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Information Ergonomics

A Theoretical Approach and Practical Experience in Transportation

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Perspectives for Future Information Systems – the Paradigmatic Case of Traffic and Transportation

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Charting a roadmap for future information systems will depend on ancillary conditions and constraints which in themselves might undergo changes.

- The future development of information systems themselves (e.g. the integration of diverse information systems by cloud computing, the integration of social and informational networks into cooperative work and live spaces sharing knowledge bases, etc.); this will necessitate novel approaches to information safety and legal safeguards for privacy
- The future developments of other organizational, societal, and technical systems, (e.g. we have to expect a higher demand for inter-modal systems in transportation for people as well as for goods, pilot-less planes, driver-less trains, or perhaps even driver-less cars)
- The future demographic development with an aging population in Europe and the Far East which has to interact with "young populations" in other regions; this entails the consequent orientation of information systems towards the demands of the user in their specific culture and situation (e.g. the integration of real and virtual mobility, that is, moving information instead of people or goods as in tele-teaching, tele-cooperative work, etc. – a good example is the development of tele-medicine systems providing general access to high quality diagnosis and therapy without moving the patient more than necessary)
- The future demands on traffic and transportation (e.g. on the one hand providing assisted mobility or virtual mobility in areas with aging populations, and on the

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other hand in developing countries tailoring the design of traffic and information systems to the demands and competences of young populations)
- The future demands for distributed and – at the same time – integrated development and production systems (e.g. the synchronization and coordination of material and informational production chains)

In parentheses are listed foreseeable developments. However, if and when these will be realized depends on the political and legal framework for them. They are difficult to predict because they – in turn – will depend on further breakthroughs in information transmission, safety, and management.

A common theme for all these developments, however, is that they presuppose novel forms of interaction between humans and technical systems. The different aspects outlined above are not independent but constitute different perspectives on what has been coined the "System of Systems". In regard to the interaction of humans and technical systems, a system of systems has the potential to provide the user with a coherent simultaneous image of the environment as perceived by the user augmented with the information given by the technical system. A necessary precondition for this feature is the identification of the situation specific user needs for information. The cultural background of the user as well as the level of expertise plus the preferred modes of interaction, which depend on the physical state, age, expertise and culture of the users has to be taken into account to built up this coherent and augmented image of the situation.

For theses reasons, future technological developments in this field the very beginning ought to take the potential user into account for whom it is of primary importance to have his situation specific information needs fulfilled. When this is given, technology related parameters of the information processing units, like the number of floating point operations or the Baud rate are not of importance for the user. Admittedly, they are of high importance for the functioning of the system but for the user they remain in the background or even become invisible and therefore unattended. For this reason specific warning measures have to be provided for the case of system overload.

The consistent orientation towards the user needs, however, has limitations. On the one hand, the users' frames of reference in information processing have to be considered, which are the precondition for situation awareness (Endsley 1997). On the other hand, the access to user related information and its proliferation has to be regulated in order to provide the necessary protection of privacy.

Especially in the field of individual mobility this is apparent and the development of assistive technologies for cars has shown that intelligent adaptations for different populations of drivers and different tasks are not only technologically viable but also accepted by the users.

In the following, information systems for traffic and transportation are used as a paradigmatic field for a comprehensive approach. Whenever possible, it is shown how these considerations can be generalized to other fields.

1 User Oriented Information for Traffic and Transportation: A Paradigmatic Example for an Efficient Mesh of Information Technology

In order to chart the further developments of user oriented information systems for traffic and transportation it is necessary to give a systematic overview of the user's demands: **what** needs **when** and **how** to be known by the user, that is, beyond what is obvious or already known by the user. It has to kept in mind that users mostly do not organize their actions according to a rule book or a formal manual but according to perceived situational demands and earlier experiences in similar situations; this has been termed 'situated action' (Suchman 1987).

As a consequence of this, future systems have to address the following main topics: situational and individual *specificity* of information, *actuality* and *relevance* of the information, and *effectivity* of the mode of transmitting this information to the user.

2 Socio-cultural Environment and Human Competence

Future developments will depend not only on technological breakthroughs but even more on organizational, institutional, and legal developments which have to be taken into account because they influence cultural differences underlying everyday behaviour including driving. Kluckhohn (1951) has already described this as follows: "culture consists in patterned ways of thinking, feeling and reacting, acquired and transmitted mainly by symbols, constituting the distinctive achievements of human groups, including their embodiments in artifacts; the essential core of culture consists of traditional ideas and especially their attached values" (p. 86).

The cultural differences do not only play a role on the global level where technical artifacts and the concomitant information systems have to be designed in such a way that they fit into the specific cultures worldwide (for the background, see Nisbett 2003), but also on a local level, e.g. the populations in metropolitan and rural differ not only in their openness to new technologies but also in their willingness to accept the transition from individual mobility to public transportation.

If – as Kluckhohn (1951) argues – cultural differences in thinking and behaving become apparent in their relation to symbols and artefacts, the ways of transmitting information from information systems to the users will be of special importance. Actually, since about 15 years an increasing awareness for these questions can be observed in the domain of human–machine interaction or human–computer communication (Fang and Rau 2003; Honold 2000; Knapp 2009; Quaet-Faslem 2005). The cultural differences play a role in the understanding and usage of menu systems (e.g. Fang and Rau 2003; Knapp 2009) as well as in the ease of understanding commands or interpreting the meaning of icons (e.g. Honold 2000).

However, – as the results of Knapp (2009) show – the usage of new technologies, in her case route guidance systems for cars, influence the cultural development, too, that is, European and Chinese users of such systems are more similar in their behaviour than Chinese users and Chinese non-users. How the detection of cultural differences could stimulate further developments in human–machine interaction can be seen in the preference for episodic information of Chinese users in comparison with European users who usually prefer conceptual information. However, novel results in cognitive psychology show that in situations of high capacity demand on the working memory Westerners, too, use episodic information (see Baddeley 2000). It might be that the support by episodic information would have added value also for Westerners, especially for situation awareness.

3 Beyond Visual Information: Multi-modal Interactions

One important mode of human–machine interaction which is probably culturally fair is haptics (for fundamentals see Klatzky and Lederman 1992): From providing information via tactile perception ("tactons" Brown et al. 2005) to directly influencing actions through force feedback (Dennerlein and Yang 2001) there are new avenues for human–machine communication, which might be of special importance for the interface design of further information systems for traffic and transportation.

Visual and acoustical information, which is still prevalent for warning and guidance share the drawback that they are exposed to strong interference from the environment and additionally put high demands on semantic processing. In contrast, tactile information can be provided selectively, in the extreme only for the hand or the foot, which has to react upon this information (for an overview, see Zimmer 1998, 2002, or Vilimek 2007). However, even further developments in the field of tactons, which are tactile equivalents to icons, will not provide anything resembling the semantic richness of spoken or written language or pictures (for the design principles for tactons, see Oakley et al. 2002). On the other hand, many compact commands or indications for orientations as traditionally provided by icons or earcons can be presented in the tactual mode, too. Examples might be "urgency" or "acceleration/deceleration".

The major advantage of tactile information however, becomes apparent when it immediately acts upon the effectors by means of force feedback or vibrations. In these cases the reaction speed is very high, the error rates are low, and the interference with other tasks e.g. those related to driving are negligible (Bengler 2001; Bubb 2001; Vilimek 2007). That in the field of car driving the highest effect for tactile information have been found in the support for regulating behaviour, e.g. lane keeping, and somewhat less in the support for manoeuvring, e.g. overtaking. For navigating map and/or speech information will be indispensable; in some situations tactile and visual or spoken information can be integrated, e.g. during the approach to an exit.

On the one hand the focus on interface design of cars is due to the fact that the drivers are so varied and on the other hand the competition between OEMs to provide innovative forms of interfacing is extremely high. This has led to a faster development in interface design for cars than – for instance – for airplanes, trains, or ships where the operators are usually highly trained and the procedures are regulated if not constrained. However, new developments in cockpit design show that even – or especially – highly trained professionals can profit from an improved user-centred interface design (Kellerer 2010).

4 The Challenge of Interaction Design

While the user-centred design for interfaces constitutes a field of development which is already consolidating, the field of interaction design is still in an emerging phase – for this reason Norman (2010) regards it as art, not as science. This is partially due to the sheer complexity of possible interactions between information users and information sources. More important perhaps is the foreseeable development from distributed *autonomous* systems to distributed *and massively interacting* systems, prototypical examples are Google's Chrome OS which gives the user access to servers without geographical constraints or the mobile-phone based navigation systems which directly access the internet and therefore are – at least potentially – more precise and up-to-date than systems which rely on CD-ROM based digital maps. Further developments in cloud computing will not only allow access to more sources of information but will also allow "information harvesting" (comparable to "energy harvesting", where all available energy is transformed into usable energy), that is, such systems will monitor all available information which might be relevant for a specific user. For instance, in the Netherlands the Tom-Tom navigation systems utilize the fact that the motion of individual mobile phones from one cell to the next can be geographically mapped and thus allow a highly valid and timely prediction of traffic congestions.

From my point of view, the future of information systems will lie in the development of situation specific but interconnected systems, providing information that fits into the actual demands of the user. E.g. for individual surface mobility as compared to air traffic this implies a very high variability in situations due to the drivers' behaviour: as long as enforced compliance is neither technically feasible, nor legally admissible, traffic information systems have to enhance and assist the competence of the driver and not to govern or override it.

The effective mesh of operator competence and information support will depend on the quality of the information given, its specificity for the situational demands, and the fit between the mode of informing and the required actions. On the one hand, it will be the task for human-factors specialists to design interfaces and modes that allow the easy and effective integration of information relying on sensor data into the individual knowledge of the operator.

On the other hand one crucial challenge for information science will lie in the communication between the systems on the different levels, (e.g. in the case of individual traffic: the communication between systems supporting the regulation of single cars and systems managing the regional traffic flow).

Due to systems architectures and concerns about safety and privacy this kind of information integration usually does not function bottom–up as well as top down; e.g. in planning a trip one can do the entire scheduling from door to door on the computer; however the information contained in the reservations usually is not shared among the different providers for the transportation on the legs of the trip and therefore cannot be used for rescheduling in cases of delays or other kinds of perturbation. Using cloud computing as a means for efficient data harvesting could provide the support for optimized transportation in productions chains, which are resilient, that is, functioning efficiently even in the face of disruptions or perturbations.

This kind of vertical information integration in transport could also serve as a model for horizontal information integration in research and development. It is not unusual that in large corporations or consortia, responsible for the development of complex systems, not only object-related knowledge and expertise exist, but also knowledge about the interaction of such objects with its environment during its lifetime cycle. Usually this information is localized in separate departments and not easily accessible for other departments. The consequences of this lack of horizontal information sharing has become apparent when in Germany a new type of fast trains was introduced which disturbed the safety relevant electronic signalling system due to high electric field forces. However, the same corporation responsible for the production of the train had planned and installed the signalling system before.

Admittedly, for the time being there is a lack of systems providing at the same time ease of use, reliability, data safety and privacy protection. Nevertheless, the traditional goals in ergonomics, namely efficiency and ease of use, will only be attainable if the information systems are designed as integrated systems and not as collections of separate data bases, tools, and interfaces. It will be a challenge to develop architectures for these "systems of systems" which overcome the pitfalls of the traditional additive procedures in combining systems where errors in local systems can influence the functionality of the global system. With a coherent systems architecture the "system of systems" cannot only be more efficient but even more resilient in the case of external perturbations or failure of components than additive systems.

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