Chapter 7
A Framework for a Priori Evaluation of Multimodal User Interfaces Supporting Cooperation

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Abstract We will present our latest research on a new framework being developed for aiding novice designers of highly interactive, cooperative, multimodal systems to make expert decisions in choice of interaction modalities given the end users, their activities and the context. Our research is conducted within the field of maritime surveillance and the next generation distributed multimodal work support in mission command centres and provide a method and tool for bridging the gap between user needs and system solution.

7.1 Introduction

The computer industry is on the brink of a new era. The future is not a solitary PC, but a diverse set of smart, cooperative devices interacting not only with its end users but also with each other while fully integrated in their environment. The interaction with these systems are multimodal where the tools become extensions of the human sensor and motor systems supporting the end users' cooperative execution of actions while trying to solve problems. The computer is thus no longer a system that just determines something by mathematical means, brings order (Fr. 'Ordinateur'), handles data (Swe. 'Dator'), count information (Hun. 'Bilgisayar'), or is a machine full of knowledge (Fin. 'Tietokone'). It is rather an infrastructure for multimodal human-computer interaction and cooperation. However, are we as designers

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equipped to meet the rapid evolution within the computer industry? We suggest that we need to find a way to minimize the gap between analysis and design to be able to continue delivering optimized and satisfactory systems to our customers and end users at a reasonable price. Our research is being conducted in the context of ATOL (Aeronautics Technico-Operational Laboratory), a joint enterprise between TELECOM Bretagne, Thales Group and Ecole Navale (the French Naval Academy), where we study multimodal computer supported cooperative work (CSCW) within the context of maritime surveillance missions.

7.2 The Designers' Challenges of Today

The vast majority of today's expert designers are still novices within the design of highly interactive, cooperative, multimodal systems. However, they are still supposed and demanded to deliver intuitive, useful systems of high quality to a reasonable cost that optimize the total system performance. The technology necessary to create these systems are mere a mash-up of existing technologies, but the design field is quite new. Model-driven languages, methods and tools are continuously being developed and enhanced to meet the demands of the industry on adaptive, flexible and robust [1] systems designed and developed at a low cost. One example of such a project is the recently finished pan-European ITEA2: UsiXML project which is based on the μ7 concept, i.e. multi-device, multi-platform, multi-user, multi-linguality/culturality, multi-organization, multi-context, and multi-modality. However, due to the designers' lack of experience and know-how in designing these new complex systems, and due to the intended end users' and customers' inability to clarify and articulate their cooperative and multimodal needs in a comprehensive way, the designers often face infoglut resulting in poor choices in interaction modalities which lead to poor utility and usability. Some of the most common challenges are:

- The intuition and decision-making of the designers regarding multimodal computer-supported cooperative work (CSCW) environments are biased by previous experiences of single-user system design
- The complexity in group interactions and activities pose great challenges:
  - Group logistics of data collection
  - Number and complexity of variables
  - Validation of re-engineered group work
- It is time and money consuming to perform evaluation of multimodal cooperation even though one focus on a smaller set of activities and well defined user groups (even for multimodal one-user applications)
- The lowest common denominator is "easily" validated for single user systems, but not for multimodal cooperative systems with a big variety of end users
- There is a disparity in activity objective and needs between who does the work (the end users) and who gets the benefit of that same cooperative work (the customer)

One way to aid the designers would be to provide a framework that can alleviate the transition from analysis to design by directing and managing the flow of accumulated data, via analyzed information to usable knowledge and design. Today, this is a tedious time consuming work biased on deficient mental models by the designers and without any promise of quality delivered. Therefore, our intention is to help novice designers of multimodal cooperative systems to make expert decisions in choice of modality or combinations of modalities given the users, the activities and the context. We believe that this will not only enable the creation of new, for the end users, adequate intuitive systems supporting their cooperative work, but it will also optimize the ROI of projects and programs alike. In the following paragraphs we will present some aspects of an a priori evaluation framework being developed based on our understanding of human behavior and cooperation, and on how multimodal interaction could be approached to solve these issues.

7.3 Design of Multimodal CSCW Systems

What ultimately determines one's productivity is actually not as much about what tools one uses, as about how one uses them. Therefore, before we describe our new framework under development we will briefly define the context within which we imagine it to be used. As we are focusing on enhancing the work of the designers to optimize time, money and quality we recommend an agile approach due to its strengths in dealing with uncertainty and high requirements volatility in a flexible and suitable manner. [2] An agile approach provides speed, short iterations and runnable software early in the project lifecycle, but it does not necessarily secure the utility and usability of the product or service per se. Hence, we suggest that in addition to an agile approach one should also make use of a User-Centered Systems Design approach as proposed by Gulliksen and Göransson [3] thus putting the focus on the end user while providing adequate support for the designers and developers. We propose that our framework should be used as an aid throughout the development process by bridging the gap between the analysis phase and the design phase of each iteration. We propose an a priori evaluation framework intended to be used as a map, or as guidance if you may, during each iteration to help the designer transform the user needs into a system solution, thus minimizing the gap between the design model and the user's model [4].

7.4 Human Behaviour and Cooperation

Human performance is considered to be a key factor in 'total system performance' and it is recognized that enhancements to human performance will correlate directly to enhanced total system performance, and reduced life cycle costs. [5] Focusing on human performance means to focus on human behavior, i.e. human activity patterns. Notably, one of the strongest assets of human beings are their ability to interact with each other in quite complex ways in order to fulfill a great number of simultaneous individual and cooperative tasks initiated from a wide variety of intentions [6]. These interactions take place within a group of people, i.e. two or more participants, who can be considered to cooperate to the extent that they (1) consider each other cognitively in interaction, (2) have a joint purpose, (3) consider each other ethically in interaction, and (4) trust each other to act according to 1–3 [7]. Novices and experts meet in different groups within which they can take on passive, active or expansive roles [8], while belonging to different communities of interest and practice at the same time [9]. Their interactions can be collective or dispersed and they can be direct, i.e. interpersonal, or indirect, e.g. mediated by computers. Furthermore, depending on their level of involvement, one can consider them to engage in no interaction, lightweight interaction, information sharing, coordination, collaboration or cooperation. In addition, the way the end users communicate with each other and with the computer system depends on the communication channels provided, i.e. the interaction modalities or combination of modalities available. Examples of input modalities are the traditional mouse and keyboard, to the more contemporary tactile, gesture and vocal interfaces, and the emerging eye-tracking and brain–computer interface (BCI), also known as mind-machine interfaces (MMI). Evidently, the complexity of human behavior and cooperation together with the challenges posed on the designer regarding the choice of interaction modality, or combinations of modalities, demands a comprehensive framework to avoid infoglut when moving from analysis to design. Stressors caused by inadequate work environments affect our ability, willingness and opportunity to perform. Hence, what we propose is a framework that takes into account the biological, mental and contextual aspects of human behavior/activity patterns.

Based on the work of prominent scientists during mid and late nineteenth century, such as Charles Robert Darwin, Gustav Theoder Fechner and Mikhaylovich Sechenov, the Russian psychologist Lev Semyonovich Vygotsky founded cultural-historical psychology, thus closing the gap between the natural sciences and the mental sciences of human behavior. He approached behavior not as a result but rather as a process in motion and in change, i.e. by studying behavior as interaction. Vygotsky's research on activities bridged the gap between the mental and the physical contexts of human behavior and consciousness [10]. Activity Theory (AT), an evolution of Vygotsky's research, provides a basic framework for human interaction and for us a useful basic unit of analysis; the activity.

The AT concept deals with a set of fundamental types [8], which are:

- An object – Activities can be distinguished by their objects. It is the object and the transformation of that set object that drives the activity.
- A collective phenomenon – The activity does not take place in isolation but is always a collective phenomenon.
- A subject (agent) – The activity has a subject or a collective of subjects who understands the motive of the activity. In our research we refer to the subject as an actor or a role.

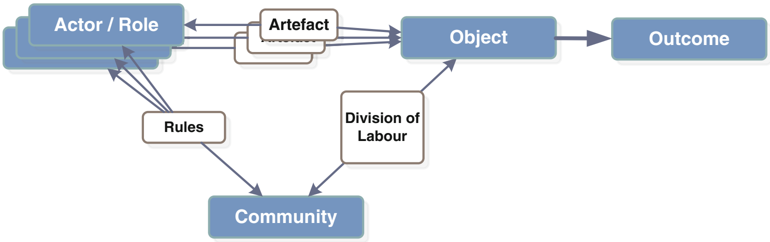

Fig. 7.1 The basic structure of a cooperative activity [11] with its properties visualized and given a relation to each other with mediating artefacts, rules and division of labour being multimodal in their character

- A material environment – The activity exists in and transforms its material environment.
- A historically developing phenomenon – The activity is a process that has a shared memory.
- Contradictions – The force behind the development of an activity are contradictions.
- Actions – Participants realize an activity through conscious and purposeful actions.
- Culturally mediated relationships

These fundamental types can easily be illustrated in a diagram together with their individual relationships. Kuutti's research [8] on AT and its fundamental types has resulted in a useful framework for research on computer-supported cooperative work. Cadier [11] extended the AT framework of Kuutti to manage both negotiation and execution of cooperative work (see Figs. 7.1 and 7.2, below), thus enabling analysis of cooperative activity.

The model in Fig. 7.1, above, depicts the 'playground' of an activity, whereas the model in Fig. 7.2, below, illustrates the actual execution process of an activity and its sub-activities/tasks and operations. Furthermore, this model also illustrates the cooperative steps of an activity where the negotiation of division of labor is the starting point, but also the result.

Based on this knowledge we can conclude that cooperation is heterogeneous where contradictions force activities [8], that it is culturally and contextually situated and that it makes use of internal as well as external communication [10], both verbal and non-verbal [7], to organize the same activities. These activities the users later execute with the help of mediating artifacts such as computer systems. We can also conclude that the level of verbal versus non-verbal communication depends on the social context of the actor/role, which are mediated via social rules and norms and the activity's division of labor. This would suggest that no person act in isolation and that one could consider all activities, if taking into account the different levels and types of human interaction and work support, as multimodal and as being either cooperative activities or task work activities [12] where the team make use of situated and distributed cognition and cognitive processes [13].

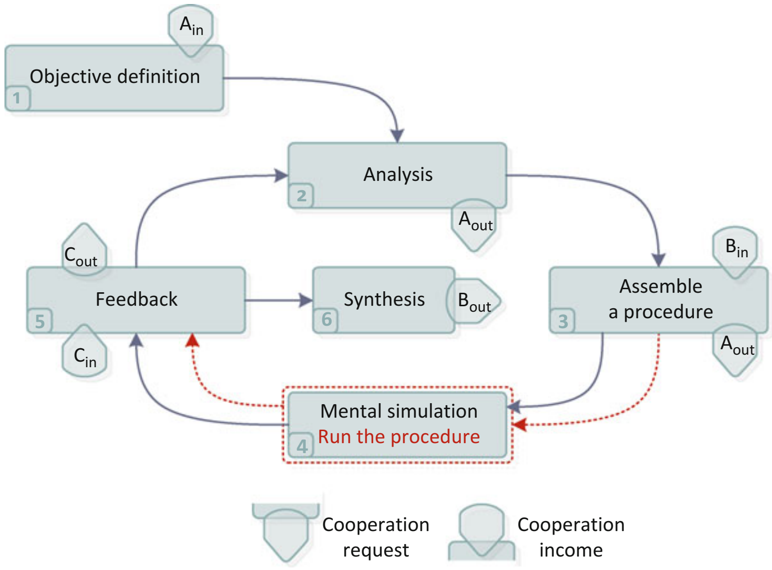

Fig. 7.2 An iterative cooperative activity process [11] where cooperative requests are multimodal acts of negotiation and decision whilst the rest of the process is multimodal (internal as well as external) actions

Based on this understanding of human interaction and CSCW we can look closer at what implications this has on the choice of interaction modalities and how we can develop a framework suitable for designers.

7.5 A Sound Choice of Interaction Modality

Human behavior, interaction and cooperation are multimodal by origin and considered natural in its essence. AT provides, as shown, a comprehensive high-level framework for organizing cooperative activities into manageable entities. However, in order to be able to provide any insight into preferred choice of multimodality for any specific context to provide a seamless natural interaction we need to enhance and develop it further. To be able to manage the cognitive aspects of the actors/roles in cooperation we can make use of Endsley's Situation Awareness (SA) model [14], which, in combination with our understanding of the human sensor and motor system provide a mind and body description of human capabilities (see Fig. 7.3, below). The actor/role has been given a physical interface in his/her motor and sensor system as well as a detailed description of his/her mental capabilities, which both take part in transforming the object mediated by an artifact, e.g. a computer system, and vice versa. The same goes for the mediated interaction with the community via cultural rules and norms. Together, the mind and body define the

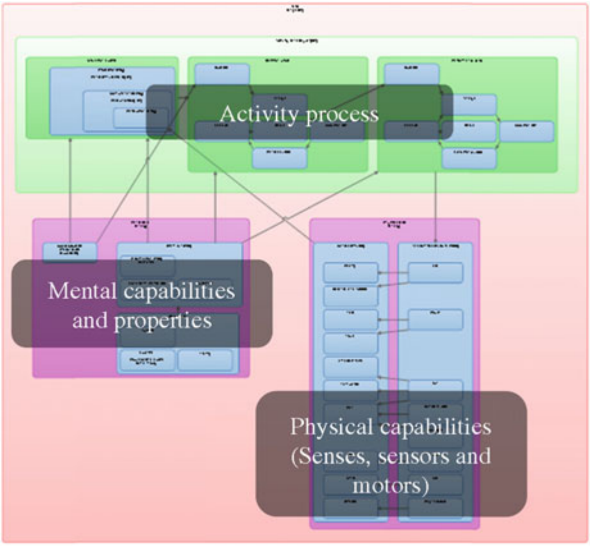

Fig. 7.3 Enhanced actor/role model based on work of [8, 9, 11], and [14]

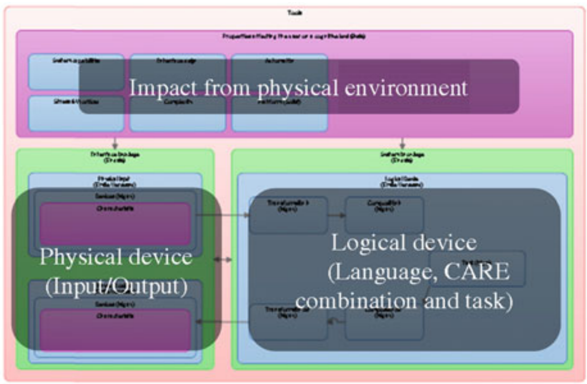

Fig. 7.4 Our latest artifact model of the computer interface based on the work of [1, 10, 15], and [16]

activity process from SA via decision to execution of the activity, either alone or in cooperation with other actors/roles. The actors'/roles' mental capabilities and properties are affected by the community's social and cultural rules and vice versa and the actors'/roles' use of artifacts to transform the object of interest into sought for outcome also transforms the actor/role in that same process.

A computer system also has a physical interface towards the outside world and an inner "mental" core based on the intentions of the system creators as well as its users' use and re-work (see Fig. 7.4, below). The physical aspects, i.e. input and output devices, together with the logical interaction language make an interaction modality which together with e.g. CARE properties can be combined into multimodal interactive systems [15] while providing plasticity [1] to correspond to the changing context.

By comparing the actors' different mental capabilities and properties, and their objectives with the logical device and the intended task support of the computer system, while taking into account both cooperative tasks and work tasks, one can evaluate the mental aspect of the activity, i.e. the systems cognitive properties [17]. Furthermore, by at the same time comparing the physical capabilities of the actors with each other and with the computer system one can find constraints as well as possibilities of interaction modalities. The actors' negotiation with the group and the community regarding division of labor while executing tasks aided by a computer system changes the way a task is conducted and what interaction modalities that are suitable for the overall activity as well as the execution and negotiation of the task work. In addition, if considering the impact of activity workload and external as well as internal stressors and its impact on human cognition and behavior one can design the system to correspond to the needs of the users regarding interaction modality.

7.6 Conclusion and Future Work

The continuous development of our models based on our cross-disciplinary research proves very promising. Our research on the next generation work support for tactical commanders and sensor operators within maritime surveillance, who work closely within highly specialized teams, while making use of different kinds of interaction modalities or combinations of modalities to execute their work, and who operates under stressful conditions, are well suited for our research. We hope that our results will shed some light on the impact of cooperation on the preferred choice of interaction modalities and vice versa. Our framework will be a welcome help for novice designers of cooperative multimodal systems when making expert decisions in choice of modality or combinations of modalities while designing for optimal performance. However, our research is only scratching the surface of a research field that needs much more attention and thorough investigation.

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