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How to support intuition in complex assembly?

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Abstract

Managing a complex assembly system includes understanding and supporting the operators' information processes. This paper presents theory (intuition, flow and guidelines for information presentation) combined with case results. The aim is to find ways to pragmatically support intuition in complex assembly. Results indicate that training and education may be a big part of supporting intuition. Other ways to support intuition include creating instructions that support: filtering, realistic tools and explanations. It is also important to consider individual differences.

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Keywords: Production complexity, intuition, cognitive processes, instructions, interaction, design, flow.

1. Background

To present information efficiently and manage information is often hindered by not being able to understand the complexity in the system in itself [1]. Complexity in a system can be seen as the difficulty in predicting the system properties [2] and can be defined as something that is '*difficult to understand, describe, predict or control'* [3].

One way to reduce complexity is to *simplify* complexity [4] e.g. the information presented to the operators [5] by giving visible hints to the operator [6] activating skill-based behaviour [7]. Having a more usable system will affect behaviour and operator performance [8]. From a cognitive perspective the tasks carried out in final assembly could be described as fast and automatic, this could also be defined as intuitive behavior [9]. To support this behavior it is important that the information is presented in a way that supports perception and attention [5] to avoid cognitive load and decreased operator performance [10]. A concept that is interesting in this context is flow where the operator performs at an optimum [11].

The aim of this paper is to discuss how intuition can be supported in complex assembly. This is done by combining theory (models of intuition, flow and guidelines for information presentation) with empirical data gathered in a case study. The case study comprised a current state analysis and a workshop where operators, production technicians and leaders discussed found results and how to better present information to the operators. Ways of supporting intuition need to be pragmatic in order for them to be included in a production context.

2. Intuition and flow

Chase and Simon [12] defined intuition as recognising patterns already stored in the memory (came from analyzing chess players) or association [13]. Studies point towards that work-related flow (work motivation, enjoyment and absorption) increase personal and organizational resources [14], a positive mood [15, 16] and that flow is connected to situational characteristics [15]. The increase in mood was in a study also connected with enhanced organizational spontaneity (suggests how overall functioning can be increased, encourages themselves and others to improve efficiency of work, spreads information and takes action to solve potential problems)[16].

2.1. Intuition model

To identify and characterize cognitive processes in a complex context a conceptual model, Fig. 1, was suggested

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based on Rasmussens model for SRK-based behavior [16], Kahnemans model of System 1 and 2 [27] and Endsleys model of situational awareness (SA) [28]. The conceptual model included two levels of intuition [11]. Level 1 can be seen as a combination of *skill-based* knowledge, SA Level 1 and System 1. The cognitive processes involved in Level 1 is gathering information and recognizing elements in a situation. There was a need for a second level due to that a comprehension of a situation is what gives awareness. In addition, *rule-base* behavior should be used in an assembly situation since signals give hints to the operator on how to behave (for example what should be done when a certain variant comes to the station). This process requires more effort, could take longer time but should also be fast.

2.2. Flow in work

Csíkszentmihályi stated that flow can be seen as joy, creativity and a process of total involvement [11]. Activities that easily could be connected to achieving can be connected to flow. The activity must have:

- Rules that require an increase in skill level
- Clear goals
- Provide feedback (fast)
- The possibility to control it

Flow pushes the person to increase his or her performance and also increases the complexity of consciousness [11]. If a state of flow is lost, it can be achieved again if the person matches the goal (challenge) to her/his skill level.

Working has been identified as a flow activity [17]. This was reported more while working than when doing leisure activities (however more motivation was connected to leisure). The study included 18 blue collar workers, 32 clerical and 28 managers and it was seen that flow activity (measured time) for blue collar workers were highest when doing assembly work (39.4% compared to the second highest flow activity fixing equipment 20.6%). Studies indicate that labor efficiency and productivity is decreased by disturbances in normal work flow [18].

In order for the quality of life to increase through job Csikszentmihalyi stated that two strategies are needed [11]:

- Jobs should be redesigned so that they resemble flow activities i.e. rules, clear goals, feedback and control.
- The person needs training to recognize the opportunities to perfect their skill and to set goals that they can reach.

The second bullet point is similar to one of the points that Taylor made, when introducing his scientific management. He also stated that in order for a person to perform their work in the most efficient way (fitting also that persons natural abilities) she/he should receive training or be educated [19].

2.3. Guidelines for information presentation

In order to support intuition five guidelines were developed to support cognitive processes in a final assembly situation. The guidelines were based on Abrahamson et al. [20] and further developed (e.g. [21]).

1 Support active cognitive processes [9]*:* 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).

2 Support mental models: How a person perceives a situation affects his/her behaviour [22, 23]. 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 [24-26]. Support the memory 7±2 things [27] and present fewer things [28], have a clear description and presentation [20, 29, 30], focus on pictures, differentiate between similar objects and use arrows, numbers and zoom [21, 31].

4 Support individual preferences/differences: Humans are different and they may want or need different types of information. Changes in demographics [32] 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) [21]*:* Where information is placed is important. Support instructions by adding a picture showing the completed product.

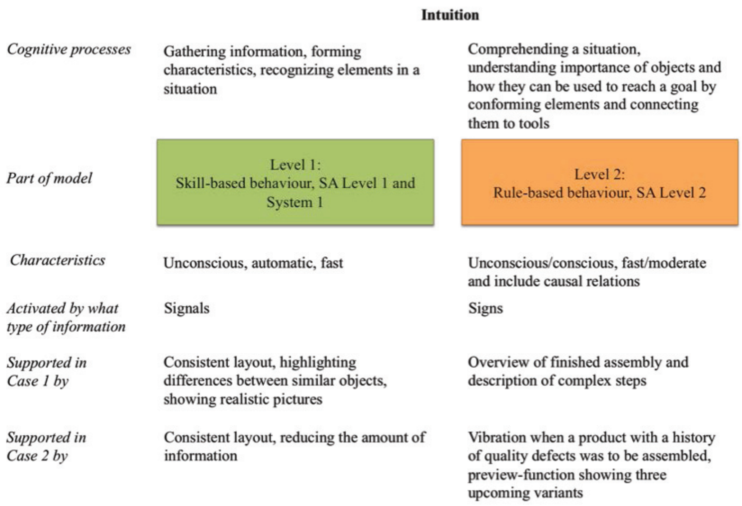

Fig 1: Model of intuition

Several case studies [33-37] 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 poorer quality than text-based instructions.

3. Case study

A case study was performed at a large automotive company. The study comprised 140 operators at 59 stations. The case included an investigation of the stations current state studying: perceived production complexity and quality errors. Perceived production complexity was measured by using the method CompleXity Index [38]. The method have been used for current state analysis and to show what problem areas contribute to complexity at a station [39, 40] and was used to give an index for how complex the stations were. Quality errors were human errors gathered by the company from January-October 2015. In addition, interviews were performed to investigate the way information is structured at the company and what stations were best and the worst to work at. First the results were presented to the production leaders and operators, then three stations were chosen as being most interesting and a workshop was performed that focused on information presentation and how to increase flow at work at those stations. This article will describe parts of the results e.g. results from the main assembly line as well as the workshop results (discussion of flow and information presentation).

The workshop included eight persons: three persons involved with competence and internal education, two department managers, one in charge of instructions and two operators. Participants were divided into two groups dividing their competences as much as possible. Theory was presented to participants regarding flow and design principles that could be used to improve information presentation at the station. The first part of the workshop included discussing how the operator can remain in flow and the second part of the workshop regarded how to present information to the operator in a learning situation.

3.1. Current state analysis for three stations

Three stations were chosen for further studies; the selection was based on interviews, the perceived production complexity and the number of quality errors:

- **Station A:** This station was by many operators seen as the worst station to work at. The station was high in complexity and had a high number of quality errors. The station was complex due to work variance e.g. there are many variants, many other work tasks except for assembly and the station takes time to learn. Operators said that the station was stressful to work at. Studying the information structure no control checkpoints were included in the station work.
- **Station B:** This station had a lot of quality error and was chosen mainly due to that. Perceived complexity was average due to work variance. Four control checkpoints were used (order and detail, to ensure quality control). Many variants were included in the learning instructions but it was noted that some of the instructions could be difficult for an operator to understand since the pictures did not include the tool and it is difficult to describe motions in text.
- **Station C:** This station was by many operators rated as the worst since it was monotonous. It had a high complexity due to work variance but only one recorded quality issue. No control checkpoints were seen. The instruction for learning was in this case good and an explanation for why a specific sub-task had to be performed was included.

In general it was seen that instructions for learning the assembly and assembly work were not the same (the systems were not connected to each other). The examples were used in the workshop to get a more specific discussion. The instructions for learning included symbols (that supported *rule-based* behavior) while the assembly work was many times supported by signals (pick-by-light, supporting *skill-based* behavior, Fig. 1).

3.2. Workshop results: Information presentation and flow

In the workshop the instructions (for assembly work and learning) were analyzed and discussed more in detail. In general the pictures were perceived as good but that the additional information could be presented in a better, more standardized way (to support intuition). The text should also include why certain things should be done (giving feedback to the operator). Group 1 stated that the instructions today were good but that the information was unclear and too much some times. Group 2 stated that it was difficult to know what the source of the information was and that the different ways of using the instructions was not known (some of them had never seen the instructions for learning). In general, they thought that the usability of the instructions could be increased. They also gave examples of a station where you had flow and suggested working with music might increase flow at Station C. A department manager stated that maybe flow could be considered on an eight hour basis instead of trying to achieve it on a station level.

In a learning situation participants stated that learning how to read the instructions could be more important than learning the actual instructions for every station. It was again pointed out that it is important to stress in the instructions why a control point should be added (due to that some operators does not have previous mechanical experience and no knowledge in why some things are important). It should also be possible to filter the information. In the teaching situation all new operators' should learn what part they are assembling and how it fits into the complete product. Operators said that they preferred oral instructions to text since they thought it was more reliable.

4. Supporting intuition in complex assembly

The aim of this article was to investigate how intuition can be supported in complex assembly. From a flow perspective work tasks could be redesigned in order to support intuition. Assembly work normally includes rules (that require an increase in skill level), clear goals and the possibility to control but often lack instant feedback. Therefore more focus could be given to provide good feedback to the operator. Theory points to the importance of training and education [11, 19], which was supported in the case study. The discussion in the workshop indicated that you need training in order to know how to read instructions in general instead of getting education on that specific product variant. The empirical result and theory also indicate that it is important to:

- Create instructions that are based on usability. Instructions should support the operators cognitive states and could include: filtering (supporting difference in skill), more realistic tools (supporting mental models) and explanations of why something is performed (feedback to the operator)
- Use control checkpoints only when needed. They might disturb flow and decrease productivity [18].

Intuition is in itself a complex process. Although it can be described according to Kahnemans system 1 and 2 it is important to remember that many things are connected to intuition (both from a conscious and unconscious perspective). More studies are needed to further investigate how intuition can be supported in complex production. It is important to note that cognition cannot be seen as a general process i.e. true for everyone. Both theory and empirical studies show that individual differences are part of producing cognitive biases (in intuition) [20, 21, 32, 41]. The differences interact with situational cues and therefore it is important to take individual thinking styles into account.

5. Conclusions

Studies have shown that complex stations can be supported by empowerment [42], which could be one way to face future challenges regarding for instance demographical changes and social sustainability. To support intuition in complex assembly the assembly work should be redesigned to some extent. To support intuition the following should be included in such a redesign: training and education, creating instructions that supports filtering, realistic tools, explanations and that checkpoints are kept only when needed. It is also advised to consider individual differences.

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References

[1] "Information and Knowledge Management in Complex Systems " in *Informatics and Semiotics in Organisations, ICISO 2015*, Toulouse, France, 2015.
[2] W. Weaver. (1948) Science and Complexity. *American Scientist.*
[3] S. Sivadasan, J. Efstathiou, A. Calinescu, and L. H. Huatuco, "Advances on measuring the operational complexity of supplier–customer systems," *European Journal of Operational Research,* vol. 171, pp. 208-226, 2006.
[4] H. P. Wiendahl and P. Scholtissek, "Management and Control of Complexity in Manufacturing," *CIRP Annals - Manufacturing Technolocy,* vol. 43, pp. 533-540, 1994.
[5] G. Bäckstrand, A. Brolin, D. Högberg, and K. Case, "Supporting Attention in Manual Assembly and its Influence on Quality," in *Proceedings of 3rd Applied Human Factors and Ergonomics (AHFE) International Conference 2010*, Miami, USA, 2010.
[6] A. C. Valdeza, P. Braunera, A. K. Schaara, A. Holzingerb, and M. Ziefle, "Reducing Complexity with Simplicity - Usability Methods for Industry 4.0," in *Triennial Congress of the IEA*, Melbourne, Australia, 2015.
[7] J. Rasmussen, "Skills, Rules, and Knowledge; Signals, Signs, and Symbols, and Other Distinctions in Human Performance Models " *IEEE Transactions on Systems, Man and Cybernetics* vol. SMC-13, pp. 257-266, 1983.
[8] P. Liu and Z. Li, "Task complexity: A review and conceptualization framework," *International Journal of Industrial Ergonomics,* vol. 42, pp. 553-568, 2012.
[9] S. Mattsson, Å. Fast-Berglund, and J. Stahre, "Managing Production Complexity by Supporting Cognitive Processes in Final Assembly," in *Swedish Production Symposium 2014, SPS14*, Gothenburg, Sweden, 2014.
[10] T. B. Sheridan, *Human and Automation: System Design and Research Issues* vol. 3. Santa Monica, CA: John Wiley & Sons, Inc., 2002.
[11] M. Csikszentmihaly, *Flow the psychology of optimal experience*. New York, USA: Harper Perennial Modern Classics, 1990.
[12] Å. Fast-Berglund and J. Stahre, "Cognitive automation strategy for reconfigurable and sustainable assembly systems," *Assembly automation,* vol. 33, pp. 294-303, 2013.
[13] E. Hollnagel, "Cognitive ergonomics: it's all in the mind," *Ergonomics* vol. 40, pp. 1170-1182, 1997.
[14] M. SALANOVA, A. B. BAKKER, and S. LLORENS, "FLOW AT WORK: EVIDENCE FOR AN UPWARD SPIRAL OF PERSONAL AND ORGANIZATIONAL RESOURCES,"

Journal of Happiness Studies, pp. 1-22, 2006.
[15] C. J. Fullagar and E. K. Kelloway, "Flow at work: An experience sampling approach," *Journal of Occupational and Organizational Psychology,* vol. 82, pp. 595-615, 2009.
[16] R. EISENBERGER, J. R. JONES, F. STINGLHAMBER, L. SHANOCK, and A. T. RANDALL, "Flow experiences at work: for high need achievers alone?," *Journal of Organizational Behavior,* vol. 26, pp. 755-775, 2005.
[17] M. Csikszentmihalyi and J. LeFevre, "Optimal Experience in Work and Leisure," *Journal of Personality and Social Psychology,* vol. 56, pp. 815-822, 1989.
[18] H. R. Thomas, "Schedule Acceleration, Work Flow, and Labor Productivity," *Journal of Construction Engineering and Management,* vol. 126, pp. 261-267, 2000.
[19] F. W. Taylor. (2005). *The Principles of Scientific Management*.
[20] L. Abrahamsson, R. Akselsson, M. Albin, M. Bohgard, J. Eklund, M. Ericson, *et al.*, *Work and Technology on Human Terms*, 1:1 ed. Solna, Sweden, 2009.
[21] C. Söderberg, A. Johansson, and S. Mattsson, "Design of Simple Guidelines to Improve Assembly Instructions and Operator Performance," in *Swedish Production Symposium 2014, SPS14*, Gothenburg, Sweden, 2014.
[22] C. F. Kurtz and D. J. Snowden, "The new dynamics of strategy: Sense-making in a complex and complicated world," *IBM Systems Journal,* vol. 42, pp. 462-483, April 24th, 2003 2003.
[23] E. Hollnagel, "Cognitive ergonomics: it's all in the mind," *Ergonomics,* vol. 41, pp. 1170-1182, 1997.
[24] C. Billings, *Aviation Automation: The search for a Human-centered approach*. Mahwah, New Jersey, USA: Lawrence Erlbaum Associates, 1997.
[25] P. L. Jensen and L. Alting, "Human Factors in the Management of Production," *CIRP Annals - Manufacturing Technolocy,* vol. 55, pp. 457-460, 2006.
[26] Å. Fasth, T. Lundholm, L. Mårtensson, K. Dencker, J. Stahre, and J. Bruch, "Designing proactive assembly systems – Criteria and interaction between Automation, Information, and Competence," in *Proceedings of the 42nd CIRP conference on manufacturing systems* Grenoble, France, 2009
[27] M. Richardson and D. Reischman, "The Magical Number 7," *Teaching Statistics,* vol. 33, pp. 17-19, 2011.
[28] R. C. Clark, F. Nguyen, and J. Sweller, *Efficiency in learning: evidence-based guidelines to manage cognitive load*. San Fransisco, CA: Pfeiffer, 2006.
[29] F. Ganier, "Factors affecting the processing of procedural instructions: implications for document design," *IEEE Transactions on Professional Communication,* vol. 47, pp. 15-26, 2004.
[30] K. Inaba, R. Smillie, and S. O. Parasons, *Guidelines for developing instructions*. New York, London: CRC Press Inc, 2004.
[31] D. Li, T. Cassidy, and D. Bromilow, "The Design of Product Instructions," ed. Leeds: licensee InTech, 2013, pp. 101-114.
[32] Regeringen, "Regeringens proposition 2012/13:30 Forskning och innovation," ed, 2012.
[33] G. Watson, J. Butterfield, R. Curran, and C. Craig, "Do dynamic work instructions provide an advantage over static instructions in a small scale assembly task?," *Learning and Instruction,* vol. 20, pp. 84-93, 2// 2010.
[34] Å. Fast-Berglund and E. Blom, "Evaluating ICT-Tools for Knowledge Sharing and Assembly Support," in *Proceedings of the 5th International Conference on Applied Human Factors and Ergonomics AHFE 2014, Kraków, Poland 19-23 July 2014*, 2014.
[35] E. Blom, "QR Codes and Video Instructions: Mobile Learning in an Industrial Setting," Institutionen för tillämpad informationsteknologi, Gothenburg, 2014.
[36] P. Thorvald, A. Brolin, D. Högberg, and U. K. Case, "Using mobile information sources to increase productivity and quality
," in *in Proceedings of the 3rd international conference on applied human factors and ergonomics,*, Miami, Florida, USA, 2010.
[37] T. Fässberg, G. Nordin, Å. Fasth, and J. Stahre, "iPod Touch - an ICT tool for assembly operators in factories of the future?," in *Proceedings of the 43rd CIRP International Conference On Manufacturing Systems (ICMS),* Vienna, Austria, 2010.
[38] S. Mattsson, M. Tarrar, and Å. Fast-Berglund, "Perceived Production Complexity – understanding more than parts of a system. ," *submitted to International Journal of Production Research* 2016.
[39] M. Karlsson, S. Mattsson, Å. Fasth-Berglund, and J. Stahre, "Could the use of ICT tools be the answer for increasing competitiveness in Swedish industry?," in *12th IFAC Symposium: Analysis, design and evaluation of Human-Machine Systems*, Las Vegas, USA., 2013.
[40] S. Mattsson, Å. Fasth, K. Dencker, P. Gullander, J. Stahre, M. Karlsson, *et al.*, "Validation of the complexity index method at three manufacturing companies," in *the International Symposium for Assembly and Manufacturing*, Xian, China, 2013.
[41] S. Shiloh, E. Salton, and D. Sharabi, "Individual differences in rational and intuitive thinking styles as predictors of heuristic responses and framing effects," *Personality and Individual Differences,* vol. 32, pp. 415-429, 2002.
[42] S. Mattsson, M. Karlsson, Å. Fast-Berglund, and I. Hansson, "Managing production complexity by empowering workers: six cases," in *Variety Management in Manufacturing. Proceedings of the 47th CIRP Conference on Manufacturing Systems,* Windsor, Ontario, Canada, 2014, pp. 212-217.