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

D3.7 – ANNEX I – Communication Guidelines

Project Number:	332933
Classification:	Public
Work Package(s):	WP3
Milestone:	M5
Document Version:	V1.0
Issue Date:	30.09.2016
Document Timescale:	Project Start Date: October 1, 2013
Start of the Document:	Month 23
Final version due:	Month 36
Deliverable Overview:	**Confidential Document:** D 3.7b - Techniques and Tools for Adaptation Vs2.0 incl. Handbooks and Requirements Analysis Update **Public document:** D 3.7a - Techniques and Tools for Adaptation Vs2.0 incl. Handbooks and Requirements Analysis Update, Public part excluding confidential information + **Annex I:** Communication Guidelines (Public) **Annex II:** Handbooks **Annex III:** Requirements analysis update
Compiled by:	Sillaurren, Sara – TEC
Authors:	Simona Collina – SVN, Roberta Presta –SVN, Zdenek Moravek HON, Martina Becker EAD-CAS-DE, Flavia De Simone – SNV, Elisa Landini – REL, Gert Weller - TAK, Sara Sillaurren – TEC
Reviewers:	Frank Jonat, EAD-CAS-DE
Technical Approval:	Jens Gärtner, Airbus Group Innovations
Issue Authorisation:	Sebastian Feuerstack, OFF

DISTRIBUTION LIST		
Copy type[1]	Company and Location	Recipient
T	HoliDes Consortium	all HoliDes Partners
D	ARTEMIS JU	Patrick Vandenberghe

[1] Copy types: E=Email, C=Controlled copy (paper), D=electronic copy on Disk or other medium, T=Team site (AjaXplorer)

RECORD OF REVISION		
Date (DD.MM.JJ)	Status Description	Author
30.09.2015	Structure change proposal	Sara Sillaurren, TEC
29.10.2015	Revision for UC4	Elisa Landini, REL
04.11.2015	SNV contribution for section 2.2	Roberta Presta, SNV
05.11.2015	Revision for UC2	Zdenek Moravek, HON
06.11.2015	Revision for UC3	Martina Boecker, EAD-GE
06.11.2015	Last document revision	Elisa Landini, REL & Roberta Presta, SNV
09.11.2015	Last guidelines text inclusion	Sara Sillaurren, TEC
22.03.2016	First review of the guidelines	Elisa Landini, REL & Roberta Presta, SNV & Sara Sillaurren, TEC
20.04.2016	Second review of the guidelines	Sara Sillaurren, TEC
	Final version	Sara Sillaurren, TEC

Table of Contents

Table of Figures

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 analyse 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 that 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? This question is answered in the section 2.3 Channels: Multimodal Communication.
- How should/can a communication strategy be implemented (visual, acoustic, tactile)? This question is also answered in the section 2.3 Channels: Multimodal Communication.
- Why should Human Factors be considered when implementing a communication strategy? This question is answered in the section 2.2 Subject: the operator and their Human Factors influencing perception.
- Are all communication strategies valid for every different domain / AdCoS? This question is answered in Appendix A.
- How can the different Human Factors influence the perception of the communication? This question is answered in the section 2.2 Subject: the operator and their Human Factors influencing perception.
- How can a communication strategy be tested? / What variables need to be considered? (Verification of the system benefits). This question is answered in the section 3 Evaluation and validation strategies.

1 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).

Extended information about the current situation in HoliDes AdCoS can be found in Appendix A.

2 Analysing the Communication Strategies

2.1 Communication objectives ("What?" and "Why?")

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 (adaptation) 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.
"What" is being communicated is widely dealt in *D3.6aPU*.

Furthermore, the second main communication objective is the "why", describing reasoning for adaptation actions. Recent studies [37] have shown the importance of providing information on the "why" to achieve, for example, a better driving experience in (semi-autonomous) adaptive vehicles. The explanation of the "why" also affects the operator's attitude and safety performance.

2.2 Subject: the operator and their Human Factors influencing perception ("Who?")

Human Perception
The main subject of the communication strategies is the own operator. Human operator perception requires sensory organs, the nervous system,

and the brain to work together smoothly. Any breakdown in this system can prevent or change human perception of the world at large. The human brain is also limited in its ability to process information and takes certain shortcuts when processing the information that is received from the senses, especially during visual perception.

Perception is the process by which individuals organize and interpret the signals received through their sensory organs to give meaning to their environment. What we perceive is definitely influenced by the environment which generates the signal received by sensory organs. But the same signals are not perceived by all individuals in the same way. There are differences. As a matter of fact there may be difference in the way an individual perceives the same object in the environment under different conditions or context.

A simplified *model of human perception* has been presented by [30].
The model describes human visual perception as a three stages process:
1 – in the first step, the information is elaborated in parallel to extract basic features of the environment;
2 – in the second stage, processes of pattern perception extract structures and segment the visual scene into regions of different colour, texture, and motion features;
3 – in the third step, the information is reduced in only a few objects held in visual working memory by attention processes.
Following this model, human perception is highly affected by individual *memory* and *attention* processes.

Memory organizes behaviour in time, making a link between past and future experiences [31]. Memory is not only the ability of reactivating, partially or totally, past events, but also the ability of generating new interpretative schemes of reality and to plan acts deferred in time [32].
In many years of research, different models of memory have been built.
Associative models of memory based on elementary mechanisms reduced the human being to a passive receptor of stimuli. To overcome this limit, further studies have allowed the development of more complex memory models - *cognitive models*. One of the most popular was made by Atkinson e Shriffin ([33],[34]). This model is based on a concept of human being like data elaborator.

The first step of the elaboration of local stimuli takes place at sensory registers level. In *sensory memory*, information is detained very little time: 250 milliseconds visual information in iconic memory and 200 milliseconds auditory information in echoic memory.

In the next step, short term memory doesn't contain only sensory images of external stimuli but make an interpretation.
Finally, *long term memory* can retain information for a long time. Memory shift between these two levels is possible through a mechanism of track repetition. Quality and quantity of repetition causes the memory traces strength.

Distinction between short-term memory and long-term memory is supported by behavioural and neurological data. As memory is not a unitary store, we can distinguish between different memory systems: *working memory, episodic, semantic* and *procedural* or *implicit memory*.

Initially, researchers attributed to *short term memory* very elementary processes like the rehearsal. Sperling [35] described this process like an internal voice with a purpose to revitalize information to prevent the loss.

Recent theories, however, suggested that short-term memory presupposes mechanisms more complex than rehearsal. Current idea of short term memory is that of a limited capacity system which temporarily holds active information and supports thought processes by connecting perception, long term memory and action. This system is also known as *working memory* [36].

As already discussed in D2.1, the first author who replaced the concept of short-term memory with that of working memory was Baddeley [37]. According to this author, working memory is a system whose role is to detain and manipulate information during cognitive tasks execution, like comprehension, learning and thinking [38].
This system is constituted by:

- the phonological loop: it is the component better illustrated by Baddeley. It includes two sub-components: a phonological store whose work is to hold linguistic information and an articulatory rehearsal process based on an internal speech. After very little time, about two seconds, information contained in the phonological store declines but it is possible to keep active memory trace with a process of sub-vocal rehearsal. This theory is supported by experimental data:
- the phonological similarity effect: a high robust effect consisting in impaired immediate serial recall of elements phonologically similar;
- the word length effect: difficulties in long words due to the fact that long words contain more elements and are more fragile;

- irrelevant sounds effect: impaired recall due to the contemporary presentation of critical elements and irrelevant material. Irrelevant material presentation interferes with phonological loop work and it doesn't allow sub-vocal rehearsal. Phonological loop seems to be very important in different processes like reading learning or written words comprehension.
- the visuospatial sketchpad: it elaborates visual and spatial information. It works like its verbal equivalent, the phonological loop, elaborating four or five objects at a time;
- the central executive: it is a control system, similar to an attentive mechanism involved in decision making processes.

With regard to *long term memory*, Tulving in 1972 undermined unitary theories of long term memory suggesting a distinction between *semantic* and *episodic* memory based on the encoding specificity principle [39]. Tulving implemented an experiment where subjects were asked to memorize twenty-four pairs of words, constituted by a target word and a weak cue for recall; afterwards a list of words closely related to the targets words were presented to the subjects asking them to create free connections between materials. The result of this experiment evidenced that, in presence of semantically related words, participants were able to recall the targets but not to identify them like critical words. So semantic information didn't allow reaching information stored in episodic memory. According to the author, episodic memory is auto-noetic because it concerns personal experiences. Semantic memory, on the contrary, is noetic because we are aware of elements not available from immediate circumstances. Tulving imaged semantic memory like a mental dictionary, which contains words, concepts and links between the two.
In addition, Tulving [40] assumed the existence of a third type of long term memory system, *procedural memory*, that refer to skills and rules acquisition, to a tacit "know how" which is essential in tasks that required cleverness, like to use a bike, to drive a car and so on. Schacter [41] prefer to call this form of memory *implicit memory*, emphasizing the fact that information about events is reactivated without awareness.

As stated before, together with memory the other factors to be taken into account when dealing with perception processes, is attention.
A theory that strongly relates perception and attention is the feature integration theory proposed by Treisman [42]. According to the author attention processes are based on a fundamental process of feature extraction, a process operating outside of consciousness that is responsible for objects detection in terms of extraction of features like shape, colour, depth, movement.

Factors affecting human perception

In the case of the HoliDes project, 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:

- Fatigue
- Distraction
- Workload
- Situational awareness

You can find examples on how the Human Factors can affect the perception of communication on Appendix B.

When dealing with situational awareness (SA), long-term memory, working memory and attention mechanisms are relevant. The concept of SA has been introduced for the first time in the late 80s in the fighter aircraft domain. The use of the concept has rapidly spread in other domains, from driving to medicine, prompted by the technological development that has required operators to deal with a lot of information coming from different sources. The emphasis on SA has been motivated by the effort of designers to project and realize decision aids and system interfaces to accomplish operator's needs in managing the huge quantity of information. Informally speaking, Endsley [43] defines SA in terms of "knowing what is going on" in a specific environment. A more formal definition describes SA as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future". SA is the base for decision making, as the way a problem is framed influences the decision to solve it. SA, even if not directly, also influences the performance: a poor performance is supposed to be a consequence of an incorrect or incomplete SA. However, an operator conscious of the lack of SA can modify the behaviour to reduce the possibility of poor performance [44].

Distraction can be defined as a state in which attention is captured by information not relevant for a primary task in a way that corrupts the performance in the primary task. Distraction effects in safety critical domains have been studied mainly in automotive. Distraction can be mainly distinguished in visual and cognitive, defined by [45] respectively "eye off-road" and "mind off-road". Cognitive distraction is related to a mental distraction, for example, concentrating on a conversation. Visual distraction can come for example from looking at a telephone keypad in order to dial, or reading or composing a text message. Research has shown that both type of distractions impairs drivers' vehicle control (especially lane position and maintenance of appropriate speed) and reduces drivers' situation awareness, resulting in slower reaction times and less use of mirrors [49].

Mental fatigue can be defined as a change in the psycho-physiological state due to a prolonged performance. That prolonged performance not necessarily relies on a single task but can also include more tasks, all involving a mental effort. Changes in the psycho-physiological state cause subjective and objective effects, as mood changes or an increasing resistance to further efforts. One of the most compelling hypothesis reported in literature links fatigue effects to an impaired executive control [46]. The executive control is conceived as a limited resource for controlled processing especially for activities such as planning, problem solving, and task scheduling. An hypothesis is that the prolonged (over)use of this mechanism is the cause for the phenomena of mental fatigue [47].

Finally, the cognitive workload can be defined as a condition that can be revealed by poor performance measures in a task due to a secondary interfering task [48]. The cognitive workload has been studied experimentally by means of the dual task paradigm in which the performances of participants are measured in terms of response times in the execution of both the primary and the secondary task. An explanation of workload effects is attributed to the limited capacity of working memory [37]. It is accepted that there is a relationship between the media by which information is transferred and presented to a decision maker and their cognitive workload. During periods of concentrated activity the balance between the different information channels (e.g., visual processing and auditory) has a positive impact on cognitive workload [51].

In a time-constrained application context, the cognitive workload can lead to human error or delayed decisions to accommodate the processing of the relevant information [52].

Human Factor	***Description***	***Influence in the information perception***
Fatigue	A state due to a prolonged mental effort	A high level of fatigue causes subjective and objective effects, as mood changes or an increasing resistance to further efforts. One of the most compelling hypothesis reported in literature links fatigue effects to an impaired executive control.
Distraction	A state in which attention is captured by information not relevant for the primary task in a way that corrupts the performance in the primary task	Visual distraction can lead to the loss of important information that is then not to be perceived at all. Cognitive distraction can worsen the processing of the perceived information in terms of time.
Workload	A state that can be revealed by a worsening of the performance measures in the primary task due to the presence of secondary interfering tasks	Delayed information processing affecting decision making
Situational awareness	The perception and comprehension of the elements in the environment and the projection of their status in the near future	A high level of situational awareness has positive impact on the successfulness of decision making processes, thanks to a better comprehension of the perceived contextual information.

2.3 Channels: multimodal communication strategies ("How?")

Multimodal communication systems process two or more combined user input modes in a coordinated manner with multimedia system output.

Of the numerous ways explored by researchers to enhance human-computer communication, multimodal interaction has shown much development in the past decade. The advantages of this multimodal interfaces are twofold:

- Users are offered a more "human" way of interacting with computers, because they are provided with alternative modes of input / output other than the usual human-computer interaction as unimodal interface [13].
- Offer a better flexibility and reliability and make the system more robust than other human-machine interaction means [14] (reducing error in the communication).

As described in [15], the generic components for handling multimodal communication in a system are mainly a fusion engine (for the combination of input modalities) and a fission module (to divide information through active outputs). In these guidelines, we are focusing in the fission process.
Here we have an example of multimodal system and its generic components:

An important issue for communication processes in general, and for multimodal interaction in particular, is the information output arrangement and organization (***multimodal fission***). Considering information structure, intonation and emphasis for the output by speech, considering moreover spatio-temporal coordination of pieces of information for visual (video, graphics, images and text) outputs, designing output for each kind of modality, and synchronizing the different outputs modalities is one of the most relevant challenges of the multimodal interaction design process, it is called ***fission***.

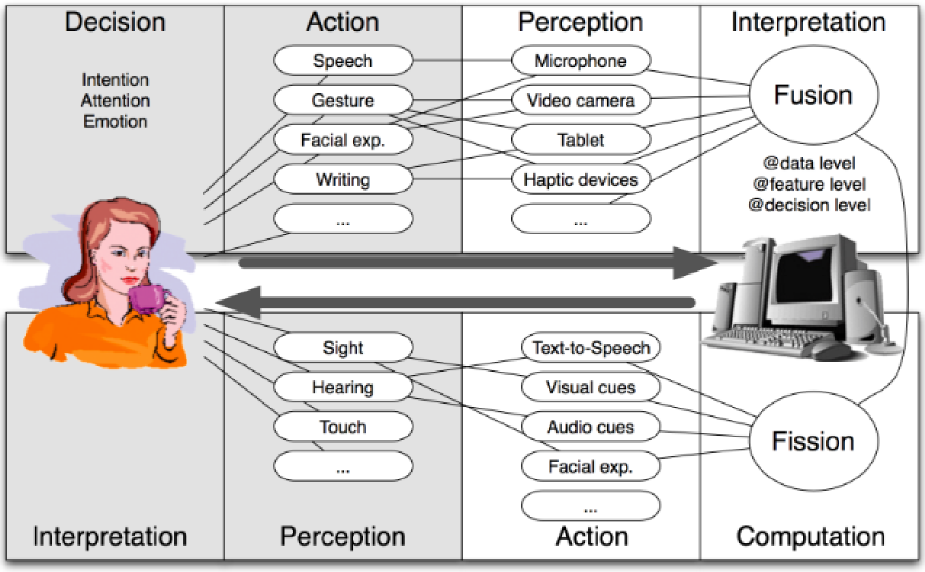


Figure 1: Multimodal fission architecture

Concretely in HoliDes project, for the action and communication in the AdCoS it is necessary to take into account the Human Machine Interaction, from the point of view of the fission module (the output of the system for the human).

This section is mainly focused in the information the machines can give about their adaptation to the operator, that's to say the fission process (multimodal output). 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.

2.3.1 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, pre-attentive 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].

Pre-attentive proccesing

Pre-attentive 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 *pre-attentive,* 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 pre-attentive 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 pre-attentive. 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, pre-attentive processing asks in part: “What visual properties draw our eyes, and therefore our focus of attention to a particular object in scene?”

Pre-attentive perception is done in parallel, but attentive processing is done serially and is, therefore, much slower [16]. Here is an example to illustrate the difference between these two types of visual perception.

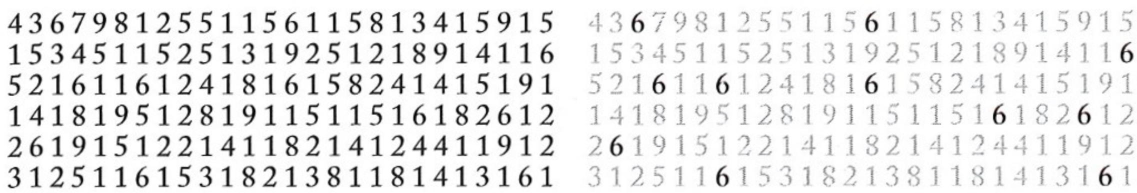


Figure 2: It is easier to spot the number 6 on the right image (pre-attentive processing) than on the image on the left (attentive processing)

This example demonstrates that the brain is much better at quickly detecting shade variations than shape differences [17].

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 recoded.
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].

2.3.2 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).

The auditory modality is highly effective at conveying instructions and other relevant information via speech [18]. Verbal instructions (rather than visual text) are particularly effective when a listener is performing a task or in motion.

Auditory cues are also well-suited for rapid cueing of critical information, such as for warning and alarms [19]. When reaction time is essential, auditory warnings are generally superior to visual warnings, as they more efficiently draw attention to critical information (30 to 40 ms faster than vision)[20], see also [21]. In fact, the acute temporal resolution of the auditory system is one of its greatest assets [22].

When it comes to the specific auditory cue to use, tones are good for communicating limited information sources; complex sounds are well-suited to alarms; speech is more effective for rapid communication of complex, multidimensional information sources [23], and timbre (i.e. sound quality) is an effective auditory grouping cue [24].

2.3.3 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.

Tactile cues, such as those conveyed via vibrations or varying pressures, can provide information concerning location, texture, softness and surface viscosity, as well as serve as effective simple alerts ([27] and [25]). The vibro-tactile sense is comparable in discriminatory ability to audition for frequencies up to about 50 Hz, after which point audition is far superior [26].

2.3.4 Other sensory communication strategies

Although the technology is not quite operational, it is informative to consider the design benefits that may be derived by incorporating additional communication modalities, such as olfaction, gustation, vestibular stimulation, pain and temperature.

Olfaction, which is best conveyed via different odours rather than variations of a given odour. Holds particular promise as it can be used to manipulate mood, decrease stress, increases vigilance and aid memory ([27] and [25]). Humans can detect approximately 10.000 different odours; however, if only intensity is varied, one can detect only about three or four different smells at a time [28].

Olfactory cues are generally most appropriate for conveying affective or ambient information, as well as slow-moving, medium duration information, as odours linger and their persistence varies. Due to the nature in which the olfactory receptors are distributed, olfactory cues are not appropriate for conveying spatial information [29].

3 Evaluation and validation strategies

Once defined, the strategy for the communication of the adaptation needs to be validated and evaluated. As stated before, the definition includes the specification of the what, why, who and how of the adaptation, i.e., the determination of the messages to be conveyed, the recipient, and the involved channels.

Considered the human agent of the system as the recipient of the what and why messages, validating the strategy means to assess that such messages can be effectively understood by the human operator within the time constraints the application scenario imposes and under the different considered state conditions (e.g., visual distraction or high level of cognitive workload). In other words, validating means to assess that the communication strategy "works", and performs correctly what is expected. Evaluating the strategy means to compute measurements along a given evaluation dimension of interest, such as trust or safety, for instance. Typically, evaluations are used to compare different (validated) strategies from a chosen perspective.

The validation is often performed leveraging the experimental analysis methodology. A customized experimental plan needs to be properly designed in order to make the participants experience the communication strategy and provide validation feedbacks. During the experiments, validation data can be collected to verify that the strategy satisfy the scenario constraints under the different considered conditions. Validation feedbacks can be gathered by means of questionnaires specifically conceived to the purpose and submitted to the participants after the experiment. Once determined the evaluation metrics, the experiments can be conceived to collect the evaluation information too. Given the safety-critical application domains of the HoliDes AdCoS, communication strategies are typically (but not necessarily) validated and preliminary evaluated in a simulation environment.

As an example of application of a similar validation and evaluation process, the case of the communication strategy to be adopted in the Adaptive Assistance AdCos in the Automotive domain is provided in the following.

The considered scenario is the one of the lane change. By means of the context assessment, the AdCoS is able to timely detect, besides the external environment condition, also the driver intention of performing a lane change manoeuvre and the driver distraction, and to adapt to such conditions. With reference to the cooperation model adopted in HoliDes, on the action level, the driver and the AdCoS cooperate in a mutual control mode, where in particular, by means of the AdCoS HMI, an action suggestion cooperation mode is implemented. That means that the AdCoS communicates to the driver the recommended actions to be performed, adapted to the internal and external context. The recommended action, in terms of "keep your lane" and "change lane – turn right/left" indications, represents the "what" message to be communicated. The HMI conveys such message using the visual channel.

But what happens if the driver is visually distracted (eyes-off-road condition)? The visual display could be out of the driver view. To the aim of recalling the driver visual attention on-road, or directed to the assistance system display, an auditory warning system could help. The communication strategy would then be composed by an auditory warning and a visual action suggestion.

On the other hand, dealing with adaption in the cooperation, an important aspect to be considered is the trust of the human agent in the adaptive automation part of the system. According to a recent study [12], trust can be enhanced enabling the machine part to communicate the why of the adaptation to the human agent. The why information allows the driver to respond appropriately to the situation and to gain trust in the actions or action suggestions performed by the automation in the car. Supposing the driver is going to perform a lane change, but there is a vehicle rapidly approaching from behind. The HMI would suggest in that moment a "keep your lane" action, but should also motivate that kind of suggestion to let the driver understand what is behind the behaviour of the assistance system. How could the "why" of the adaptation be effectively communicated? Given the task analysis already provided in D3.5, one of the possibilities to provide that kind of "why messages" (i.e., "obstacle approaching from the rear/left/right/front") without overloading the driver's communication channels, is the one of using a *vibratory warning mode*. Directed haptic feedbacks could be provided to the driver by means of vibrating seat to indicate the provenance direction of the approaching vehicle that hinders the lane change manoeuvre. The communication strategy of that kind is then made by a vibratory warning and a visual action suggestion.

The three proposed communication strategies need to be validated, evaluated and compared with each other, to the aim of selecting the best one. The selected methodology to perform the validation and evaluation is the one of the experimental analysis. Experiments have been designed by SNV to be conducted using the REL driving simulator.

The experiment is conceived as a within-participant analysis where each participant tries all the different communication strategies. Further details about the protocol are going to be discussed in *D5.6 - Techniques and Tools for Empirical Analysis*.

For the validation, an ad-hoc questionnaire has been produced. The purpose of the questionnaire is to assess if the "what" message and the "why" messages are clearly understandable and if the auditory warning is comprehensible too.

As to the evaluation, we are interested in safety considerations as well as in technology acceptance parameters. As to the safety, we selected macro-indicators in the automotive domain and plan to compute them in the different communication configurations during the simulated driving trials: number of accidents, number of traffic lights violations, number of stop violations, number of out-of-road events, and duration of the driving trial.
On the other hand, we consider the Davis' technology acceptance model and the related questionnaire [42], since the human machine interface and the communication implemented by means of it influences the acceptance of the overall assistance system. From Davis' questionnaire, we selected four evaluation dimensions of interest to assess people's technology acceptance: intention, attitude, perceived usefulness and perceived ease of use. As defined by Davis, "intention" is the strength of the intention of a person to use the considered technology; "attitude" expresses a feeling, positive or negative toward the use of the technology; "perceived usefulness" and "perceived ease of use" are subjective considerations referring to the people's perception about respectively the usefulness of the system and the ease of use of the system.

The experiments results will determine the best strategy to be implemented in the Adapted Assistance AdCoS demonstrator. A similar experimental approach with the appropriate customization of the validation questionnaire can be applied also to test the communication strategies in the other domains. In particular, if the technology acceptance is considered a dimension of interest for the evaluation, the Davis questionnaire could be involved as well.

4 Guidelines for communication

The following section will give the full list of these Human Factors guidelines for communication the adaptation.

These guidelines will be analysed from the point of view of the different sensory modalities: visual, acoustic and tactile.

4.1 Visual modality communication guidelines

GUIDELINE #1
Name of guideline
Visual design should have into account the pre-attentive attributes of perception
Description
Preattentive processing, the early stage of visual perception that rapidly occurs below the level of consciousness, is tuned to detect a specific set of visual attributes. These visual attributes aren't perceptually equal. Some are perceptually stronger than others. Some can be perceived quantitatively and can therefore be used to encode numeric values, and others can't.
Examples
A complete description of the preattentive principles and some explanatory examples can be found at Appendix C, section 0
Sources
Information Dashboard Design, Stephen Few [55] Perception for Design, Colin Ware [30] The Functional Art, Alberto Cairo [56] Tapping the Power of Visual Perception, Stephen Few [57] Principles of Data Visualization – What we see in a visual (White Paper from FusionCharts) [58]

GUIDELINE #2
Name of guideline
Visual design should take into account the Gestalt Principles to bring out patterns in visualization
Description
Gestalt principles describe how our mind organizes individual elements into groups. We can use these principles to highlight patterns that are important, and downplay other patterns.
Examples
A complete description of the Gestalt principles and some explanatory examples can be found at Appendix C, section 0
Sources
Information Dashboard Design, Stephen Few [55] The functional Art, Alberto Cairo [56] Principles of Data Visualization – What we see in a visual (White Paper from FusionCharts) [58]

GUIDELINE #3
Name of guideline
Display the data as clearly and simply as possible and avoid unnecessary and distracting decoration.
Description
This guideline is directly related to maximize the data-ink ratio, within reason. Every bit of ink on a graphic requires a reason. And basically that reason should be that the ink presents new information.
Examples
A complete description of the data-ink ratio and some explanatory examples can be found at Appendix C, section 0
Sources
Information Dashboard Design, Stephen Few [55] The functional Art, Alberto Cairo [56] The Visual Display of Quantitative Information, Edward R. Tufte [59]

GUIDELINE #4
Name of guideline
Choose the paradigm in the visual design depending on the communication objective (the "What or the Why")
Description
This guideline is to explain the different interface paradigms in the visual design of user interfaces. Historically the paradigm has been implementation-centric (where the users must understand how the software works internally→technical knowledge), but today it is changing to a metaphoric (where users recognize the imagery of the metaphor→intuition) and idiomatic paradigm (where the communication is based on the learning of simple behavioural idioms).
Examples
A complete description of the visual paradigms and some explanatory examples can be found at Appendix C, section 0
Sources
About face 3: the essentials of interaction design. Alan Cooper [70]

GUIDELINE #5
Name of guideline
Create hierarchy in the visual elements
Description
In looking at any set of visual elements, users unconsciously ask themselves "What's important here?" Based on scenarios, determine which controls and bits of data users need to understand instantly, which are secondary, and which are needed only by exception. This ranking informs the visual hierarchy.
Examples
A complete description of the visual paradigms and some explanatory examples can be found at Appendix C, section 0
Sources
About face 3: the essentials of interaction design. Alan Cooper [70]

GUIDELINE #6
Name of guideline
Establish relationships to convey which elements are related.
Description
To convey which elements are related, return to your scenarios to determine not only which elements have similar functions but also which elements are used together most often. Elements that tend to be used together should generally be grouped **spatially** to minimize mouse movement, while elements that aren't necessarily used together but have similar functions may be grouped **visually** even if they are not grouped spatially.
Examples
A complete description of the visual paradigms and some explanatory examples can be found at Appendix C, section 0
Sources
About face 3: the essentials of interaction design. Alan Cooper [70] Communicating with Visual Hierarchy. Luke Wroblewski [71]

GUIDELINE #7
Name of guideline
Create a logical path for users to follow through the interface
Description
The visual layout in a design must also properly structure an efficient **logical path** for users to follow through the interface, taking into account the fact that (in Western languages) the eye will move from top to bottom and left to right.
Examples
A complete description of the visual paradigms and some explanatory examples can be found at Appendix C, section 0
Sources
About face 3: the essentials of interaction design. Alan Cooper [70] Communicating with Visual Hierarchy. Luke Wroblewski [71] F-Shaped Pattern for reading web content. Jacob Nielsen [72] Understanding the Z-Layout in web design. Brandon Jones [73]

GUIDELINE #8
Name of guideline
Use rich visual modeless feedback
Description
Rich visual modeless feedback is referred to information that can be

provided to users in the main displays of your application, which doesn't stop the flow and can all but eliminate pesky dialogs.
Examples
A complete description of the visual paradigms and some explanatory examples can be found at Appendix C, section 0
Sources
About face 3: the essentials of interaction design. Alan Cooper [70]

4.2 Acoustic modality communication guidelines

GUIDELINE #9
Name of guideline
Recommendations about *acoustic general thresholds of the sounds*
Description
Acoustic threshold of the sounds should be modulated in order both not to disturb the user and be correctly perceived.
Examples
• Sounds for acoustic communication should be approximately 500 ms. in duration to be heard. • Sound intensity for acoustic communication should be between 40 to 120 dB (SPL) to be heard. Sounds above 120 dB can cause pain.
Sources
Human Factors in Engineering and Design (7th Edition), Sanders [60]

GUIDELINE #10
Name of guideline
Recommendations about *auditory cues* in acoustic communication guidelines
Description
Use the correct auditory cue (tones, complex sounds or speech) to communicate a certain type of information (simple, alarm or complex, multidimensional information).
Examples
• Use tones for communicating limited information sources (e.g. start and stop time). • Use complex sounds for alarms (e.g. deviation in rhythm, pitch, loudness, timbre) • Speech is most effective for rapid communication of complex, multidimensional information sources.
Sources
Tactical display for soldiers: human Factors consideration. Blackwood, W. [23]

GUIDELINE #11

Name of guideline
Recommendations about *speech* in acoustic communication guidelines
Description
Speech is most effective for rapid communication of complex, multidimensional information sources.
Examples
• Set speech output speed at 150 to 160 words per minutes, do not exceed 210. • Utilize intensity differences to aid in the discrimination of speech stimuli. • Never present two verbal tasks at the time (e.g. two messages).
Sources
European Telecommunication Standards Institute [61] Intensity Coding of auditory Stimuli. Jancke L. et al. [62]

GUIDELINE #12
Name of guideline
Recommendations about *sound localization and pitch* in acoustic communication guidelines
Description
Designer should be conscious when using sound locations for absolute judgments, as distance is general overestimated and front-back directional reversals can occur.
Examples
• When using spatialized audio cues to communicate movement, the audio source should be positioned in front of the listener. • Use specialized audio to aid identification of auditory messages in noisy environments.
Sources
An introduction to auditory display. Kramer, G. [22] Minimum audible movement angle as a function of the azimuth and elevation of the source, Strybel T. Z. [63] Human/machine interfaces modalities for soldier system technologies. Mulgund, S. et al. [25]

GUIDELINE #13
Name of guideline
Recommendations about *alerts and warnings* in acoustic communication guidelines
Description
When reaction time is essential, auditory warnings are generally superior to visual warnings, as they more efficiently draw attention to critical information (30 to 40 ms. Faster than vision).
Examples
• Use auditory cues for rapid cueing of critical information, such as for warnings and alarms. • Keep auditory messages simple and short.
Sources
Human Factors in Engineering and Design (7th Edition), Sanders [60] Handbook of perception and the human performance. Welch, R. [20] Interactive multimedia for instruction: a cognitive analysis of the role of audition and vision. Hapeshi, K. [18]

4.3 Tactile modality communication guidelines

GUIDELINE #14
Name of guideline
Recommendations about *tactile general features*
Description
Tactile cues should be modulated in order both not to disturb the user and be correctly perceived.
Examples
• To ensure user perceives individual signals, stimuli must be separated by at least 5.5 ms. and preferably more than 10 msec. • Tactile input must consider sensitivity to stimuli across various skin locations (i. e. 2-point threshold becomes smaller from palm to fingertips). • Amplitudes above 0.6 mm to 0.8 mm are painful. • Be aware that surface characteristics of a stimulus influence sensation of touch. • Avoid use of tactile displays in low temperature environments because tactual sensitivity is degraded. • If response time is critical, do not use haptics alone because user will take longer to perceive and attend to information.
Sources
Cutaneous Sensitivity. Sherrick, C.E. [64]

GUIDELINE #15
Name of guideline
Recommendations about *alerts and warnings*
Description
Tactile cues, such as those conveyed via vibrations or varying pressures can serve as effective simple alerts.
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
The Human Senses (2nd Ed.). Geldard, F.A. [65]

GUIDELINE #16
Name of guideline
Recommendations about *tactile localization*
Description
Tactile cues can make clear distinction between orthogonal directions as well as identification of spatial location.
Examples
• Humans can detect about seven haptic locations on the chest. • Tactile location cues (e.g. up and down) can resolve spatial disorientation. • To convey movement, the spatiotemporal illusion of movement (i.e. sensory saltation) can be leveraged using 3 to 6 mechanical sensors placed no greater than 10 cm apart along the back, which emit vibratory pulses with an interstimulus duration of 50 ms.
Sources
The Human Senses (2nd Ed.). Geldard, F.A. [65] Cutaneous Sensitivity. Sherrick, C.E. [64]

4.4 Multimodal communication guideline

GUIDELINE #17
Name of guideline
Maximize human cognitive and physical abilities
Description
Designers need to determine how to support intuitive, streamlined interactions based on user's human information processing abilities (including attention, working memory and decision making)
Examples
Avoid unnecessarily presenting information in two different modalities in cases where the user must simultaneously attend to both sources to comprehend the material being presented. Maximize the advantages of each modality to reduce user's memory load in certain tasks and situations, as illustrated by these modalities combination: • System visual presentation coupled with user manual input for spatial information and parallel processing • System auditory presentation couple with user speech input for state information, serial processing, attention alerting or issuing commands.
Sources
Research into Cognitive Load theory and instructional design at UNSW (1997). Cooper. G. [66] Managing split-attention and redundancy in multimedia instruction. Kaluga, S. et al. [67] A paradigm shift in interactive computing: Deriving multimodal design principles from behavioural and neurological foundations. Stanney, K. et al. [68] Engineering Psychology and human performance. Wickens, C.D. [69]

5 Review of use of guidelines per AdCoS

In this section is provided a summary of the use of the guidelines from the side of different AdCoS (at least one per domain). The results provided for the different AdCoS and the conclusions of the use related to the different Human Factors dealt are shown in **Fehler! Verweisquelle konnte nicht gefunden werden.**

References

[1] Endsley, M. R.1996, Automation and situation awareness, in R. Parasuraman and M. Mouloua (eds), Automation and human performance: Theory and applications (Mahwah, NJ: Lawrence Erlbaum Associates), 163–181.
[2] Sarter, N. & Woods, D.D. (1992). Pilot interaction with cockpit automation. I. Operational experiences with the Flight Management System. International Journal of Aviation Psychology, 2, 303-321.
[3] Endsley, M. R. and Gardland D.J (Eds.) (2000). Situation awareness Analysis and Measurement (pp. 349–366). Mahwah, NJ: Laurence Erlbaum Associates.
[4] Healey, C. G., Booth, K. S., & Enns, J. T. (1996). High-speed visual estimation using preattentive processing. *ACM Transactions on Computer-Human Interaction (TOCHI)*, *3*(2), 107-135.
[5] Rensink, R.A. et al. (1997) To see or not to see: the need for attention to perceive changes in scenes. Psychol Sci. 8, 68–373
[6] Levin, D.T. and Simons, D.J. (1997) Failure to detect changes to attended objects in motion pictures. Psychonomic Bull. Rev. 4, 501–506
[7] Simons, D.J. and Levin, D.T. (1998) Failure to detect changes to people during a real-world interaction. Psychonomic Bull. Rev. 5, 644–649
[8] Mack, A. and Rock, I. *Inattentional Blindness*. MIT Press, Menlo Park, California, 1998.
[9] Simons, D. J. Current approaches to change blindness. *Visual Cognition 7*, 1/2/3 (2000), 1–15.
[10] Levin, D. T. and Simons, D. J. Failure to detect changes to attended objects in motion pictures. *Psychonomic Bulletin and Review 4*, 4 (1997), 501–506.
[11] Simons, D. J. In sight, out of mind: When object representations fail. *Psychological Science 7*, 5 (1996), 301–305.
[12] Koo, J, Kwac, J, Ju, W, Steinert, M, Leifer, L, & Nass, C. Why did my car just do that? Explaining semi-autonomous driving actions to improve driver understanding, trust and performance. In International Journal of Interactive Design and Manufacturing. Springer. April 2014.
[13] Oviatt, S.L.: Advances in Robust Multimodal Interface Design. In: IEEE Computer. Graphics and Applications, vol. 23, september 2003 (2003).

[14] Oviatt, S.L.: Multimodal interfaces. In: J. Jacko, J., Sears, A. (eds), The Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies and Emerging Applications, 2nd edition, CRC Press, 2008, chap. 14, pp. 286—304 (2008)
[15] Dumas B., Lalann D., Oviatt S., Multimodal Interfaces: A Survey of Principles, Models and Frameworks. In Human Machine Interaction, Lecture Notes in Computer Science, 2009
[16] "Tapping the Power of Visual Perception". Stephen Few. September 4, 2004. https://www.perceptualedge.com/articles/ie/visual_perception.pdf
[17] Alberto Cairo. The functional Art: an introduction to information graphics and visualization. New Riders, 2013.
[18] Hapeshi, K. & Jones, D. (1992). Interactive multimedia for instruction: A cognitive analysis of the role of audition and vision. International Journal of Human-Computer Interaction, 41, 79-99
[19] Sanders, M. S. & McCornick, E. J. (1993). Human Factors in Engineering and Design (7th Edition). New York: McGraw-Hill.
[20] Welch, R. & Warren, D.H. (1986). Intersensory interactions. In K.R. Boff, L. Kaufman, & J.P. Thomas (Ed.). Handbook of perception and human performance. Vol I: Sensory processes ans perception(pp. 25.1-25-36). New York: Wiley.
[21] Bly, S. (1982). Presenting information in sound. In Proccedings of the CHI '82 Conference in Human Factors in Computer Systems (pp. 371-375). New York: ACM Press.
[22] Kramer, G. (1994). An introduction to auditory display. In G. Kramer (Ed.), Auditory display (pp. 1-77). Reading, MA: Addison-wesley.
[23] Blackwood, W. Anderson T., Bennett, C.T., Corson, J., Endsley, M., Hancock, P. et al. (1997). Tactical display for soldiers: human Factors consideration (National Research Council Report No. PB97-138044). Washington, DC: National Academy Press.
[24] Brewster, S. (2003). Nonspeech auditory output. In J. A. Jacko & A. Sears (Eds.). The human –computer interaction book: Fundamentals, evolving technologies and emerging applications (pp. 220-239). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.
[25] Mulgund, S., Stokes, J., Turieo M. & Devine M. (2002). Human/machine interface modalities for soldier systems technologies (Final report No. 71950-00). Cambridge, MA: TIAX, LLC.

[26] Goff, G.D. (1967). Differential discrimination of frequency of cutaneous mechanical vibration. Journal of Experimental Psychology, 74, 294-299.
[27] European Telecommunications Standards Institute, 2002. Human Factors (HF) guidelines on the multimodality of icons, symbols and pictograms (Report No. ETSI EG 202 048 v 1.1.1; 2002-08). Sophia Antipolis, France.
[28] Goldstein, E.B. (1999). Sensation and perception (5th Ed.). Pacific Grove, CA: Brooks / Cole.
[29] Kandel, E.R., Swartz, J.H. & Jessell, T.M. (1995). Essentials of neural science and behaviour. Norwalk, CT: Appleton & Lange.
[30] Colin Ware. 2004. Information Visualization: Perception for Design. Morgan Kaufmann Publishers Inc., San Francisco, CA, USA
[31] Spinnler , H. (1971) Deficit in associating figures and colours in brain damaged patients. Brain research 31, 370-371
[32] Tiberghien, A. (1994). Modeling as a basis for analyzing teaching-learning situations. Learning and Instruction, 4(1), 71–87
[33] Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: A proposed system and its control processes. In K. W. Spence & J. T. Spence (Eds.), The psychology of learning and motivation: Advances in research and theory (Vol. 2, pp. 89–195). New York: Academic Press
[34] Atkinson, R. C., & Shiffrin, R. M. (1971). The control of short-term memory. Scientific American, 225, 82–90
[35] Sperling, George. The information available in brief visual presentations. Psychological Monographs: General and Applied, Vol 74(11), 1960, 1-29. http://dx.doi.org/10.1037/h0093759
[36] Miyake, A., & Shah, P. (Eds.) (1999). Models of working memory: Mechanisms of active maintenance and executive control. New York: Cambridge University Press.
[37] Baddeley, A.D. (1986) Working Memory. Oxford: Clarendon Press.
[38] Baddeley, A. D. (2003) Working memory and language: An overview. Journal of Communication Disorders, 36 (3): 189-208.
[39] Tulving, E. (1972). Episodic and semantic memory. In E. Tulving and W. Donaldson (Eds.), Organization of Memory (pp. 381–402). New York: Academic Press
[40] Tulving, E. (1985). How many memory systems are there? American Psychologist, 40, 385–398

[41] Schacter, D. L. (1987)."Implicit memory: history and current status". Journal of Experimental Psychology: Learning, Memory, and Cognition, 13, 501-518

[42] Anne Treisman and Garry Gelade (1980). "A feature-integration theory of attention." Cognitive Psychology, Vol. 12, No. 1, pp. 97–136.

[43] Endsley, M.R. & Garland, D.J. (Eds.) (2000). Situation awareness analysis and measurement. Mahwah, NJ: Lawrence Erlbaum Associates.

[44] Endsley, M.R. (1990). Predictive utility of an objective measure of situation awareness. Proceedings of the Human Factors Society 34th Annual Meeting (pp. 41–45). Santa Monica, CA: Human Factors Society.

[45] Victor, T. Keeping eye and mind on the road. PhD thesis. http://www.diva-portal.org/smash/get/diva2:167500/FULLTEXT01.pdf

[46] Dimitri van der Linden, Michael Frese, Theo F Meijman, Mental fatigue and the control of cognitive processes: effects on perseveration and planning, Acta Psychologica, Volume 113, Issue 1, May 2003, Pages 45-65, ISSN 0001-6918, http://dx.doi.org/10.1016/S0001-6918(02)00150-6.

[47] Hockey, G. R. J. and Earle, F. (2006).Control over the scheduling of simulated office work reduces the impact of workload on mental fatigue and task performance. Journal of Experimental Psychology: Applied, 12, 50-65.

[48] Terry E. Goldberg, Karen Faith Berman, Kirsten Fleming, Jill Ostrem, John D. Van Horn, Giuseppe Esposito, Venkata S. Mattay, James M. Gold, and Daniel R. Weinberger. Uncoupling Cognitive Workload and Prefrontal Cortical Physiology: A PET rCBF Study, NEUROIMAGE 7, 296–303 (1998)

[49] National Highway Traffic Safety Administration (NHTSA). (1997). An Investigation of the Safety Implications of Wireless Communications in Vehicles. November 1997, USA

[50] Saad et al. Deliverable D1.2.1 of project AIDE (Adaptive Integrated Driver-Vehicle Interface), http://www.aide-eu.org/pdf/sp1_deliv_new/aide_d1_2_1.pdf, 2005.

[51] Wickens, C.D. (1984). "Processing resources in attention", in R. Parasuraman & D.R. Davies (Eds.), Varieties of attention, (pp. 63–102). New York: Academic Press.

[52] Smith, K.T., Mistry, B (2009) Predictive Operational Performance (PrOPer) Model. Contemporary Ergonomics 2009 Proceedings of the International Conference on Contemporary Ergonomics 2009

[53] Koo, J, Kwac, J, Ju, W, Steinert, M, Leifer, L, & Nass, C. Why did my car just do that? Explaining semi-autonomous driving actions to improve driver understanding, trust and performance. In International Journal of Interactive Design and Manufacturing. Springer. April 2014.
[54] MacLeod, C. M. (1991). Half a Century of Research on the Stroop Effect: An Integrative Review. Psychological Bulletin, 109(2), 163-203.
[55] Stephen Few (2006). Information dashboard Design: the Effective Visual Communication of Data. O'Reilly Media, Incorporated.
[56] Alberto Cairo (2012). The Functional Art: an Introduction to Information Graphics and Visualization (Voices That Matter). Pearson Education (US).
[57] Stephen Few (2004). Tapping the Power of Visual perception. Perceptual Edge.
[58] http://www.fusioncharts.com/whitepapers/principles-of-data-visualization/
[59] Edward R. Tufte, The Visual Display of Quantitative Information (Cheshire, CT: Graphics Press, 1983), 93.
[60] Sanders, M.S. & McCornick, E.J. (1993). "Human Factors in Engineering and Design (7th Edition)" New York, McGraw-Hill.
[61] European Telecommunications Standards Institute (2002). "Human Factors (HF) guidelines on the multimodality of icons, symbols and pictograms (Report No. ETSI EG 202 048 v 1.1.1; 2002 -08). Sophia Antipolis, France.
[62] Jancke, L. et al. (1998). Intensity coding of auditory stimuli. Neuropsychologia, 36, 875-883.
[63] Strybel, T.Z., Manlingas, C.L. & Perrot, D.R. (1992). Minimum audible movement angle as a function of the azimuth and elevation of the source. Human Factors, 34, 267-275.
[64] Sherrick, C.E. and Cholewiak, R.W. (1986). Cutaneous Sensitivity. In K. Boff, L. Kauffman and Thomas (Eds.) Handbook of perception and human performance (pp, 12-1-12-58). New York: Wiley.
[65] Geldard, F.A. The Human Senses (2nd Ed.). New York: Wiley.
[66] Cooper, G. Research into Cognitive Load theory and instructional design at UNSW (1997).
[67] Kaluga, S., Chandler, P. and Sweller, J. (1999). Managing split-attention and redundancy in multimedia instruction. Applied Cognitive Psychology 13 (1999), 351-371.
[68] Stanney, K., Samman, S., Reeves, L.M. Hale, K., Buff, W., Bowers, C.. Goldiez, B., Lyons-Nicholson, D. and Lackey, S.A. A

paradigm shift in interactive computing: Deriving multimodal design principles from behavioral and neurological foundations. International Journal of Human-Computer Interaction, 17 (2), 229-257.

[69] Whickens, C.D. Engineering Psychology and human performance (2nd Ed.). Harper Collins, NY, 1992.

[70] Alan Cooper, Robert Reimann, David Cronin and Christopher Noessel. About Face: The Essentials of Interaction Design (3rd edition). 2007. Wiley Publishing, Inc.

[71] L. Wroblewski. Communicating with Visual Hierarchy. Writers UAConference, March 2008.

[72] J. Nielsen. F-Shaped Pattern for reading web content. Nilesen Norman Group: https://www.nngroup.com/articles/f-shaped-pattern-reading-web-content/

[73] B. Jones Understanding the Z-Layout in web design. Web Design Theory: http://webdesign.tutsplus.com/articles/understanding-the-z-layout-in-web-design--webdesign-28

[74] Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS quarterly, p. 319-340.

[75] Parasuraman, Bahri, Deaton, Morrison & Barnes, 1992. Theory and design of adaptive automation in aviation systems (Technical Report No. NAWCADWAR-92033-60). Warminster, PA: Naval Air Warfare Center, Aircraft Division.

Appendix A

1. UC1 Guided Patient Positioning

1.1 Current situation analysis

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)	

1.2 AdCoS communication description

The Guided Patient Positioning system provides guidance to operators of MRI scanner during preparing and positioning patients for MRI examinations. Correct positioning of the patient for the MRI examination and using the right coils and other devices are important to get good diagnostic quality images, but also important to avoid safety issues. Currently, operators are trained for this. The on-line guidance system intends to improve usability and to reduce risks, also in case of novice, less experienced users.

The communication of the adaptation in the system is achieved through the guidance display. The display will be re-configured automatically to show the relevant steps of the positioning procedure, which includes information to give to the patient.

Figure 3 shows an example of a display that has been re-configured to communicate the structure of the guidance procedure based on the context information.

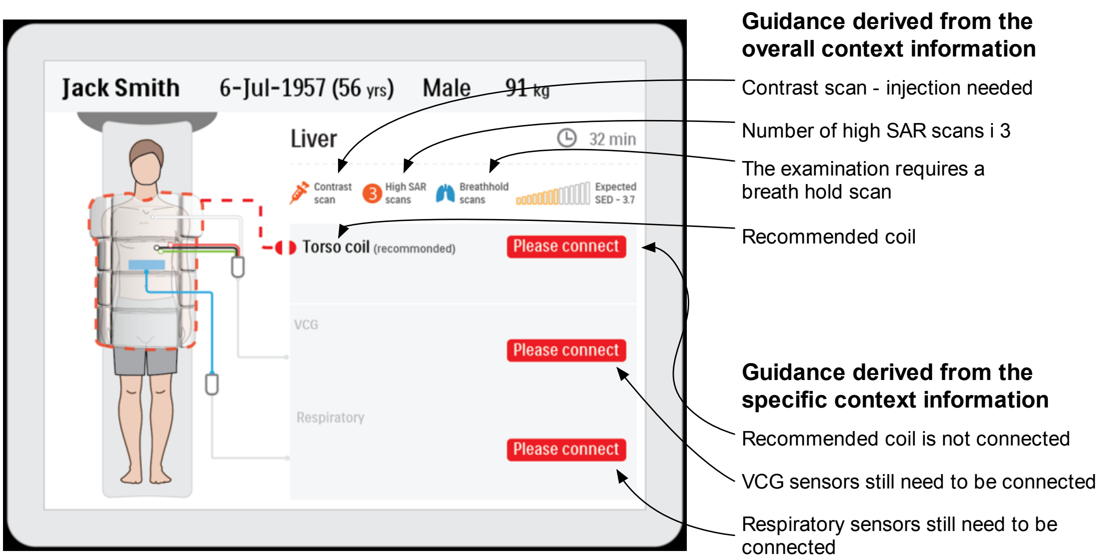


Figure 3: A display showing the guidance given to the operator

From the overall context information, the necessary steps of the procedure are shown:

- An injection is needed as the examination includes a contrast scan.
- The number of high SAR (Specific Absorption Rate, the RF energy deposited in the tissue) scans is three, so for three scans in the examination the patient may experience additional heating. The operator can use this to inform the patient.

- The examination requires a breath hold scan, for which special instructions to the patient are needed.

From the specific context information, the progress of the positioning is monitored, and the advice on next steps is given – in this case to connect the coil and VCG (for the heart-rate detection) and respiratory sensors.
In a later stage, if the required devices are connected, the display will provide information on the status of the connection. In case of coils it will show if the coils are properly connected. For physiology signals (VCG and respiratory) the display will directly show the heart-rate and respiratory graphs, including an indication of the quality.
If the quality is low, additional guidance may be provided to the operator on the display.

2. UC2 Diversion Airport

2.1 Current situation analysis

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***
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, change in calculation strategy, visual prioritization	
Type of Interaction	
Visual	
AdCoS / MTT responsible	
External pilot models and pattern classifier	

CASE 2	
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	

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 there are several options ordered by computed relevance in DivA UI.
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.

2.2 AdCoS Communication Description

Diversion assistant (DivA) is an application that will assist the pilot in the integration and evaluation of various types of information in situations when original destination and alternates become unavailable due to airport closure and/or weather restrictions. In such situations, pilots need to consider various sources of information – for aircraft performance, overall weather situation, parameters for airports in reach etc. Based on the updated information, pilots are supposed to evaluate options for available airports and negotiate approach and landing for the selected one.
DivA will take into account cockpit conditions, workload, or fatigue of the pilot, i.e. the calculations and HMI will be adapted to actual situation.

The development process of DivA HMI prototype has started from interview of HON pilots. Based on that, the functions and scope of the system were defined (coarse analysis, detailed analysis selected candidate airport among others), together with several HMI and workflow alternatives. HON and external pilots reviewed the concepts and selected the final design.
From the first series of user interviews, the graphical elements with required features were selected (airport option list, geographical area selection circle, brief airport information and detailed airport information).
In another series of interview with the pilots, the final design concept was decided.
The workflow of diversion assistant AdCoS (DivA) will be the following:

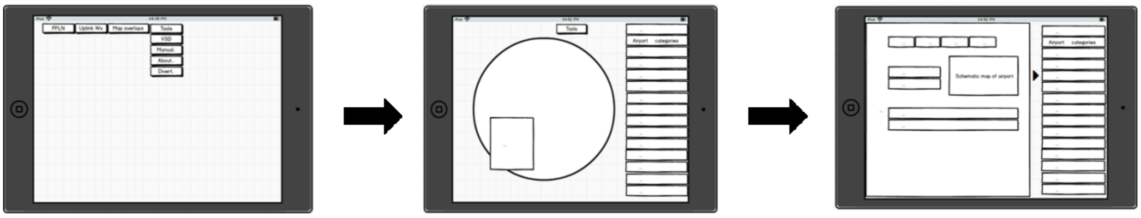


Figure 4: Selected communication workflow of diversion assistant

In this communication workflow, two modes are supported:

- Fast debrief that brings a default solution at the least amount of time. This solution shows overall status and pilots use it in time pressure to reduce his workload (second screen).
- A configurable interface allowing pilots to exploit the information of their situation (by use of floating window or a summary list with extending info-table) (third screen).

3. UC3 Command and Control Room

3.1 Current situation analysis

UC3 is the Command and Control Room use case, concerned in particular with a Border Security Control Room.
In UC3, the AdCoS helps the operators/supervisors by providing support in task execution or task allocation when border surveillance efficiency is needed.

CASE 1	
Human Factor	***Process***
Workload	Task workload distribution assessment
Adaptation	
Propose a workload re-balance among all available operators. Re-assignment is performed with involvement of the supervisor. Workload calculation is achieved by the AdCoS taking various human factors (e.g. experience, fatigue, number of successfully handled critical events) into account.	
Communication	
Once a load balancing proposal has been made it is communicated to the supervisor. This will be done through an electronic messaging system. If operators are absent from work place, the system calls them back to their workstations.	
Type of Interaction	
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 UC3.1.

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

UC3.5 Load Balancing on Operator Level*:* The re-assigning of individual events will be supported by appropriate information of the operator and his supervisor.

3.2 AdCoS Communication Description

The Airbus DS demonstration will concentrate on the Response Operators, whose primary role is to deal with events, that were reported from the surveillance operators. The following description of the command and control room communications will focus on the Workload Balancing use case. Figure 5 shows all communications that enable a functional allocation of tasks between operators.

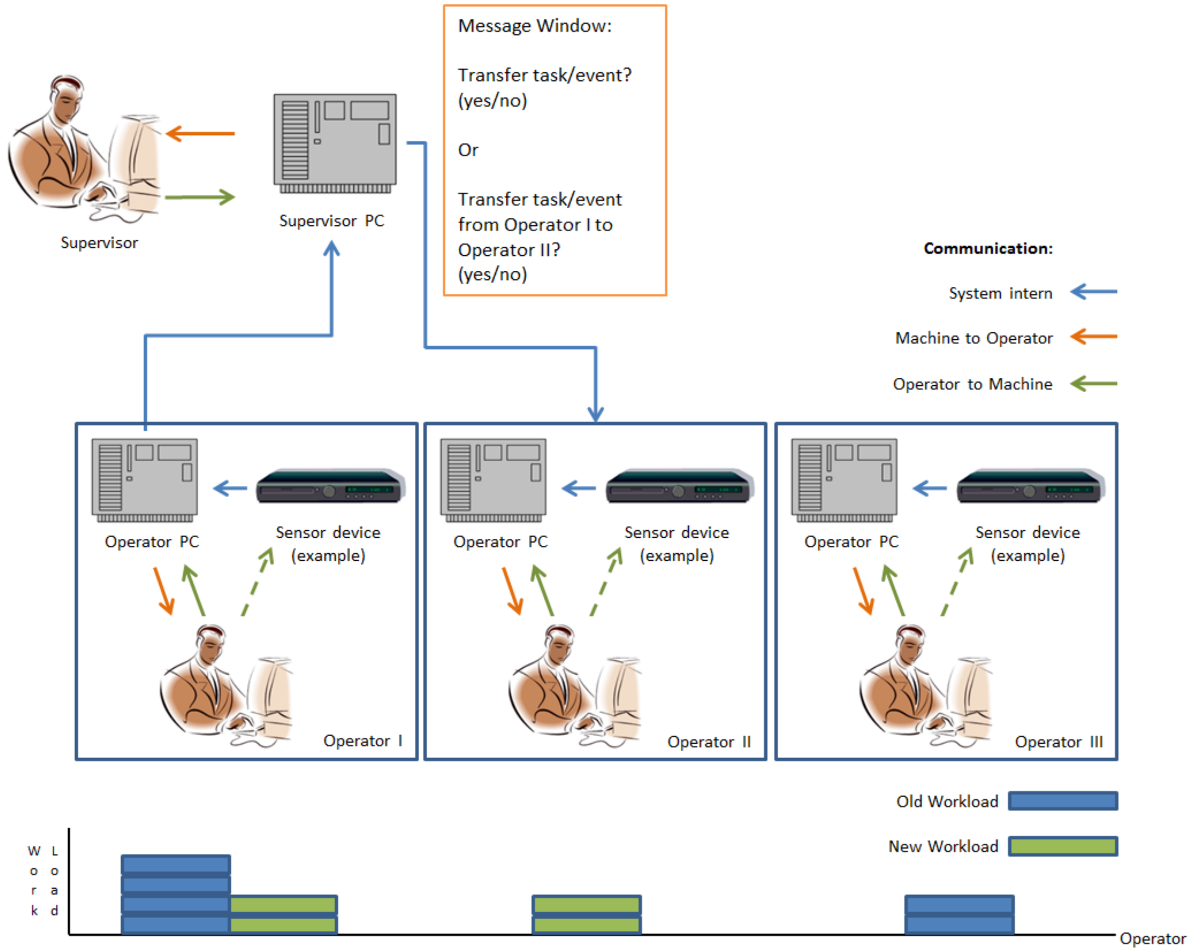


Figure 5: Communications in UC3 and workload-transfer-diagram

The communications in the specific use case can be categorized into system internal, machine to operator, and operator to machine communications. A sensor device and the operator PC collect data about the objective and subjective workload of the operator measured by direct (via hardware like keyboard) and indirect (via sensor device) inputs. The information is processed and sent to the supervisor PC. The PC generates a message window that informs the supervisor in one of two ways (depending on the selected scenario). One message indicates the affected operator and proposes another operator to transfer to. The supervisor needs to accept or reject the task re-allocation, but he can request the rationale behind the proposed re-allocation.

If the supervisor confirms the re-allocation of a task both operators receive a message window informing them that a task was taken from them or that a new task had been transferred to them. The operator does not have the chance to reject a request.

When considering Human Factors the communications between machine-operator and operator-machine are most relevant. For evaluating the current state of the operator system internal communications between sensors and computers are of interest. To achieve a complete picture of all communicators in the selected use case, Table 1 and Table 2 give detailed information.

Machine (Sensor) to Machine (Computer) Communication	
Parameters evaluated by sensor or operator pc	**Category of criteria triggering notifications to supervisor** (Categories by Parasuraman, Bahri, Deaton, Morrison & Barnes, 1992)**Fehler! Verweisquelle konnte nicht gefunden werden.**
Number of critical events (task load)	Critical event
Level of fatigue	Psychophysiology
Level of experience	Operator performance
Keyboard/mouse activity, input frequency, Respond time, accuracy of response	Model-based
Time to solve incidents	Model-based (workflow-time-schedule)
Number of errors	Operator performance

Table 1: System intern communications

Operator → Machine		
Type of communication	**Execution**	**System requirements**
Haptic/motoric	press button, move and press mouse	Buttons (Keyboard, Mouse, Touch Pad etc.)
Machine → Operator/Supervisor		
Visual	Message window	Screen/Display

Table 2: HMI communications

Requirements/risks for the communication-design in the use case
Criteria need to be well designed to generate reliable messages in an appropriate manner (e.g. pop-up rate).
Each notification will distract the operator/supervisor in his current workflow. Therefore the operator/supervisor should only be interrupted when the workload is low or one task is finished. Other rules should be applied for safety critical tasks.
Information need to be clear with respect to the questions which task is transferred and who is in charge. Otherwise errors could occur due to forgetting tasks because the operator is not aware of the tasks currently assigned to him/her (situation awareness).

4. UC4 Overtaking including lane change assistant

4.1 Current situation analysis

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).

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 manoeuvre	
Communication	
Information delivery Warning Actions on vehicle commands Automated driving	
Type of Interaction	
Visual / Acoustic / Haptic, depending on the level of distraction and the behavioural intention	
AdCoS / MTT responsible	
ADAS UI (joint user interface for FCW, OTA and LCA)	

CASE 2	
Human Factor	***Process***
Behavioural 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 manoeuvre	
Communication	
Information delivery Warning Actions on vehicle commands Automated driving	
Type of Interaction	
Visual / Acoustic / Haptic, depending on the level of distraction and the behavioural intention	
AdCoS / MTT responsible	
ADAS UI (joint user interface for FCW, OTA and LCA)	

4.2 AdCoS Communication Description

In Task 3.5 REL was expected to implement techniques and tools for the multi-modal (visual, acoustic, haptic and tactile) interface and communication between Humans and Machines addressing the HMI models developed in WP2.
The precondition for the definition of these interfaces and communication strategies was the creation of a model of a concrete AdCoS developed in WP6-9.
The AdCoS selected for the modelling was the Overtaking Assistant developed in WP9, and in particular its HMI.

As already described in *Deliverables D9.3* and *D2.4*, task modelling and task analysis have been carried out by REL on the Overtaking (OT) Manoeuvre.

The task modelling provides a general description of the tasks involved with making an Overtaking (OT) Manoeuvre. These tasks are preliminary cognitive, motor, visual or some combination thereof.
According to the cognitive, motor and visual tasks that the driver must complete in each phase, he/she has different cognitive, motor and visual loads, summarized in Table 3.

Task		Decision	Preparation	Execution
1. Changing the original lane	**Cognitive load**	medium	medium	medium
	Visual load	high	high	medium
2. Vehicle passing	**Cognitive load**	low	low	low
	Visual load	medium	low	medium
3. Re-entering into the	**Cognitive load**	medium	medium	medium
	Visual load	high	high	medium

Table 3: Cognitive, motor and visual loads in each subtask

Table 3 provides a relevant support for the design of the HMI of the AdCoS.
In fact, the HMI of the AdCoS (OT assistant) can adapt to the status of the driver (distraction, intention, etc.) and the status of the environment (other cars approaching) and provides different information to the driver with different interaction modalities (visual, haptic and acoustic) **according to the expected cognitive and visual load in each task.**

The preliminary HMI concept (shown in Table 4) has been based on the information included in Table 3.

Task		Decision	Preparation	Execution
1. Changing the original lane	**Cognitive load**	medium	medium	medium
	Visual load	high	high	medium
	Information based on driver intention?	Information provided **only** if intention of changing lane was detected (driver intention module OR left indicator activated)	Information provided **only** if intention of changing lane was detected (driver intention module OR left indicator activated)	Information based on detection of LC manoeuvre
	Interaction modality	**Option 1.1** (driver not distracted AND no car approaching on the left): **visual** **Option 1.2** (driver distracted OR cars approaching on the left): **visual + acoustic**	**Option 1.1** (driver not distracted AND no car approaching on the left): **visual** **Option 1.2** (driver distracted OR cars approaching on the left): **visual + acoustic**	**Option 1.1** (driver not distracted AND no car approaching on the left): **visual** **Option 1.2** (driver distracted OR cars approaching on the left): **visual + acoustic**
2. Vehicle Passing	**Cognitive load**	low	low	low
	Visual load	medium	low	medium
	Information based on driver intention?	Information provided **only** if intention of changing lane was **NOT** detected (driver intention module OR right indicator **NOT** activated)	Information provided **only** if intention of changing lane was **NOT** detected (driver intention module OR right indicator activated)	Information provided **only** if intention of changing lane was **NOT** detected (driver intention module OR right indicator activated)
	Interaction modality	**Option 2.1: Visual**	**Option 2.1: Visual**	**Option 2.1: Visual**
3. Re-entering into the original lane	**Cognitive load**	medium	medium	medium
	Visual load	high	high	medium
	Information based on driver intention?	Information provided **only** if intention of changing lane was detected (driver intention module OR indicator activated)	Information provided **only** if intention of changing lane was detected (driver intention module OR indicator activated)	Information based on detection of LC manoeuvre

	Interaction modality	**Option 3.1** (driver not distracted AND no car on the right): **visual** **Option 3.2** (driver distracted OR cars on the right): **visual + acoustic**	**Option 3.1** (driver not distracted AND no car on the right): **visual** **Option 3.2** (driver distracted OR cars on the right): **visual + acoustic**	**Option 3.1** (driver not distracted AND no car on the right): **visual** **Option 3.2** (driver distracted OR cars on the right): **visual + acoustic**

Table 4: HMI overall concept (information provided and interaction modalities)

Alternative graphics for the adaptive HMI have been designed by using the information provided in Table 4, as shown in Figure 6 and Figure 7, which represent the HMI to support the driver while changing the original lane (Task 1).

Figure 6: Option 1.2.1 (driver distracted), visual and acoustic interaction

Figure 7: Option 1.2.2 (car approaching on the left), visual and acoustic interaction

So far, the activity conducted by REL was meant to identifying 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).

Therefore, we mainly focus on the "what", i.e. what the driver should do in each condition (e.g. "keep the lane", "change the lane", etc.).

However, recent studies [53] have shown the importance of providing information on the "why" describing reasoning for actions to achieve better driving experience in (semi-autonomous) adaptive vehicles. The explanation of the "why" also affects the driver's attitude and safety performance.

Therefore, the preliminary HMI concept has been improved in by including innovative communication strategies to describe the "why" in a way that is suitable to the cognitive and visual load of the driver, by also considering additional multi-modal (visual, acoustic, haptic and tactile) interfaces (that will be embedded in the vehicle to complement the information provided by the app).

In particular, alternative HMI concepts and solutions will be developed to provide the information about the "why", e.g. direction haptic feedback in the seat when a car is approaching from the back and the "keep the lane" message is displayed (the haptic feedback intuitively explains that the driver should keep the lane because a car is approaching from behind).

In order to avoid any annoying effect, we planned to provide haptic/acoustic feedback for the "why" (in addition to the visual message) only in case of real danger, where the driver is expected to suddenly react in order to avoid a collision.

Therefore, we identified 3 safety-critical conditions where to provide "why" information with haptic/acoustic signals:

1. When the driver wants to change the lane but a car is approaching on the left (Figure 8)
2. When the driver wants to re-enter the lane but a car is on the right lane (
3. Figure 9)
4. When the driver has to brake in order to avoid a collision with the car ahead (Figure 10)

Figure 8: HMI to support the driver if s/he wants to change the lane but a car is approaching from behind

Figure 9: HMI to support the driver if s/he wants to re-enter the lane but a car is on the right lane

Figure 10: HMI to support the driver when s/he has to brake in order to avoid a collision with the car ahead

For each condition we'll define a set of most appropriate delivery modes to intuitively provide the driver with the "why" information.
Moreover, in order to evaluate this concept and assess the benefit of providing additional haptic/acoustic feedback for the "why" in safety-critical conditions, we plan to conduct experiments in simulation scenarios in collaboration with SNV (that will provide the experimental design of the tests).
More in detail, one of the issues concerning the effectiveness of each multi-modal message has to do first with the choice of the best channel to perform the task and the subtask and second with the ability to reduce as much as possible interference effects able to slow down the performance and increase the error risk. According to the channel that can be chosen there are different possible levels of interference that can act in a driving task. The first has to do with the modality: verbal vs nonverbal.
Any device able to answer to the "why" describing reasoning for actions has to be tested in order to see whether and under which conditions interference can be reduced and avoided. It is well known from the

literature that verbal codes can interfere each other in production and comprehension. So far, the choice of the correct lexical items and sentences to alert of an incoming danger can represent a problem given the different semantic effects that can be evoked by words differing for lexical dimensions as frequency of use, imageability, and concreteness.

On the other side nonverbal devices have not been sufficiently investigated to be sure that any intra/intermodality device will not interfere with driving. In a series of experiments verbal dimensions and non-verbal dimensions (acoustic, visual, tactile) will be investigated using the classic interference paradigms derived by the Stroop task [54] by assessing intra and intermodality of stimulus presentation and different effectors for the answers. Interference paradigms will be modulated also with respect to the low and high visual processing with particular attention to the first stages of pre-processing until the cognitive load induced by central processing and consequently load.

Appendix B

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 manoeuvre 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 manoeuvre, such critical information may determine AdCoS actions that can lead from warning the driver to the inhibition of the dangerous manoeuvre. 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.

Appendix C

Guideline #1: Pre-attentive attributes examples

The pre-attentive attributes of visual perception can be organized into four categories: color, form, spatial position and motion. A summary of these attributes can be found in the following graphic:

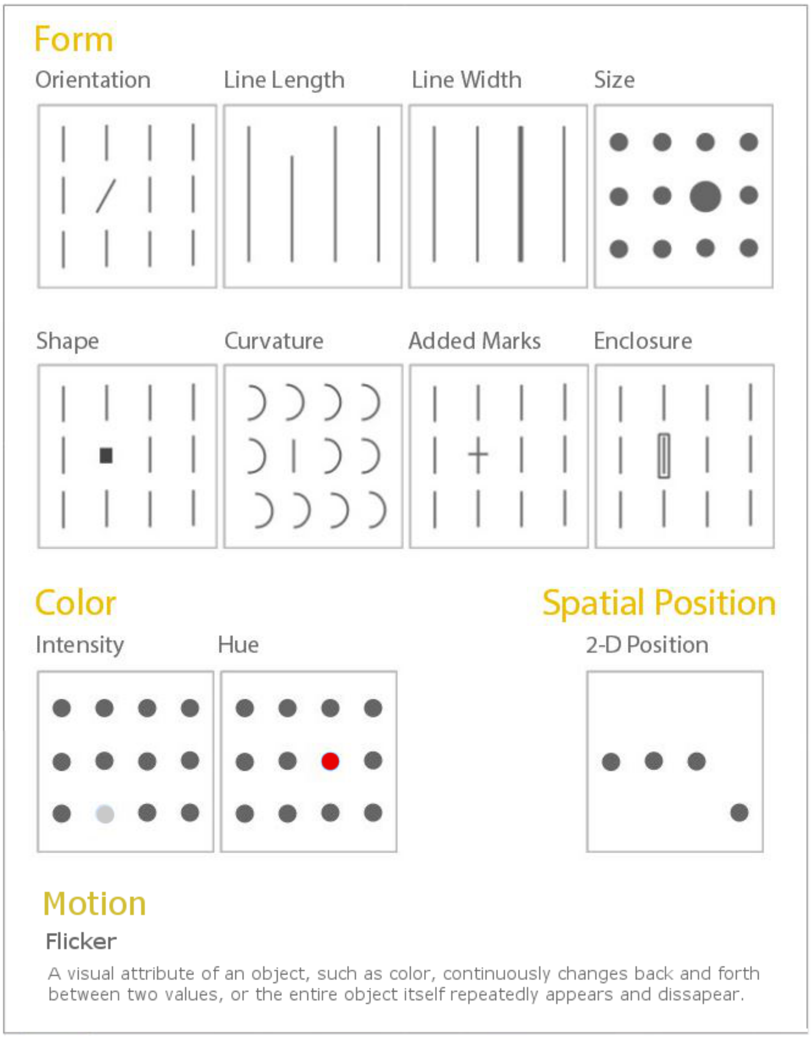


Figure 11: Pre-attentive attributes of visual perception

These attributes come into play when we analyse any visualization. Of this list, only ***Position*** and ***Length*** can be used to perceive *quantitative data* with precision. The other attributes are useful for perceiving other types of data such as categorical or relational data.

1.1 Attributes of Form

For example, both the pie chart and the bar chart below show the same data. But you can't easily tell from the pie chart which is the biggest pie. Our inability to reliably compare the size of 2D areas makes pie charts difficult to interpret. That is more clearly visible in the bar chart as it calls on the pre-attentive attribute of length.

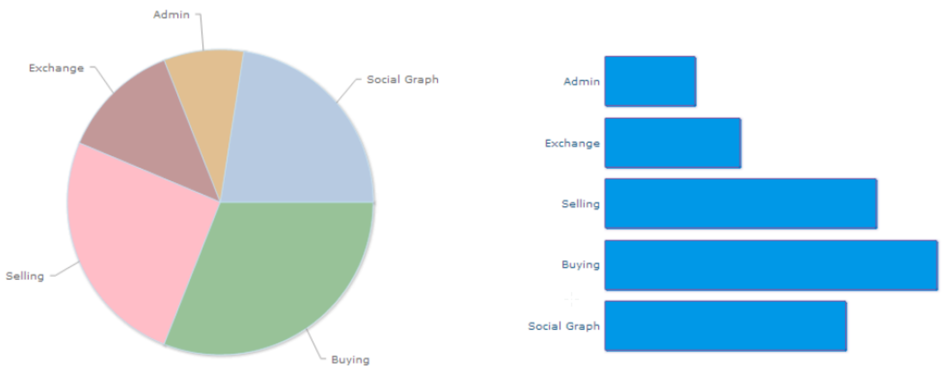


Figure 12: Size attribute is badly used to describe quantitative data

In dashboard design, the attribute of ***line length*** is most useful for encoding quantitative values as bars in a bar graph. Line width, on the other hand, can be useful for highlighting purposes. You can think of ***line width*** as the thickness or stroke weight of a line. When lines are used to underline content or, in the form of boxes, to form borders around content, you can draw more attention to that content by increasing the thickness of the lines.

The ***relative sizes*** of objects that appear on a dashboard can be used to visually rank their importance. For instance, larger titles for sections of content, or larger tables, graphs, or icons, can be used to declare the greater importance of the associated data.

Simple shapes can be used in graphs to differentiate data sets and, in the form of icons, to assign distinct meanings, such as different types of alerts. Added marks are most useful on dashboards in the form of simple icons that appear next to data that need attention. Any simple mark (such as a circle, a square, an asterisk, or an X), when placed next to information only when it must be highlighted, works as a simple means of ***drawing attention***.

Last on the list of form attributes is ***enclosure***, which is a powerful means of grouping sections of data or, when used sparingly, highlighting content as important. To create the visual effect of enclosure, you can use either a border or a fill colour behind the content.

1.2 Attributes of Colour

One of the interesting (but hardly intuitive) things about colour is that we don't perceive color in an absolute way. What we see is dramatically ***influenced by the context*** that surrounds it. Take a look at the grey squares in Figure 13. They appear to vary in intensity, but in fact they are all exactly the same as the lone square that appears against a white background at the bottom.

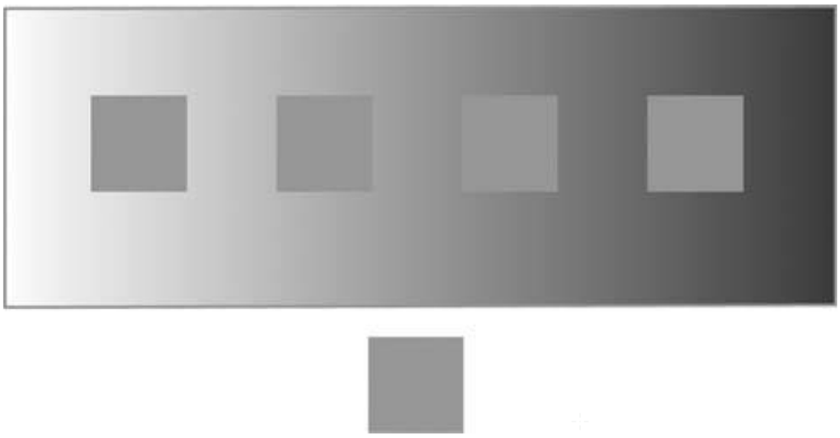


Figure 13: Context affects our perception of colour intensity

Colour must be used with a full awareness of context. We not only want data to be fully legible, but also to appear the same when we wish it to appear the same and different when we wish it to appear different.

On the other side, colour intensity, such as different shades of gray ranging from white to black can be quantitatively perceived to a degree (by making one value darker, for example, we can tell that is greater than another). But not well enough to decode specific shades into specific values.

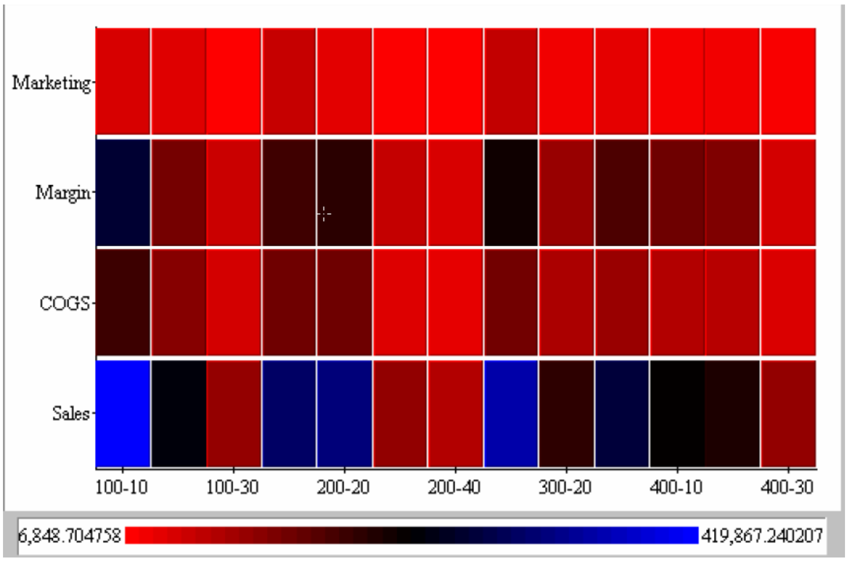
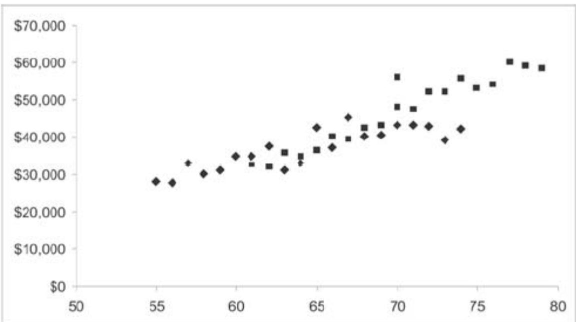


Figure 14: Example of a misuse of hue for the display of quantitative values

Another example on how the preattentive attributes do their job of grouping two datasets in a scatter plot. We have ***orientation*** on the left and ***hue*** on the right. Which of them does a better job? They both work to a degree, but hue works better.



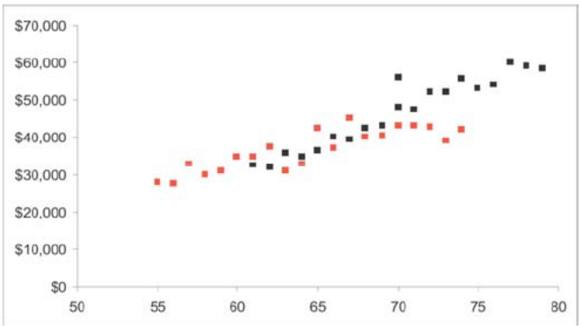


Figure 15: Comparison of the relative strength of orientation and hue

1.3 Attributes of Spatial Position

The pre-attentive attribute 2-D position is the primary means that we use to encode quantitative data in graphs (for example, the position of data points in relation to a quantitative scale). This isn't arbitrary. Of all the pre-attentive attributes, differences in 2-D position are the easiest and most accurate to perceive.

In Figure 16 is shown an example of ***2D position*** of documents. It has the advantage to map properties of the underlying document data on the two axes. It is easily to find most relevant documents and most important. On the other side using position to visualize makes difficulty to select documents with same relevance factor. Solution to this to avoid occlusion of documents is to translate them on one of the axes, inhibiting the mapping of a second property axis.

Figure 16: Left side: less important documents are tilted away from the user. Right side: effect of colour and intensity is used

1.4 Attributes of Motion

Flicker refers to an element that appears and disappears. This pattern is normally measured in cycles per second, the frequency of repetition. For example, flicker was chosen as the means to help us locate the cursor because it is a powerful attention-getter.

Although flickering objects on a screen can be quite annoying and thus should usually be avoided. Still, there are occasions when flicker is useful. This is especially true for dashboards that are constantly updated with real-time data and are used to monitor operations that require immediate responses.

Guideline #2: Gestalt principles examples

Gestalt principles describe how our mind organizes individual elements into groups. We can use these principles to highlight patterns that are important, and downplay other patterns. The image below illustrates the principles of Gestalt which are relevant to visualization.

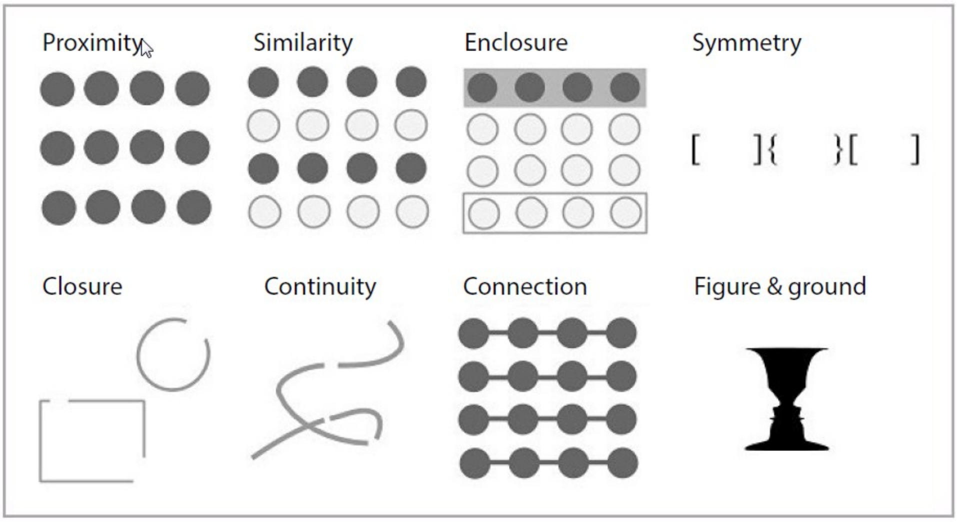


Figure 17: Gestalt principles relevant for visualization

An explanation from each of the illustrations:

- *Proximity:* We see three rows of dots instead of four columns of dots because they are closer horizontally than vertically.

- *Similarity:* We see similar looking objects as part of the same group.
- *Enclosure:* We group the first four and and last four dots as two rows instead of eight dots.
- *Closure:* We automatically close the square and circle instead of seeing three disconnected paths.
- *Continuity:* We see one continuous path instead of three arbitrary ones.
- *Connection:* We group the connected dots as belonging to the same group.
- *Symmetry:* We see three pairs of symmetrical brackets rather than six individual brackets.
- *Figure & ground:* We either notice the two faces, or the vase. Whichever we notice becomes the figure, and the other the ground.

A good example of using the Gestalt principles to communicate information in a visual way is the following visualization that compares the mentions of Apple, Google and Microsoft across the Web.

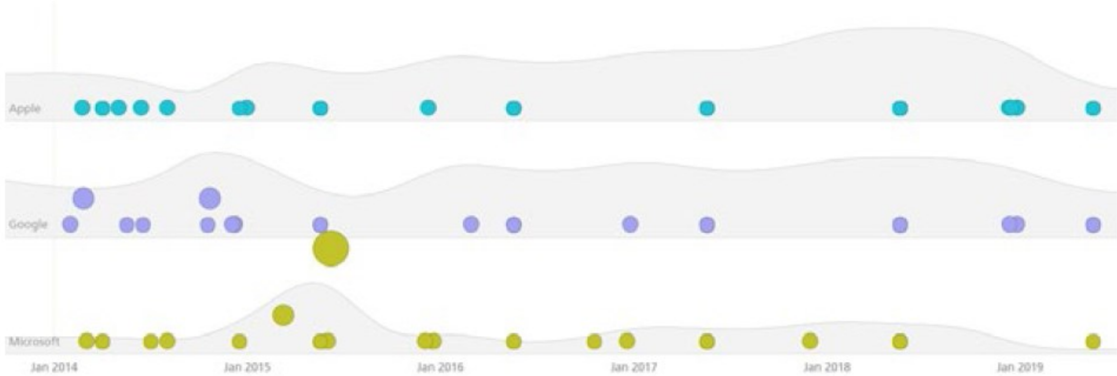


Figure 18: Good visualization example following the Gestalt principles

This visualization features two chart types - An area chart, which is greyed out in the background, and a bubble chart, which is color-coded in the foreground. Let's analyse this simple visualization, and identify which elements from this guideline it uses:

- *Figure & ground:* The first thing noticed when looking at this visualization is that the bubbles stand out against the backdrop of the area charts. This shows the Gestalt principle of figure & ground.

- *Proximity:* Zoning in on the bubbles shows 3 distinct groups of bubbles. We can identify this easily because of how close the bubbles are to each other.
- *Similarity:* Further, we notice that the bubbles are of three colours - green, purple, and blue. This similarity brings out the grouping even more clearly.

Furthermore, linking with the previous guideline related to **pre-attentive attributes**, we can also analyse some of them in the visualization:

- *Spatial position:* the pre attentive attribute of position is used to track the rise and fall of the area chart. Similarly, we notice the abnormal bubble in Microsoft's chart because of its higher position compared to the other bubbles.
- *Size / Area:* The bubbles vary in size. Their size corresponds to the number of web mentions for a particular topic. This makes it easy to spot the important mentions, and explore them in detail.
- *Hue / Color:* As mentioned earlier, the colour of the bubbles makes it easy to classify them into three groups. This employs the pre attentive attribute of Hue.
- *Intensity:* Finally, the low intensity of the area chart places it in the background, giving priority to the bubbles.

Guideline #3: Display the data as clearly and simply as possible

In 1983, Edward R. Tufte introduced the concept of "data-ink ratio" in the book The Visual Display of quantitative Information. When quantitative data is displayed (mainly in printed form), some of the ink that appears on the page presents data, and some presents visual content that is not data (a.k.a. non-data).

Tufte defined the data-ink ratio in the following way:
"A large share of ink on a graphic should present data information […]. Data-ink is the non-erasable core of a graphic, the non-redundant ink arranged in response to variation in the numbers represented. Then:

Data ink-ratio= data-ink / total ink to print the graphic"

This is to say 1.0 – proportion of a graphic that can be erased without loss of data-information. The nearer this data ink-ratio is to 1.0, the more accurate this guideline is followed.

This principle can be extended to computer screens, and the term "ink" can be changed to "pixels".

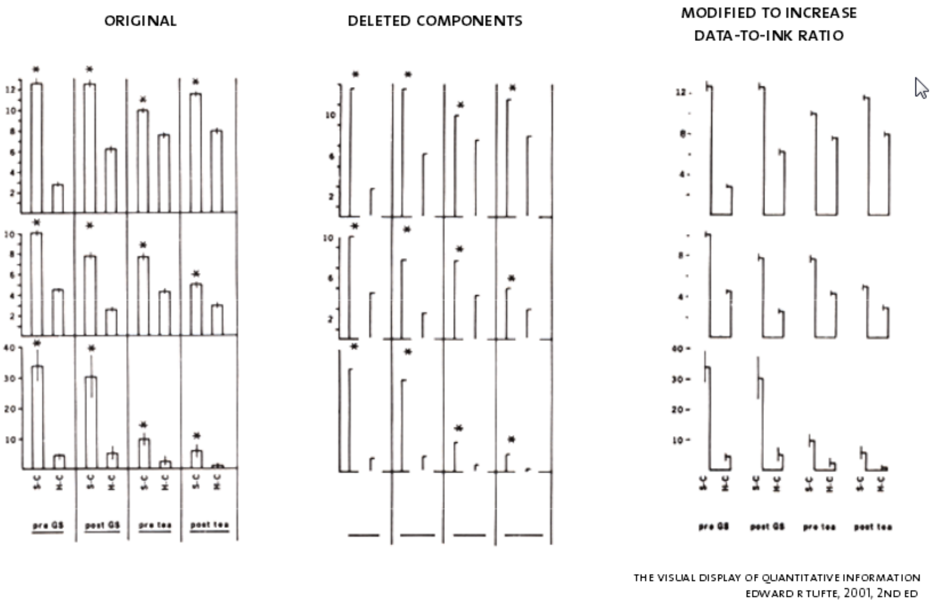


Figure 19: Example on how to simplify data to ink-ratio

So reducing the non-data pixels to a reasonable minimum is a key objective that places us on the path to effective visual communication. Much of visual communication design revolves around two fundamental goals:

- Reduce the non-data pixels
- Enhance the data pixels

3.1 Reduce the non-data pixels

The next figure provide one example of non-data pixels that often appear in a screen but can usually be removed without loss.

One few operative ink-ratio could be the variations in colour that don't encode any meaning, as in Figure 20:

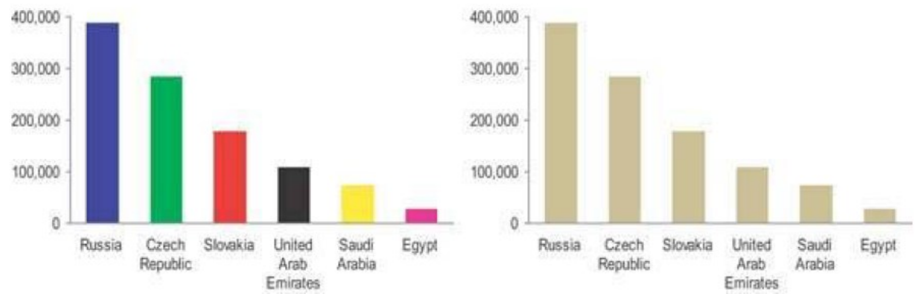


Figure 20: Example on how to eliminate bars varying in colour for no meaningful reason

Another bad example of non-operative ink-ratio is using the 3D in graphs when the third dimension doesn't correspond to actual data:

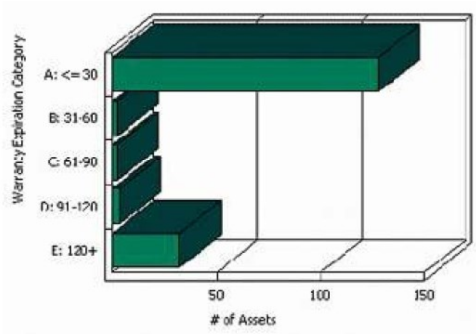


Figure 21: 3D should always be avoided when the added dimension of depth doesn't represent actual data

Visual components or attributes of a display medium that serve no purpose but to make it look more like a real physical object or more ornate:

Figure 22:
Visualization filled with visual components to simulate real physical objects

3.2 Enhance the data pixels

All the information that is shown in visualization should be important, but not all data is created equal: some data is more important than other data. The most important information can be divided into two categories:

- Information that is *always* important
- Information that is only important *at the moment*

These two categories of important information require different means of highlighting on a screen. The first category information that is always important can be emphasized using ***static means***, but the second category information that is important only at the moment requires ***dynamic means*** of emphasis.

The location of data on the screen the layout is an aspect of a dashboard's appearance that doesn't, or at least shouldn't, change dynamically (because after some use viewers will come to expect specific data to appear in specific locations). Because location is static, this is a variable that we can leverage to highlight information that is always important.

Few aspects of visual design emphasize some data above the rest as effectively as its location. Figure 23 identifies the emphasizing effect that different regions of a dashboard provide. The top-left and centre sections of the dashboard are the areas of greatest emphasis. Contrary to the influence of reading conventions, however, the very centre of the screen is also a region of strong emphasis, due to a more fundamental inclination of visual perception.

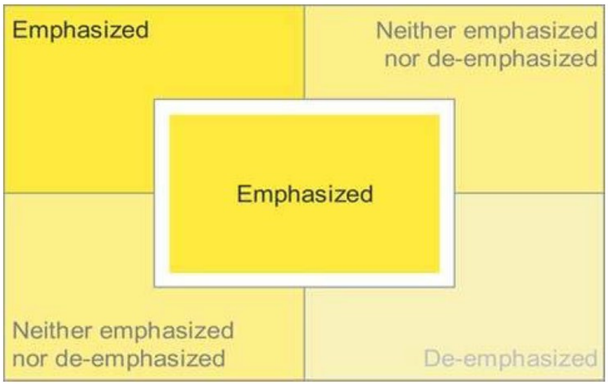


Figure 23: Different degrees of static visual emphasis

Visual attributes other than location on the screen are usually easy to manipulate in a dynamic manner on a dashboard. As such, dynamic techniques can be used to highlight information that is of great importance only at particular times. Many of the visual attributes examined in Guideline#1 and Guideline#2 can be used effectively to highlight data, both statically and dynamically. Here are two approaches that can be taken:

- Use expressions of visual attributes that are greater than the norm (for example, brighter or darker colours).
- Use expressions of visual attributes that simply contrast with the norm (for example, blue text when the norm is black or grey).

Color is especially useful because distinct differences in colour stand out very clearly and because it is a variable that is normally easy to change dynamically using dashboard software based on predefined data conditions.

Guideline #4: Use the correct paradigm for interface design

There are three dominant paradigms in the conceptual and visual design of user interfaces: *implementation-centric*, *metaphoric*, and *idiomatic*.

The field of user-interface design progressed from a heavy focus on technology (implementation) to an equally heavy focus on metaphor. There is ample evidence of all three paradigms in contemporary software design, even though the metaphoric paradigm is the only one that has been named and described.

In this section all of them will be analysed, in order to provide information to decide which paradigm use depending on the objective of the communication. If the communication is related to the "What" is happening a more intuitive paradigm should be used (metaphoric or idiomatic). On the contrary, if our purpose for communicating is the "Why" something is happening, the paradigm should provide information on how systems are working internally (implementation-centric).

4.1 Implementation-centric interfaces

Implementation-centric user interfaces are widespread in the computer industry. These interfaces are expressed in terms of their construction, of how they are built. In order to successfully use them, users must understand how the software works internally. Following the implementation-centric paradigm means user-interface design based exclusively on the implementation model.

Engineers like to know how things work, so the implementation-centric paradigm is very satisfying to them. Engineers prefer to see the gears and levers and valves because it helps them understand what is going on inside the machine. That those artefacts needlessly complicate things for users seems a small price to pay. Engineers may want to understand the inner workings, but most users don't have either the time or desire. They'd much rather be successful than be knowledgeable, a preference that is often hard for engineers to understand.

The unique exception to use this paradigm, in our case, would be the necessity to present the user a complete explanation about the "Why" the system has adapted.

Example:

A close relative of the implementation-centric interface worth mentioning is the "org-chart centric" interface. This is the common situation where a product, or most typically, a Web site, is organized, not according to how users are likely to think about information, but by how the company the site represents is structured.

On such as site, there is typically a tab or area for each division and a lack of cohesion between these areas. Similar to the implementation-centric product interface, an org-chart-centric Web site requires users to have an intimate understanding of how a corporation is structured to find the information they are interested in.

4.2 Metaphoric interfaces

Metaphoric interfaces rely on intuitive connections that users make between the visual cues in an interface and its function. There is no need to understand the mechanics of the software, so it is a step forward from implementation-centric interfaces.

We talk about metaphors in the context of user interface and interaction design, we really mean visual metaphors: a picture used to represent the purpose or attributes of a thing. Users recognize the imagery of the metaphor and, by extension, can presumably understand the purpose of the thing or the message to be transmitted.

In our case, metaphoric interfaces could be very useful to communicate in a very simple and quick manner "What" is happening in the system (mainly when the "What" is referred to danger or preventing an immediate action.

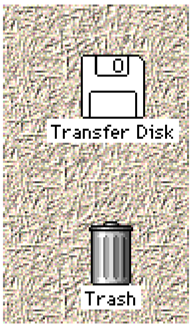
Nonetheless, metaphors have some limitations. For one thing, metaphors don't scale very well. A metaphor that works well for a simple process in a simple program will often fail to work well as that process grows in size or complexity.

Metaphors also rely on associations perceived in similar ways by both the designer and the user. If the user doesn't have the same cultural background as the designer, it is easy for metaphors to fail. Even in the same or similar cultures, there can be significant misunderstandings. Does a picture of an airplane mean "check flight arrival information" or "make airline reservations?"

Example of metaphor:

As a means of deleting files and documents, the *Macintosh* trashcan is a perfectly intuitive metaphor and it has been used in a lot of systems since, e.g. in Microsoft's Windows, a lot of graphical workstations etc.

When we are using the Macintosh desktop and we want to get rid of a document because we no longer need it, we "grab" it with the mouse, take it above the trash can and release it i.e. drop it into the can. The document will stay in the trash can until we explicitly empty the trash can or until we recover the document from it (if we change our mind about it and decide that we need it).



The trash can is a very appropriate metaphor, which nicely fits into the desktop metaphor. It is not bothering that usually people do not keep their trash cans on the top of their desks (and there actually exist some trash cans which can be attached to the side of the desk, not to speak of ashtrays which are actually on the desk).

However, there is an aspect to this trash can which has been widely criticised. The problem is the following: if, in the Macintosh, there is a diskette in the drive, and we want to take it out (i.e. we want to have it ejected by the system), then the icon symbolising the diskette has to be grabbed, and dropped into the trash can! There is no EJECT button on the machine or on the desktop. The *Macintosh* simply took the trashcan metaphor too far.

A lot of people feel badly about this. Even some experienced Macintosh users talk about an uncertain feeling experienced before ejecting the disk: maybe the contents of the diskette would be erased? Some resolve the problem by switching off the whole machine (then the diskette is ejected automatically).

It can be said in defence of the system that throwing the disk into the trash can means simply that we take it out of the "world" of the desktop (of virtual reality, if you like), and put it into our "real" world. This argument does not really dissolve the uneasiness of users, but it weakens the trust in the desktop metaphor.

4.3 Idiomatic interfaces

Idiomatic design, what Ted Nelson has called "the design of principles," is based on the way we learn and use idioms — figures of speech like "beat around the bush" or "cool." Idiomatic user interfaces solve the problems of the previous two interface types by focusing not on technical knowledge or intuition of function, but rather on the learning of simple, non-metaphorical visual and behavioural idioms to accomplish goals and tasks.

Idiomatic expressions don't provoke associative connections the way that metaphors do. We understand the idiom simply because we have learned it and because it is distinctive, not because we understand it or because it makes subliminal connections in our minds. Yet, we are all capable of rapidly memorizing and using such idioms: We do so almost without realizing it.

The human mind has a truly amazing capacity to learn and remember large numbers of idioms quickly and easily without relying on comparisons to known situations or an understanding of how or why they work. This is a necessity, because most idioms don't have metaphoric meaning at all, and the stories behind most others were lost ages ago.

Example of idiomatic elements:

It turns out that most of the elements of intuitive graphical interfaces are actually visual idioms. Windows, title bars, close boxes, screen-splitters, hyperlinks, and drop-downs are things we learn idiomatically rather than intuit metaphorically.

The ubiquitous mouse input device is not metaphoric of anything, but rather is learned idiomatically. There is a scene in the movie *Star Trek IV* where Scotty returns to 20th-century Earth and tries to speak into a mouse. There is nothing about the physical appearance of the mouse that indicates its purpose or use, nor is it comparable to anything else in our experience, so learning it is not intuitive.
However, learning to point at things with a mouse is incredibly easy. Someone probably spent all of three seconds showing it to you the first time, and you mastered it from that instant on. We don't know or care how mice work, and yet even small children can operate them just fine. That is idiomatic learning.

Here is an idiomatic symbol that has been imbued with meaning from its use, rather than by any connection to other objects. For anyone who grew up in the 1950s and 1960s, this otherwise meaningless symbol has the power to evoke a shiver of fear because it represents nuclear radiation. Visual idioms, such as the American flag, can be just as powerful as metaphors, if not more so. The power comes from how we use them and associate them, rather than from any innate connection to real-world objects.

Guideline #5: Create hierarchy in the visual elements

This guideline is about the use of hue, saturation, value, size, and position to distinguish levels of hierarchy (see Guideline 0). The most important elements should be larger, have greater contrast in hue, saturation, and value in relation to the background, and be positioned above or out dented in relation to other items. Items meant to stand out are best rendered in saturated colours. Less important elements should be less saturated, have less value and hue contrast against the background, and should also be smaller, or indented. Desaturated, neutral colours tend to recede.

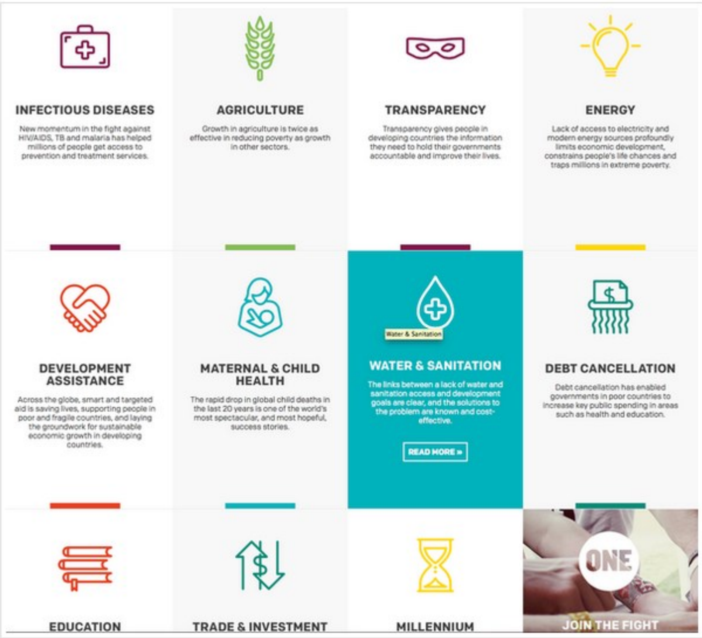
Of course, adjust these properties with restraint, since the most important element doesn't need to be huge, red, and out dented— often, varying just one of these properties will do the trick. If you find that two items of different importance are competing for attention, it's often a good approach to "turn down" the less important one, rather than "turn up" the more important. This will leave you with more "headroom" to emphasize critical elements. (Think about it this way: If every word on a page is red and bold, do any of them stand out?)

Establishing a clear visual hierarchy is one of the hardest challenges in visual interface design, and takes skill and talent. A good visual hierarchy is almost never noticed by users — it is only the lack of one and an accompanying confusion that tends to jump out at most people.

Example of creating hierarchy:

The example in the left has no hierarchy, so it makes it almost impossible for the viewer to review the information quickly and identify specific important elements.

The example of the right incorporates hierarchal elements, such as headers, different type size and color, and spacing create a much easier way for the viewer to find the specific information they are looking for.



The One.org website uses colours to create a hierarchy classification system.

Guideline #6: Establish relationships

Spatial grouping makes it clear to users what tasks, data, and tools relate to each other, and can also imply sequence. Good grouping by *position* takes into account the order of tasks and subtasks and how the eye scans the screen: left to right in Western languages, and generally from top to bottom.

Items in proximity to one another are generally related. In many interfaces, this grouping is done in a heavy-handed fashion with bounding boxes everywhere you look, sometimes even around just one or two elements. In many cases, you can accomplish the same thing more effectively with differences in *proximity*. For example, on a toolbar, perhaps you have four pixels between buttons. To group the file commands, such as open, new, and save, you could simply leave eight pixels between the file command buttons and other groups of buttons.

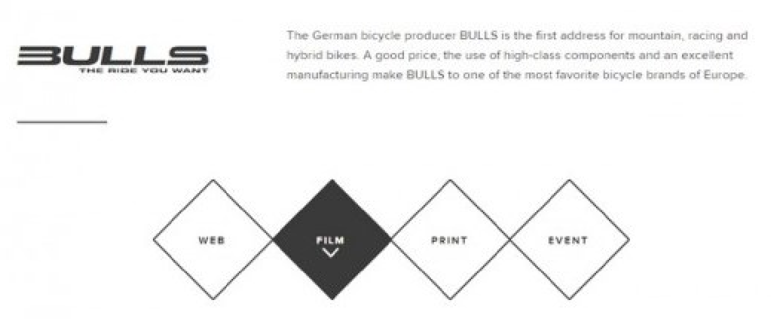
Group items that are not adjacent by giving them common visual properties, forming a pattern that eventually takes on meaning for users (see Guideline 0). For example, the use of dimensionality to give the feel of a manual affordance is perhaps the most effective way to distinguish controls from data or background elements. Iconography is a common application of this strategy.

After you have decided what the groups are and how best to communicate them visually, begin to adjust the contrast between the groups to make them more or less prominent in the display, according to their importance in context. Emphasize differences between groups, but minimize differences between items within a group.

TIP! A good way to help ensure that a visual interface design employs hierarchy and relationships effectively is to use what graphic designers refer to as the **squint test**. Close one eye and squint at the screen with the other eye in order to see which elements pop out and which are fuzzy and which items seem to group together. Changing your perspective can often uncover previously undetected issues in layout and composition.

Examples of creating hierarchy:

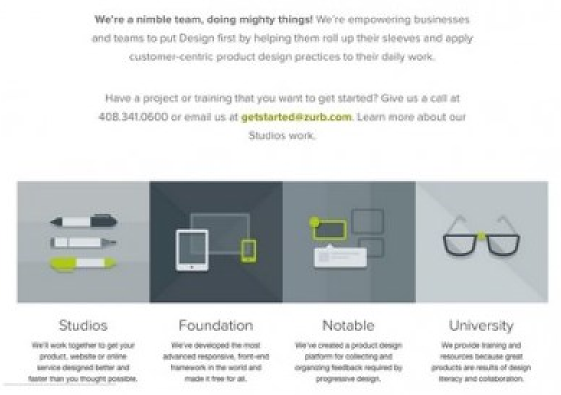
Contrast remains a core element in their interaction design, as you can see below. Again, this minimalist treatment reverses the contrast on hover, helping to blend navigation into the main content without feeling intrusive.



Contrast between warm and cool colours can draw attention to — or away from — certain areas of the interface. In the below example from on **TV Safety.org**, especially how the red navigation buttons stand out because they're offset by the green.


TV SAFETY
SANUS
DON'T GOOF AROUND WITH TV SAFETY
Did you know EVERY THREE WEEKS A CHILD IS KILLED from a tipping TV? Learn more below...
READ OUR STORY
THE MAP
SIMPLE SOLUTIONS

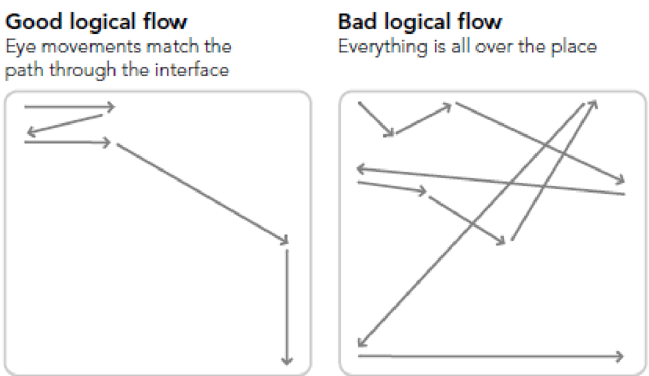
An example on how the ZURB homepage communicates relationships through similarity.



ZURB applies a consistent visual treatment to its different products. The similar colour palette and square shape immediately communicate that the 4 objects are somewhat related. Once you read the description for a product, say Foundation, you can quickly assume that all the other similarly styled objects are also products created by ZURB. In this case, consistency of visual presentation suggests consistency of category and context.

Guideline #7: Create a logical path

Eye movement across an interface should form a logical path that enables users to efficiently and effectively accomplish goals and tasks.



F-Pattern logical path:

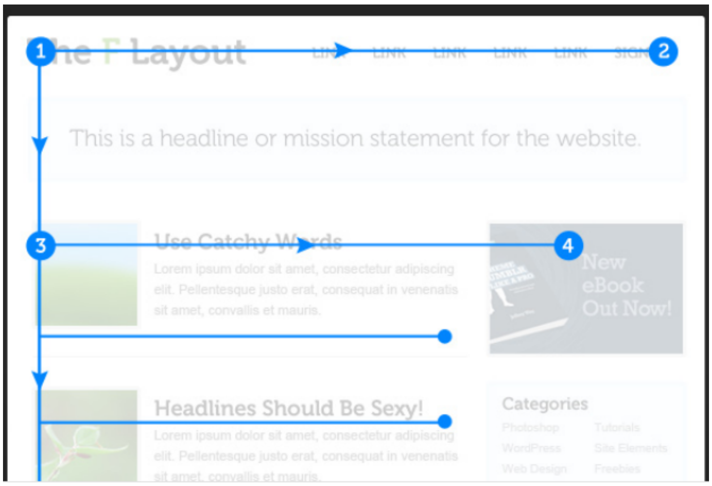
Typically for text-heavy websites like blogs, the F-Pattern comes from the reader first scanning a vertical line down the left side of the text looking for keywords or points of interest in the paragraph's initial sentences.

When the reader finds something they like, they begin reading normally, forming horizontal lines. The end result is something that looks like the letters F or E. CNN and NYTimes both use the F Pattern.

Jakob Nielson of the Nielsen Norman Group conducted a readability study based on 232 users scanning thousands of websites and elaborates on the practical implications of the F-Pattern:

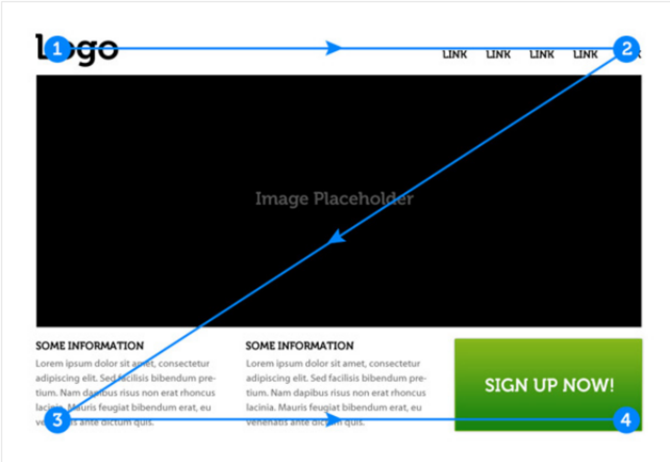
- Users will rarely read every word of your text.
- The first two paragraphs are the most important and should contain your hook.
- Start paragraphs, subheads, and bullet points with enticing keywords.

Example of F-Pattern



Z-Pattern logical path:

Z-Pattern scanning occurs on pages that are not centred on the text. The reader first scans a horizontal line across the top of the page, whether because of the menu bar, or simply out of a habit of reading left-to-right from the top. When the eye reaches the end, it shoots down and left (again based on the reading habit), and repeats a horizontal search on the lower part of the page.



The Z-Pattern is applicable to almost any web interface since it addresses the core website requirements such as hierarchy, branding, and calls to action. The Z-pattern is perfect for interfaces where simplicity is a priority and the call to action is the main takeaway.

Forcing a Z-pattern for a website with complex content may not work as well as the F-pattern, but a Z-pattern can help bring a sense of order to simpler layouts.

CONCLUSION:

Predicting where the user's eye will go can be a huge advantage. Before arranging the elements on your interface, prioritize the most and least important ones. Once you know what you want your users to see, it's just a simple matter of placing them in the pattern's 'hot spots' for the right interactions.

Guideline #8: Use rich visual modeless feedback

Most computers (and many devices) come with high-resolution displays and high quality audio systems. Yet, very few applications (outside of games) even scratch the surface of using these facilities to provide useful information about the status of the program, the users' tasks, and the system and its peripherals in general. An entire toolbox is available to express information to users, but designers and programmers have stuck to using the same blunt instrument — the dialog— to communicate Information.

Rich visual modeless feedback is a type of feedback that is:

- *rich* in terms of giving in-depth information about the status or attributes of a process or object in the current application.
- It is *visual* in that it makes idiomatic use of pixels on the screen (often dynamically),
- and it is *modeless* in that this information is always readily displayed, requiring no special action or mode shift on the part of a user to view and make sense of the feedback.

Imagine if all the objects that had pertinent status information on your desktop or in your application were able to display their status in this manner. Printer icons could show how near they were to completing your print job. Disks and removable media icons could show how full they were. When an object was selected for drag and drop, all the places that could receive it would visually highlight to announce their receptiveness.

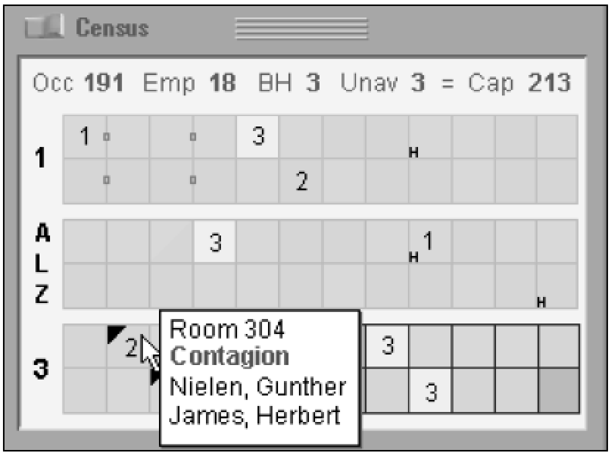
Think about the objects in your application, what attributes they have—especially dynamically changing ones — and what kind of status information is critical for your users. Figure out how to create a representation of this. After a user notices and learns this representation, it tells him what is going on at a glance. (There should also be a way to get fully detailed information if the user requests it.) Put this information into main application windows in the form of RVMF and see how many dialogs you can eliminate from routine use.

One important point does need to be made about rich modeless visual feedback. It isn't for beginners. Even if you add ToolTips to textually describe the details of any visual cues you add (which you should), it requires users to perform work to discover it and decode its meaning. RVMF is something that users will begin to use over time. When they do, they'll think it's amazing; but, in the meantime, they will need support of menus and dialogs to find what they're looking for. ***This means that RVMF used to replace alerts and warnings of serious trouble must be extraordinarily clear to users***. Make sure that this kind of status is visually emphasized over less critical, more informational RVMF.

Examples of rich visual modeless feedback:

In Microsoft Outlook 2007, a small icon next to an e-mail sender's name visually indicates whether that person is available for a chat session or a phone call, if it turns out that a real-time conversation is preferable to an e-mail exchange. This small icon (as well as the ability to start a chat session from a right click menu), means that users don't have to open their chat client and find the sender's name to see if that person happens to be available. This is so easy and convenient that a user literally does not have to think about it.

Another example of the strategy, as designed for a Cooper client, can be seen beside. This pane from a Cooper design for a long-term health-care information system is a good example of RVMF. The diagram is a representation of all the rooms in the facility. Color-coding indicates male, female, empty, or mixed-gender rooms; numbers indicate empty beds; tiny boxes between rooms indicate shared bathrooms. Black triangles indicate health issues, and a tiny "H" means a held bed. This RVMF is supplanted with ToolTips, which show room number and names of the occupants of the room, and highlight any important notices about the room or the residents. A numeric summary of rooms, beds, and employees is given at the top. This display has a short learning curve. Once mastered, it allows nurses and facility managers to understand their facility's status at a glance.



Appendix D

Application of the Guidelines to UC4 - Overtaking including lane change assistant (REL)

		Human Factors			
		Fatigue	***Distraction***	***Workload***	***Situational Awareness***
Acoustic Communication	*Guideline #9: Recommendations about acoustic general thresholds of the sounds*		Sounds for acoustic communication is approx. 500 ms. Sound intensity is between about 80db.		
	Guideline #10: Recommendations about auditory cues in acoustic communication guidelines		Complex tones will be used for alarms.		
	Guideline #13: Recommendations about alerts and warnings in acoustic communication guidelines		Since RT is essential in LC maneuver, auditory warnings are used as complementary source to visual warnings to draw attention to critical information 30 to 40 ms. faster than vision.		

		Human Factors			
		Fatigue	***Distraction***	***Workload***	***Situational Awareness***
Tactile Communication	*Guideline #14: Recommendations about tactile general features*		Since RT is critical, haptics are used to complement visual (for the *what*) and acoustic signals (for the alert).		Tactile cues are modulated not to disturb the user.
	Guideline #16: Recommendations about tactile localization				Tactile cues are used to make clear distinction between orthogonal directions as well as identification of spatial location (direction of risk).
Multimodal Communicatio	*Guideline #17: Maximize human cognitive and physical abilities*		Acoustic signals for attention alerting (*warning*)	Visual signals for parallel processing (*what to do*) + acoustic signals for attention alerting (*warning*) + haptic signals for spatial information (*direction of risk*)	Visual signals for parallel processing (*what to do*) + haptic signals for spatial information (*direction of risk*)

Application of the Guidelines to UC4 – Manual mode – dis-attentive driver (TAK)

		Human Factors			
		Fatigue	***Distraction***	***Workload***	***Situational Awareness***
Visual Communication	*Guideline #1: Visual design should take into account the preattentive attributes of perception*		Critical information is displayed in red (refers to "color"; "hue")		
	Guideline #2: Visual design should take into account the Gestalt Principles to bring out patterns in visualization				Relevant other objects (such as cars that might result in a collision) are displayed in close proximity to the Ego-vehicle and in the position that corresponds to the real position.

	Guideline #3: Display the data as clearly and simply as possible, and avoid unnecessary and distracting decoration.		Only the most relevant information is shown.		
		Human Factors			
		Fatigue	***Distraction***	***Workload***	***Situational Awareness***
Visual Communication	*Guideline #4: Choose the paradigm in the visual design depending on the communication objective (the "What or the Why")*			The way the symbol for the take-over from automatic to manual driving is implemented could be called an idiomatic design (which in this case results in fast perception and thus reduces workload)	
	Guideline #5: Create hierarchy in the visual elements			Cars that are more important are displayed in red and thus have a higher hierarchy than grey cars.	

	Guideline #6: Establish relationships to convey which elements are related.			In order to easily detect that state (manual or automatic) the display background is matched to the background color of the icon / the word indicating state	
	Guideline #8: Use rich visual modeless feedback				The emergency state (e.g. driving too close behind a car) is displayed independent of operator input.

		Human Factors			
		Fatigue	**Distraction**	**Workload**	**Situational Awareness**
Acoustic Communication	*Guideline #9: Recommendations about acoustic general thresholds of the sounds*		Acoustic alerting sounds were chosen to be lasting long enough and be loud enough but not causing pain. Thresholds named were kept.		
	Guideline #10: Recommendations about auditory cues in acoustic communication guidelines		Alarms were chosen to result in utmost attention.		
	Guideline #13: Recommendations about alerts and warnings in acoustic communication guidelines		Since RT is essential in LC maneuver, auditory warnings are used as complementary source to visual warnings to draw attention to critical information 30 to 40 ms. faster than vision.		

		Human Factors			
		Fatigue	***Distraction***	***Workload***	***Situational Awareness***
Multimodal Communication	*Guideline #17: Maximize human cognitive and physical abilities*		In the adaptive mode, distracting visual information is not displayed and warnings are presented acoustically.		

Application of the Guidelines to UC7 of WP6 – Operator task schedule and guidance (INTEGRASYS)

		Human Factors			
		Fatigue	***Distraction***	***Workload***	***Situational Awareness***
Visual Communication	*Guideline #1:* *Visual design should take into account colour contrast for a good readability.*	Ensure that all visual designs meet the minimum color-contrast ratio for normal and large text on a background. The W3C recommends the following contrast ratios for body text and image text: Small text should have a contrast ratio of at least 4.5:1 against its background. Large text (at 14 pt bold/18 pt regular and up) should have a contrast ratio of at least 3:1 against its background			

		Human Factors			
		Fatigue	**Distraction**	**Workload**	**Situational Awareness**
Visual Communication	*Guideline #2: Visual design should take into account the number of colours to be applied to the same layout.*	No use more than five colours in a single layout. Colour should be used sparingly to highlight important information.			
	Guideline #3: Visual design should take into account the typography.	All the fonts should be legible.			
	Guideline #4: Visual design should take into the space in the layout	Keep significant negative space. When too much information is in a layout, messaging becomes clustered and incoherent.			
	Guideline #5: Visual design should follow a clear and intuitive hierarchy.	The application should show clearly how the operator can interact with it and which elements are clickable and which are not. A minimalistic but intuitive interface design will lead to a better experience and a clear understanding of the application.		Avoid overloading the operator with unnecessary actions, easing its operation. Important actions are located on the top or are reachable by shortcuts. Related actions of a similar	

		Human Factors			
		Fatigue	***Distraction***	***Workload***	***Situational Awareness***
Visual Communication	*Guideline #6:* *Visual design should take into account the pre-attentive attributes of perception.*		Critical and alarm information will be displayed in red.		
	Guideline #7: *Visual design should take into account the size and location of interactivity elements.*	The interactivity elements should have a minimum size of 7mm/26pixels and a minimum spacing between them of 2mm/8px.			
Acoustic Communication	*Guideline #9:* *Recommendations about acoustic general thresholds of the sounds*		Sounds for acoustic communication is approx. 500 ms. Sound intensity is between about 80db.		
	Guideline #10: *Recommendations about auditory cues in acoustic communication guidelines*		Complex tones will be used for alarms and critical messages.		
	Guideline #11: *Recommendation about speed verbal instructions.*	Use a comfortable output speed about 160 words per minute.			

		Human Factors			
		Fatigue	**Distraction**	**Workload**	**Situational Awareness**
Acoustic Communication	*Guideline #12: Recommendations about clarity and compression verbal instructions.*		The output is modulated as much as possible to human voice for the synthetic speech systems.		
Acoustic Communication	*Guideline #13: Recommendation about acoustic tones to increase the attention.*		Acoustic tones are used together visual alarms and critical messages to increase the attention of the operator.		
Mutltimodal Communication	*Guideline #17: Maximize human cognitive and physical abilities*	Number of elements on the layout should be reduced in function of the operator status (e.g. overwork, tiredness, etc.).	Use acoustic signals for attention alerting (*warning and critical messages*)	Visual cues to facilitate the worker performance in his working day.	Show high priority elements on the top of the layout to increase the attention of the worker.

Application of the Guidelines to UC2 – Diversion Airport (HON)

		Human Factors			
		Fatigue	**Distraction**	**Workload**	**Situational Awareness**
Visual Communication	*Guideline #1: Visual design should take into account the preattentive attributes of perception*				*Position: list ordered by relevance Color: color coding status consistent among different parts of display. Critical information highlighted*
	Guideline #2: Visual design should take into account the Gestalt Principles to bring out patterns in visualization				*Airports grouped together by their status*
	Guideline #3: Display the data as clearly and simply as possible, and avoid unnecessary and distracting decoration.	*Display overall status related to the goal of the task, all other information is hidden. Minimum interaction required. Consistence with other similar applications*	*Minimum colours used*	*Display overall status related to the goal of the task, all other information is hidden. Minimum interaction required. Consistence with other similar applications.*	
	Guideline #5: Create hierarchy in the visual elements		*Hierarchical ordering of information*	*Hierarchical ordering of information*	

		Human Factors			
		Fatigue	***Distraction***	***Workload***	***Situational Awareness***
Visual Communication	*Guideline #6: Establish relationships to convey which elements are related.*				*Common highlight of related information in different parts of display after selection, airport grouping, status grouping (airport/status grouping)*
	Guideline #7: Create a logical path for users to follow through the interface			*Consistent layout, navigation through display and interaction within diversion assistant and also with other map-using EFB applications*	

Application of the Guidelines to UC3 – Command and Control Room AdCoS (EAD-UK/EAD-GE)

		Human Factors			
		Fatigue	***Distraction***	***Workload***	***Situational Awareness***
Visual Communication	*Guideline #3: Display the data as clearly and simply as possible, and avoid unnecessary and distracting decoration.*	Simple text will be used to inform about fatigue			Attention will be raised by vibrating actuator
Tactile Communication	*Guideline #14: Recommendations about tactile general features*	Vibrating actuator is used to guide attention to visual message on actuator			Tactile cues are standard cues of a COTS product
	Guideline #15: Recommendations about alerts and warnings	Vibrating actuator is used to guide attention to visual message on actuator			Attention will be raised by vibrating actuator
Multimodal Communication	*Guideline #17: Maximize human cognitive and physical abilities*	Vibrating actuator is used to guide attention to visual message on actuator			

Conclusions about the use of the guidelines by the AdCoS owners

Regarding to the different channels of communication described previously in this document, ***visual communication*** is used mainly in most of the studied AdCoS, basically related to the first three guidelines referred to pre-attentive attributes of perception, Gestalt principles and simplicity and typography, this is the main channel of communication for the aeronautic domain, as tactile and acoustic are not allowed by aeronautic regulations.

About ***acoustic communication***, it's mainly used in automotive domain a complementary source to visual warnings and alerts. They are mainly related to guidelines #9, #10 and #13, about thresholds, auditory cues and alerts and warnings.

Tactile communication is only used in the automotive and control room domains, due to the own nature of the AdCoS. In the first domain (automotive), are mainly related to recommendations about general features and tactile localization, but in the second domain (control rooms), apart from the general features, the guidelines used is related with alerts and warnings.

All the consulted AdCoS have used ***multimodal communication*** (mainly Guideline #17 about maximizing human cognitive physical abilities), except in the aeronautic domain, due to the nature of their own restrictive regulations in terms of communication.