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Evaluation of Guidelines for Assembly Instructions

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Abstract: In production industry assembly instructions are often in need of improvement. Today's instructions are often text based and are used only when learning the assembly. Due to a high product variety the instruction quality need to be perceptual in order for the operator to make fast and correct decisions. To educate and support personnel making instructions five guidelines that support operators' cognitive abilities have been developed. The guidelines were tested in three case studies with three different used groups: production technicians, students from higher vocational education and bachelor students. Results indicate that the theory behind the instructions is useful and valuable and that further development and testing is needed. The main thing both technicians and students learnt was to support the active cognitive processes, that instructions should be picture based and be as simple as possible.

Keywords: Information presentation, guidelines, cognition, case study.

1. INTRODUCTION

Final assembly of products is becoming more and more mass customized. The concept of mass customization has emerged as a major manufacturing strategy and is increasing in importance focusing on changes in demand and technology (Fogliatto, da Silveira and Borenstein 2012). Managing these future production systems includes successfully managing the interactions between humans and technology (ElMaraghy et al., 2012). In order to manage mass customized production i.e. high variety of products, the system has to provide the operator with the right information at the right time (Fässberg, Fasth and Stahre 2012). With high (product) flexibility comes an increased complexity i.e. there is a positive correlation between dynamic complexity and flexibility (Chryssolouris et al. 2013). Complexity in a system can also be defined as something that is "difficult to understand, describe, predict or control" (Sivadasan et al., 2006) which is directly coupled to cognitive processes e.g. how a person understands situations and processes information.

To support interaction in this context is therefore increasingly important (Lee, 2008, Galster et al., 2002, Sanchez, 2009). How this complexity is perceived by the operators is important to be able measure in order to design the right support (Mattsson et al. 2014b).

This paper aims to evaluate five guidelines developed to improve assembly instructions and to show the importance to consider cognitive aspects when designing assembly instructions. Two groups were evaluated according to the following:

1. The ability to learn and use the guidelines
2. Differences between experience level and exercise time
3. Implications and possible improvements of the guidelines.

1.1 Cognitive processes

Cognitive processes can been divided into two types: intuition and reason (Hollnagel 1997b, Passer et al. 2009). Chase and Simon (2013b) defined intuition as recognising patterns already stored in the memory (came from analyzing chess players) or association (Hollnagel 1997b) while reasoning is connected to more effort, motivation and concentration. In final assembly the task of assembling a component is connected to intuition (Mattsson, Fast-Berglund and Stahre 2014a).

Attention allocates the cognitive resources and helps to focus the resources on relevant data in the instructional environment (Clark et al, 2006), while the memory helps to make sense of and store the information. The memory can be divided into long-term and short-term memory (Osvalder & Ulfvengren, 2009). In an assembly situation the short-term memory, also known as working memory, is active and process the information that is needed to perform the task (Ganier, 2004). The working memory, however, is a limited resource and can only keep 7±2 mental models active at a time (Miller, 1956). Mental models are reconstructions of external phenomena in our long-term memory that are used to interpret new information (Rook, 2013).

To be able to optimize human performance, information given to the human should be arranged so that it fits the operator's cognitive processes (Rasmussen, 1983). Information should not be used to support a detailed data processing, but instead support the possible behavioural characteristics used and tasks should be described in terms of mental models instead of system requirements (Rasmussen, 1983). Instructions that are developed without consideration of these processes can cause unnecessary cognitive load and

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lead to poor operator performance (Kahneman, 2003).

1.2 Cognitive automation and use of instructions in industry

In order to support the cognitive processes, automation could be a solution. Cognitive automation could be divided into seven different levels (Fasth and Stahre 2013) and can be defined as; information to support to the operators so that she knows what to assemble and how to assemble it at the lower levels and monitoring support at higher levels. The popular cognitive view on how any information is processed is centred on the idea that we construct internal representations from information presented through external representations (Watson et al. 2010). The way in which we do this will differ depending on the form of the external representation. The cognitive levels must therefore be further divided into information carrier and information content i.e. what media is the information presented and what kind of technology is used (Fässberg et al. 2012). It could also be described as *descriptive* i.e. no similarity to its represent, for example text-based instructions or *depictive* i.e. were the information is more similar to its representation for example pictures or movies (Kosslyn 2005).

Case studies in industry show that over eighty percent of assembly is carried out by operators own experience(Fast-Berglund and Stahre 2013a). A survey was given to forty-five production engineers at three global companies. At these companies text based assembly instructions were the most common and they were often presented on papers (Fast-Berglund 2014) further studies was done at an international level for one of the companies with fifty-eight production engineers. Still text-based instructions at papers and oral instructions over phone was the most common instructions(Johansson, Fast-Berglund and Moestam 2015).

Several case studies (Watson et al. 2010)(Fast-Berglund and Blom 2014)(Blom 2014, Thorvald et al. 2010, Fässberg et al. 2010) shows that depictive work instructions i.e. pictures and movies instructions tends to be much better both regarding cycle-time, quality, flexibility in time and space and learning curve over descriptive instructions i.e. text-based. Hence oral representation of instructions takes much longer time and result in poor quality than text-based instructions.

1.3 Five guidelines to support cognitive processes and cognitive automation

1. Support active cognitive processes (Mattsson et al. 2014a)*:* If too much information is presented it is easy to miss what's important and mistakes can be done. Consider also differences in experience levels (novices and experts). The guidelines also include a figure of Kahneman's System 1 and System 2 model that describe the differences between the two cognitive processes (Smith and Kirby 2004).

2. Support mental models: How a person perceives a situation affects his/her behaviour (Kurtz and Snowden 2003, Hollnagel 1997a). Consider the tasks that you've done using different information techniques to support how you would like the information to be presented.

3. Support abilities and limitations: The memory and attention is limited. Also support the fact that humans are good at handling dynamic situations (Billings 1997, Jensen and Alting 2006, Fasth et al. 2009). Support the memory 7±2 things (Richardson and Reischman 2011) and present fewer things (Clark, Nguyen and Sweller 2006), have a clear description and presentation (Abrahamsson et al. 2009, Ganier 2004) (Osvalder & Ulfvengren, 2009; Inaba et al, 2004)(Ganier, 2004), focus on pictures, differentiate between similar objects and use arrows, numbers and zoom (Söderberg, Johansson and Mattsson 2014, Li, Cassidy and Bromilow 2013).

4. Support individual preferences/differences: Humans are different and they may want or need different types of information. Changes in demographics (Regeringen 2012) will result in a more differentiated personnel that might have differences in hearing, vision and also other physical aspects e.g. height.

5. Support perception (placement) (Söderberg et al. 2014)*:* Where information is placed is important. Support instructions by adding a picture showing the completed product.

2. EMPIRICAL DATA

Two different groups were part of the evaluation the guidelines. 29 participants were divided as: Group 1: production technicians from a global company (7 participants, ages 30-60) and Group 2: experienced operators that were studying to become production engineers (22 participants, average age 28.5). Both groups were novices in cognitive sciences. Group 1 had much more experience of thinking about instructions while Group 2 had just started their education (although having an average of 7.6 years of production work).

2.1 Learning and use of guidelines

The groups were part of learning and using the guidelines following the following five steps: *Building knowledge, oral instructions, testing different information carriers, making improvements using guidelines* and *evaluation of the new instructions, learning and use of guidelines.*

Step 1: Building knowledge. A three hour lecture about cognitive ergonomics, cognitive processes, ICT-tools used in industry, cognitive automation and a presentation of the guidelines. This step also included an exercise were participants played a memory game were they hade to find the correct cognitive term to the correct explanation.

Step 2: Oral instructions. In this exercise participants were divided into two teams, experts and novices. The experts had to give an oral explanation of the instruction, building a Lego engine, illustrated in figure 1. The cycle time and quality was documented.