The ergonomics interventions evaluation. A study based on usability

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Abstract. ISO 9241-11 and ISO 13407 are recognized as important standards related to usability. ISO 9241-11 suggests that usability measures should cover: effectiveness (the ability of users to complete tasks using the system, and the quality of the output of those tasks), efficiency (the level of resource consumed in performing tasks) and users' satisfaction (subjective perception when using the product, process or system). Based on these basic knowledge on usability concept the article aims to describe a proposed methodology for the global assessments of the ergonomics interventions in the case of industrial system. The research scenario consists in a survey based on a developed questionnaire that evaluate the ergonomics interventions, in terms of usability. In addition, the results of an experimental research demonstrate the testing and validation of the proposed approach. The method could be seen as an ergonomics continuous improvement one.

1 Introduction

The concept of usability has evolved in the man-machine-environment system studies and was strongly debated for users interface, user-centred design subject of interest [1-2]. Usability is "about learnability, efficiency, memorability, errors, and satisfaction" [2]. The above definition refers in addition to efficiency in normal use and satisfaction with use, learnability in early use, memorability after a period of non-use and aspects related to errors during use, in order to avoid undesirable consequences.

ISO 9241 series and ISO 13407 are two important standards related to usability: the former one (part 11) provides the definition of usability and the latter one guidance for designing usability [3-4]. According ISO 9241-11 usability is seen as "the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use" (this is the main reference of usability) [3]. The standardize approach of the concept represent both users and business requirements: effectiveness means success in achieving goals, efficiency means not wasting time and satisfaction means willingness to use the system. In addition, Figure 1 shows the main aspects that have to be considered when a usability analysis and evaluation is

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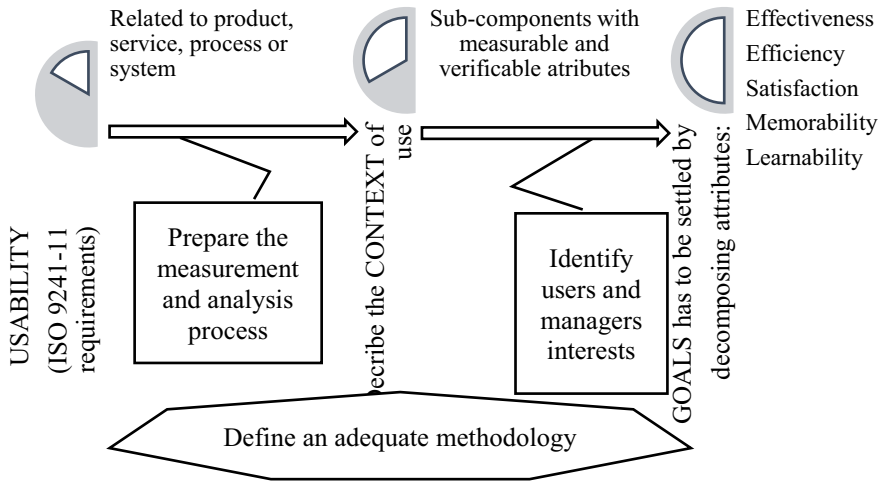
developed, together with its benefits. The perspective introduce by the ISO 9241-11 standard has been extended to product, service, processes and systems.



The approach is used to identify the usability measures and context of use when designing, analysis or evaluating usability.	Attributes are used to analysis and measure the extent to which a product, process or system is usable in a particular context.	Measures of usability attributes can provide the basis for comparison and dynamics analysis.

Fig. 1. Relevant aspects related to the usability approach.

In this context, the article describes a proposed methodology for the global assessments of the ergonomics intervention in the case of industrial system. The research scenario consists a survey based on a developed questionnaire that evaluate the interventions impact usability. In addition, the results of the experimental research will validate the proposed approach. The method could be included in the ergonomics continuous improvement programs, in order to collect periodical feed-backs from the affected employees and managers.

2 The proposed methodology

In the case of industrial systems, the continuous improvement dynamics is high. Ergonomics interventions and corrections are correlated with the health and safety strategy, with quality management requirements and finally, to ergonomics improvements that support workplace well-being [5-6].

Usability is seen as an adequate attribute to a purpose (applicable for ergonomics continuous improvement) of any particular product, service, process or system. It means to collect structured feed-back from users that express their opinions regarding a particular context of use, relatively to their work place. This is related to participatory ergonomics.

When selecting usability metrics, it is often desirable to have measures which do not require vast effort and expenses to collect and analyse data. Complex systems or tools of participatory ergonomics were analysed but their main disadvantage is related to additional high costs for external consulting and implementation [1, 7]. Other references have indicated methods or techniques for participatory ergonomics having the primary purpose of: idea

generation and concept development, concept evaluation, problem solving or process recording [1, 8].

For practical purposes, there have been adopted the survey approach developed with the support of the work places users, employees of an industrial system. A questionnaire was developed and it was inspire by the System Usability Scale (SUS) described in [9].

Table 1. The proposed questionnaire for the ergonomics interventions evaluation.

#	**Question/usability item evaluated:** **Strongly disagree** **1 2 3 4 5** **Strongly agree**	**Usability capacities or attributes evaluated*:**
1	I think that I would like to use the new working system frequently	S (-1)
2	I found the new working system un-useful un-helpful, too complicated, too complex	M (-5)
3	I suppose that the new working system was easy to use in terms of my work effectiveness including error avoiding	O (-1)
4	I think that I would need guidance from the technical person in order to attend high level of efficiency of my work in the new conditions	E (-5)
5	I found the different handling working movements very easy to be learned within the new working system	L (-1)
6	I think that I can do the different handling working movements more quickly, but after a period of adaptation and conformation	O (-5)
7	I imagine that most of my co-workers would learn to use this new working system quickly	E (-1)
8	I found the new working system very difficult to use: embarrasses me sometime or limited my working movements	S (-5)
9	I am very confident using the new working system	M (-1)
10	I have to learn a lot of things before I could get using the new working system very good	L (-5)

*) E – Efficiency including error avoiding; O – Effectiveness including error avoiding; L – Learnability; S – Satisfaction; M – Memorability

The questionnaire has been developed during three focus groups done with the involvement of the external consultants (the researchers), supervisors and the middle managers of the industrial system. The creative sessions have been take into considerations the objectives followed by the ergonomics intervention.

Based on the final solutions implementation, positive/negative aspects related to usability have been considered for the questions formulation (Table 1). Each item that was evaluate has been measure using a 5 point Likert scale in order to identify aspects or things which lead to extreme expressions of the attitude being captured by users collected opinions.

The questionnaire was distributed after users had a period of time of using (get familiar with) the facilities created by the ergonomics, but before any debriefing or discussion between them or with their supervisors. Users/respondents were asked to record their responses as spontaneous opinions, rather than reflecting about items for a long time. If a user feels that he/she cannot respond to a particular question, this was marked in the centre point of the respond scale (3).

The final score has been calculated similar to the procedure mention in [9]. First there have to be sum the score contributions from each item. Each item's score contribution will range from 0 to 4. For items 1, 3, 5, 7 and 9 the score contribution is the scale position minus 1; for items 2, 4, 6, 8 and 10, the contribution is 5 minus the scale position. The final

ergonomics usability interventions evaluation score is the result of multiplying the sum of the scores by 2.5.

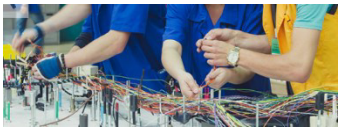
3 A practical application of the ergonomics intervention usability evaluation using the proposed methodology

The study was developed in the context of a participatory ergonomics program implementation in an automotive company's practice (an assembly line for automotive cables and wires manufacturing). Participatory ergonomics is defined as "the involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goal" [10]. According to previous researches, participatory ergonomics process is believed to encourage workers to be involved in controlling their own work, consequently decreasing work-related risk factors and thereby improve occupational health and safety [11].

In the presented case study, the defined research protocol provide an a priori program logic [12], that describes the pathway from the ergonomics intervention to the reduction of work stress and the usability assessment. There have been anticipated that the employees in the study would be able to identify risks and implement solutions together with the external consultants and their managers, in order to reduce physical work demands (physical exertion and occupational lifting) which in turn would contribute to the improvement of their work comfort (Table 2). The proposed approach, described in section 2 of this article, has been developed, tested and validated, and the ergonomics usability interventions evaluation are shown in Table 3.

Table 2. Inventory of the ergonomics interventions in the studied production system.

Work places or areas of intervention	Improvements operated	Benefits
Control and defect prevention work places (Figure 2a)	Re-organizing work places with respect of succession movements; Re-organization of the local logistics; Re-orientation in an horizontal plan of the control and test panels	Improve employees postures (reduce back pains); Increase work rhythms and efficiency; Use of gravity for handling materials; Improve work place design
Cables assembly work places (manual operation with visual inspection) (Figure 2a)	Correct gripping and grasping of objects; Eliminate repetitive tasks; Tools were suspended when possible; Implement ergonomic chairs	Avoid hands fatigue and adopt good tool-work piece contact; Improve reaching and grasping; Assembly time cycle reduction; Improve employees postures
In-circuit defection work places	Eliminating postures as bending, twisting, eye movements, lifting against gravity by re-organization and re-design	Eliminate back pain, shoulder pain, wrist pain, neck pain etc.; Increase of work efficiency
Packaging work places	Re-design of the work place by intensive using of gravity; Introduce a handling system for big packages (vacuum grip)	Reduce back injuries; Eliminate some human movements because of using gravity; Automate the process of packaging and shipment
In-door training area (Figure 2c)	Design and implementation of an adequate area of training; Define a group of Ergo Coaches to support employees	Reduce time for adopting a new assembly tasks through demonstrations and practical exercises; New employees are taught the proper technique, including safety and quality



a. b. c.

Fig. 2. Details of the ergonomic intervention final solutions: a. re-orientation in a horizontal plan of the control and test panels, b. ergonomic organization of the work places, c. in-door training program.

Table 3. The ergonomics usability interventions evaluation – research results.

Work places or areas of intervention	**Global score gained by each user / questionnaire applied**	**Average**	**Conclusions**
Control and defect prevention work places (10 users investigated)	55, 67.5, 84, 72.5, 70, 77.5, 90, 95, 100, 67.5	77.90	Most of the improvements were made in these areas. Users appreciate well the usability but new developments should positively affect *learnability* and *satisfaction* attributes.
Cables assembly work places (manual operation with visual inspection) (24 users investigated)	75, 80, 77.5, 55, 62.5, 87.5, 84, 90, 90, 55, 80, 80, 65, 67.5, 84, 72.5, 70, 77.5, 90, 95, 100, 82.5, 90, 77	78.65	
In-circuit defection work places (10 users investigated)	65, 77.5, 67.5, 90, 84, 72.5, 70, 77.5, 90, 84	77.80	
Packaging work places (6 users investigated)	75, 80, 77.5, 82.5, 70, 95	80.00	Usability has been very well appreciated. Improvements can be done for *effectiveness* attribute.
In-door training area (10 users investigated)	90, 82.5, 87.5, 84, 90, 95, 100, 95, 82.5, 87.5	89.40	
Total users investigated: 60 subjects		80.75	Very good score gained in comparison with the investments done for the ergonomic interventions.

4 Conclusions and future work

The aim of this study was to analyse the effectiveness (in terms of usability) of the implementation of a participatory ergonomic program taking into account an ergonomic evaluation and workers' work comfort together with their perception about the work stress and the risk factors related to task performance. The ergonomics intervention attempted to improve the fit between the worker possibilities and the work task (processes and associated activities) by decreasing the physical workload.

The presented research approach has underlined the strong link of usability with ergonomics (improvements done exploiting ergonomics knowledge have a positive, direct impact on usability attributes). The perspective of usability is closely aligned with business goals: effectiveness, efficiency and satisfaction have a direct impact on work productivity and finally, on profitability.

The presented approach has demonstrate that the framework defined by ISO 9241-11 and ISO 13407 standards (refers to visual display terminals work places) could be extended to other working areas, from different industries. The developed questionnaire has proved to be a valuable evaluation tool, accepted by researchers and managers, practitioners from the

industrial system; the questionnaire is considered robust and reliable. Research results demonstrate a significant improvement regarding task performance indicating a workload decrease, suggesting that workers' satisfaction has considerably increased.

Future applicative researches should extend the data process, as suggested by the SUMI inventory, in order to refine the description of users' behaviour related to the usability attributes.

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