Effects of Concurrent Cognitive Task Loading on Warning Compliance Behavior

Michael S. Wogalter and Mary O. Usher

Department of Psychology
North Carolina State University
Raleigh, NC 27695-7801

ABSTRACT

This research examined whether increased cognitive task loading decreases warning compliance behavior. Participants performed a task in which they installed an external disk drive to a computer. Inside the accompanying owner's manual were a set of specific procedures that were to be followed during the installation to avoid damaging the equipment (i.e., to turn off the computer, to touch the computer's rear metal connector to discharge static electricity, and to eject a transport disk from the disk drive). Concurrent with this task, participants in the low and high task load conditions had to speak the answers to a series of single-digit or double-digit addition problems that were presented by a tape player. A control condition lacked the addition task. The results showed reduced compliance to the discharge static electricity instruction in the high load condition compared to the no load condition. The low load condition produced intermediate compliance, but was not significantly different from the other two conditions with one exception: the high load condition produced significantly lower compliance for the discharge static electricity instruction than the low load condition. These results suggest that warning effectiveness can be reduced when the mental resources necessary to carry out compliance are being absorbed by other concurrently performed tasks. Implications for further research on task loading and warning compliance are described.

INTRODUCTION

Over the past 15 years, warning research has identified numerous factors that can influence the effectiveness of safety communications. Most of the factors have concerned aspects that are internal to the design of warnings (e.g., signal word, color, and font size). Research has shown that when warnings lack certain design characteristics, measures of effectiveness tend to decrease. Clearly the influence of these internal warning factors have implications for the composition of warning signs, labels, and product related documentation.

Warning effectiveness is also influenced by factors that are external to the design of a specific warning. These can include person-related factors such as user familiarity and experience, time stress, and gender. External factors also include environmental-related effects such as weather conditions and the behavior of other people. While there have been numerous studies concerned with the facilitating and restraining influences of various internal characteristics of warnings, there have been surprisingly few studies that have examined the influence of external factors on behavioral compliance. Studies that have examined external influences on compliance behavior have shown effects of a cluttered context (Wogalter, Kalsher, & Racicot, 1993), social influence (Wogalter, Allison, & McKenna, 1989), video instruction (Racicot & Wogalter, 1995), and time stress (Wogalter, Magurno, Rash, & Klein, 1998).

Another external factor that may influence the warning's effectiveness is task load. Generically, task load refers to the number of activities that an individual may be performing at a particular time. Some research and theory indicates that there is a single limited pool of mental resources that is distributed to different activities (e.g., Kahneman, 1973). Tasks can be performed if there are adequate resources available for their enactment. Sometimes a single task (such as one that is less practiced) will overload the individual's limited capacity resulting task performance is less than perfect. Other theory and research (e.g.,Wickens, 1972) suggests that there are multiple pools of limited resources. In these models, two tasks will only interfere if they use the same resources and those resources are insufficient to carry out the tasks concurrently. However, tasks that do not use the same resources will not interfere with each other.

Over the past 25 years, numerous studies have been carried out by researchers demonstrating various kinds of interference in task performance using the primary-secondary task technique. In this method, two tasks are performed concurrently, one being labeled the more important or primary task, and the other, the less important or secondary task. Interference is measured in term of performance decrements in one or both of the tasks. Generally, the more difficult the tasks (and according to the multiple resources model, the more similar the resources used) the greater the interference. Difficulty is sometimes manipulated by influencing the rate of information that must be processed, producing greater cognitive load. A large body of literature currently exists on the effects of task loading with respect to the performance of pilots, automobile drivers, and nuclear power plant operators. In the warnings literature, some authors have speculated that increased task loading may have a detrimental effects on warning effectiveness (e.g., Lehto & Miller, 1986; Rousseau, Lamson, & Rogers, 1998). However, there has been no study that has shown effects of task load with respect to warnings. There is one earlier study in the literature that has examined the effect of task load with respect to warning effectiveness. Duffy, Kalsher, and Wogalter (1995) had participants attach several pieces of video equipment. In the task loading conditions, participants were also given another task to perform, whereas in the control condition this extra task was absent. No significant difference in compliance to a warning attached to an extension cord was found. However, Duffy et al. (1995) noted that participants tended to perform the tasks in a serial order, rather than concurrently, and this might be a possible reason no difference was found for task load in that experiment.

The present experiment examines the effect of cognitive task load in a situation where two tasks are performed concurrently. The primary task that participants performed was to correctly install an external disk drive by taking it out of a box and connecting it to a computer. In the task load conditions, participants were given an extra task to perform concurrently with the disk drive installation procedure. Human information processing theorists have suggested that high levels of workload can negatively affect performance on a primary task (e.g., Wickens, 1992). Greater task loading produced by a high load secondary task could degrade performance on a primary task. Similar effects might be expected for warning-related behaviors with higher levels of secondary task load producing lower levels of compliance.

The present experiment examined the influence of increasing task load (no load, low load, and high load addition problems) on the performance of a computer disk drive installation task. To perform the installation task correctly, the accompanying disk drive owner's manual instructs that three steps be carried out before the drive is connected to the computer in order to prevent damage to the equipment.

METHOD

Participants

Forty-eight North Carolina State University undergraduates participated for research credit in their introductory psychology courses. The sample included 23 males and 21 females. Four did not indicate gender. Mean age was 19.25 years, *SD* = 1.8. Racial composition was 75% white, 15% black, 2% Asian, 2% Hispanic, and 6% other.

Apparatus and Materials

An Apple Macintosh computer, a Fujitsu 800 KB external disk drive with its owner's manual, packing materials (protective bubble wrap and cardboard box), and a cassette tape player were used. The relevant installation instructions appeared on the sixth and seventh pages of the owner's manual. These pages showed in picture and text form the three procedures that were to be performed so that the external disk drive could be installed without damaging the equipment.

In the low and high task load conditions, two 15-min. cassette tapes with a series of either single digit or double digit addition problems were used. For both recordings the addition problems were spoken by a female every 15 s. The materials also included a questionnaire asking demographic information (e.g., age, sex), a questionnaire asking participants their experience installing electronic equipment (computers, video, and high fidelity sound systems), and a sheet that the experimenter used to record the participants' behavior.

Procedure

The computer disk drive installation procedures employed in this study were similar to the procedures described in Wogalter, Barlow, and Murphy (1995) and Conzola and Wogalter (1999). The basic method is briefly described below. For additional detail see the two above named references.

Participants were tested individually. Upon arrival, they first entered a small closed-off area separated by upright office panels. This area contained only the computer (which was turned on), and a box (containing an external computer disk drive surrounded by bubble wrap). The experimenter gave oral instructions describing the task. Participants were told that they would be performing in an engineering psychology study that is evaluating the ease of use of various high-tech consumer products including video cassette recorders (VCRs), music systems, and computers. (However, this was partially a ruse, because all participants in the study performed the disk drive installation task.) Participants were told that they were to assume that they received delivery of a computer disk drive and they needed to install the drive in order to do a disk-to-disk copying task. In the two task load conditions, participants were to say aloud the answers to the math problems within the allocated time frames of 15 s each while simultaneously installing the disk drive to the computer. Participants were told to do best that they could with the math problems (the secondary task), but to focus mainly on the disk drive installation task (the primary task). The experimenter did not provide any assistance to the participant after the initial instructions were given. The participant was instructed to give

Table 1. *Mean proportion compliance and total compliance as a function of task load conditions (n = 16 per condition; Total N = 48).*

	Individual Compliance Behaviors			Composite Compliance Measures	
Task load Condition	Turn off Computer	Eject Disk	Discharge Static	Complete Compliance (Did All 3 Behaviors)	Total Compliance (0-3)
No/Control	1.00	.94	.88	.81	2.81
Low	.81	.75	.63	.56	2.19
High	.69	.81	.25	.25	1.75

an indication to the experimenter when they were finished with the installation task.

In the two task load conditions a cassette player presented a long sequence of math problems. In the course of watching the participant perform the installation task, the experimenter recorded whether the three disk drive installation instructions given in the owner's manual were correctly performed: (a) Was the computer turned off? (b) Was the protective transport/packing disk ejected by pressing a button on the front of the drive? (c) Was the metal connector on the back of the computer touched so as to release static electricity before being connected to the drive? Participants' oral answers to the math problems were recorded and later evaluated for accuracy. Also, the amount of time to complete the installation procedure (from the experimenter's directive to begin the task to the point that the participants said that they finished the task) was recorded. Later they completed demographics/experience questionnaires, and before being excused from the session, they were debriefed and thanked.

RESULTS

All participants were able to attach the external disk drive to the computer within the allotted 15 min. The effects of three levels of task load were examined: no (control), low, and high task load.

Compliance Measures

Compliance with each of the three installation instructions was analyzed separately and together. For all three precautionary instructions, if the participant complied they were given a score of "1," otherwise they were given a score of "0." There were also two other compliance measures, both based on a composite of all three precautionary instructions. For one, complete compliance, participants were given a score of "1," or if they did anything other than all three behaviors, they were given a score of "0." For the other composite compliance measure, total compliance, participants were assigned scores depending on the number of the instructions they complied with; the scores ranged from 0 to 3. The first four sets of scores were analyzed using chi square tests, whereas the fourth was examined using analysis of variance (ANOVA) and post hoc comparison tests. The means for the above-described measures are shown in Table 1.

Individual compliance behaviors. Data on the discharge static electricity instruction showed a significant effect of task load, $\chi^2 = 13.0$, $df = 2$, $N = 48$, $p < .002$. Paired comparisons using chi square tests among the three conditions showed that participants in the high task load condition complied significantly less often than participants in the no ($\chi^2 = 12.70$, $df = 1$, $N = 32$, $p < .001$), and low ($\chi^2 = 4.57$, $df = 1$, $N = 32$, $p < .05$) task load conditions. There was no significant

difference between the low task load and the control conditions ($p > .10$).

The behavior of turning off the computer just missed being significant at the conventional probability level of .05, $\chi^2 = 5.70$, $df = 2$, $N = 48$, $p < .002$, $p = .058$. Paired comparisons among the conditions using chi square tests showed that fewer high task load participants turned off the computer compared to the no task load participants ($\chi^2 = 5.93$, $df = 1$, $N = 32$, $p < .02$). No significant effects were found with the eject-disk measure ($ps > .05$.

Composite compliance measures. The complete compliance measure showed a significant effect of conditions, $\chi^2 = 10.24$, $df = 2$, $N = 48$, $p < .007$. Paired comparisons using chi square tests showed that the high load participants less frequently completely complied (with all 3 instructions) than the no-load participants, $\chi^2 = 10.17$, $df = 1$, $N = 32$, $p < .002$, respectively. No other comparison was significant.

The total compliance measure showed a significant effect of conditions, $F(2, 45) = 5.15$, $p < .01$. Paired comparisons using the Tukey HSD test showed that high task load participants had lower total compliance scores than the no-load participants ($p < .05$). No other comparison was significant.

Math Task Performance

Accuracy in the math task was significantly greater in the low task load (97.2% correct) than in the high task load condition (52.8% correct), $t(30) = 6.82$, $p < .0001$. High task load participants who reported being more experienced in installing electronic equipment, also produced more correct answers in the addition problem task than high task load participants who reported less electronics installation experience ($r = .77$, $n = 16$, $p < .001$). No other association with experience was found in the analyses.

Task Completion Time

While high task load participants took longer to complete the installation task ($M = 325.8$ s, $SD = 190.2$) compared to the low load ($M = 236.5$ s, $SD = 101.0$) and no-load ($M = 352.5$ s, $SD = 94.13$) conditions, there was no significant differences among the conditions in analyses using the raw and log transformed time scores.

DISCUSSION

In this experiment, participants performed a primary task of installing an external disk drive to a computer. Concurrently with this task, participants performed a low or high load secondary task of adding single or double-digit numbers, respectively, or performed no secondary task (the control). Measured was whether they preformed three precautionary behaviors prior to connecting the disk drive to the computer. The results showed that the high task load condition produced significantly lower compliance compared with the no-load (control) condition for the discharge static electricity measure, and both composite compliance measures. The results also showed that the high task load condition produced significantly lower compliance than the low task load condition in one analysis (discharging static electricity).

Analysis of the addition answer data in the low and high task load conditions showed that fewer problems were correctly answered in the latter compared to the former condition. This result confirms that the double-digit addition task was more difficult than the single-digit addition task as reflected in the accuracy scores. The difficulty difference is also reflected in the compliance scores in the primary task.

Interestingly, individuals in the high task load condition who reported having more experience installing electronics equipment also performed more accurately in the addition problems task than those who reported having less electronics installation experience. This result is consistent with the notion that increased experience on a task (in this case, electronics installation) frees up capacity and makes available more resources that could be used to perform another task (in this case a fairly difficult set of two-digit math problems). Experience had no relation to performance in the low task load condition, possibly because the single-digit addition problems did not require much mental resources and so the extra capacity provided by experience could not be revealed in this condition.

The results support the notion that the more difficult tasks use more mental resources thereby limiting performance in other concurrently performed tasks. Wickens (1992) suggests that when performing any task, different mental operations must be carried out (responding, rehearsing, perceiving, etc.), and performance of each requires some amount of the operator's limited processing resources. The high task load condition apparently reduced the processing resources available to perform the installation task properly (i.e., it reduced warning compliance). The present study cannot differentiate the underlying causes of the interference, e.g., whether it is due a single-resource or multiple-resource processing system, as both could predict the results that were found. The results are, however, inconsistent with the idea that the resources required in performing the primary and secondary tasks are independent (because if they were independent, no interference would be seen). The interference demonstrated in the present research indicates that there is some overlap in the processing resources required to perform the tasks. What those resources are cannot be determined by this study, but they probably involve cognitive, and perhaps more specifically, verbal and analytical skills.

Wogalter et al. (1998) found the time stress reduced participants' compliance to a warning to wear personal protective equipment (PPE) in a chemistry laboratory demonstration task. Although the present study is quite different from the Wogalter et al. (1998) situation, the high task load condition in present study could be described as producing greater "mental stress" than the low or no task load conditions, producing the compliance effects that were shown.

A few aspects about the methodology of the present research are worth mentioning. First, while we manipulated the task load difficulty by changing the type of problem (single- vs. double-digit addition problems), the loading could have be done in other ways. Another method would be to hold the problems themselves constant but to change the rate at which they problems must be performed, e.g., one every 10 s compared to one every 15 s. Another method would be to manipulate the type of processing resources absorbed by the secondary task. If the tasks are selected well, it may be possible to hone in on the processes involved the primary task, as indicated by the interference patterns that they generate.

A second, but related, comment about the methodology is that the present study cannot determine where the interfering effects of task loading occurred. We do not know if the bottleneck occurred to limit encoding of the warning information or just to limit responding. Further research in this area could use probing techniques to discern the processing mechanisms taking place to produce compliance.

A final comment about the methodology is that the present experiment employed a scenario where the underlying reason for having warnings was not personal injury (like most studies on warnings), but rather the issue concerned property damage. While property damage is generally not as critical as personal injury, property damage can involve a wide range of loss. In fact, some indirect results of property damage can be life threatening (e.g., failing to comply with a no digging warning could result in cut underground cables that in turn could influence emergency response times). We believe that many of the principles revealed in research on personal injury warnings are applicable to property damage warnings, and vice versa. A warning about underground cables can be more important than a warning about mild skin abrasion.

Lastly some recommendations can be offered based on the results of this study. High levels of secondary-task loading can decrease performance on a primary taskùincluding compliance to warnings. The present results suggest that task loading should be minimized when the situation requires warning compliance. Alternatively, cost of compliance could be reduced to decrease the effort needed to carry out the primary compliance task (e.g., Wogalter et al., 1989; Wogalter, Godfrey, Fontenelle, Desaulniers, Rothstein, & Laughery, 1987).

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