Towards a Balanced Human Systems Integration Beyond Time and Space: Exploroscopes for a Structured Exploration of Human–Machine Design Spaces

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ABSTRACT

This paper sketches a potential direction of future methods and techniques for the systematic investigation of future human-machine-systems. It describes the concept of exploration, a pre-cursor of the development phase, and complement of tests and experiments, as an underlying principle providing a systematic way to explore the design and use space of potential systems. The overall methodological framework of an "exploroscope" will be sketched and defined as a human-machine system combined with a set of tools and procedures e.g. in a dedicated room specialized on the exploration of human-machine design spaces. Ontologically, exploroscope is related to the concept of a microscope, a tool that is specialized to help humans to see smaller and smaller details of the world, and to the concept of a telescope, a tool that helps humans to see details of the world further away. Exploroscopes belong to the class of macroscopes, initially proposed by de Rosnay [1], a tool that is specialized to help humans to see more or bigger relationships and connections in the world. Exploroscopes can help interdisciplinary design and development teams to develop and experience new human-machine-systems in their specific use situation and space, independently from the question whether the realization of such systems is beyond time and space, or is just around the corner.

The paper structures the design space of exploroscopes, and describes the research questions that are open to be investigated. As early examples of exploroscopes, the design exploration laboratories of DLR, RWTH Aachen University, and Fraunhofer FKIE and their application in the research of human-machine-system integration are briefly described.

1.0 INTRODUCTION

Cultural, political, scientific and technological progress enables human-machine systems that break the traditional barriers of time and space increasingly. Regarding the spatial distance, humans and machines are now able to cooperate over vast distances, e.g. in tele-cooperation, tele-maintenance, tele-medicine and remote operation of (unmanned) ground-, air-, space-, maritime- and cyberspace systems. Regarding the time distance, knowledge and automated or "autonomous" behavior is defined by designers and developers at a certain time and in a specific setting and instantiated in a totally different time and setting. More and more data e.g. about the action and interaction of humans and machines is collected and stored, and will be assessed at a different time and location.

Korzybsky calls this binding between different situations in time "time binding", and describes this as one of the most important abilities humans have developed [2]. In a similar way, binding together situations that are usually separated through a spatial distance into one virtual situation can be called space binding. Designing and assessing human-machine systems involves quite some time and space binding, especially with future, not yet existent human-machine systems. How can we put the designer and developer into the shoes of the user of a future human-machine system, in different time and space?

The design space of different options for those future human-machine-systems is rather large; the challenge to integrate these complex technological systems with humans into well-integrated and well-balanced human-machine systems becomes even more challenging. Scientific effort should be invested not only in technology, but to a similar extent in the improvement of methods and techniques for the Human Systems Integration, as well.

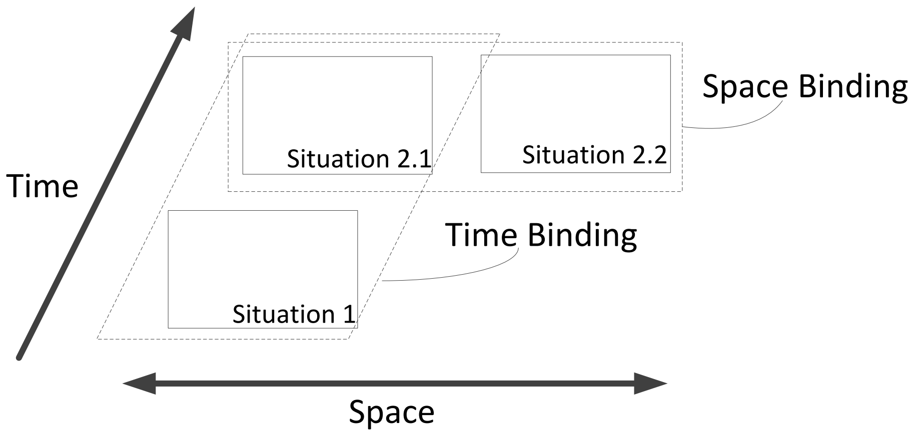

Figure 1 Binding of situations in different time and space into virtual situations (beyond (Korzybsky 1933))

2.0 HUMAN FACTORS, ERGONOMICS AND (BALANCED) HUMAN SYSTEMS INTEGRATION

Transforming the design space into proper combination of humans, technology and organizations has been more of an intuitive art for a long time, but it was the military domain which, as one of the first domains, turned this art into a systematic craft and combined it with research and science. Ergonomics and human factors as the science of the human characteristics and research on human performance and effectiveness in socio-technical systems were developed in the domain of military aviation, and from there spread into all safety and security critical domains. Systems engineering as a combination of system science and engineering actually started in the military, and spread from there e.g. into the space program, where it enabled e.g. the moon landing. As a synthesis of human factors, human performance, human effectiveness, systems engineering and many more disciplines, the umbrella concept of Human Systems Integration was coined by e.g. NASA, US DOD and increasingly used. Parallel developments in the UK lead to the umbrella term Human Factors Integration. Apart from some differences in the perspective on complex socio-technical systems, it becomes increasingly clear that only a constructive, integrative, pragmatic combination of different perspectives leads to good systems and that forces have to be joined.

Besides the challenge of integrating different – or sometimes even diverging - views, a design group's major challenge is to balance requirements, ideas and methodologies on the one hand, and money, time, quality and quantity on the other hand. Balance can be described as a guiding motif for a combination of methods or as one method for solving conflicts and dilemmas of opposing perspectives or conflicting requirements in the exploration process. In order to reach a balanced human-systems design subjective perspectives, e.g. of the user, have to be combined with objective perspectives e.g. of a system evaluation. To accomplish this, qualitative techniques can be combined with quantitative techniques.

Professionals working in the ergonomics or human factors domain often experience a lack of time and capacities to find creative, innovative solutions which are able to fulfill challenging demands on time to production deadline, budgets and operational usability. The concepts of exploration and of exploroscopes aim at efficient innovation and set a framework of methodologies and principles to meet the ambitious demand of balanced HSI. The very early examples of explorations introduced in this paper demonstrate the usefulness of the exploroscope framework as a methodological framework. Based on these fruitful experiences, there is a high potential to investigate the human factors of explorations even further.

3.0 EXPLORATION AS A DEDICATED PHASE IN BALANCED HUMAN SYSTEMS INTEGRATION

To explore means a) to investigate, study, or analyze, b) to become familiar with by testing or experimenting e.g. "explore new cuisines" , c) to travel over (new territory) for adventure or discovery, d) to examine especially for diagnostic purposes (Merriam-Webster online 2013). In the context of design and development of human-machine-systems, the term "(design) exploration" stands for a temporally and thematically connected series of activities, techniques and tools to invent, design, prototype and assess the effects of different options of human-machine systems. The concept of exploration is on a similar ontological level as the concept of experiment. While an experiment uses methods, tools and techniques optimized to test hypotheses and to control the probability of error e.g. with the help of statistics, explorations try to optimize the way from initial questions via ideas to an understanding of the different options, selection of options and a working system design. "System" in the context of this paper is understood as socio-technical or system of humans and technical subsystem (human-machine system).

What is explored in design explorations? Helpful metaphors here are "design space" and "use space". Like physical space can be thought of in at least 3 dimensions (plus time), the design space can be thought to be made up of design dimensions, i.e. all aspects or qualities of an artifact that can make a difference in design. Examples for simple design dimensions are size, color or haptic quality. Design dimensions can also be more complex, like assistance and automation levels in highly automated air-, ground- or maritime vehicles, or connectivity in a computer network. Design dimensions span the design space. During the exploration the design space can be limited by functional, cost or human factors aspects (Fig. XXX), but can be explored in width and depth virtually unlimited.

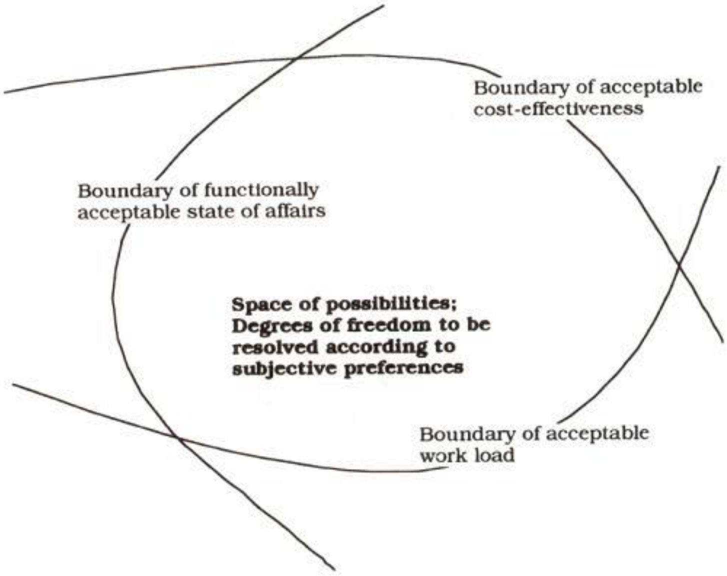

Figure 2 Boundaries in the design space, (adapted from Rasmussen et al. [3])

The design space consists of all the design dimensions as well as their combination (see figure 3). To structure what Rasmussen calls “space of possibilities” it is crucial to give the many subjective decisions in the exploration process an objective structure. Figure 3 shows a mind-net map of the design space, a special form of mind map that helps to structure the many dimensions of a design space in a way that the goal of the whole exercise, the design variant as integrated combination of dimensions, are in the center. This mind-net map can also be used as a creativity tool to explore new combinations that nobody has thought of before.

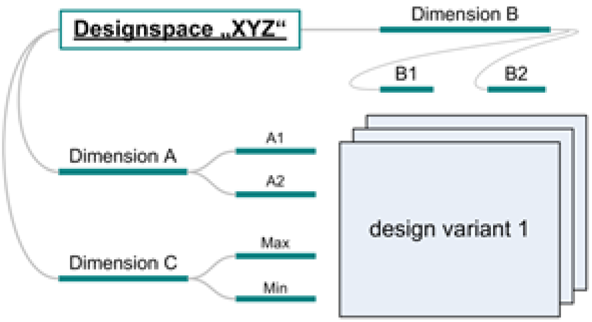

Figure 3 Mind-Net map of design space (Flemisch et al. 2008)

Exploration is not only about exploring the design space, but also the use space. Use space is the combination of all possible instances of use with all possible combinations of design dimensions. To structure the use space, it can make sense to group certain parts of the use space into use situations or their abstract sisters use cases, which can be easily understood by users, designers and developers alike.

The challenge here is that the situation in which design and development happens can be vastly different from the situations in which the actual use happens, which in analogy to Normans “gulf of execution and evaluation” [4]could be called the fundamental “gulf of time and space between design and use” (Figure 4). To make things even more challenging, it is very clear that in most human-machine systems, the number of use situations will be far too high for all of them to be assessed in appropriate design situations. Vast spaces to explore, easy to get lost!

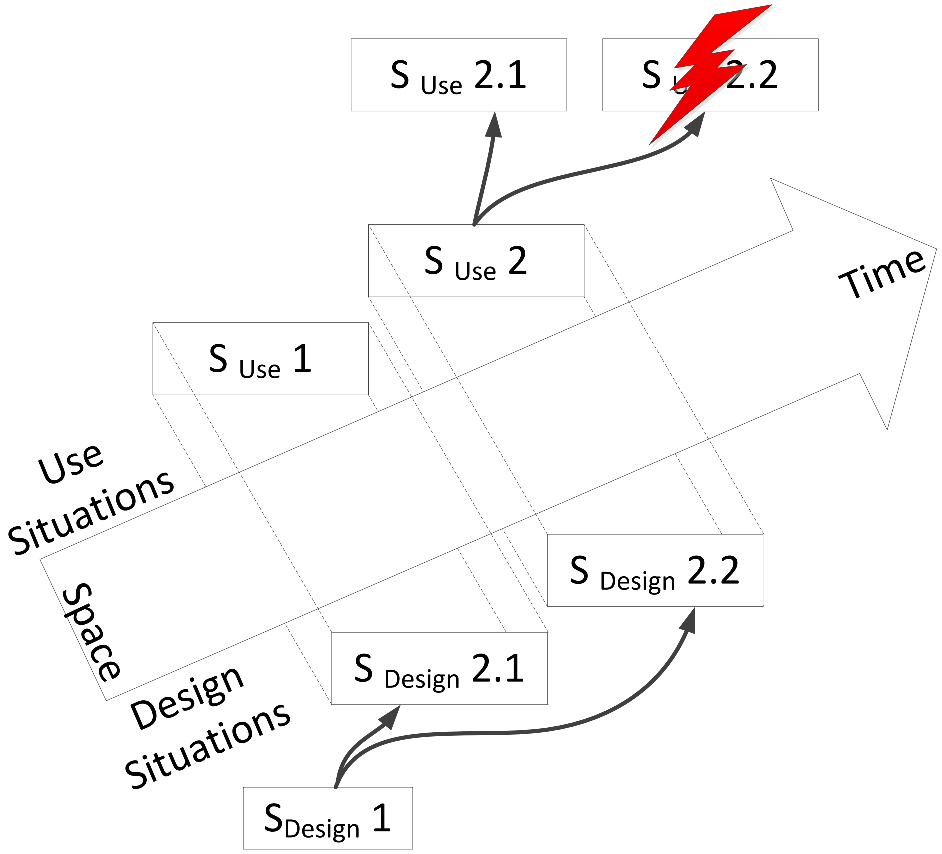

Figure 4 The gulf of time and space between design and use

Not only the design and use space but also the potential users of a system can be explored, since the design of a system is not only influenced by the theoretical degrees of freedom in design (the design space) or the situations in which the system might be used (use space), but also by the kind of user group and its characteristics. Even if the members of the design team or other stakeholders are important in the exploration, the characteristics of a design team are certainly a factor influencing the design – a design often depends on the kind of user and his or her experience, expectations, mental models and motivation. It makes a difference if the user is a highly skilled and trained pilot or if the user is just a normal driver of a passenger car. One method to explore and nevertheless structure the variety of users is to use "Personas" (see e.g. [5]), where virtual persons are invented and even re-enacted by members of the design team. The most important way to explore the "space" of users is to involve a realistic but high variety of real users into the exploration.

Now after a basic introduction to explorations, design and use spaces, let's take a deeper look into the human factors that "fuel" an exploroscope.

4.0 HUMAN FACTORS AND HSI OF EXPLORATIONS: TOWARDS A CONVERGENCE AND CRISPNESS OF MENTAL MODELS AND IMPLEMENTATION

Especially important for explorations is the psychology of the design and evaluation teams who come together with constructive and critical approaches. Proposed methods and techniques for explorations take into account human strengths and limitations on creativity, sharing mental models and dealing with complex decisions in the process of designing and understanding working systems and their Effects.

4.1 The balance of fuzziness and sharpness, uncertainty and certainty

At the beginning of investigating the design space the complexity that the design team and other relevant stakeholders are confronted with could be huge. For design teams the complexity in terms of the amount and variety of design options, the combination of design options and use cases as well as the challenges in learning new procedures and methods might be a source of perceived uncertainty. When uncertainty is overwhelming, individuals tend to encounter resistance against the whole activity. The feeling of high demands and stress due to the complexity also leads to cognitive biases and the tendency of so called „premature cognitive closure“ [6]. The feeling of uncertainty that individuals might feel exploring an unknown space or complex problems is likely to be triggered by typical and inherent characteristics of non-routine design situations. Examples for those characteristics are the multiple design options or the amount of relevant design factors with multiple interdependencies and their changes over the time as well as the lack of a design routine. Other examples of dimensions of complexity are the fuzziness of the design goal or preferred use case or the unknown end state to be reached for the final design prototype. These tension fields between fuzziness – sharpness and certainty – uncertainty can be quite critical because an important part of the people in the design and development process, like engineers and managers, are more trained in pursuing solutions with a high certainty rather than allowing for metaphors or fuzzy concepts, and easily get uncomfortable when things are fuzzy and uncertain, like getting out of the "comfort zone".

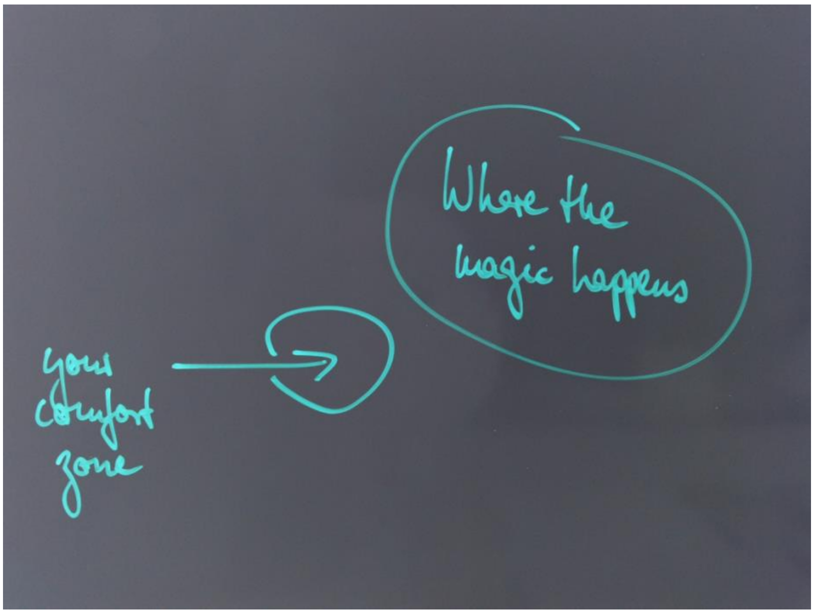

Figure 5: "Getting out the comfort zone" [1]

Comparable to an auto-focus in cameras, their cognition tries to sharpen the thinking process and, based on their motive of competence, they might be tempted to fall back into routine behaviour, which is mandatory later on in the development process but sometimes too early and counter-productive in the design process [7].Besides the potential for uncomfortable affective states, explorative behavior also offers the experience of an increase in intrinsic motivation and the perception of flow when positive feedback and self-control is experienced. If this reinforcing loop has been established, the more new spaces are explored the higher the variation of experience and the lower the feeling of uncertainty will be experienced [8].

This perception of flow can indeed fuel explorations and can be an important driving motive for exploring new ideas. Another major ingredient for the fuel is certainly curiosity, which is "the desire to know"

[1] http://chrisredmond100.blogspot.de/2012/09/easy-exit-from-your-comfort-zone.html

(Merriam-Webster Online) and ambition, a desire to achieve a particular end even if it seems impossible at a first glance. The so called “Gestaltungsmotiv” [9] is a valuable resource for the design motivation and should be stimulated by the exploroscope methodology. In this respect, design explorations are not so different from explorations of physical space like the Lewis & Clark expeditions or the moon landing, they are new, investigative and promising in the case of success.

The balance of negative and positive dynamics in the exploration process is quite crucial: Positive dynamics has to be stimulated and hedged in order to activate creativity and divergent thinking in the design team, to get and keep things going. Negative dynamics has to be taken serious and can nevertheless be used to shape the exploration process.

This underlines the important role of the HSI experts to open the design space at the beginning of the process and encourage design teams to use the motivation of curiosity and ambition and cope with high levels of uncertainty. This is to be realized in a semi-structured process when at the beginning some feed-forward on a first structure for the space to be explored is provided with the provision of prototypical use cases or scenarios. Continuous feed-back or even feed-forward on the working results should be provided and cognitive challenges and competences in the meaning of knowledge, experience and operational background of the design team members has to be balanced.

4.2 Mental models in design team coordination in non-routine conditions

An important premise for bridging the potential gap between user goals and the physical system is the common knowledge ground as a shared conceptual framework in the design team [4]. This common knowledge ground can be achieved by the exchange between the mental models of designers and users: The design model is transferred into the system image that enables users to build the user‘s model of the system [4]. A mental model is what we have in mind about a part of the world, here a human-machine system. Mental models in the meaning of cognitive structures depend on a person’s prior knowledge and understanding [4]. Especially in heterogeneous and interdisciplinary design teams a common knowledge base cannot be presumed and additional effort in sharing ideas, building a glossary and introducing a common methodology has to be invested in order to synchronize the mental models. Mental models are hypothetical constructs and the individual cognitive representation of the outside world changes or adapted due to incoming information and the experience of new situations. “Shared mental models are defined as the degree of convergence among team members with regard to the content of known elements as well as the structure between elements (from [10], [11]). Shared or team mental models are assumed to be more than the sum of their parts. They are reflecting internalized beliefs, assumptions and perceptions of the team members concerning their task and the design goals, requirements, the methodology or the means to be used. As their structure and content is changing and adapting during the exploration process, their sharpness can vary from a blurry and fuzzy understanding of the design idea up to precise mental images and representation of the functionalities, technical specifications or use cases. This process of changing and reflecting the mental model becomes more and more implicit over the time.

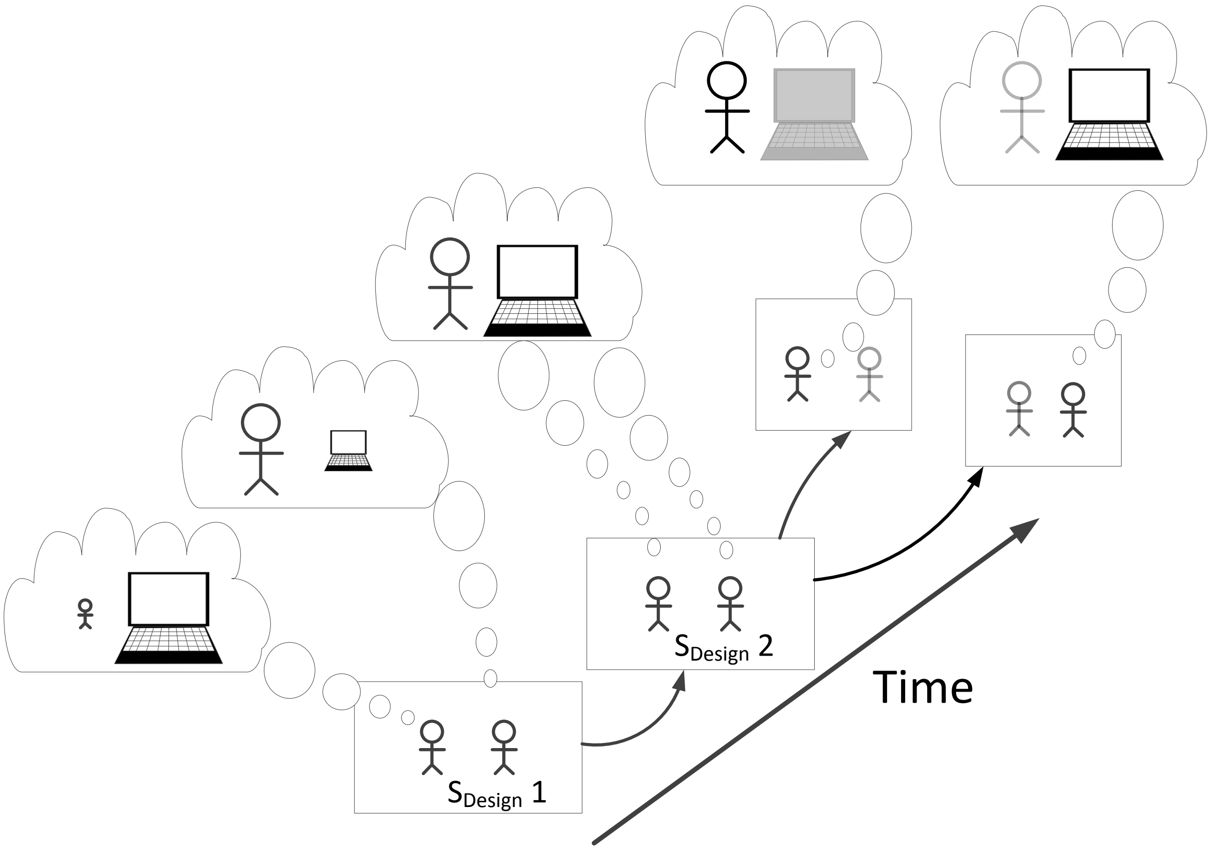

Figure 6: shows an idealistic development of mental models in the design team: Often at the beginning of a design and development activity, technical people in the design and development process have a much larger mental model of the technical aspects of the design, and users, psychological/human factors people have a larger mental model of the user (S design 1). Through mediated interaction they can develop a shared mental model of the socio-technical system that is more balanced between human and technological aspects (S Design2). This shared mental model can also serve as a common ground for the future development activities that can then be in parallel again (S Design 3.1, 3.2), until the user is on his own using the socio-technical system (S Use 1).

Findings from Human Factors indicate that at the beginning of the exploration explicit communication leads to better performance due to the development of shared understanding in the team (see Badke-Schaub, 2011) and as the figure below shows, the main demand on the teaming is to support communication and share first ideas to build a common ground. In terms of a design team better performance might be shown via easier integration of design solution, a better requirement-solution fit and a better understanding of future applications of the prototype. Research on design teams has shown that the increase of sharedness leads to more implicit coordination and in turn saves resources, reduces information load and smoothens joint activities.

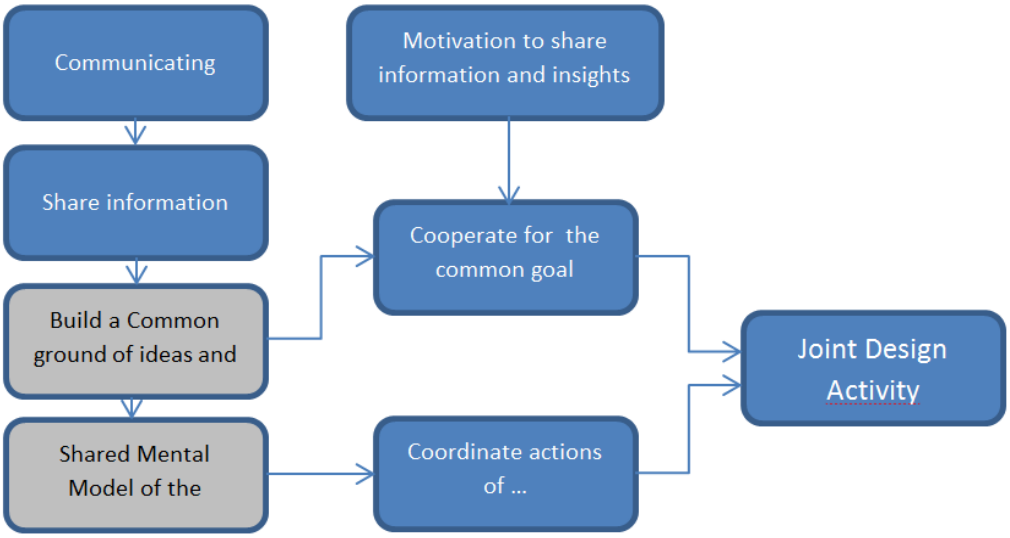

Figure 7 Communication, Coordination and Cooperation as the foundation of joint activity (adapted from Badke-Schaub [7])

To gain a common understanding of the system design it might be necessary to reflect the process and the creation of the mental model within the design team and its specific work domain which leads to a second-level description in the meaning of Herczeg [12]. The effort and time teams need to develop a shared mental model depend on the complexity of the design task, the stage of exploring design possibilities and the time team members have worked together in the past.

4.3 The theater method as a means for reducing complexity and alignment of mental models

One approach to stepwise reduce the complexity of design and use space a design and development team is confronted with, is to deal with it in a rather playful way. So it is often not necessary or even counterproductive to try to do justice to the overall complexity. One method for playful, tentative progress in reducing design space complexity is the so called "(design) theater method" (originally invented at NASA Langley, see e.g. [13], [14]), where designers, developers, stakeholders and future users play through use cases of new systems as if they are on the stage of a theater. Like in the Wizard-of-Oz method, the behavior of new technology can be played by members of the design team. Unlike the Wizard-of-Oz method, the fact that the new technology is emulated by a human is known to all participants, and the curtain is open.

The theater method offers at least three advantages:

a) In an early stage of the design process, members of the design team can synchronize their mental models by directly getting a concrete impression of the concepts and ideas for interaction and automation concepts. Additionally, also software engineers can "feel" how new systems should work, such that this experience can be used as an addition to written requirements and specifications.

b) The method can be used as a valuable tool for participatory design within a user-oriented, balanced design process. Potential users of new systems are invited to the lab and are involved in a direct dialogue with the design team while being asked about their expectations and playing around with potential new functions.

c) The theater method also allows an early evaluation of design ideas by emulating the new functionalities and the interaction with the user by one or more members of the design team (so called confederate).

With the theater method it is possible to easily produce, and to play through, prototypical use situations. It also enables the members of the design team to take the perspective of a user. On the one side it can induce or improve qualitative models of the artifacts and situations, but also time and spatial models of new functionality and interaction processes in certain use situations.

It is often sufficient not to experience how technical artifacts would function or act in every single detail, but to get an impression of the underlying ideas of a concept. Therefore it is adequate to experience a simplified and rather rough version of e.g. an interaction/automation concept or any functionality of artifacts. This is related to the concept of marking (e.g. [15]): The marking method is applied in dance and the exercise of complex choreographies. In marking, dancers go through the choreography in a very simplified way, often not even moving their feet, but reproducing movements and forms just with their hands instead. This simplified walkthrough leads to significant improvement in the choreography when it is fully danced out. A comparable approach is often used in the production of movies, the so called storyboards. Here often quite rough sketches in comic book style help to structure whole movie scenes and they help the members of the film team as well as the actors to understand even complex scenes. In the design of complex artifacts this reduction to some basic principles can reduce cognitive load and help the design teams to cope with complexity. It is also important for users in participatory design. When new artifacts are developed potential users often only have very vague ideas of these artifacts. They often feel overwhelmed by all the new information they get, when participating in the design process. So the user must be introduced into the topic stepwise. Here the method of storytelling can be fruitful. By the means of storytelling a use situation and the general idea which underlies the artifact can be induced step by step and the user is better prepared.

Role-playing methods like the theater method lead the designer to change his perspective in order to see the world through the eyes of the user. As mentioned above, this step-wise reduction of uncertainty helps individuals to experience flow-feelings which in turn set up the cognitive scene for creativity and innovative thinking.

5.0 EXPLOROSCOPE AS A PLACE SPECIALIZED FOR EXPLORATION

(Human-machine design-) Exploroscopes are human-machine systems combined with a set of tools and procedures e.g. in a dedicated room specialized on the (meta-method) of exploration of human-machine design spaces.

The idea of the exploroscope is to bring members of interdisciplinary design and development teams and users together from a very early stage of the design and development process on and to offer them a proper environment with appropriate tools and procedures throughout a certain period of the design process. During the process of exploration one of the first steps is to open the design space in a very divergent way with respect to the objective. This often can happen in form of discussions, brainstorming etc., that can be quite abstract and theoretical, but also quite concrete and practical.

Different viewpoints of members from different disciplines have to be taken into account and different mental models must be made graspable to the members of the design team. Therefore the exploroscope needs methods, tools and techniques for discussion on a more abstract and theoretical basis but also methods to transfer abstract ideas and mental models into viewable and also touchable examples. For example, the method of visualization is an important issue to make certain aspects of concepts more clear. Here whiteboards and video projectors but also model kits or even toys like matchbox cars are imaginable and suited.

The next steps during the exploration are to iteratively reduce complexity of theoretically possible interaction approaches yielded by the design space. Here the previously mentioned divergent process of opening the design space is turned into a more convergent process of deduction. An important goal is to exclude inapplicable concepts and to identify and pursue the best suited and sustainable ideas. This happens during an iterative process and cannot be done on a theoretical basis alone. The exploroscope should offer the opportunity to easily transfer these ideas for concepts etc. into quite concrete and feelable prototypes. One example for a method to transfer abstract ideas into first instantiations of prototypes is the rapid prototyping approach, which in turn yields a broad variety of submethods like the wizard of Oz technique or the theater method. Exploroscopes contain a bunch of various methods and techniques which enable and facilitate the design process and which also bear the potential to create a constructive and creative atmosphere. By means of an exploroscope the gap between at first abstract and vague ideas for concepts and first instantiations of prototypes can be bridged.

What are the essential ingredients, the essential dimensions in the design space of exploroscopes?

- **Enough open, empty space that appeals to be filled with use and design ideas.** This might be empty whiteboards or 'blank' simulators which are not yet modified in the direction of a specific assistance system by e.g. means of rapid prototyping. At the beginning of the design process it can be crucial to start from scratch. Especially in the design of complex systems it can be helpful not to be distracted by irrelevant information. Another aspect is that – empty space like empty whiteboards can inspire an urge to fill it with good ideas.
- **A set of toys and tools, hardware and or software that can be easily combined to prototypes.** This might be graphical interface prototyping tools, model or construction kits, a toolkit, and several modules which can be variably combined like displays, speakers, inceptors etc.
- **A set of tools, hardware or software, that can be easily arranged to produce instances of the use space**, e.g. by means of improvisation theater or simulation. The described theater technique is an example for that.
- **Means to assess and select design and use options**. These could be methods like expectancy assessment with the theater method, the Wizard-of-Oz technique, usability testing, methods to assess the suitability of e.g. icons or graphical symbols.
- **Means to document design and use situations.** These can be in the simplest form photos and videos of the design situations. Other means are so called interaction diagrams, mind maps, and the so called mind-net maps (e.g. [16]). A further method to structure the aforementioned methods and to document the whole process of exploration is the exploration map. Here every step in the exploration, beginning with the definition of the design space and ending with the results of e.g. usability assessments, can be documented.
- **A team skilled to man and run an exploroscope, and curious and bold enough to explore the unknown**

6.0 EARLY INSTANTIATIONS OF EXPLOROSCOPES FOR VEHICLE ASSISTANCE AND AUTOMATION AT DLR, RWTH-IAW, FHG-FKIE

One essential aspect of an exploroscope is to give the members of the design team the opportunity of role taking and to deal with design and use space in a playful way. As mentioned above, the theater method offers this opportunity. The theater method can theoretically be used without any help of technical systems, but depending on the kind of system which should be developed, a technical base system - a theater system - can support and facilitate the method. One instance of the theater method was developed for the exploration of the design space of highly automated air and ground vehicles. Here the theater method is supported by a theater system in form of a mechanical or electronic coupling of the actuators of the two driving simulators. This coupling offers the possibility to use the theater system in way similar to the so called Wizard-of-Oz method (originally used for testing speech recognition systems [17]; adapted for testing driver assistance systems [18] based on Flemisch [13]: Vehicle assistance and automation and interface functionalities are emulated by a member of the design team by giving input to the inceptors of one of the driving simulators while the user in the other simulator can already experience how the design for the assistance and automation might feel like in the future. This can be done before the automation and interface functionalities are implemented in software. The theater technique and theater systems are used in the exploroscopes described in the last part of the publication.

6.1 DLR – IDeE-Lab

One early instantiation of an exploroscope was implemented at the German Aerospace Center in Braunschweig. The IDeE-Lab (Interaction Design and Ergonomics Laboratory) is conceptualized as a hybrid of team working room and driving simulators for the design, development and early evaluation of driver assistance systems and vehicle automation. The laboratory is equipped with several tools to facilitate the shared design process, for example whiteboards and video projectors. Here several members of the design team can come together so that first ideas for interaction design concepts can be collected and discussed. The other part of the laboratory consists of a theater system and is described e.g. in Schieben [14]. In the DLR IDEeLab the theater system consists of a combination of two coupled fixed base passenger car simulators. The simulators are designed for rapid prototyping, so that new configurations can be realized in a very straightforward manner. Different displays, buttons and other input devices can be mounted. Also different forms of steering wheels can be used. Each of the two simulators has an active steering wheel and pedals as well as an active sidestick as an alternative inceptor.

Overall, the IDeE-Lab and its theater system is an important part of the DLR tool chain reaching from basic to complex research environments. It fosters the design and evaluation process at an early stage of the automation and interaction functionalities before these are implemented in software and evaluated by experimental studies in more complex driving simulators or the test vehicles at DLR.

Figure 8: DLR theater system in the IDeE-Lab exploroscope with two coupled basic driving simulators

6.2 RWTH-IAW-SmpLab

Another early instantiation of an exploroscope can be found at the RWTH Aachen IAW-SmpLab (see Figure 9). Here is a brief description of the layout: The entrance area has the function to present ideas before an exploration starts and can be separated from the exploration area using a curtain that incorporates two aspects: First and obviously it is a (soft) barrier to hide the setup area from the visitor/subject. Secondly, since it is not a firm barrier, it allows increasing tension and curiosity of the visitor/subject who might get a glance at the setup area, or who might even get beguiled to (secretely) peep in the setup area. The large window front also incorporates several design process improvements: Two major aspects are a bright design and development environment and creativity enhancement due to the view on dynamic scenes outside the lab.

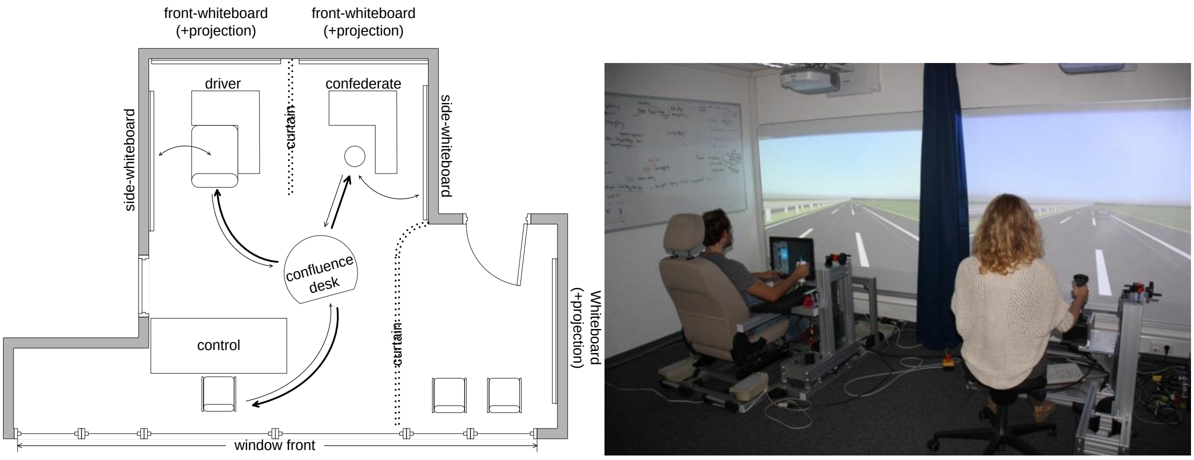

Figure 9 IAW-SmpLab exploroscope: left layout, right exploration in progress

The exploration area is composed of a control desk and two mock-ups: one for the subject and one for the confederate; if necessary both mock-ups can be made identical. Depending on the exploration task, a closed curtain (Wizard-of-Oz technique) can be used to separate subject from confederate or an open curtain (theater technique) can be used to share experiences between subject and confederate. For easy and quick documentation all walls of the SmpLab have whiteboards, which means that the projection areas are projection-optimized whiteboards as well. In order to document remarks or ideas stemming from an exploration in a fast manner, the confederate sits on an ergochair that allows quick movement between mock-up, whiteboard and the confluence desk in the center of the SmpLab. This confluence desk offers many possibilities during an exploration: For instance, it can be used by the controller and the confederate to make quick notes and/or share these notes or other paper documents with each other, and/or it can be used for consolidation between driver, confederate and controller in the beginning, during or after the exploration – it is therefore used as a shared desk for the confluence of different information streams coming from different perspectives (subject, confederate and controller).

The current setup incorporates two short distance projectors that create the (visual) simulation in which the subject and confederate immerse. The sound system is adjustable to produce acoustics from the place where the subject would suspect it to come from in real life. Active sidesticks and steering wheels can be used to measure e.g. steering commands and to convey forces. Miscellaneous devices like touch screens and various kinds of buttons (like turn signal) and sensors (like grip force on active devices) can be incorporated quickly. The interaction software that is used at the IAW-SmpLab was developed in a way that new interaction devices can be quickly incorporated in the setup to explore new ideas that evolve from explorations and to switch between different interaction methods quickly as well. The software takes advantage of the SMPL++ (Straightforward Modular Prototyping Library), a compilation of C++ libraries developed at NASA [19], that allow communication between the different modules of complex automation and interaction prototypes.

Furthermore it makes use of concepts developed in early H-Mode prototypes e.g. [20]. The interaction prototype developed at the IAW offers the possibility to use several input-, or better interaction-devices during the exploration (that can be switched on-the-fly) and to harmonize the interconnection e.g. of haptics, visuals and acoustics. That way subject and confederate can be haptically coupled, for example, when using the theater-technique (see Figure 9, right with active sidesticks), where the subject feels the torque (felt as a certain force in a certain direction) the confederate induces via the haptically coupled active interaction device and vice versa. The subject can also be decoupled from the confederate and be coupled with a cognitive automation on-the-fly, where forces (induced by the active device) or grip force thresholds (induced by the subject on the active device) can be altered during a running exploration.

6.3 Fhg-FKIE-SMP-Lab

The focus of research in the FKIE-SMPLab is on military vehicles. In compliance with military features new interaction concepts for assistance and automation systems are developed and evaluated in an interdisciplinary team.

To make the different mental models of the design team members and the often vague and abstract ideas for concepts more graspable, the laboratory is equipped with different methods and techniques and it can be easily adapted to different situations depending on the kind of requirements.

To identify and refine use cases they can be interactively adjusted in an interdisciplinary team with the help of model cars in a rather playful way. Complex concepts or relationships can be visualized and developed with the help of smart boards. The FKIE Smplab is also equipped with a theater system. The FKIE theater system itself consists of two fixed based low fidelity simulators. Each simulator has an 88" projection screen at the front and comes with active inceptors. The simulators are designed in a flexible way, so that both the ergonomic configuration of a car and a truck can be set. To design the environment as realistic as possible, the simulators possess a virtual dashboard realized by a wide screen display that makes it possible to easily switch between either a car or lorry configuration. As active control devices side sticks as well as active steering wheels with associated pedals are used. As a simulation environment VBS2 and Cryengine are used. This allows the implementation of various civilian and military vehicles and scenarios.

Figure 10: FKIE Smplab Exploroscope during a workshop on vehicle automation with German defense procurement and military personal

7.0 OUTLOOK: HOW TO SURVIVE AS AN EXPLORER IN A WORLD BEYOND TIME AND SPACE, WITH INCREASING KNOWLEDGE GRAVITY

Explorations can be exciting for curious people and exploroscopes are the right tool not only for explorers, but for almost any human systems development and integration task, whether in civil or in military applications. The beginning of the third millennium is still an el dorado, a gold land for explorers of human-machine systems. But like the formerly unknown el dorados of the second millennium that are now discovered and mapped, there are also potential challenges in this third millennium for the endangered species of explorers: Besides the danger that the progress brought about by new technology or methods might slow down in the future, e.g due to global warming and the scarcity of fossil ressources, there is a chance but also a risk that most information will be available online at a finger tip. People might be tempted to first explore the known and documented solutions e.g via the internet, and give away the chance to discover something really new. While the known gets bigger and better accessible, it might create a gravity of its own, swallowing all curiosity and ambition for the unknown and innovation like a black hole swallowing the light.

Besides the technical and scientific aspects of exploroscopes and exploration, we also need to establish a culture of innovative exploration especially in the times of increasing knowledge gravity. One helpful technique for that is what David Katz, one of the founding fathers of haptics and phenomenology, called “disciplined naivete”, where we should at first suspend all presuppositions [21]. Applied to design, instead of starting with a Google search, we should start with a disciplined design naivete, a clean slate and an open mind for innovation. If we later on discover that others had similar ideas before, we should appreciate the moment where we discover that – even beyond time and space – we are in good company of explorers and should joyfully keep on exploring the vast universe of human systems integration.

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