	HoliDes **Holi**stic Human Factors **Des**ign of Adaptive Cooperative Human-Machine Systems	

D3.7a – ANNEX III– Human Factors Guidelines

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Guidelines

The following guidelines are aimed to highlight important human factors for the design of AdCoS. The factors, that are also included in the adaptation framework, are explained in a straightforward fashion in order to provide novices an easy and quick access to the field of human factors. For each human factor, generic examples and literature recommendations are given.

GUIDELINE #1
Name of guideline
Design for Cognitive Capacity Limits
Description
Cognitive capacity is limited by working memory span and the attentional bottleneck. Working memory can hold a few chunks of information depending on the information and the task itself. Attention operates on a limited number of channels and resources that should be exploited with caution. Generally speaking, competing for attentional resources and items to hold in working memory should be kept to a minimum. If possible, do not ask the operator to keep information in mind. Instead try to split up the task in more easily processible chunks and display/repeat critical information to serve as an external memory to the operator. When asking the operator for attention, make sure the channel (e.g. visual input channel, speech output channel) is not occupied by a different task. Wickens' Multiple Resource Theory is a good source for expansion on interface design optimized for cognitive resources. The theory divides attentional resources into four dimensions: Processing stages (perception, cognition, action), perceptual modalities (visual, tactile, auditory), visual channels (focal or ambient), and processing codes (analogue/spatial or symbolic/verbal). When multiple task compete for the same resource in one of these dimensions, performance decreases. In an AdCoS, attention will be required to monitor the automation and its changing states. If the AdCoS autonomously adapts to help the operator in a stressful situation, make sure that the operator has spare attentional resources to notice and process the state change.
Examples
• *Do A. Then do B. Then do C.* instead of *Before doing C, do A and B*
Sources
Wickens, C. D. 2002. Multiple resources and performance prediction. *Theoretical issues in ergonomics science* 3, 2, 159–177. Wickens, C. D. 2004. *An introduction to human factors engineering*. Pearson/Prentice Hall, Upper Saddle River, NJ. Wickens, C. D. 2008. Multiple resources and mental workload. *Human*

Factors 50, 3, 449–455.

Young, M. S. and Stanton, N. A. 2002. Attention and automation: new perspectives on mental underload and performance. *Theoretical issues in ergonomics science* 3, 2, 178–194.

GUIDELINE #2
Name of guideline
Design for Communication
Description
The ability to exchange information is an essential component of cooperative systems. Define what are the communication affordances, modalities and develop a communication strategy that covers the issues of What, When and Where to communicate Why and how (modalities) to whom. The communication guidelines in this deliverable provide a well-structured approach to communication design for AdCoS. In order to prevent automation surprise, the AdCoS should communicate its state to the operator. Communication of state changes may only be neglected when the adaptation is perfect and no re-adaptation from the operator to the changed functionality of the AdCoS is required.
Examples
If using tactile cues for warnings, it is important to note humans can identify: • About four haptic intensities • About five durations and • About nine different frequencies (with 20% difference needed between levels)
Sources
D 3.7 - Communication Guidelines Banbury, S., Gauthier, M., Scipione, A., Kanata, O. N., and Hou, M. 2007. Intelligent adaptive systems. Defence R&D Canada (DRDC) Toronto, CR, 75(269), 41.

GUIDELINE #3
Name of guideline
Design for Cooperation
Description
In a cooperation, the involved agents perform both tasks individually and cooperatively. This requires the agents to have a) task specific knowledge and capabilities and b) the ability to communicate and understand other agents in the cooperation. Typical components of cooperative work are task allocation and authority of agents. A truly cooperative system allows all agents to take supervisory control depending on their competency and capability. This way, the design takes advantage of the automation's ability to enhance the operator without revoking authority completely. When designing an AdCoS, define what agent takes which role with what level of authority. An AdCoS showing only little cooperative features will most likely receive little acceptance from the user. For design patterns and recommendations consult Deliverable 3.10 of EU-D3CoS.
Examples
• Provide feedback on the status of the respective partner's task
Sources
Banbury, S., Gauthier, M., Scipione, A., Kanata, O. N., and Hou, M. 2007. Intelligent adaptive systems. Defence R&D Canada (DRDC) Toronto, CR, 75(269), 41. Millot, P. and Lemoine, M. P. 1998. An attempt for generic concepts toward human-machine cooperation. In *Proceedings of the IEEE 1998 International Conference on Systems, Man, and Cybernetics*, 1044–1049. DOI=10.1109/ICSMC.1998.725555. Miller, C. A. and Parasuraman, R. 2007. Designing for flexible interaction between humans and automation: delegation interfaces for supervisory control. *Human Factors* 49, 1, 57–75.

GUIDELINE #4
Name of guideline
Design for Decision-Making
Description
Decision-Making is defined as choosing an option from alternatives based on available information under (at least some) uncertainty. The quality of the decision made greatly depends on the data the decision maker can access. The process is a key step in information processing Decision making capabilities are bound by a number of factors. Human computing power is limited and the results greatly depend on the decision maker's mental state and experience. Decisions should not be detached from context; holistically designed systems therefore store operators' decisions linked to the context features they were situated in. When asking an operator to make a decision, make sure that he/she is provided with the necessary information cues, adequate degrees of freedom and feedback for his/her decision.
Examples
• Provide reference points based on historic data when operator is evaluating an option
Sources
Wickens, C. D. 2004. *An introduction to human factors engineering*. Pearson/Prentice Hall, Upper Saddle River, NJ.

GUIDELINE #5
Name of guideline
Design for Fatigue
Description
Decreases in performance related to fatigue may occur as a consequence of lack of stimulation or depleted resources of the operator. Adaptive systems have to keep the operator engaged when stimulation and demands drop below a critical level and support the operator when vigilance and wakefulness are low. Fatigue depends on many factors that will be outside the control of the AdCoS to be designed. If adapting to operator fatigue, make sure that the detection method is sensitive to the type of fatigue critical for your task, as tiredness and lack of task engagement might result in forms of fatigue with symptoms different in nature. Even if the to be designed AdCoS will be able to cope with fatigued operators, this cooperation setup is far from ideal. Find ways to relieve the operator of control and encourage him/her to take action when fatigue reaches a critical level.
Examples
• Keep the operator in the loop and advise him/her to take actions when detecting fatigue
Sources
Desmond, P. A. and Hancock, P. A. 2001. Active and passive fatigue states. *Stress, workload and fatigue*. Gander, P., Graeber, C., and Belenky, G. 2012. 17 Operator Fatigue: Implications for Human–Machine Interaction. *The Handbook of Human-Machine Interaction: A Human-Centered Design Approach*.

GUIDELINE #6
Name of guideline
Design for Situation Awareness
Description
Situation Awareness can be seen as the basis for Decision-Making. The quality of how the operator makes sense of a situation and his/her decision directly depends on the access and awareness of situation information. Therefore, at all times the operator needs to be provided with information essential to the task in an adequate way. Situation Awareness ranges across three levels. Level one reflects the perceptive level and is achieved when the operator has perceived all bits of critical information. The second level is called interpretation and consists of making sense of the perceived information. The third and last level, projection, allows for the mental simulation and prediction of what states the critical dynamics of the situation will take in the future. First, define what constitutes optimal awareness for the operator's tasks. Next, think of ways to make sure that all needed information cues reach the operator in a fashion that he/she is able to process. Last, monitor his/her actions to verify adequate situation awareness.
Examples
• Signal AdCoS state to the operator when adapting automatically
Sources
Wickens, C. D. 2004. *An introduction to human factors engineering*. Pearson/Prentice Hall, Upper Saddle River, NJ. Endsley, M. R. and Jones, D. G. 2012. *Designing for situation awareness. An approach to user-centered design*. CRC Press, Boca Raton, Fla.

GUIDELINE #7
Name of guideline
Design for (User) Satisfaction
Description
In order to create positive attitudes and beliefs towards the AdCoS to be designed, the system will have to satisfy the user's needs. The feeling of satisfaction is governed by the systems perceived effectiveness, usability and appeal. That is, the system is judged by the user based on the quality of the results it produces and the effort that has to be spent to achieve these results. Rather than putting a single focus on fulfilling its purpose, perform a needs assessment for comparable systems and check what other aspects (hedonic properties, etc.) the user will be looking for in your design. User satisfaction is a good indicator for the quality of system design, but it does not accurately predict system usage. Research has shown that accuracy of adaptive components has a greater impact on user satisfaction than predictability. Although some context assessment algorithms might be complex in nature, avoid trading in accuracy for simplicity.
Examples
• Prefer accurate machine learning over simplistic, but inaccurate static algorithms for context assessment
Sources
Wixom, B. H. and Todd, P. A. 2005. A Theoretical Integration of User Satisfaction and Technology Acceptance. *Info. Sys. Research* 16, 1, 85–102. Gajos, K. Z., Everitt, K., Tan, D. S., Czerwinski, M., and Weld, D. S. 2008. Predictability and accuracy in adaptive user interfaces. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, Florence, Italy, 1271–1274. DOI=10.1145/1357054.1357252.

GUIDELINE #8
Name of guideline
Design for Technology Acceptance
Description
Technology Acceptance is one of the key factors of an AdCoS' success. The design should therefore account for the user's future attitude towards using the system. Technology Acceptance is determined by a systems usefulness and ease of use in the eyes of the user. However, other aspects such as costs or subjective norms and image. In summary, acceptance is driven by performance expectancy, effort expectancy, social influence, and facilitating conditions. Anticipate what might keep users from accepting the AdCoS. In later development stages, conduct user tests on acceptability. Until then, aim for high trust, usability and satisfaction as a shortcut.
Examples
• Anticipate acceptance problems
Sources
Venkatesh, V., Morris, M. G., Davis, G. B., and Davis, F. D. 2003. User Acceptance of Information Technology: Toward a Unified View. *MIS Quarterly* 27, 3, 425–478. Venkatesh, V. and Bala, H. 2008. Technology acceptance model 3 and a research agenda on interventions. *Decision sciences* 39, 2, 273–315. Wixom, B. H. and Todd, P. A. 2005. A Theoretical Integration of User Satisfaction and Technology Acceptance. *Info. Sys. Research* 16, 1, 85–102.

GUIDELINE #9
Name of guideline
Design for Trust in Automation
Description
Trust in automation can be defined as the attitude that the automation will help in achieving the user's goal. It depends on the user's attitudes and beliefs and is merely moderated by the automation's actual reliability. Refrain from invoking the maximum of trust in the system, but define what level of trust is fits the automation's reliability in order to prevent complacency. Try to maximize transparency of the design in terms of showing past performance, explaining algorithms and functionality (either directly or by intermediate results) and display purpose, goals and boundaries. Help the user to acquire a thorough understanding of how the adaptive component works so he/she can develop an adequate amount of trust in your system while remaining critical when the situation demands it.
Examples
• Explain to operator how and when the AdCoS adapts
Sources
Parasuraman, R. and Riley, V. 1997. Humans and Automation. Use, Misuse, Disuse, Abuse. *Human factors* 39, 2, 230–253. Lee, J. D. and See, K. A. 2004. Trust in Automation. Designing for Appropriate Reliance. *Human Factors: The Journal of the Human Factors and Ergonomics Society* 46, 1, 50–80.

GUIDELINE #10
Name of guideline
Design for Usability
Description
Make sure that the system is not only effective but also efficient by promoting usability. Find interaction modes the user is familiar with and keep the interface design consistent, simple, and transparent. Conventional interaction elements, real world examples and metaphors are a good start when designing for familiarity. Consistency is achieved by uniformity in interaction and information presentation requirements (e.g., eliminating synonyms, uniform color coding, standardized input syntax, etc.). Simplicity can be promoted by communicating in natural language, allowing him/her to take shortcuts and promoting intuitive interactions. Enable the user to track and change his/her actions and provide him/her with feedback wherever possible. When designing an AdCoS, make sure the user understands the adaptive component by providing him/her with a simple and transparent trace and feedback of the adaptive algorithms and modified system behavior.
Examples
• Display accurately and transparently how and when the AdCoS will adapt
Sources
Wickens, C. D. 2004. *An introduction to human factors engineering*. Pearson/Prentice Hall, Upper Saddle River, NJ. Kniewel, R., Evers, C., Schmidt, L., and Geihs, K. 2014. Designing Usable Adaptations. In *Socio-technical Design of Ubiquitous Computing Systems*, K. David, K. Geihs, M. J. Leimeister, A. Roßnagel, L. Schmidt, G. Stumme and A. Wacker, Eds. Springer International Publishing, Cham, 211–232. DOI=10.1007/978-3-319-05044-7_12.

GUIDELINE #11
Name of guideline
Design for Visual Distraction
Description
Distraction is defined as a diversion of attention away from the critical task. Promote task focus by eliminating sources of distraction and by keeping the user engaged in the task. The underlying mechanisms and consequences for performance are explained by the Multiple Resource Theory. Be aware that the simultaneous access of different resources does not guarantee that the design is immune against distractions. Competition for the same resource however should be avoided at all times. First, list up visual task demands for using the AdCoS to be designed. Then find out what environmental dynamics might attract visual focal or ambient visual attention and how these effects can be mitigated.
Examples
• Congregate visual information for one task on the same display
Sources
Wickens, C. D. 2002. Multiple resources and performance prediction. *Theoretical issues in ergonomics science* 3, 2, 159–177. Liang, Y. and Lee, J. D. 2010. Combining cognitive and visual distraction: less than the sum of its parts. *Accident; analysis and prevention* 42, 3, 881–890.

GUIDELINE #12
Name of guideline
Design for Workload
Description
The concept of workload reflects the subjective demands an operator faces. The correlation between operator workload and performance resembles an inverse U-shape: Underload may lead to fatigue and boredom, overload to lack of resources. Both are undesirable states and sources of error. Define an acceptable level of workload and keep the operator within its boundaries by holding him/her in the loop. Critical workload has direct effects on other human factors such as situation awareness, attention and performance. If the AdCoS' functionality will not be directly adapted to operator workload, workload needs to be considered in dynamic function allocation. Make sure to assess workload holistically to avoid relieving the operator when he/she is underloaded or adding tasks to overload in critical situations.
Examples
• Assess operator's workload and identify too high/low workload levels • Shift tasks away from operators with too high workload and towards operators with low workload
Sources
Young, M. S. and Stanton, N. A. 2002. Attention and automation: new perspectives on mental underload and performance. *Theoretical issues in ergonomics science* 3, 2, 178–194. Wickens, C. D. 2004. *An introduction to human factors engineering*. Pearson/Prentice Hall, Upper Saddle River, NJ. Young, M. S., Brookhuis, K. A., Wickens, C. D., and Hancock, P. A. 2015. State of science: mental workload in ergonomics. *Ergonomics* 58, 1, 1–17.