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Procedia CIRP 57 (2016) 510 – 515

www.elsevier.com/locate/procedia

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

Usage Frequency and User-Friendliness of Mobile Devices in Assembly

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Abstract

The rising number of variants and more individualized products increase the physical and mental load for assembly workers. Assistance systems ease the stress in these situations especially when they offer assembly instructions for products. There are different requirements such systems must fulfill in order to be used efficiently. They must be adaptable to the special needs of the using employee, they need to be location-independent as well as capable to react in real-time to process changes. Assistance systems must offer significant flexibility to cope with shortening product life-cycles as the need for individualized products increases. Paper-based work instructions cannot meet these requirements. Instead new technologies like mobile devices (e.g. smart watch, tablet) are established on the market. They satisfy the market induced requirements due to their inherent characteristics like mobility, user-friendliness and adaptability. Nevertheless it must be ensured that these devices are accepted and properly used by the employees in order to tap their full potential for increasing the productivity in assembly lines. For this reason possible barriers in usage and acceptance must be examined. This paper presents results of a first study which compares two mobile devices, used as assistance systems, concerning usage frequency and user-friendliness. The aim is to identify the preferred device as well as potential for optimization. In the study the test persons get an unknown assembly task, a simple paper-based work instruction and two kinds of assistance systems - a smart watch and a tablet. Observations about the preferably used device are conducted while they are performing the assembly task. A subsequent interview illustrates specific potential for optimization, which supports a productive interaction between user and device.

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

Keywords: mobile devices; user-friendliness; acceptance; assembly systems

1. Changing production environments

The production environment is influenced by different factors which can be sectioned into the elements human, technology and organization. These three are core elements of every industrial organization [1]. Nowadays significant changes in all three sections of this concept can be monitored. Especially since the German federal government announced Industrie 4.0 in 2011 as the leading key initiative for the high-tech strategy, the discussions about these changes increased noticeably [2].

The fourth industrial revolution (Industry 4.0) facilitates the vision of a smart factory [2]. In this context **technological** developments like mobile devices, cyber-physical systems and the setup of networks with other smart elements play a major role [3]. The so-called smart factory allows a full horizontal and vertical integration of all processes needed for the production and therefore offers new possibilities for the production, for example in the field of customer individual products [2]. In manufacturing mobile devices like tablets and smartphones offer a variety of possible applications. As assistance systems, for example, they can display assembly instructions, which can be designed individually for the worker and can be shown dynamically due to his working manner or speed [2]. In this context the right time and amount of information brought to the employee is crucial, so that he can process it effortlessly and does not get overstrained by the system [4]. If these systems are laid out suboptimal, they do not offer any increase in productivity of the worker [5].

The **organization** is strongly changed by shortening product life-cycles and an increasing number of variants. As more customers demand individual products and want to participate

Peer-review under responsibility of the scientific committee of the 49th CIRP Conference on Manufacturing Systems
doi:10.1016/j.procir.2016.11.088

in the product-development-process, companies are constrained to develop new methods of organization in order to provide the necessary flexibility in their production units [6].

These changes can be reflected in increasing requirements for **human** workers on the shopfloor of a production environment. In order to cope with highly flexible working conditions means quickly changing and more complex manufacturing tasks, which can lead to excessive demand and mental stress [7].

At the same time western industrial nations suffer from a demographic change, which over time leads to an over aging population [8]. This makes it difficult for companies to find young and highly qualified employees. As a result they need to remain longer in an active employment. Companies have to come up with solutions to preserve the physical and mental performance of their older employees under permanently increasing requirements [8]. Measures for reducing physical and mental load as well as measures to integrate employees with impaired or under-qualified abilities into productive operation become an important way to cope with this challenge [9]. However the determination of humans is very difficult as everyone has a unique set of characteristics and abilities. This makes it difficult to define general measures and to evaluate their outcome. That is why a research team at the Institute for Machine Tools and Industrial Management (*iwb*) at the Technical University of Munich pursues an empirical approach to validate research ideas and their effectiveness. For this purpose an educational laboratory called “Future Factory Lab” was set up.

2. Educational laboratory “Future Factory Lab”

2.1. Objectives of the “Future Factory Lab”

The “Future Factory Lab” (in short FFL) pursues three core purposes which will be described in the following.

First of all, it was built up in order to examine the potential for success and industrial applicability of new research topics. This offers the possibility to evaluate the future outcome of a research approach at an early stage. In the lab it is for example possible to set up a hands-on, simplified test-scenario for a future research projects and evaluate if at all the desired outcome can be reached with this approach. With the help of this evaluation an aberration in the development of the researchers can be prevented. Another context where an early-stage potential evaluation is used, are new technical developments which should be used in production environments in the future. In the FFL it is possible to examine those products in a semi-realistic assembly environment and identify possible strengths and weaknesses of these products. Especially products from formerly only customer-related markets, for example smart wearables like smart-watch or data glasses can be integrated in the Lab as a new asset. With the help of different scenarios in experiments possible ways of application can be identified and evaluated concerning their positive outcomes for future assembly applications. Especially for industrial partners in research projects this is an interesting opportunity as they can also use the Lab in an early stage of the project to inform themselves about future application methods and requirements.

Secondly it is used to conduct empirical studies in a laboratory environment to test and confirm theoretical hypotheses. An example what kind of statements can be evaluated is described in the following chapter *3. A study on the usage frequency and user-friendliness of mobile devices in assembly*. The laboratory environment, where certain parameters for an experiment can be defined exactly and external influencing factors can be avoided, ensures an objective and specific validation of those hypotheses.

The third purpose of the FFL is to transfer newly developed approaches or methods into industrial application. For this reason trainings and qualification workshops are offered to interested companies and especially to the different project partners. For the industrial partners the Lab offers an opportunity to find a realistic environment to train new skills and methods without disturbing or interrupting the normal production process which would be the case if a training has to take place in the real production environment immediately. Therefore it offers a cost-saving and low-risk yet still effective way to train employees with new devices or methods.

2.2. Setup and realization of the Lab

The main characteristic of the Future Factory Lab is the high flexibility to represent any diverging setup for assembly situations. In order to gain significant results in the studies and experiments it is important that the laboratory setup resembles a real production environment as close as possible (Fig. 1). This is why the Lab is mainly set up with standard components like for example assembly tables which are broadly used in real assembly lines.

All elements used in the Lab are mobile and have a modular structure so that highly flexible and dynamic compositions are possible.

Fig. 1. Setup of the Future Factory Lab at *iwb*

Each assembly table offers different possibilities to install further devices like assistance systems or monitoring devices as for example cameras. Currently as assistance system devices different tablets, smartphones, a smart watch, data glasses or the projection of information directly on the working surface can be used. All the elements of the Lab can be exchanged and extended with further components to design new testing situations.

The Future Factory Lab offers three different types of demonstration products which can be assembled by the test subjects in studies or experiments. Depending on the level of building complexity and building variety which is needed for the actual situation the suitable product can be chosen. Available are a planetary gear which is applied in express trains for opening and closing the automatic doors. It consists of a large number of parts which makes the assembly process rather complex. Therefore it offers little variance. If, however, a product with high variance in the assembly is needed, the battery modules for energy storing facilities in private households can be used. They offer a great variance in the pattern in which the single components have to be assembled whereas the assembly process itself is quite easy. The third product is a LEGO-truck without any variants and with a manageable number of parts. The following Fig. 2 shows a scene from an experiment in which usage possibilities of projections onto the workplace have been evaluated. In this experiment the battery modules were used as demonstration products because of the high assembly variance they offer.

Fig. 2. Experiment with the battery module as demonstration product

With the help of these adjustable elements the required assembly environment for each testing scenario can be created. Aim of this flexibility in setup and design is to establish an assembly environment as realistic as needed for the experiment.

3. A study on the usage frequency and user-friendliness of mobile devices in assembly

In the wide context of developments regarding Industry 4.0, changes for employees in production play a significant role. The trend of an interconnected and, in huge areas, autonomous factory changes the requirements and competences of these employees. The increasing usage of assistance systems in production and assembly leads to workers having to use more and more software. The fundamental question arises: Are they willing to accept the way in which their daily work will be influenced by digital systems? Are they even willing to use them at all or are there certain prejudices that an increasing amount of digitalization implicates, especially compared to conventional systems? In order to answer a part of those questions, a first empirical research study has been carried through by the FFL.

In this context, empirical studies serve the purpose of gaining knowledge based on real experiments, where the informational gain happens through observation, interview or experiment to describe the reality as closely as possible [10]. That is why in the study a combination of experiment and interview was used to obtain answers on the above questions. The structure and results of this study will be described in the following paragraphs.

3.1. Objective and research questions for the study

The goal of this research study is to analyse if workers in assembly, if given the choice, are more willing to use a digital assistance system to answer questions and solve problems, or personally ask an expert for support. In order to call the assistant, a smart watch is used. Apart from the total number of times in which both options have been used, detailed reasons for choosing one over the other shall also be gathered. The findings lead to basic conclusions which might help to design digital assistance systems and improve usability.

The following research questions should be examined:

- Question 1: Which system is preferred when questions during the assembly occur, the tablet or the smart watch?
- Question 2: Does the assembly time influence the decision from question 1?
- Question 3: What are the main reasons for choosing one over the other?
- Question 4: Does the smart watch influence the performance of the assembly task?

3.2. Setup and assembly scenario

In order to examine the above questions 30 test subjects conduct the defined assembly task. The group of probands consists of students and employees of the Institute for Machine Tools and Industrial Management. Therefore every participant has a technical background and a certain level of assembly knowledge by what inhomogeneity in the study results based on different level of experiences is prevented. The age of the test subjects ranged between 20 years and 35 years.

The procedure of the research study is as follows: The test subject (male or female) will be confronted with an unknown assembly process. He will then attempt to assemble a product (see LEGO-truck in paragraph 2.2) consisting of 16 separate parts and modules. His only aid in order to accomplish this task is a paper-based work instruction that describes the assembly process in a very basic and high-level way. It consists of four pictures. Each of the pictures represents several consolidated steps in the assembly process.

In case he needs more detailed information of how to assemble the product, he can use one of two ways to get them. First, a tablet (as is can be seen in Fig. 2) is present on which more detailed instructions can be found. Second, he can request an expert via his smart watch (see Fig. 3) who can give him feedback and help with the issue if required.

Fig. 3. Smart watch with the button to call for an expert

The instruction manual on the tablet can be used with the help of the usual touch gestures that people got used to over the last years (e.g. swipe, pinch). In this digital format, every assembly step consists of two levels of detail which the test subject can choose from. In contrast to the high-level analogue work instruction, the tablet provides the test subject with illustrated step-by-step instructions. In case this data is not sufficient for the test subject, he has the option to get even more data in form of more detailed assembly information such as the appearance of the part or the direction in which the assembly has to be performed.

If the proband decides that he is in need of personal assistance from an expert, he can call one by touching the appropriate icon on his smart watch. The expert will arrive at his assembly station in short notice and is able to deliver verbal help regarding the current assembly step. In addition to that the expert is allowed to answer a test subject's specific questions regarding the assembly of the product.

The research study has been performed in two separate parts. First, a group of test subjects with no time limit for the assembly of the LEGO-truck has been observed (scenario 1). In this scenario the assembly time varies between 4 and 10 minutes with an average of 7.16 minutes. Then, a different group of test subjects had to perform the assembly process within a time limit of 6 minutes. If the time limit has been reached, the assembly process is being stopped immediately. This way it was analysed if a time limit, and therefore the pressure to complete a task in a certain amount of time, has an impact in the way the assembly worker requests assistance. At the end of the assembly run, each of the test subjects was given a number of questions regarding their decision making process and personal feelings during the study.

3.3. Results of the study

Comparing the usage statistics of the tablet in scenario 1 and 2, a slight increase of 3.4% in 2 can be stated. While the test subjects used the tablet 59-times without having a time-limit for assembly, the number increased to 61 when a time limit of 6 minutes was set. We defined a single "use" if the test subject looked at the next assembly step on the tablet and proceeded with the actual assembly step afterwards. A more significant increase is to be seen when it comes to asking the expert for help. While in scenario 1 the expert got called a mere 10 times, giving the test subjects a fixed time limit, thus increasing the pressure, increased the willingness to request personal assistance to a total number of 18, which is a relative increase of 80%. This leads to the conclusion that, if the assembly worker is given a time limit to perform an unknown assembly step, he is much more likely to ask an expert for personal assistance instead of just using an assistance system and finding the information by himself. Overall, the assembly worker in scenario 1 tends to make use of a digital assistance system in 85.5% of the cases while only asking for an expert 14.5% of the time. In scenario 2 these numbers shift to 76.25% where the test subject prefers the digital assistance system while asking an expert for help in 23.75% of the time. Fig. 4 displays the usage statistics by type of help.

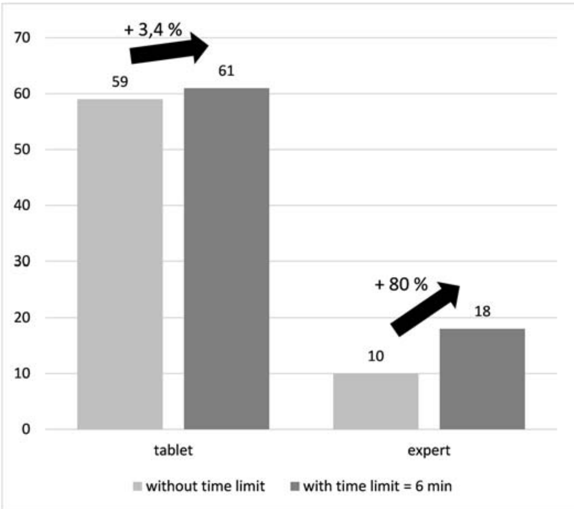

Fig. 4. Usage frequency by type of help

So under the given circumstances the answer to research question 1 is, that the tablet is the preferred medium for assistance during the assembly task.

The arising follow-up question in this context is, why such a clear increase in the usage of the smart-watch and therefore the demand for an expert can be recognized. As this increase only takes place in scenario 2, a possible explanation might be the induced time pressure. So research question 2 might be answered as follows: A rising time pressure leads to increasing demand for personal assistance. So in this study the assembly time influences the decision for an assistance system.

Moreover the significant difference in the usage frequency of the tablet and the smart-watch is eye-catching. In order to find an explanation for this finding, the answers of two questions in the interview, which took place with every proband after finishing his assembly task, can be consulted. Fig. 5 shows the relevant questions and the answer-allocation of the test subjects.

When asked if they feel uncomfortable when they have to admit a problem with the assembly of the LEGO-truck to the expert, 63% of the test subjects answered with “yes”, 33% negated and one abstained. The following question is aimed at identifying whether or not the probands feel more observed by the expert than by the usage of the tablet. 50% stated that this assumption is correct and that they feel monitored if they call the expert for help. 46% answered that they do not feel under more surveillance as they do with the tablet and one participant abstained.

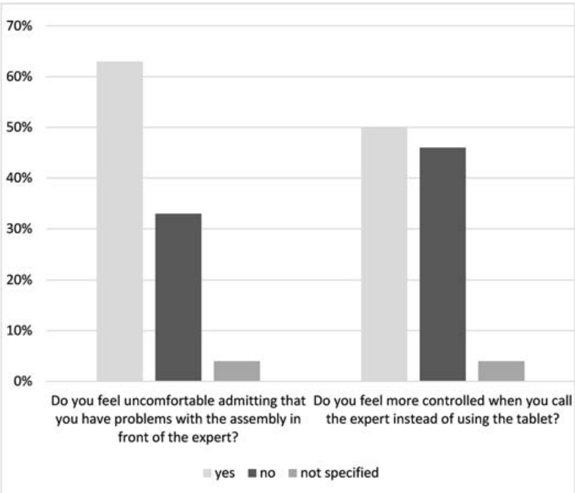

Fig. 5. Personal feelings of the test subjects

An interesting finding in the empirical study is, that the expert-call by smart watch did not play a significant role for the test subjects. None of the participants had problems with the handling of the watch or thought it was interfering with the assembly process in a negative manner. So the technical environment of the study is not one of the reasons why the expert was not called as often as the tablet was used.

No one of the 30 persons claimed that the wearing of the smartwatch was uncomfortable, however, 63% of the respondents remarked that they would like to get some more information concerning the call for the expert. This could be for example a feedback that the call reached the expert or a note how long it will approximately take for the expert to arrive at their work station. Furthermore, the functionality of the smartwatch was very satisfying, as the call for support worked out immediately every time. Concerning research question 4 it can be stated that no negative influence by the smart watch on the assembly task can be observed.

All 30 test persons preferred pictures instead of textual instructions on the tablet and therefore attested the tablet a high comprehensibility. Four of them would even favour both, an illustrated guidance with short written assembly commands. Furthermore only two of 30 persons would find an additional acoustical support useful.

3.4. Interpretation and critical reflection of the study results

As a general outcome of the study, it can be stated that rising time pressure leads to an increasing demand for personal support by an expert. Possible reasons for this correlation have been found in this empirical study. One possible interpretation of this context might be, that the intuitive comprehensibility of images, as they are used on the tablet to support the assembling person, decreases in stressful situations and it takes more time to analyse and understand them as before. This might be one reason why personal assistance is requested. Yet in order to validate this correlation further examinations are necessary.

To conclude, some critical aspects of the study will be analysed and their influence for the study results discussed in the following section.

The target group included participants between the ages of 20 to 35, so it focused on younger people who are used to smart interfaces in their daily life. Due to their personal experiences the interaction with the tablet was very intuitive. The usage of smart advices by older people could differ from the presented results. However, considering the ongoing digitalisation, even seniors get used to digital equipment and this trend will further continue.

93% of the test persons already had experience with assembling LEGO-products, therefore they were used to the typically illustrated construction guidance on paper. Due to their personal know-how and experience the participants mentioned that they would be truly ashamed if they were unable to cope with a small LEGO-assembly as they already did in childhood. The arising question could be if the right assembly-product has been used in this study. Though, since the study wants to test the interaction and usage of smart devices in the assembly, the product is not the important aspect here.

4. Conclusion and outlook

This paper describes the results of a study concerning the usage frequency and usability of mobile devices in a manual assembly. The test subjects should execute an unknown assembly task. With the help of a tablet and a smart watch they are able to call for personal help of an expert. Findings of this experiment are that the tablet is used more frequently due to the uncomforting feeling the test subjects have about personally admitting that they have problems with this “assumed-to-be simple” assembly of a LEGO-product. Nevertheless the number of expert-calls increased distinctively under time pressure.

In the future, follow-up studies should be set up to confirm these first findings and examine further relations. Especially the correlation shown in Fig. 4 (increasing number of expert-calls with rising time pressure) is promising for further research as their might be interesting aspects for the design of assistance systems especially in cycle-time related production environments.

Acknowledgements

The author would like to thank the two involved students in this study, Julia Lorenz and Barbara Tropschuh, for their extensive support and excellent work in the conduction of the study.

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