. You are banked (tilted) too much to the left or right. This is a dangerous condition and therefore a critical signal for detection.

Whenever you think you've seen a critical signal, you are to respond by pressing the spacebar on the keyboard, but please don't respond indiscriminately because this may lower your score.

Please press the spacebar to view the neutral events and critical signals.

(Exposure to Signals)

Prior KR Training

We are now ready to begin the last part of the experiment. However, during this session you will not be receiving feedback regarding the quality of your performance. This means you will not hear the words "correct," "false alarm," or "miss" from the computer.

Remember to respond by pressing the spacebar whenever you think you've seen a critical signal, but please don't respond indiscriminately.

Any questions?

No Prior KR Training

We are now ready to begin the last part of the experiment. However, during this session the computer will not be indicating that it has recorded your responses. This means that you will not hear the word "save" from the computer.

Remember to respond by pressing the spacebar whenever you think you've seen a critical signal, but please don't respond indiscriminately.

Any questions?

Appendix C: ANOVA Tables

Table C-1. Analysis of variance summary table for perceptual sensitivity during training.

Source	df	SS	MS	F	p
Between	95	186.39			
KR group(A)	1	19.45	19.45	13.41	0.0004
Task(B)	2	34.79	17.40	12.00	<0.001
AB	2	1.97	0.98	0.68	----
Subject/group	90	130.18	1.45		
Within	192	58.47			
Period(C)	2	1.01	0.50	1.78	0.174
AC	2	0.20	0.10	0.36	----
BC	4	5.00	1.25	4.46	0.002
ABC	4	0.85	0.21	0.75	----
Csubject/group	180	51.41	0.28		
Total	287	244.86			

Table C-2. Summary table for the tests of the simple effects for periods within each task.

Source	df	SS	MS	F	p
Periods/criterion	2	0.39	0.20	0.71	----
Periods/simultanous	2	1.28	0.64	2.28	>0.05
Periods/successive	2	4.34	2.17	7.75	<0.001
Periods x Subject/group	180	51.41	0.28		
Total	186	57.42			

Table C-3. Analysis of variance summary table for perceptual sensitivity during transfer for groups that did not receive KR-training.

Source	df	SS	MS	F	p
Between	47	114.09			
Task(A)	2	0.85	0.42	0.17	----
Subject/group	45	113.24	2.52		
Within	144	34.44			
Period(C)	3	4.45	1.48	6.73	0.0003
AC	6	0.31	0.05	0.23	----
Csubject/group	135	29.68	0.22		
Total	191	148.53			

Table C-4. Analysis of variance summary table for perceptual sensitivity during transfer for three groups that received KR-training and the Criterion/No-Kr control group.

Source	df	SS	MS	F	p
Between	63	115.81			
Task(A)	3	16.56	5.52	3.34	0.025
Subject/group	60	99.25	1.65		
Within	192	54.72			
Period(C)	3	8.27	2.76	11.04	<0.0001
AC	9	1.81	0.20	0.80	----
Csubject/group	180	44.64	0.25		
Total	255	170.53			

Table C-5. Analysis of variance summary table for response bias during training.

Source	df	SS	MS	F	p
Between	95	63.20			
KR group(A)	1	22.27	22.27	54.32	<0.0001
Task(B)	2	0.49	0.24	0.58	----
AB	2	3.48	1.74	4.24	0.017
Subject/group	90	36.96	0.41		
Within	192	22.54			
Period(C)	2	4.89	2.44	27.11	<0.0001
AC	2	0.09	0.04	0.44	----
BC	4	1.40	0.35	3.89	0.0039
ABC	4	0.36	0.09	1.00	----
Csubject/group	180	15.80	0.09		
Total	287	85.74			

Table C-6. Summary table for the tests of the simple effects for KR within each task.

Source	df	SS	MS	F	p
KR Criterion	1	11.98	11.98	29.22	<0.001
KR Simultaneous	1	12.27	12.27	29.93	<0.001
KR-Successive	1	1.44	1.44	3.51	>0.05
Subject/group	90	36.96	0.41		
Total	93	62.65			

Table C-7. Summary table for the tests of the simple effects for periods within each task.

Source	df	SS	MS	F	p
Periods/Criterion	2	1.30	0.65	7.22	<0.01
Periods/Simultaneous	2	0.70	0.35	3.89	<0.05
Periods/Successive	2	4.29	2.14	23.78	>0.01
Subject/group	180	15.80	0.09		
Total	186	22.09			

Table C-8. Analysis of variance summary table for response bias during transfer for the Criterion and Simultaneous/ alternate groups that did not receive KR-training.

Source	df	SS	MS	F	p
Between	31	34.41			
Task(A)	1	0.07	0.07	0.06	----
Subject/group	30	34.34	1.14		
Within	96	11.02			
Period(C)	3	2.35	0.78	8.67	<0.0001
AC	3	0.27	0.09	1.00	----
Csubject/group	90	8.40	0.09		
Total	127	45.43			

Table C-9. Analysis of variance summary table for response bias during transfer for the Criterion and Simultaneous/ alternate groups that received KR-training and the Criterion/No-KR control group.

Source	df	SS	MS	F	p
Between	47	45.20			
Task(A)	2	14.79	7.40	10.88	0.0001
Subject/group	45	30.41	0.68		
Within	144	16.09			
Period(C)	3	4.27	1.42	15.78	<0.0001
AC	6	0.19	0.03	0.33	----
Csubject/group	135	11.63	0.09		
Total	191	61.29			