Information Presentation in Manual Assembly – A Cognitive Ergonomics Analysis

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Abstract

In current practice, information is often presented to the operators under the false belief that more information leads to better quality. However, one must consider the cognitive capacity limitations of the human operator and design information systems based on these constraints. Important questions include what medium to use; audio, visual, paper based or computer screen systems? Also the syntax in terms of symbols and text, together with information content and the formatting of the system are important factors that will require much focus to result in a good information system. The paper describes a case where paper-based assembly instructions of a major automotive company have been studied, focusing on information design and cognitive ergonomics in information seeking behaviour. Within the case study, the paper-based information system has been evaluated with two focuses: automatic information behaviour (automatism) and consistency of information presentation in the operator graphical user interface (GUI). It is suggested that systems that do not offer clear and easy-to-find entry points to information will eventually cause quality issues in production.

1 Introduction

The increasing demands for mass customization and better quality in the automotive industry calls for increasing accuracy and flexibility of information sources used in manual assembly. The human operator is often treated like a robot in the sense that it is often thought that information provided can be equated with information received. However, this is not always the case. Humans respond differently to different types of information and disregarding this fact can result in quality problems.

This paper presents an analysis of assembly instructions, provided by a major automotive manufacturer. The analysis focuses on the instructions themselves; an in-depth empirical study of how the instructions are used by the assembly workers has not been conducted at this stage. Whilst such a study is planned for future work, it was deemed unsuitable to carry it out at this stage, as it would have influenced the results of the current study. For instance, instructions that in themselves are perfectly alright may not be used correctly due to the socio-technical culture in a specific company or department, and such variables needed to be eliminated for the current study. The information at hand and the conclusions drawn are based on information about how the work *should* be done according to documentation and the technicians that define the work. The assembly instructions are presented on paper. At the assembly station of interest, there are four assembly workers, each with their own set of individual instructions. For this analysis, one actor has been selected on the basis of the comprehensiveness of the instructions for that actor.

This paper will discuss potential weaknesses and dangers to the assembly instructions as they are designed today. With respect to automatism (Shiffrin & Schneider, 1977), usability design principles including information noise (Preece, et al., 2002) and entry points (Garcia & Stark, 1991; Kirsh, 2001), the paper provides analysis and suggestions on where potential problems may arise. A clear parallel to human errors with a basis in James Reason's (1990) and Donald Norman's (1988) works, is expected.

2 Automated behaviour

It is a known and generally accepted fact in the scientific community that humans continuously strive towards less effort in their everyday lives (Reason, 1990; Shiffrin & Schneider, 1977; Wickens & Hollands, 2000). As a result of this, recurring tasks often become automated processes and naturally coincide with a passive attention mode. Consider the task of driving a car. As you are learning to drive, it takes all the attention you can procure to keep the car on the road, switch gears, and to keep track of the road signs. Later on, when you have become an experienced driver, all these things seem to have become automatic. They are done without a thought at times, passively. In the case of assembly personnel it might be that the subject is so automated in the assembly behaviour that he or she passively performs the work.

Studying a hierarchical task analysis based on the assembly instructions, one can identify potential problems with respect to automatism. For example, if assuming that the processes involved in assembling a chassis become automated, a problem might arise when disturbing the sequence of actions to be performed. A common work sequence today is presented below (translated from Swedish).

> Consult assembly instructions and specify hole groups ➔ Place orders for pull material ➔ Handle packaging material ➔ Assemble V-stay

Assuming that this sequence of tasks becomes automated in that they are performed following each other seamlessly, what would happen if the sequence was disturbed? In one of the assembly instructions provided the work sequence looks like this:

> Consult assembly instructions and specify hole groups ➔ Place orders for pull material ➔ Handle packaging material ➔ Assemble mudguard stay[1] ➔Assemble V-stay

The problem that might arise here is anchored in the scientific literature as a capture error (Norman, 1988). When making a capture error, a frequently or recently performed action captures (takes over) the one intended. As an example, consider a man who every day before work, drives his children to day care. Close by where he drops them off is the supermarket where he frequently buys his groceries and every now and then, when he is to drop off his children, he ends up at the supermarket, and vice versa. An error of this type appears when two different actions begin with the same sequence (Norman, 1988), or when the sequences have a common ground. The tasks might not be very similar but there are critical points where they overlap and where the two tasks have some form of common ground. In the example of the man leaving his children at day care, this common ground is great and stretches from getting into the car and driving off, to the final turn where one way leads to the supermarket and the other to the day care.

Looking at figures 1 below, it can be compared to the work sequences discussed earlier, illustrated in figure 2.

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[1] This item is a form of bracket but it literally translates to a *stay.*

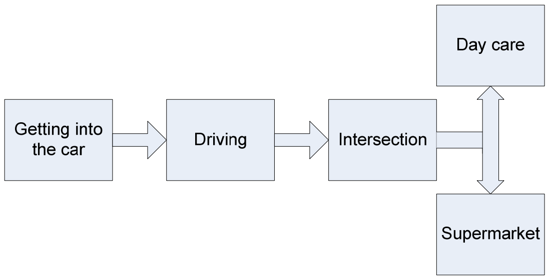

Figure 1. Illustration of the similar origins to the tasks of driving to day care and driving to the supermarket.

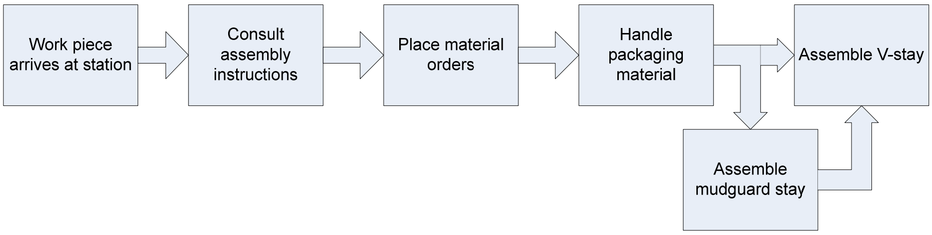

Figure 2. Illustration of the similar origins of two work sequences.

By comparing these two figures, it is evident that they both represent similar origins for two tasks and where a capture error might be prone to appear. However, a difference between the two sequences, that can be identified, relates to the feedback and points of evaluation. In figure 1, when the man ends up at either place, he is forced to somehow reflect on the result of the task. He should relatively soon discover if he has ended up at the right place. It might be conceivable but not very likely that he goes on to buy groceries when this was not the plan without reflecting over his mistake. In the case in figure 2, there is no obvious point of evaluation. Whether the mudguard stay is assembled or not, the worker goes on to assemble the V-stay, not having to reflect or evaluate his work in direct connection to the critical task.

On the basis of the assembly instructions available, it is hard to predict critical points as they do not contain much detailed information about the tasks being performed. However, it is conceivable that the two work sequences above might be mixed up and result in a capture error as they are so similar. To a large extent it would depend on the level of automated behaviour being dealt with. To extend these thoughts to assembly operations in general, it can be argued that these critical points might arise quite easily in many contexts.

3 Inconsistency in information presentation

In Human-computer interaction (HCI), one of the main usability principles for design is consistency and standards. This implies that you should “avoid making users wonder whether different words, situations, or actions mean the same thing” (Preece, et al., 2002, p. 27). If an element has certain properties at one place in the system, it should incorporate the same properties in the rest of the system. These properties might include everything from placement, design, and response to interaction.

The concept of consistency applies to our assembly instructions when the same task is portrayed differently across time and vehicle variant. In one of the instructions, assembly of an air tank is presented first with information of which tank is to be assembled, comments and instructions, followed by information about where the tank is to be situated on the chassis. In another instruction, assembly of the air tank is presented simply with information about where the tank is to be assembled. Consider figures 3 and 4 as an illustration of these differences within the assembly instructions. Though the language is Swedish, the point is not the information content but its presentation.

Lufttankar höger sida CI 67723

Part	Qty	Description	Alias	C1	C2	Comment	Emb	UP
[redacted]	4	FLÄNSMUTTER,M14*2				Till tank utsida ram	00100	70650
	1	Främre kretstank (15L)(				Insida ram höger sida. På lösen om den sammanfaller med hålbild för bränsletank.	0	70600
	1	Främre kretstank (15L)(				Utsida ram högersida. Tank skall placeras så nära ramfläns som möjligt.	0	70600
	2	FLÄNSSKRUV,M14*80				Till tank utsida ram	00100	70650
	2	FLÄNSMUTTER,M14*2				Till tank utsida ram	00100	70650

Hålgrupper för lufttankar CI 43345

Vänster sida 2+2 hål
Från underkant ram Z = 180mm & 240mm
Från framkant Ax1 = 4361mm & 4561mm

Höger sida 2+2 hål
Från underkant ram = 120mm & 180mm
Från framkant Ax1 = 4411mm & 4461mm

Höger sida 3 hål
Från underkant ram = 60mm, 120mm, 180mm
Från framkant Ax1 = 4561mm

Figure 3. The part of the assembly instructions that handle air tank assembly for one chassis.

Hålgrupper för lufttankar CI 43345

Vänster sida 2+2 hål
Från underkant ram = 60mm & 180mm
Från styrhål Ax2 = -940mm & -740mm

Figure 4. The part of the assembly instructions that handle air tank assembly for a second chassis.

In these figures differences in information presentation between chassis is obvious. In the instructions in figure 3, the worker is presented with rather extensive information about tank, fasteners, comments, and position. In figure 4, all that is presented is the assembly position. Disregarding the fact that there is no information about what tank is to be assembled and assuming that this information is gathered elsewhere, there are still two different sets of instructions for virtually the same action. Granted that the information volume is in question, there is also a situation where it is very difficult to know what to look for, what to expect. In the field of visual search, a lot of work has been done on these kinds of problems, resulting in various theories on how visual search is performed. According to Rookes and Willson (2000), pattern perception and object recognition is largely based on matching. In the case with our assembly instructions, matching becomes much harder as it is also very dependent on the environment where it is presented (for further reading, see Wolfe, 1998). Another similar issue arises when tasks are added in the middle of a sequence as in the previous section. When this happens, there is a rearrangement of the structure in our information source and this also leads to problems in finding the correct information quickly and easily.

3.1 Entry points

In a study on newspaper reading, Garcia and Stark (1991) suggested the use of entry points to scan the paper and determine where to start reading. The entry point is basically the point of entry to an information space and this concept has also been elaborated on by Kirsh (2001). He used entry points as a kind of trigger and described how certain properties, such as visibility, freshness, and intrusiveness, define how the entry point attracts attention.

The entry points in the assembly instructions are few and unstructured. Elaborating on the points that Garcia and Stark (1991) and Kirsh (2001) make, one could conclude that entry points are used as introductions to information space on a basis of their ability to attract the observer. They do this by *standing out*. As Kirsh (2001) describes them, entry points have to incorporate some kind of intrusiveness to even begin to attract attention to themselves. In our assembly instructions, nothing stands out, no one thing is more intrusive to our attention than anything else. Designing with entry points in mind would result in a more structured information design where there are clear introductions to the information about each task and something that identifies each unique information space amongst the others.

3.2 Information noise

An extension of the unstructured entry points is the information noise that is present in the assembly instructions. While one part of the entry points not standing out is due to their inability to be intrusive, another part is that there is a lot of unstructured text and information on the instructions that makes anything that might stand out, get lost in the noise. Consider trying to find a word printed in bold within a section of text, it is obvious that in an environment without other words printed in bold, it would stand out, but its intrusiveness would be based on the context in which it is presented. If other words are also printed in bold, the word would be much harder to find. The information noise is something that one needs to be very cautious with. Using special fonts, sizes, colours, etc., to attract attention is usually a great idea and often a simple solution to these kinds of problems. However, this is something that can easily go too far. Suddenly we find ourselves making everything stand out, only to find that nothing does.

In figures 3 and 4, the information noise is present primarily by the different types of fonts and also by the sheer amount of information. The comments in figure 3, although surely important to the task, are so extensive and closely coupled spatially, that they are hard to distinguish from each other.

4 Conclusions

Despite first impressions, automatism should not necessarily be discouraged, but needs to be supported to a greater extent as there are several advantages to it (Thorvald, et al., 2008). For example, instead of disturbing work sequences with additional tasks in the middle of an automated behaviour, one needs to be careful with where these additional tasks are placed. Perhaps they are better suited between sequences, after a sequence is finished, or before it even starts. Relating back to the problem of feedback and point of evaluation discussed within the context of figures 1 and 2, one could argue that placing critical or deviant tasks at the end of the work sequence, might allow for feedback and evaluation in closer coupling to the critical task. Another way to support automatism is to use a clearer mapping between representation and real world. A red symbol on the information system might correspond to a red symbol on the shelves, allowing for a quicker and more efficient way of working.

The current medium used in the assembly factory to present information is to the largest extent paper based. It might be interesting in future investigations to analyze different types of mediums as information conveyers. A computerized system is probably not far from being realized but there are other alternatives or complements to this. One might consider using pick light systems where the correct item is indicated with lights or other similar identifiers. Our intentions are to further investigate these questions in future work.

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