Definition and Use of 'Human-Automation Interaction' - Time in Production

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ABSTRACT

There is a need to further develop measureable methods and models in the 'Human-Automation Interaction' area. Since time is a decisive factor in production, the aim of this paper is to define interaction in relation to time i.e. interaction-time, and to investigate how this can be used in practice. Results from a case study show that interaction-time can be used to study bottlenecks and to suggest training or support tools.

Keywords: Human-Automation Interaction, Levels of Automation, Production performance, Measuring interaction, Complexity

1. INTRODUCTION

There is a need in the 'Human-Automation Interaction' area to further develop measureable methods and models to describe the relation [1-3], and further, the human factors connected to Human-Automation Interaction (HAI) [2, 4, 5]. In a production context measurability is crucial in order to increase production performance and reduce time by finding a more detailed description of HAI.

Understanding HAI is complicated through demands on increased customization. For an operator this could mean smaller batches, an increased amount of new variants and components and high demands on cycle time and product quality. This contributes to a stressful and complex working environment that is hard to evaluate and measure.

Although HAI is a studied area no consensus of HAI can be found [6]. Especially the effects of interaction are hard to predict [7, 8].

This paper aims to define HAI in a measurable way in terms of interaction-time. The context is tasks that have high mental workload i.e. includes many variants/components or are flexible or unstandardized work and/or have many tool changes.

In order to investigate the definitions practical usefulness a case study is presented.

2. Performance indicators

Traditionally, in order to understand human-automation systems, time and other performance indicators have been used. Therefore, the importance of time and Levels of Automation as performance indicators will be further explained in the following sections.

2.1 Time

Frederick Winslow Taylor believed that humans could be seen as resources that should work under maximum efficiency according to the natural abilities that fit the person [9]. In order to do that, he stressed that the person should receive training and be developed so that he can learn to do his work in the best possible way. This means that the greatest prosperity for the company could be achieved, when the greatest possible productivity between men and machine has been established. Performing anything else than at this optimal level was seen as waste.

He believed that although workers learn by observation, which is in many cases still true, there is always one methods or one implement that is best. Taylor argued that operators should be in control of their own work and that they should do this with little help advice from management. Management must instead to everything in order to enable the worker to work better or quicker than he did before. He argues further that the best method can only be found by using scientific methods to study use according to accuracy, motion and time studies.

Taylors waste, regarding not using a persons full capacity, is also seen in Toyotas Production System (TPS) [10]. In TPS eight types of waste was used to identify what adds value to a product of process. This is seen from a customer point of view, where the customer could be an internal customer ahead in the production line or an external customer. Tasks can be, according to time, divided into Value added or Non-Value Added time (waste). Another concept Necessary but Non-Value Added time is since there are actions that are necessary but does not add value to the customer [11]. For instance this might include tasks done according to legal or ethical issues.

Looking at TPS waste connected to complex tasks connected to the presented focus times three types of waste are important: *Waiting, Unnecessary movement* and *Unused employee creativity* [10]. Waiting is when an operator monitors a process in order to, in the next-step, work with a product. Waiting could also be due to bottlenecks or production delays. Unnecessary movement is any movement that is unnecessary for instance reaching, stacking material, and walking to get something. Unused employee creativity is “Losing time, ideas, skills, improvements, and learning opportunities by not engaging or listening to your employees”, page 29 [10].

2.2 Levels of Automation

Production system settings involve many processes and tasks that may have different emphasis on precision and speed. This indicates that a scale of automation, rather than just fully automated or fully manual is needed. Studies concerning Level of Automation (LoA) have been used to:

- increase production quality and consistency; decrease production cycle times [9];
- maximise system performance [10];
- increase flexibility [11]; and
- in general, how to allocate work between human and machines.

Identifying and implementing the correct level of automation, in a controlled way, has been used to maintain the effectiveness of a system [12].

Fasth et al. developed a method DYNAMO++ that included a matrix where joint physical and cognitive automation could be described [13]. Further, Fasth [12] defined Levels of Automation (LoA) as: ‘*The allocation of physical and cognitive tasks between resources (humans or technology), described as discrete steps from 1 (totally manual) to 7 (totally automatic), forming a 7x7 LoA-matrix containing 49 possible types of solutions’*. The matrix is presented in Figure 1.

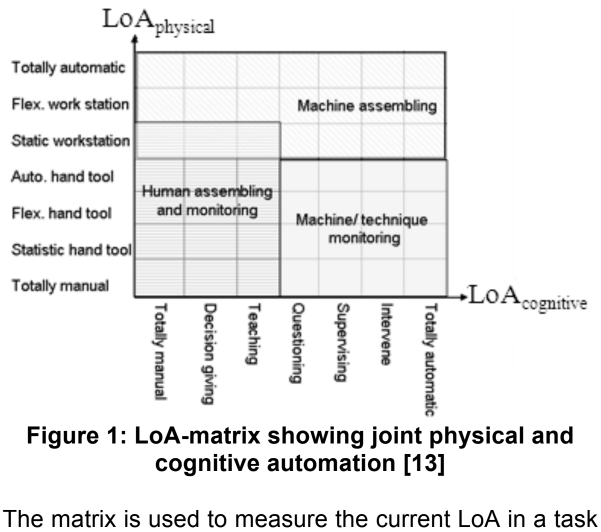

Figure 1: LoA-matrix showing joint physical and cognitive automation [13]

The matrix is used to measure the current LoA in a task [14]. Later the matrix served as a basis for discussion for why did a company want to change their LoA at that area and help visualize the change in clear and more objective way. It was seen in many case studies, although not all of them, that a higher cognitive level of automation was needed. This means that the operator needed better support in the final assembly task.

3. DEFINING INTERACTION-TIME

Interaction can be defined as the way a human is affected by, controls and receives information from automation while performing a task, Sheridan et al. 2006 [16]. Interaction can generally be seen as an action occurring between at least two objects, which have an effect on one another. In production and especially in final assembly the operator uses the automation to achieve a goal. The interaction is often, if it is not dealing with gathering material or other preparatory work that is not assembly, time driven. Since time is a decisive parameter used for measuring efficiency and productivity time can be used to divide an interaction into smaller, and more comprehensive, parts. This means that the definition of interaction may be extended with where performing a task is defined as having a goal-driven action.

The definition of LoA introduced in DYNAMO++ is interesting from an interaction perspective since it is used both to understand what happens at a station, in relation to what automation is used, and has been used to describe the effectiveness of a system, as well as solving problems regarding product quality, time and perceived complexity

Here, Interaction can be defined as the way a human is affected by, controls and receives information from automation while performing a task, *where performing a task is defined as having a goal-driven action. (Sheridan et al., edited)* and LoA as: “*The allocation of physical and cognitive tasks between resources (humans or technology), described as discrete steps from 1 (totally manual) to 7 (totally automatic)” [15].*

Combining the two definition a definition of Interaction-Time can be found:

“Interaction-Time can be defined as the interaction between one human and a specific LoA-solution performing one or several tasks restricted by time.”

The interaction time could be seen as a task time were one task is carried out but could also be seen as a time when several tasks, using different LoAs, is carried out by the operator. If several operators are working together on the same assembly part the analysis of their work could be two interaction times where some of the parts would be characterized as a joint interaction.

Interaction time is, according to the definition of LoA, characterized into one physical and cognitive part.

4. CASE STUDY

Result from the case study show how LoA-Time was used to measure skill different related to experience [16]. The case study comprised one production station for final assembly of engines in a Swedish automotive industry. The method, LoA-Time, is based on the LoA-matrix (Figure 2) with the aim of giving a more detailed description of the work done at a station. The direct work of the operators was studied through video recording and analysed using nVivo. Using the average time spent with a specific type of LoA, i.e. interaction time, results showed that difference in skill could be connected to specific LoAs. In this case giving appropriate training to the less skilled operator could reduce the difference in time. The bottleneck LoAs are seen in Table 2. In the table LoA cog=1 and phys=2-4 have a much higher average time for Operator 2 than for Operator 1.

Table 2: LoA Bottlenecks by average interaction-time (time in sec)

LoA(cog, phys)	Operator 1	Operator 2
LoA(1,1)	4.56	4.89
LoA(1,2)	3.4	6.27
LoA(1,3)	5.4	18.67
LoA(1,4)	5.19	7.61
LoA(5,4)	2.84	3.17
LoA(5,5)	1.62	2.22
LoA(6,1)	4.1	3.4

The different interaction-time was further studied by looking at what type of interaction is performed. Since most final assembly work, 87% [14, 15], of the tasks is performed in LoA(1,1) the total manual work LoA(1,1) and that in LoA the manual level is not further explained an analysis was made to study both LoA in terms of time spent and the total manual work. All interactions bigger than 4 seconds were included in the analysis.
A list was made of all types of interactions: one with the type of tool that was used i.e. LoA and one that describes what type of manual works that is done. Studying Table 3 it is possible to see again that the time spent by Operator 2 is higher on the tasks LoA(1,2-4). However Operator 1 had a longer time on LoA(5,5).

Table 3. Interaction-Time

LoA	Description	Operator 1	Operator 2
LoA(1,2)	Use clippers	6	6
LoA(1,2)	Use tool to place list	8	36
LoA(1,2)	Glue pistol	7	10
LoA(1,2)	Glue brush	9	20
LoA(1,3)	Drill	35	86
LoA(5,5)	Automated drill	57	35
LoA(6,1)	Turn engine	16	19
	Total time	**138**	**212**

Table 4 shows the result from the total manual interaction-time study. Here the total time spent on total manual work is higher for Operator 1. And some sub-tasks were not even performed by Operator 2 for instance unpacking and placing things.

Table 4. Total Manual Interaction-Time

Description	Operator 1	Operator 2
Insert list	36	35
Pre-screw by hand	66	38
Unpack	6	
Place	38	
Place stripes	26	59
Total time	**172**	**132**

5. DISCUSSION

The ultimate goal of measuring and handling complexity is to improve the end users´ performance – in this context – the operator's performance, i.e. to decrease process errors, achieve high quality, good working conditions, fast processes/work and quick change-overs. And as Taylor stated the only way to reach the best possible way of solving a task is to analysing and studying the methods that are used today [9].
By defining interaction-time using LoA, defined by Fasth et al. [13], it is possible to take advantage of the many benefits of the method. It has a pragmatic approach and has been used for identifying required changes in LoA and as an objective discussion tool. Incorporating this into the definition of interaction it was possible to form a definition that included one person and one type of automation at the time. To study one person at the time makes a description of interaction more detailed. Including also one type of LoA, means that the description is even further detailed. Since the task performed should be goal-driven this can be applied to a case study conducted in final assembly.
LoA-Time that was used is similar to the way Value added and Non-Value added tasks are evaluated in TPS. With the method the average time spent on each time is evaluated. Both LoA-Time and the additional analysis were useful in order to state which LoAs that are the bottlenecks.
In this example the more skilled operator, Operator 1, spent more time on pre-placing or pre-screwing parts and the less skilled operator, Operator 2, spent more time on handling tools.

In order to describe complex systems it may sometimes be important to handle an analysis including two tasks or two humans at the same time. This will be tested in future study. Also according to Taylor and TPS: S view of waste was to perform at an optimal level and at the same time maintain creativity in a worker. This is an important aspect that requires more investigation since delimiting time does not always create value for the actual worker. In the case study the difference between the workers could be due to difference in skill. However it is important to consider that other factors might be used in order to increase the human performance and increase the awareness of what can be achieved i.e. training and support tools.

6. CONCLUSIONS

This paper argues for how interaction between humans and automation can be described in a more detailed way by using interaction time. This is seen both via needs seen in academia regarding finding a method or model for measuring interaction [1-3] as well as needs seen in industry where complexity and mass-customization complicates the understanding of interaction breakdowns. Interaction time was defined as *"Interaction-Time can be defined as the interaction between one human and a specific LoA-solution performing one or several tasks restricted by time",* by combining definitions of interaction and levels of automation. According to the LoA definition interaction time was divided into a physical and cognitive part, which was shown useful in the case study. In addition to measuring the interaction-time aspects it is important to consider that a restricted time does not create value for the worker in terms of for instance creativity. Understanding and measuring HAI in a pragmatic way could: increase the understanding and awareness of measureable aspects between humans and automation in order to identify LoA bottlenecks and to suggest training or support tools.

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