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Supporting Attention in Manual Assembly and Its Influence on Quality

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ABSTRACT

Modern manufacturing information systems allow fast distribution of, and access to, information. One of the main purposes with an information system within manual assembly is to improve product quality, i.e. to ensure that assembly errors are as few as possible. Not only must an information system contain the right information, it must also provide it at the right time and in the right place. The paper highlights some of the concerns related to the design and use of information systems in manual assembly. The paper describes a study that focuses on the correlation between active information seeking behaviour and assembly errors. The results are founded on both quantitative and qualitative methods. The study indicates that by using simplified information carriers, with certain characteristics, the assembly personnel more easily could interpret the information, could to a higher degree be prompted (triggered) about product variants and could also be able to prepare physically and mentally for approaching products arriving along the assembly line. These conditions had positive influence on quality, i.e. gave a reduction of assembly errors.

Keywords: Manual Assembly, Active Attention, Passive Attention, Situation Awareness, Information System, Product Quality

INTRODUCTION

In a modern manufacturing environment the information system is a vital part of the assembly process. The “receiving” of information is an important part of the flow of information between the information system and the receiver. The receiver must interpret the information so that an appropriate action can take place. That is, one has to comprehend the meaning of the information so that an action can take place, and one has to understand how this action will affect the future status of a product. This follows the definition of Situation Awareness (SA).

There are many concerns related to the flow of information in a manual assembly context. One concern is related to active and passive attention. James (1890/1950) describes active attention as a state where humans actively seek information, whereas passive attention is when humans are passively awaiting a situation where active attention is required.

Related to information system use in a manual assembly context, the main focus for the personnel should be to translate the information into actions to reach a specific goal. This requires that the information is available at the right time, in the right place and that the assembly personnel have identified a need for the specific information. During a study at an engine assembly plant an evaluation of some of the workstations indicated that there are problems connected to the distribution of information that can be defined as “Delivery versus Demand” of information (Bäckstrand, et al., 2005). They further argued that *Information Delivery* is the event that occurs when a specific type of information must be accessible in a specific work environment, for example an assembly workstation. *Information Demand* occurs when an “object”, in this case one of the assembly personnel, has identified a need for information. This need originates from a need to fulfil a goal (Figure 1), and possibly the satisfaction of fulfilling the goal (Losee, 1990).

Figure 1. The information flow with respect to demands and goals (Bäckstrand, et al., 2006).

For the goal driven assembly personnel there are two ways to view visual attention: top-down (goal driven) or bottom-up (stimulus driven). Attention is said to be both goal-driven and stimulus-driven, according to Yantis (1998).

- Goal-driven (active attention): The product is known to have a specific marker, and one searches for that marker. This product is likely to be selected by our attention and recognized.
- Stimulus-driven (active or passive attention): All products look similar or the same, except one, that seems to “pop-out of the background and draw attention automatically”.

The ability to actively detect information in our environment is of great importance in an assembly context. An interesting aspect is whether there is a connection between attention and assembly errors. According to Reason (1990), attention can

be seen as work performed on discrete elements in a restricted work space, our working memory. Hence, the work uses energy from a strict limited “pool of attention resources” (Wickens, 1992; Downing, 2000), and it is important to use this energy in an optimal way. If one presumes that passive attention draws less energy from the “pool of attention”, one of the goals with information must be to support the personnel in a way that makes it possible to continue working in a passive attention mode, where the use of skills and sub skills is more or less automatic, (Shiffrin and Schneider, 1977). Norman (1990) describes this kind of automation as a useful advance that can replace tedious or unnecessary tasks and monitoring. This must (if one presumes that the Reason and Norman theories are correct) result in less use of cognitive resources. Less use of cognitive resources by one process, for example the information search process, should make it possible to use the limited resources more effectively (Downing, 2000).

If one focuses on the need of information for the assembler, one realises that there are some issues that the discussion regarding active and passive attention can explain. The move from passive to active attention is triggered by an exogenous event (from outside, in this case the body) that cannot be suppressed or ignored by the assembly personnel. This exogenous event is the trigger that should start the expected information search process. Therefore, an information system that triggers the information search process is essential, and when the information search process has started it should support a passive attention mode. This means that the need for an active (active from an attention perspective) use of the information is to be kept at a minimum.

An interesting finding when one studies the theories of Situation Awareness (SA) is the absence of the important issue concerning how triggers can create change of state, from passive to active attention, from active to passive attention. For example a trigger that indicates when it's time to relax from a mentally point of view. Endsley (1999) states that due to several factors, although the information is directly available, it is not observed or included in the scan pattern, due to for example not looking at the information, attention narrowing etc. This is according to Endsley, the main contributor within SA related errors and is where it is believed that triggers can be a major contributor to preventing this type of human error. The trigger in this case is the event that creates awareness of the presence of important information, and that draws the personnel's attention to the correct information source. It is obvious that if an assembly worker is not aware of a need for information, a correct information search process will not be started. This will result in a quality risk that can influence the assembly errors severely.

Based on this argument it is hypothesised that by using simplified information carriers, in this case based on a colour coded information system, the assembly personnel more easily could interpret the information, could to a higher degree be prompted (triggered) about product variants and could also be able to prepare physically and mentally for approaching products arriving along the assembly line.

Accordingly, it is assumed that these conditions will have a positive influence on quality, i.e. will cause a reduction of assembly errors.

METHOD

The experiment consisted of testing how the colour coded information system could affect the personnel and how that would affect the quality.

The field experiment focused on four assembly stations in an engine assembly plant (two stations S0800 and two stations S1100 on parallel assembly lines) where the main component for S800 was servo pumps assembly and for S1100 cable harness assembly. The gathering of empirical data consisted of recoding assembly errors, complimented by semi-structured interviews. Historic data on assembly errors was used as reference performance indicators. Approximately 33000 historic data was recorded from the reference period: 13th March 2006 to 22nd December 2006. The most relevant data included: date and time, engine family, engine variant, effect number, effect description, part number and a free text field (this field could be used by the quality assurance personnel to describe the cause of rejection).

The production at the assembly line continued during the experiment and the conditions were more or less the same as on regular production days. The personnel involved in the study were all employed by the company and performed their regular duties. The experimental environment and the assembly environment, as it was before and after the case study, differed only in the parts that was included in the study: the *informative triggers*. The triggers were coloured magnetic rubber sheets with a size of approximately 300x300x0.85, 300x50x0.85 and 60x60x0.85 millimetres (length, width and thickness) attached to the carrier (Figure 2) and 400x300x0.85 attached to the material racks (Figure 3 and 4). The triggers had two purposes: firstly, to create awareness that a different engine variant was to be assembled; secondly, to give information regarding what part should be used.

Figure 2. The location of the informative triggers on the engine carriers.

Figure 3. The location of the informative triggers on the material racks in assembly station S0800.

Figure 4. The location of the informative triggers on the material racks in assembly station S1100.

At the beginning of the assembly line a station was built specially for the experiment. This station was manned day and night during the study period: 24th May 2007 to 6th June 2007, and was responsible for engine identification, attachment and detachment of the triggers to the carriers (Figure 2).

The result from the study was obtained by comparing number and type of assembly errors during the reference period and during the experiment. June is traditionally the month where summer employees are hired, therefore it was decided to consider this month specially, since the experiment was conducted during June.

A qualitative approach was added in the later part of the study with a questionnaire answered by 171 workers. The main purpose was to establish if there were connections between the results from the quantitative evaluation and what the assembly personnel had experienced.

RESULTS

In the figure, the results for three periods are presented, the reference period, the case period and the amount of reject during the month of June 2006, a period within the reference period. The purpose of investigating and presenting data for June 2006 was to determine if a major difference could be present during the month of June. However, during the case study period now summer employees were present when the study was conducted. The quantitative results showed that the assembly errors reject data during the study decreased to a normalized value of 59 (baseline = 100), for station S0800 (Figure 5) and to 0 (baseline = 100) for station S1100 (Figure 6).

Figure 5. The assembly errors reject data for station S800.

Figure 6. The assembly errors reject data for station S1100.

The decrease during the study for station S800 was approximately 41 points compared to baseline while for station S1100 the decrease was 100 points, i.e. no rejects occurred during the case study period.

An overall evaluation of the data gave:

- Quality: There was a decrease in the number of assembly errors at assembly station S800 and S1100 during the experiment period, compared to the reference period.
- Productivity: No effect could be found regarding the assembly time for each station, i.e. there were no differences in assembly time when comparing the reference and the experiment period

The qualitative survey gave that the colour coded way the information was presented improved the information by:

- Presenting the information so that the assemblers can see the information from their station.
- Making it easier to identify from a distance what to assembly.
- Providing the information so that the information is presented when a need has occurred.
- Eliminating the need to learn by heart where in space the parts that should be assembled are located.
- Creating a less demanding workload due to the elimination of noise (i.e. redundant information).
- Triggering the information search process when it is needed.
- Supporting part changes, for example when a design change note is initiated. When this occurs, it is possible to make the change without changing the colours in the work environment. If a new part is added, a new colour can be added. By using the existing colours or just adding a colour, the need to learn by heart where the parts are located, the

productivity losses during the learning and the training needs are lowered by a considerable amount.

DISCUSSION

The main purpose with the study was to try to find explanations of the quality problems that occur in the assembly environment at the company involved in this study, and to try to understand how information and the use of information can influence humans in both negative and positive ways.

The simplified system that was used during the experiment reduced the number of assembly errors, i.e. it gained quality, while productivity was not influenced. It is believed that the reasons for this effect are that the simplified information system made it easier for the personnel to interpret the information, and they were to a higher degree prompted about product variants. They were also able to prepare physically and mentally for approaching products arriving along the assembly line.

The survey revealed that a common reaction was that the reduction of the amount of information was a main benefit with the colour coding. This made it possible for the personnel to quickly find relevant information without noise from redundant information.

It is obvious that if an assembly worker is not aware of a need for information, a correct information search process will not be started. This will result in a quality risk that can influence the assembly errors severely. Knowledge and how to gain it is an important part of manufacturing, but in this case, attention is the subject of interest. This is because of the strong connection between attention and the investigated assembly errors. An interesting part of Jones and Endsley's causal factors is that 76% of the errors in situation awareness are in their study caused by problems in perception of needed information (Endsley, 2000). If one assumes that there is a connection between "problem in perception" and attention, one can argue that there is a high risk of exclusion due to changes of state in the information flow. This exclusion can be caused by a framing effect that limits the possibilities to choose information (Beach and Connelly, 2005), or a failure to observe provided information. The framing can be connected to a suppression of endogenous signals (signals from the brain) so that the information for some reason is not observed, i.e. a person misses the exogenous signals in the work environment.

To summarize, the results from the study clearly indicate that information and the way it is presented has a strong effect on quality as well as on the ability for the assembler to identify information needs. The study supports the hypothesis that the use of a triggered information system affected the assembly personnel in a positive way, which increased the quality.

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