Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 57 (2016) 504 – 509

www.elsevier.com/locate/procedia

49th CIRP Conference on Manufacturing Systems (CIRP-CMS 2016)

Static versus dynamic provision of worker information in manual assembly: a comparative study using eye tracking to investigate the impact on productivity and added value based on industrial case examples

Mario Lušić[a][b]*, Christian Fischer[b], Konrad Schmutzer Braz[a], Marina Alam[b], Rüdiger Hornfeck[a], Jörg Franke[b]

[a]*Technische Hochschule Nürnberg, Institute for Chemistry, Materials and Product Development, Keßlerplatz 12, 90489 Nürnberg, Germany*
[b]*Friedrich-Alexander-University Erlangen-Nuremberg / Institute for Factory Automation and Production Systems, Egerlandstraße 7, 91058 Erlangen, Germany*

* Corresponding author. Tel.: +49-911-5880-1906; fax: +49-911-5880-5900. *E-mail address:* mario.lusic@th-nuernberg.de

Abstract

Manual product assembly is usually done by providing worker information accordingly to the present assembly task. Traditionally, paper-based systems are used for this purpose, but nowadays, IT-based worker information is gaining ground. Those systems in particular allow the transmission of dynamic information and, thus, enable a realistic and timely representation of assembly sequences. Previous comparative studies on the effective difference between static and dynamic provision of worker information have two gaps. On the one hand, the majority investigated less manual assembly tasks close to real industrial cases. The experiments take place rather on abstracted assembly models under research laboratory conditions. On the other hand, there is a lack of studies on the efficiency of the interaction between the information providing medium, the available assembly objects and the actual worker's behaviour. This is regarded in a way simultaneous to the assembly process and from a real view of the worker. To be able to draw conclusions about the efficiency of this interaction, a real view registry, which is provided by the yet sparingly applied eye tracking technology, is feasible. The experiments described in this article draw on both aspects to realise a lifelike as possible comparison between static and dynamic provision of worker information: Based on industrial case examples, and thus close to a real working environment, the worker's eye movement is documented specifically for the assembly tasks and afterwards holistically analysed in concern of the impact on productivity and value adding.

Peer-review under responsibility of the scientific committee of the 49th CIRP Conference on Manufacturing Systems

Keywords: Assembly; Information; Productivity; Value adding; Eye tracking.

1. Introduction

Assembly information support improves the working performance of a worker [1]. Traditionally, paper-based systems are used for this purpose [2], recently, however, IT-based worker information systems are to be found [3,4]. These in particular allow the transmission of dynamic information and thus enable realistic representation of assembly sequences [5]. As addressed in the following chapter, previous comparative studies on the effective difference between static and dynamic provision of worker information have two gaps.

2. Need for action

There is a bunch of publications differentiating static and dynamic representation of information. These publications are previously filtered by some elimination criteria that are described in the following paragraphs.

One criterion is the kind of knowledge that is actually requested by a worker. As this study only concerns the usage of an information system in a real assembly environment, we can exclude publications based on declarative knowledge. Examples for the latter are academic topics like photosynthesis [6], the functionality of a cable pulley system [7] or first aid theory [8]. The mentioned publications

Peer-review under responsibility of the scientific committee of the 49th CIRP Conference on Manufacturing Systems
doi:10.1016/j.procir.2016.11.087

predominantly concern the test of knowledge and comprehension, only within a few experimental series, actual assembly tasks are included. However, most experimental subjects were pupils that had to knot [9] or to fold paper airplanes [10]. To get a relation to manual assembly processes in an industrial context, we choose publications with realistic assembly tasks. We go on analysing publications which deal with the subjects' motor skills as well as problem-solving and procedure-oriented methods. This paper focusses industrial assembly processes with real parts from automotive production, which is one gap identified within the concerned pertinent research. The used working instructions base on three-dimensional (3-D) computer-aided design (CAD) models. For worker guidance either screenshots or animated 3-D models, that show the assembly paths of parts, were used.

An important differentiator for literature analysis is the role of animations used within experiments. They can be merely decorative and, thus, may contribute to a subject's motivation or attention, or they indeed carry an informational value [11]. In addition, according to that meta-analysis of Höffler and Leutner, that focuses predominantly on declarative than procedural knowledge, representing animations are more effective than representing static pictures. However they don't identify significant differences between decorative animations and static pictures [11]. Consequently, we only consider publications with representing animations.

A further publication about the effect of different kinds of signals, like coloured high-lighting on an experimentee [12], can be excluded although eye-tracking has been used, hence the dynamic in information provision only means signal change. Table 1 gives an overview about the selected publications for further consideration after our analysis.

Table 1. Comparison of relevant papers and their experimental parameters

Publication	Working period	Number of errors	Number of correctly done working steps	Number of attempts	Frequency of look up and required look up time	Recognition of previous/subsequent steps	Duration of initial reading in
[9] – exp. 1	✓		✓			✓	
[9] – exp. 2			✓				
[13]			✓				
[14]	✓		✓	✓			
[15]	✓	✓					✓
[16]	✓		✓			✓	
[17]	✓		✓				
[18]	(✓)			✓	✓		✓
[19]	✓	✓					
[20]	✓		✓				✓
[21]	✓	✓			✓		
[10] – exp. 1			✓				✓
[10] – exp. 2			✓				
[10] – exp. 3			✓			✓	

Another gap concerning the pertinent research is the scarce application of eye tracking technology [22] so far. In some studies it is involved to track, if a subject notices certain signalling techniques [12], but its potential for a documentation of the actual behaviour of workers has not yet been exploited.

In this context, one should have a look at processing time as an important parameter, especially for assembly processes. The processing time is a sum of the working time for actual activity on parts and of the look up time for reviewing working instructions, which can be determined as a no-value-adding activity. Eye tracking technology enables the measurement and the evaluation of periods in an easy, detailed, and reproducible way. The real watching time on distinct areas of interest [23] is recorded and can be redrawn later for evaluation. Certain areas of interest might be working instruction on screens or assembly environments.

3. Experimental setup

Following an approach close to industrial reality, the present study focuses on variables that are essential for pertinent categories like productivity and added value. The crucial elements of the experimental setup that is methodologically based on the conceptualisation of the psychological experiment by Sarris [24], are described below.

3.1. Dependent variables

Subsequent to the findings of chapter 2 the following dependent variables were measured: working duration, time for additional look up at instruction, frequency of additional look up at instruction and number of properly performed assembly steps.

Working duration and time for additional look up at instruction. The working duration is basically divided into assembly time and look up at instruction time. During the assembly time the worker is executing value-adding activities, such as assembling parts or using tools. The additional look up at instruction time means, in contrast, not value-adding periods, since the worker interrupts the assembly process for reading or looking on the worker information system. The additional look up, due to the repeated understanding of the assembly task, occurs after the initial read in time, which is not limited but determined by the worker himself, if he decides to start the assembly. Fig. 1 illustrates the structuring of assembly time existent from once initial read in time, multiple value-adding assembly periods and multiple periods for additional look up at instruction.

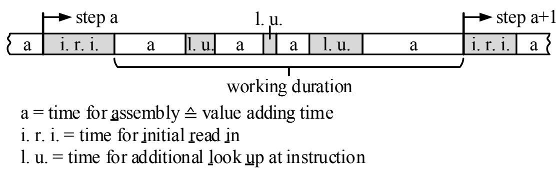

Fig. 1. Structuring of time required for each assembly step

Frequency of additional look up at instruction. The rate of the participants' looks ups back at the instruction is