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Compiled by:	Sillaurren, Sara – TEC
Authors:	Simona Collina – SVN, Roberta Presta –SVN, Zdenek Moravek – HON, Morten Larsen – AWI, Ian Giblett – EADS-UK, Martin Boecker – EADS-CAS-
Reviewers:	Miriam Quintero – ATO Holger Prothmann – TWT
Technical Approval:	Jens Gärtner, Airbus Group Innovations
Issue Authorisation:	Sebastian Feuerstack, OFF

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1. Introduction

The user interface, system design and implementation of adaptation are essential parts of the adaptive-cooperative human-machine system. The human *operator needs to be informed about the system status*. Therefore, the machine agents have to provide *intuitive feedback* and visualization to increase the operator's understanding of the "*Why?*" and "*What?*" of the intended, anticipated or performed adaptation. For example, a machine agent within an Aeronautics AdCoS might communicate: "I display the fuel consumption for validation (the "*What?*") because we fly over a waypoint (the "*Why?*")".

When operating automated systems, partially due to their complexity, understanding the meaning of displayed information can represent a significant difficulty [1]. For instance, in aircraft systems, pilots have reported *significant difficulties* in understanding what their automated flight management systems are doing and why [2]. This problem can be directly linked to a lower level of situation awareness and conveys that AdCoS need to constantly communicate changes and adaptations to the human operators.

Due to the previous reasons, the focus of these guidelines will lie on the *communication strategies of the system adaptation*. As humans are limited by working memory and attention [3], it is crucial that AdCoS ensure perceptual salience of the most important information. To achieve this goal, the guidelines will analyze the different communication systems (visual, acoustic and tactile) for the "What" (adaptation that has occurred) and the "Why" (reason for the adaptation → context assessment).

To define a communication strategy, some main points should be addressed properly. The first of them will be the *objectives of the communication*. In the case of the different AdCoS, this will be the adaptation that occurred in the system and at has to be communicated to the operator.

On the second place, for our communication strategy to be widely effective, *the audience* to whom the communication is prepared for is fundamental. The operators and their specific state (Human Factors in context assessment) will be taken into account, provided that the perception of the communication could require extensive cognitive processing on the part of the user.

The next main issue in a communication strategy is the communication channel, understood as medium through which a message is transmitted to its intended audience. In our case, multimodal communication channels will be studied in order to define the best ones to achieve the communication objectives. In this sense three different channels will be taken into account:

1. visual (e.g. as pictures and characters),
2. acoustical (verbal or nonverbal) or
3. physical / tactile (e.g. vibration).

To finalize, strategies for evaluation and validation should be defined in order ensure the achievement of the communication objectives.

Summarizing, the Communication Guidelines will address the *following questions*:

- Which are the *different types of communication* with the operator?
- How should/can a communication strategy be implemented *(visual, acoustic, tactile)*?
- Why should *Human Factors* be considered when implementing a communication strategy?
- Are all communication strategies *valid* for every different domain / AdCoS?
- How can the different Human Factors *influence the perception* of the communication?
- How can a communication strategy be *tested*? / What variables need to be considered? (Verification of the system benefits)

2. Current situation in HoliDes AdCoS

The first step to determine the best way to communicate the adaptation changes to the operator is to analyze the current situation of the HMI in the different AdCoS. This analysis has been linked both with the context assessment (to determinate which Human Factors are involved in each AdCoS) and the adaptation produced in the system (the one that has to be communicated to the operator).

2.1 UC1 Guided Patient Positioning

UC1 is the Health use case, Guided patient positioning.

In the Guided patient positioning use case, assistance is provided to an operator aiming at safely positioning a patient in an MRI device for medical examination purposes.

CASE 1	
Human Factor	***Process***
Non-standard activity (measures by scanner signals and respiratory sensor for the patient breathing)	Assessment of operator's compliance with standard procedure and guidance in case of deviations
Adaptation	
On-line guidance and information about current system configuration during preparation of the patient for the MRI scanning procedure. The system includes transparent adaptive algorithms, mostly based on fall-back procedures. This for instance means that if a specific coil (say, a knee coil) has not been mounted, the system will allow continuing with the scan using the built-in generic coil. This system adapts by modifying the positioning procedure and the UI that presents that procedure.	
Communication	
The change in the UI is the visible manifestation of the adaptation. Adaptation in the UI of the guidance system is obtained by modifying the graphical representation of the positioning steps according to the requirements of the examination as obtained from the overall context information. The display will be re-configured automatically to show the relevant steps of the positioning procedure, which includes information to give to the patient.	
Type of Interaction	
Visual, one-way	
AdCoS / MTT responsible	
Gantry display (guidance display)	

Figure Figure 1 shows an example of a display that has been re-configured to communicate the structure of the guidance procedure based on the context information.

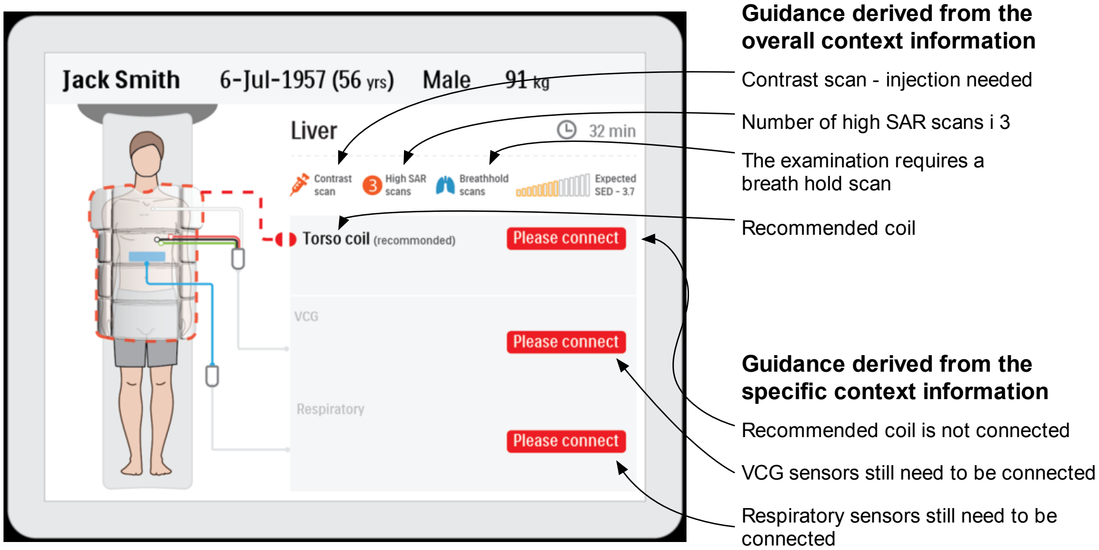

Figure 1: A display showing the guidance given to the operator

2.2 UC2 Diversion Airport

UC2 is the Aeronautics use case, Diversion Airport.

In UC2, Diversion Airport, assistance is provided to the pilot through the DIVA (DIVersion Assistant) system. DIVA helps the pilot by providing tentative diversion flight plans (F-PLN) when a diversion is needed.

Analyzing the different Human Factors related with the adaptation and the communication to the pilot, the following information is available:

CASE 1	
Human Factor	***Process***
Non-standard activity	Pilot's procedure assessment
Adaptation	
Monitoring of actions the pilot performs and evaluating how appropriate they are with respect to current situation. The display is adjusted to inform about a suboptimal solution.	
Communication	
Display change with saliency increasing with severity of deviation	
Type of Interaction	
Visual	
AdCoS / MTT responsible	
Diversion Assistant itself	

CASE 2	
Human Factor	***Process***
Fatigue	Pilot's state assessment
Adaptation	
Methods for operator state inference being evaluated (physiological metrics, camera monitoring, voice detection)	
Communication	
Info reduction – pre-selection of options, visual prioritization	
Type of Interaction	
Visual	
AdCoS / MTT responsible	
External pilot models and pattern classifier	

CASE 3	
Human Factor	***Process***
Distraction	Missed event detector (MED)
Adaptation	
Methods for operator state inference being evaluated (physiological metrics, camera monitoring, voice detection)	
Communication	
1. Test case - auditory warning about the event 2. AdCoS - holding the event from disappearing until observed	
Type of Interaction	
Visual	
AdCoS / MTT responsible	
MED (Missed Event Detector) and Diversion Assistant	

CASE 4	
Human Factor	***Process***
Usability/Preferences	Display setting monitoring and assessment
Adaptation	
System based on video recording and recognition is planned to identify suboptimal display layout due to change in lightning, vibrations etc. Automatic adjustments linked to pilot acceptance will create a learning system that should be able to react appropriately (acceptably for pilots) to the situation.	
Communication	
No need to communicate the adaptation, it is immediately visible.	
Type of Interaction	
Visual	
AdCoS / MTT responsible	
CoDA (Cooperative Display Adaptation) and diversion assistant	

Summarizing, the pilot gathers information on the F-PLN through user interfaces (UI) resources: the Navigation Display/Vertical Display (ND/VD) UI and the Flight Management System (FMS) UI. The pilot acts on the F-PLN through the FMS UI. The pilot also *receives assistance* from the DIVA system through the *DIVA UI*. That assistance is provided at the level of the Action

Planning (AP) cognitive step: The pilot has to plan a new diversion plan and a tentative one is provided by DIVA.

For the moment, in this Use Case there are only basic ideas on adaptation, which will be implemented in future milestones. So the communication of adaptation is not being done at this step.

2.3 UC3 Border Control Room

UC3 is the Border Control Room use case, concerned in particular with the Sector Headquarter Control Room sector, and within it, the Surveillance capabilities (at the moment the Response capabilities are not concerned by the AdCoS).

In UC3, assistance is provided to the surveillance operators/supervisor through the Adaptation Assistant Modules (AAM). AAM helps the operators/supervisor by providing several supports in task execution or task allocation when border surveillance efficiency is needed.

CASE 1	
Human Factor	***Process***
Workload	Task workload distribution assessment
Adaptation	
Rebalance workload among all available operators / re-assignment can be performed either with or without involvement of the supervisor. Workload balancing is achieved by the Adaptation Assistant Modules (AAM).	
Communication	
Once a load balancing decision has been made it is communicated to the operators involved, in terms of task assignment. This can be done verbally, directly by the supervisor and/or through an electronic messaging system (e.g., mobile phones, kinesthetic bracelet). These operators are then monitored to ensure their actions correctly follow the new instructions.	
Type of Interaction	
Verbal / Visual / Tactile	
AdCoS / MTT responsible	
workstation	

In term of **communication,** WP3 contributes to the following UC:

UC3.1 Operator Absent from Work Place: If operators are absent for longer than the permitted time, the systems calls them back to their workstations by means of discrete actuators worn by the operators.

UC3.2 Operator Idle at Work Place: If operators display a lack of movement for a longer period of time, the system wakes them by same means as UC1.

UC3.3 Operator Tired at Work Place*:* If the operator displays symptoms of fatigue, the system suggests to the operator to take appropriate measures.

UC3.4 Load Balancing on Operator Level*:* The re-assigning of individual events will be supported by appropriate information of the operator and his supervisor.

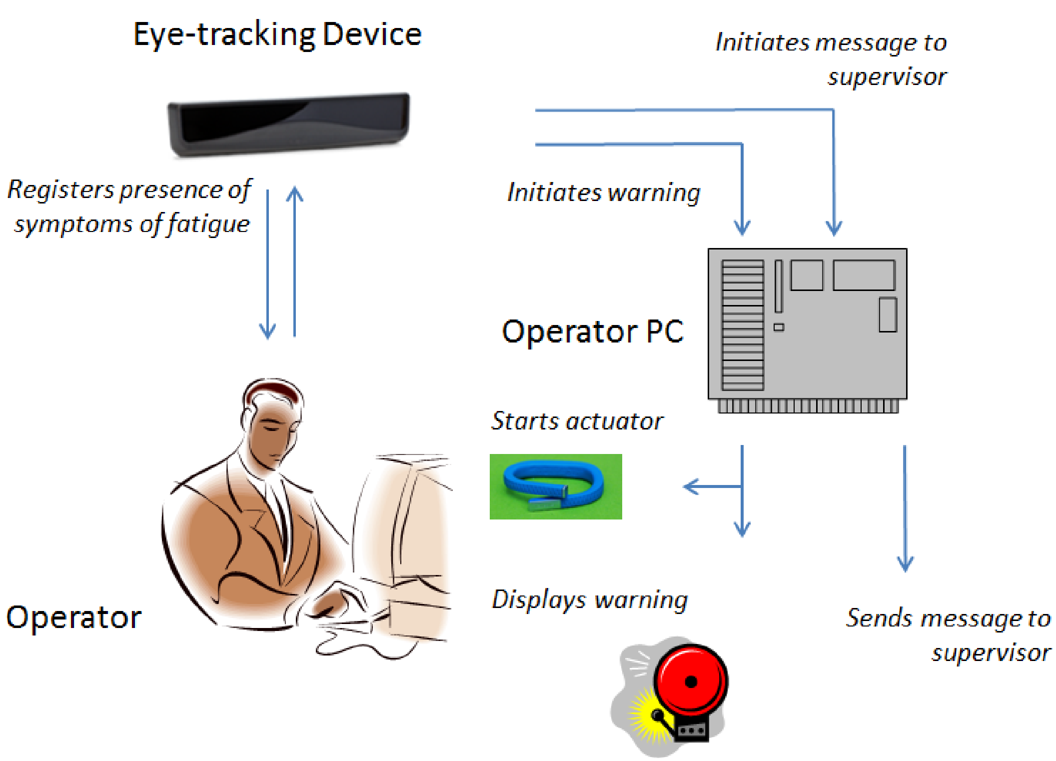

Figure 2 High Level Interaction Diagram for Control Room UC 3

2.4 UC4 Overtaking including lane change assistant

UC4 is the automotive use case, Overtaking including lane change assistant.

In UC4, Overtaking including lane change assistant, assistance is provided to the driver through the co-pilot concept, which can be regarded as composed of three functionalities: FCW (Forward Collision Warning), OTA (Over Taking Assistant), and LCA (Lane Change Assistant). In these guidelines, only the last one, Lane Change Assistant will be taken into consideration.

CASE 1	
Human Factor	***Process***
Distraction	Driver's visual distraction Driver's distraction level assessment
Adaptation	
Lane Change Assistant (LCA) will provide a level of support, depending on the driver's state, from a simple warning to the possibility to inhibit the maneuver	
Communication	
Information delivery Warning Actions on vehicle commands Automated driving	
Type of Interaction	
Visual / Acoustic, depending on the level of distraction and the behavioral intention	
AdCoS / MTT responsible	
ADAS UI (joint user interface for FCW, OTA and LCA)	

CASE 2	
Human Factor	***Process***
Behavioral intention	Driver's intention recognition
Adaptation	

Lane Change Assistant (LCA) will provide a level of support, depending on the driver's state, from a simple warning to the possibility to inhibit the maneuver
Communication
Information delivery Warning Actions on vehicle commands Automated driving
Type of Interaction
Visual / Acoustic, depending on the level of distraction and the behavioural intention
AdCoS / MTT responsible
ADAS UI (joint user interface for FCW, OTA and LCA)

Alternative graphics for the adaptive HMI has been designed by using the processed information, as shown in Figure 3 and Figure 4, which represent the HMI to support the driver while changing the original lane (Task 1).

Figure 3: Option driver distracted, visual and acoustic interaction

Figure 4: Option car approaching on the left, visual and acoustic interaction

So far, the activity conducted by REL was meant to identify the cognitive and visual load of each task to provide appropriate information to the driver (by also considering the most suitable interaction modality to allow the driver processing this information in continuously changing conditions).

3. Communication objectives ("What?")

In the case of these guidelines and the specific chosen AdCoS, the communication objectives will be focused mainly in the appropriate communication and "explanation" of changes in the AdCoS to human agents. It is important in order to ensure safety – especially in the use cases which involve operating a vehicle. Beyond that, it is crucial for the development of an adequate degree of situation awareness and trust.

4. Audience: the operator and their related HF ("Why?")

The "Why" concerns the reasons of the adaptation: Why is an adaptation triggered? This is determined by measuring, interpreting and/or predicting the internal context (e.g. the status of the human operators) and the external context. In these guidelines, we will stress the importance of the internal context in terms of Human Factors.

The AdCoS should communicate changes to human agents to keep the human agent actively involved in the decision making loop. However, if the provision of such feedback requires *extensive cognitive processing* on the part of the user, any benefit may be counteracted by increased cognitive load. Consequently, there is a need to develop interfaces that provide feedback on automation states and behaviors in a manner that requires *little* *or no cognitive effort* but can be directly apprehended by a quick glance at a display that provides the appropriate avenue for rapid action.

The aim of this section is to analyze the different states in which the operator can be and also the way these Human Factors *can affect to the perception* of the information.

Till the moment, the different Human Factors that are being considered in the different chosen AdCoS are:

- Non-standard activity
- Fatigue
- Distraction
- Usability/Preferences
- Workload
- Behavioral intention

As an example, fatigue effects can lead to reduced decision making ability and increased reaction time that can lead to failures by the human agent to successfully respond to changes in the current operational context. The more the task performed by the human agent is safety-critical (like the plane operation considered in UC2), the more such a human state represents a dangerous condition. The AdCoS should come into play when high levels of fatigue are detected in the human operator agent, by adapting the driving support provided by means of its interface, i.e., by adapting the content and the way in which the information needed to preserve the pilot situation awareness is provided to the operator. The communication strategy needs to contrast the fatigue of the operator to deliver the necessary message in a timely and effective way.

Let us consider as another example the automotive use case UC4. Besides assessing the external environment context (road, traffic, obstacles, other vehicles, etc.), the AdCoS needs to correlate both the distraction state of the operator with his detected intention (i.e., the evaluation of the maneuver the driver is going to perform) in order to assess the risk of the current driving situation and to provide accordingly warnings or action suggestions. When in case of a detected visual distraction, the driver is not currently looking on the road ahead and critical information about the external environment may be not perceived. If in case of a lane changing maneuver, such critical information may determine AdCoS actions that can lead from warning the driver to the inhibition of the dangerous maneuver. By considering the visual load of the operator, other communication channels for providing both the performed adaptation and the motivation of the adaptation need to be carefully considered.

5. Channels: multimodal communication strategies ("How?")

For the action and communication in the AdCoS it is necessary to take into account the Human Machine Interaction. This section of Action/Communication is mainly focused in the information the machines can give about their adaptation to the operator. From their side, machines can give information mainly in three ways:

- visually (e.g. as pictures and characters),
- acoustically (verbal or nonverbal) or
- physically/tactile (e.g. vibration).

In conclusion, the AdCoS should provide information via different output modalities, exploiting the various different *sensory channels available* to humans by providing tactile, auditory, and peripheral visual feedback.

6. Visual communication strategies: Interface Design

There is a need for communicating the adaptation in a visual way to the operator. Like with any language the machine needs to understand the individual parts, how to organize those parts and re-arrange them in order to transmit the message.

One explicit goal of visualization is to present data to human observers in a way that is informative and meaningful, on the one hand, yet intuitive and effortless on the other.

Visualization in general has the potential to closely interact with users and adapt to their needs, e.g. *mental models, cognitive processes and affective states*, in order to improve performance and increase user satisfaction. These visualization systems should be aware of user emotions and needs, in this way increasing the adaptability of the representation and the overall impact of visualization effectiveness.

The beginning for visualization strategies definition is to try to get advantage of some of the built-in capabilities and also to take into account the limitations of the human visual system.

In this sense of human capabilities, preattentive vision refers to cognitive operations that can be performed prior to focusing attention on any particular region of an image. In [4], the authors argue that results from research on this ability could be used to assist in the design of visualization tools.

As a limitation of visual human capabilities, we can find the term of "Change blindness". It refers to the finding that large changes to the visual world go undetected if attention is not already focused on the objects or area in which the change occurs [5][6][7].

6.1 Preattentive proccesing

Preattentive processing is defined as the ability of the low-level human visual system to rapidly identify certain basic visual properties.

For many years vision researchers have been investigating how the human visual system analyses images. An important initial result was the discovery of a limited set of visual properties that are detected very rapidly and accurately by the low level visual system. These properties were initially called *preattentive,* since their detection seemed to precede focused attention.

We now know that attention plays a critical role in what we see, even at this early stage of vision. The term preattentive continues to be used, however, since it conveys an intuitive notion of the speed and ease with which these properties are identified.

Typically, tasks that can be performed on large multi-element displays in less than 200 to 250 milliseconds (msec.) are considered preattentive. Eye movements take at least 200 msec. to initiate, and random locations of the elements in the display ensure that attention cannot be pre-focused on any particular location, yet viewers report that these tasks can be completed with very little effort. This suggests that certain information in the display is processed in parallel by the low level visual system.

As a summary, preattentive processing asks in part: "What visual properties draw our eyes, and therefore our focus of attention to a particular object in scene?"

6.2 Change Blindness

New research in psychophysics has shown that an interruption in what is being seen (*e.g.,* a blink, an eye saccade, or a blank screen) renders us "blind" to significant changes that occur in the scene during the interruption. This *change blindness* phenomena can be illustrated using a task similar to a game that has amused children reading the comic strips for many years [5], [8], [9].

A second hypothesis is that only the initial view of a scene is abstracted. This is plausible, since the purpose of perception is to rapidly understand our surroundings. Once this is done, if the scene is not perceived to have changed, features of the scene should not need to be reencoded.
This means that change will not be detected except for objects in the focus of attention. One example of this phenomenon is an experiment conducted by Levins and Simon [10], [11].

7. Acoustic communication strategies

Acoustic signals are omni directional (i.e. they travel in all directions) and can be broadcast to a large audience including intended and unintended listeners, and those in view and hidden from view. Being short-lived and deliberate, acoustic signals are useful for giving information about an *immediate situation*, rather than about a constant state (as it can happen for example in an alert or emergency situation).

8. Tactile communication strategies

The sense of feel *is not typically used* as a man-machine communication channel, however it is every bit as acute as the senses of sight and sound. Using an intuitive body-referenced organization of vibro-tactile stimuli, information can be "displayed" to a person. Tactile displays can reduce perceived workload by its easy-to-interpret, intuitive nature, and can convey information without diverting the user's attention away from the operational task at hand.

The key to successful implementation of tactile displays lies in the ability to convey a strong vibro-tactile sensation to the body with compact, lightweight devices that can be *comfortably incorporated* in the user's workspace, or clothing, without impairing movement. These devices must be safe and reliable in harsh environments, and drive circuitry should be compatible with standard digital communication protocols.

9. Evaluation and validation strategies

In order to set up the evaluation of the multichannel communication strategies, some elements should be taken into account.

For example in the case of the automotive domain, the interface should communicate to the driver "what" to do (e.g. turn right; turn left; keep the lane) in a visual or visual and verbal manner according to the context, which means being in presence of obstacles, being distracted, having a specific intention and so on. Several studies have shown that the drivers tend to trust more in semi-automatic systems if the devices communicate in an efficient manner and explain the "why" of certain actions and decisions suggested (e.g. keep the lane and avoid overtaking because a car is approaching). However, it is difficult to transfer these messages verbally.

One possibility consists in using other perceptual channels that in a given moment result free from processing, as for example the haptic channels (vibration of the seat or of the steering wheel). While the use of an alternative channel can be considered reasonable and easy to understand on an intuitive ground, the effectiveness of the different available alternative channels needs to be verified on a scientific basis. Empirical analysis is a possible applicable methodology to this aim.

In order to evaluate and compare the effects of the different strategies for the communication of the "why" of the adaptation, a series of experiments will be created.

In the first series of experiments acoustic, visual and haptic stimuli will be compared in the driving simulator to evaluate which one interfere less with the driving activity.

Once established the channels that better adapt to a specific task, a series of experiments using intra/intermodal paradigms will be set up to verify which specific features of, for example, an acoustic channel, are better processed by the driver or on which frequency the vibration of the seat/the wheel can alert the driver of an imminent danger.

Finally, participants will be interviewed to collect information useful to eventually modify the interface. Combined the results will provide evidence on the evaluation of the interface.

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