

Assessment of Operators' Workload, Visual Attention, and Satisfaction in an Upgraded Control Room After Changes of Work Procedures

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Abstract

The adoption of new equipment in a work environment is usually meant to improve technology, increase safety and strengthen environmental protection. At the same time, however, technological changes can influence workers' performance, thus workload and tasks' reallocation should always be evaluated whenever new equipment is introduced. The aim of this study was to evaluate the effects on operators' workload of new procedures adopted in a Marine Terminal Control Room following recommendations provided in a previous study (Plet, Gerbino, Tognolli, & Marcatto, 2013). Moreover, operators' acceptance and satisfaction of the new procedures were assessed. Results show that the new procedures have improved work performance leaving the overall subjective workload unchanged at a medium-low level.

Keywords: Workload; visual attention; human factors; work organization.

In 2011, a new control console (Thermonav) was introduced in SIOT's (Società Italiana per l'Oleodotto Transalpino) Marine Terminal Control Room (CR), located in the Gulf of Trieste. The CR needs to operate 24 hours a day, with a focus on safety and security. The new control console shifts the monitoring activity from the outdoor to the CR, with the aim of enhancing the probability of promptly detect negative events. This new instrument required changes in the consolidated existing work procedures, thus a field study was conducted and results identified a new way to rearrange the existing organization (Plet, Gerbino, Tognolli, & Marcatto, 2013). However, only some of the changes suggested in the previous study were put in place at the time of the current assessment.

Pre-existing procedures were redefined in order to:

- Enhance alertness during quiet periods by shifting indoor and outdoor tasks frequently;
- Reduce outdoor security and oil spill monitoring;
- Set up instrument layout following operators' preferences;
- Support operators' work in CR by introducing a new professional profile (Junior Pier Master, JPM), which interfaces with the Pier Master and CR operators.

Aims

After the new work's organization have been reached full operation, the present study, by using the same ad-hoc

integrated methodology adopted in the previous study, was conducted to assess:

1. Operators' workload;
2. Operators' visual attention level;
3. Operators' acceptance and satisfaction of the new procedures.

Method

Participants

Eighteen participants (out of a total of 24 operators working at the Marine Terminal) participated in this study (5 JPMs and 13 operators). In each work shift the work team is formed by 3 operators and 1 JPM.

Procedure

The evaluation period lasted a week, and an ad-hoc integrated methodology, used in the previous study, was adopted.

First, to measure the change of attention level during the work shift, at the beginning and at the end of each work shift (afternoon, night, and morning), each member of the work team (which was composed by 3 operators and 1 JPM) performed a modified computer version of the visual search test originally developed by Neisser (1964).

Then, in order to measure workload at the end of work shift, participants were asked to complete the NASA-Task Load Index (Hart & Staveland, 1988), a multi-dimensional scale consisting of six subscales that evaluate the following dimensions: Mental, Physical, and Temporal Demands, Frustration, Effort, and Performance.

At the end of each work shift a questionnaire was administered to each worker to evaluate the effective work shift difficulty depending on number of docked, unloaded, sailed away ships, weather conditions, and unforeseen events.

Finally, to investigate how operators evaluate the new procedures adopted at the Marine Terminal, participants were asked to rate their acceptance and satisfaction of the new procedures on six dimensions, by using a five-point scale from 1 ("not at all") to 5 ("very much"). Participants were also required to write any suggestions aimed at improving the overall ergonomics of the control room.

The principal expected results were a reduction of subjective workload and a less decrement in the visual

attention level during the work shift, with respect on previous study.

Main Results

End-shift questionnaire

As in the previous study, an index of difficulty of the shift work was calculated. This index takes into account the type of shift (afternoon, morning, night), and five concurrent events (number of docked, unloaded, sailed away ships, weather conditions, unforeseen events).

The difficulty shift work index resulted not significantly different from the one obtained in the previous study (average 2014 study = 32.84, average 2013 study = 35.92; $t_{78} = 1.25, p = 0.21$). This means that the two studies are comparable because of unchanged objective conditions of work.

NASA-Task Load Index

The NASA-Task Load Index uses six dimensions to assess perceived workload and provides also an overall workload score from 0 to 100. The average overall workload index was not significantly different from the one obtained in the previous study (average 2014 index = 49, average 2013 index = 47.9; $t_{77} = 0.33, p = 0.74$).

The only difference between the two studies was in the Temporal Demands workload dimension, which resulted to be significantly lower than the 2013 study (2014 average = .15, 2013 average = .53; $p < 0.002$). This result can be explained by the fact that the new procedures lead to a better organization of the activities on the temporal dimension, leaving unchanged the other components of the workload.

Visual search test

While in the previous study the operators' visual attention performance got worse from the beginning to the end of the shift work, in the present study we observed a totally reverse trend. Results obtained in the visual search test showed faster reaction times at the end of the shift work compared to those of the beginning (RT begin average= 3.33s vs. RT end average= 3.03s, $t_{92} = 1.92, p < 0.05$) regardless of the kind of shift work (all $ps < 0.05$).

This performance improvement indicates that changing work activities during the shift work causes an activation of attentional resources (at least of the visual attention resources), and such activation is maintained throughout the duration of the shift.

Relationship between visual search performance and overall workload index

To investigate how the overall workload index predicts the performance improvement in the visual search test in the three work shifts (afternoon, morning and night), a regression analysis was performed. JPMs were not included in the regression analysis, since as their tasks are not homogeneous with the other operators' ones.

Figure 1 shows the relationship between visual search performance and overall workload index in the three work shifts: afternoon (a), morning (b) and night (c). Results indicate that during the morning and night shifts the improvement in the attention performance decreased as the subjective workload increased (morning: $F_{1,10} = 20.13, p < 0.001$, adjusted $R^2 = .63$; night: $F_{1,12} = 5.37, p < 0.04$, adjusted $R^2 = .25$). While no relationship between the two indices in the afternoon shift was found ($F_{1,15} = 0.14, p = 0.71$, adjusted $R^2 = .06$).

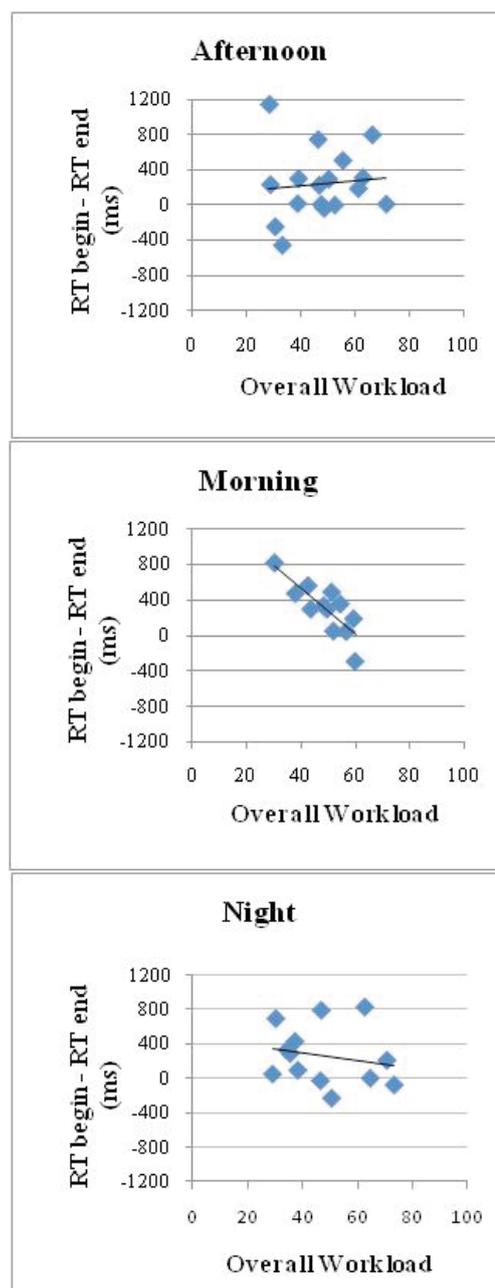


Figure 1: Workload and Attention in the three work shifts: afternoon (a), morning (b) and night (c).

Therefore, the afternoon work shift seems to have different characteristics in terms of attentional activation. Since the attentional performance remained high even in the less easy shifts (morning and night), it seems that the workload does not have adverse effects on performance in visual search tasks, relevant to the job in the CR and outdoor.

Subjective evaluation of the new procedures

A factor analysis (principal component analysis with Varimax rotation) was conducted on the six dimensions of the subjective evaluation of the new procedures. Since the sample size was small a note of caution should be included in factor analysis interpretation. The analysis yielded two factors, “Utility” (consisting of *useful*, *satisfactory*, *inadequate**, and *frustrating**) and “Simplicity” (composed of *simple to follow* and *complicated**)¹.

The mean scores of both factors (Utility = 2.91, SD = 1.00; Simplicity = 3.00, SD = .071) resulted to be at or very near the midpoint of the 1-5 scale. Taking into account that these evaluations were related to changes in the previously existing working procedures, it seems that the adopted changes were perceived as not particularly complicated, but at the same time their utility has not been fully understood by operators. This latter consideration is reinforced by the data concerning the increase of security and support to the work due to the inclusion of the JPM and the changes of work tasks. Indeed, the evaluation of security (average = 2.5, SD = 1.09) and support (average = 2.69, SD = 1.08) of the JPM, and of the security (average = 2.38, SD = 0.72) and support (average = 2.25, SD = 0.86) of frequent change of tasks between operators within their shift work were always below the midpoint of the scale, indicating a poor perceived benefit of the new procedures.

Operators’ suggestions about the improvement of CR ergonomics were relative to a reorganization of information on the CR monitors, as they contained too much information that resulted too difficult to read and handle (an issue already reported in the previous study, but not yet changed). Another suggestion was to streamline procedures of exchange deliveries, considered inflexible and too complex to be performed during high workload shifts.

Conclusion

The new procedures have improved work performance (with respect to the visual-spatial attention and Temporal Demands), leaving the overall subjective workload unchanged at a medium-low level. However, the usefulness of the new procedures was not fully perceived by the operators, possibly because the motivations underlying security were not sufficiently clear and shared by operators.

Results showed a trend of continuous improvement of the security, not followed by an improvement in terms of the

subjective perception of the organization and work at the Marine Terminal.

Given the low level of acceptance of the new procedures and the subjective perception of few benefits in terms of many security checks required to operators, it is suggested an intervention at the communication level between operators and management. For example, a focus group with the staff of the Marine Terminal on the improvement of the organization in terms of safety and documented explanations may lead to increase satisfaction and active participation by operators.

References

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¹ The scores of the items marked with a * have been reverse scored so all the items have the same polarity.