Applied Ergonomics 46 (2015) 144–157

Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

Understanding the complex needs of automotive training at final assembly lines

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ARTICLE INFO

Article history:
Received 1 June 2012
Accepted 26 July 2014
Available online 15 August 2014

Keywords:
Assembly
Virtual
Training

ABSTRACT

Automobile final assembly operators must be highly skilled to succeed in a low automation environment where multiple variants must be assembled in quick succession. This paper presents formal user studies conducted at OPEL and VOLVO Group to identify assembly training needs and a subset of requirements; and to explore potential features of a hypothetical game-based virtual training system. Stakeholder analysis, timeline analysis, link analysis, Hierarchical Task Analysis and thematic content analysis were used to analyse the results of interviews with various stakeholders (17 and 28 participants at OPEL and VOLVO, respectively). The results show that there is a strong case for the implementation of virtual training for assembly tasks. However, it was also revealed that stakeholders would prefer to use a virtual training to complement, rather than replace, training on pre-series vehicles.

1. Introduction

Final assembly lines in automotive manufacturers typically have a low degree of automation due to their requirement for flexibility and robustness (Hajarnavis, 2012). It is also common that several models of the same product share the capacity of one assembly line to support the competitiveness of automotive manufacturing. As a consequence, operators on the final assembly lines are required to switch effortlessly between assembly operations for one model to the next.

Nof et al. (1997) defined assembly as “*the aggregation of all processes by which various parts and subassemblies are built together to form a complete, geometrically designed assembly or product (such as a machine or an electronic circuit) either by an individual, batch or continuous process*”. Assembly operations can be considered as skill-based operations that require *procedural skill* i.e. an ability to execute action sequences to solve problems (Rittle-Johnson et al., 2001). This means that an assembly operator knows how and when certain procedures should be performed in order to accomplish a given task. By having procedural skill related to a specific assembly task, an operator will have a mental representation of the assembly task details (e.g. the number and order of steps involved, and detail of what needs to be done in each step). Therefore, training is crucial in developing operators' procedural skills when a new product and its variants are introduced. Operator training is commonly performed on pre-series (prototype) vehicles (Krammer et al., 2011). This approach has substantial limitations such as: high cost; only a low number of vehicles and product variants are built to keep the cost down; and parts wear from repeated exposure to assembly and disassembly operations.

In contrast to training on pre-series vehicles, the use of training in virtual environments has been associated with several advantages such as a standardised approach to training and flexibility in conducting, progressing and evaluating training. Kraus and Gramopadhye (2001) also argued that virtual training is cost effective for several reasons: elimination of travel expenses for trainers/trainees as training can be delivered on-site; minimising down-time as training can be flexibly undertaken around trainees' work schedule; and less demanding on personnel resources as trainees can train independently. Boud et al. (1999) found that operators who have used a virtual training system learned new procedures effectively and performed better on real assembly tasks than those using solely written instructions. Similar trends have also been shown in the application of virtual training in other areas such as aircraft maintenance (Barnett et al., 2000), machine

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http://dx.doi.org/10.1016/j.apergo.2014.07.014
0003-6870/

Table 1
List of questions in the semi-structured interview.

Roles and responsibilities	1.1. Summary of your role[a] 1.2. What is your current involvement with operator training[a] 1.3. Please provide a task level description of the operators job, i.e. the detail of what they actually do[b] 1.4. Does the task that the operators perform vary considerably, i.e. do they do many different operations, or are they mostly similar?[c] 1.5. What is your production rate? i.e. how many assembly operations are required per hour?[b] 1.6. Do any of the assembly tasks pose particular difficulties to the operators? Do any tasks cause frequent problems?[a] 1.7. How are issues with assembly operations recorded?[a] 1.8. Do you receive feedback on assembly operations which are difficult or time-consuming? If so, how?[d]
Workplace and work environment	2. What are the conditions in which the operators work? E.g. shift work, noise, lighting, please describe the physical workplace and social environment[b]
Training	3.1. What are the tasks that the operators need to be trained for (e.g. fitting components on vehicle assembly lines)?[b] 3.2. How are they currently trained to do these tasks?[b] 3.3. What is the timeframe of the training (i.e. when does it take place in relation to vehicle launch?)[c] 3.4. What is your opinion of the training?[a] 3.5. What are the key skills or knowledge being taught?[a] 3.6. What is good about the current approach to the training?[a] 3.7. What are the difficulties with the current approach of the training, or what problems exist?[a] 3.8. Can you suggest how to improve the training?[a] 3.9. What do you consider the most important performance measures and goals?[a] Human: Of the operators' job (e.g. time, errors, …) Operational: Of the training (e.g. operator must complete task correctly XX% of the time) Business: (e.g. a Timeframe reduction for the training)? 3.10. What are the requirements for authoring training sessions (time available, man-power etc.)?[e] 3.11. Does training improve productivity? If so, how?[e]
Process and workflow	4.1. What software tools do you currently use as part of the training process? (e.g. CAD systems or production planning software?)[a] 4.2. What is the communication/information flow (i.e. who provides what information to who)?[a] 4.3. What information is required by planners/trainers?[a] 4.4. Within the vehicle development lifecycle, what information related to training is required and when? i.e. when are engineers required to specify assembly instructions[a]
Game-based virtual training	5.1. What are your initial thoughts about training using virtual systems?[a] 5.2. Do you think this approach could improve training?[a] 5.3. What problems would you anticipate?[a] 5.4. What are your initial thoughts about a game-like system for training?[a] 5.5. What are your thought on the capture and feedback of assembly issues to the product designers and manufacturing systems engineers?[a] 5.6. Do you own, use or have been tried an X360, PS3 or WII based game console? What is your impression or experience controlling a game using a wireless controller?[a] 5.7. Would you like to be involved in the VISTRA project? i.e. can we contact you again to obtain your feedback on the developed technologies?[a]

[a] All stakeholders.
[b] Operators.
[c] Operators, engineers, supervisors.
[d] Engineers.
[e] All stakeholders except operators.

operations (Lin et al., 2002), surgical operations (Seymour et al., 2002; Larsen et al., 2009), and the military (Gerbaud et al., 2008).

There have been many virtual training systems which were developed to aid the acquisition of procedural skills related to assembly tasks. However, most systems are aimed at supporting training of maintenance tasks in which knowledge of both assembly and disassembly are part of what is acquired during the training of the tasks (Webel et al., 2013; Xia et al., 2012; Peniche et al., 2011; Gutiérrez et al., 2010; Abate et al., 2009; Oliveira et al., 2007; Wang and Li, 2004; Bluemel et al., 2003; Vora et al., 2002); only a few are dedicated solely to support training of assembly tasks (Lili et al., 2009; Brough et al., 2007; Abe et al., 1996). On studying these publications further we also found an indication that formal user requirements elicitation was rarely conducted prior to the development of the systems. Failure to perform user requirements gathering means that the system is at risk of being unable to address users' real needs and its usability is reduced (Nielsen, 1993; Maguire and Bevan, 2002). To the extent of the knowledge of this paper's authors, there are limited studies (e.g. Anastassova and Burkhardt, 2009) that focus specifically on user needs and requirements for training of assembly tasks in the context of automotive manufacturers. This paper aims to fill this gap in the hope that the information could be used to promote the development of a virtual training system that matches the requirements of assembly task training. This paper's contribution lies on its wealth of findings which were gathered from two different automotive manufacturers to reflect the complex needs of training in automotive manufacturers.

Furthermore, game-based training has received increased interest over the last decade and is applied in a variety of fields including business (Leger, 2006), education (Jong et al., 2008) and military (Beal, 2009). This popularity is attributed to the hypothesis that it can lead to skill acquisition and retention due to its ability to engage learners (Colquitt et al., 2000; Prensky, 2001) and is supported by empirical research evidence (Corbeil, 1999; Engel et al., 2009; Garris et al., 2002). There have also been indications that skills learned in game-based training environments transfer to real-life situations (Gopher et al., 1994; Topolski et al., 2010). Despite the latest evidence of the effectiveness of game-based training there has not been any study that investigates the possible application of game-based training within a manufacturing setting in the automotive sector. This paper aims to