TIME DESIGN

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The goal of this panel is to discuss theoretical and methodological approaches that may inform and support the design of temporal aspects of interactive systems. *Time Design* is an emerging research and development domain that emphasizes the functional, causal role of time in human control behavior. It draws on a diverse literature on time in cognitive psychology, psychophysics, sociology, computer science, engineering, Human Factors and HCI. Relevant research domains include heuristics and biases in temporal decisions, temporal aspects of human-automation interaction, planning and scheduling, visualisation of temporal information, and the timing of alarms and interruptions.

INTRODUCTION

Temporal requirements are among the main drivers of design efforts and innovations in socio-technical systems: the real-time economy relies on fast and timely transport of goods and people, technical progress has led to the acceleration of work processes, and the role of the human in these systems is transformed increasingly into that of supervisory controller of a multitude of concurrent functions. Many of the design challenges that arise in these systems are well supported by, for instance, methods in Operations Research (e.g. scheduling and queuing models) and Human Factors (e.g. Dynamic Function Allocation). Where time is considered in design decisions, it is usually viewed as an external constraint (deadline view), as a descriptive property of behaviour (epiphenomenal view), as a stressor acting on the human operator, or as a variable that is to be controlled or optimized.

More recently, there has been a growing interest in a *functional* view of time supported by research into higher-level aspects of temporal decision-making (c.f. Varey and Kahneman, 1992). A functional, or causal, view of time explores the ways in which human control behavior is sensitive to temporal information and temporal knowledge, what heuristics and biases occur in the temporal control decisions, and how temporal aspects of the system constitute *degrees of freedom* that the operator can use to make adaptive control decisions. Together, these notions of time begin to chart a design space that consists of, at least, the following dimensions:

- *Time as property of the automation, machine or interface:* e.g. service rate, responsiveness, display of temporal information, temporal validity, interface support for temporal awareness,
- *Time as an aspects of user behaviour:* e.g. perceptual and physiological timing issues, temporal orientation, anticipative or reactive control mode, temporal reasoning, temporal memory, reaction to time stress, pace of interaction, personal or social attitudes towards time,
- *Time as a property of the task:* e.g. interleavability, pre-emptability
- *Time as a property of the environment:* e.g. predictability and regularity of task arrival, self-paced vs. system-paced interaction, deadlines.

The term "Time Design" can be used to designate the process of exploring this design space, a process that is supported by a diverse literature on time in cognitive psychology, psychophysics, sociology, computer science, engineering, Human Factors and HCI, as well a variety of representation, analysis and modelling techniques. The three main aims of Time Design are

(a) to make explicit to the designer the temporal design options available,
(b) to support the designer in exploring the trade-offs involved in these options, in particular where a human operator and an automation are involved, and
(c) to provide empirical knowledge, theories and models that can inform time design decisions.

RESEARCH CHALLENGES

The diversity of Human Factors research into temporal aspects of behavior is highlighted by the position statements below. Other research challenges we hope to address include the following:

Biases in temporal decision-making

A growing literature on temporal factors in judgment and decision making (e.g. Varey and Kahneman, 1992) argues that conventional utility models, where costs and benefits are usually described in terms of money or similar commodities, may not be valid models for describing the perception of temporal costs. Duration neglect appears to be a common phenomenon both in temporal reasoning and temporal memory. Similar biases are found in Human Factors research on human scheduling performance (for a review, c.f. Sanderson, 1989).

Of particular interest for human-automation interaction are premature and late decision biases associated with *when-to-act* problems. Many control tasks require an operator not only to decide *what* action to take, but *when* to take it. Kerstholt (1996) found evidence for a late decision bias in a task where the operator could have acted on the advice of a decision support system (DSS), but decided to gather additional information, thereby passing the deadline for implementing the control decisions (judgement- vs. action-oriented control strategy). Conversely, operators may take premature decisions when they act on the advise of a DSS in situations where enough time would have been available to gather additional information. The research challenge here is to identify configurations of task, system and environmental parameters that trigger or mitigate against *when-to-act* biases (e.g. visualisation of urgency, timing and reliability of an alarm; c.f Jürgensohn et al., 2001), as well as to provide insights into the psychological mechanisms that underlie these biases (e.g. duration neglect, time perception).

Temporal error

The term temporal error suggests a wide range of error phenomena, but is often used specifically to refer to sequence errors such as omissions, intrusions or inversions. As Hollnagel (1991) notes in his discussion of the phenotypes of human error, "[s]urprisingly, few of the existing action and error taxonomies include the aspect of time, but rather describe and classify human error on an atemporal (static) basis […] In many domains it is, however, necessary to include time in a much more conspicuous way, as, perhaps, one of the principal 'mechanisms' or 'error areas' of human action […] This is particularly true with respect to planning and scheduling."

System response times

Human-Computer Interaction research into system response time has challenged the widespread assumption that *faster* is always *better* (Shneiderman, 1984). Instead, task and interface characteristics, user expertise and goals, and the regularity and distribution of delays are important moderating variables. For applications where decisions are critical and non-reversible, it may be advisable not to reduce delays as much as technically possible, as fast response times have been shown to induce a faster (and sometimes less thorough) work style. Thus the responsiveness and pacing of a device are no longer just an emergent property of the system, but have become a design feature in their own right.

The temporal aspects of Dynamic Function Allocation (DFA)

By focusing predominantly on allocation along the human-automation resource dimension ("snapshot allocation"), current DFA paradigms may provide an insufficient basis for design decisions as they fail to take account of alternative function management strategies. Dynamic Function Scheduling (Hildebrandt and Harrison, 2003) represents an extension of DFA concepts that considers the allocation of functions along a joint human-automation time line.

Temporal awareness

Temporal awareness refers to the operator's knowledge, implicit or explicit, of process durations, deadlines, arrival rates, etc. In one of the few empirical studies on this subject, Grosjean and Terrier (1999) found that temporal awareness improved performance both in terms of errors committed and multiple-goal optimisation. However, there is still a lack of conceptual clarity in the concept of temporal awareness and in particular in its relation to overall situation awareness.

Representation and analysis

Task representation techniques are well equipped for modeling the sequential structure of single tasks, but are often inadequate for representing multiple concurrent or interleaved tasks and their durational properties. Of particular interest is the modeling of strategy switches where multiple tasks are no longer executed as a collection of single tasks, but transformed into a new compound function. Queuing and scheduling models, on the other hand, support the analysis of multi-task environments, but often treat tasks as atomic units with no representation of their sequential structure. The panel will discuss the feasibility of integrating these types of approaches.

POSITION STATEMENTS

The Design of Time

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When we think of design, our thoughts tend to focus on objects, things, or entities, and the materials of which they are composed. Thus, we are centrally concerned with the spatial aspects of design. In emphasizing the 'fit' between the human and the machine-environment complex, Ergonomics also tends to focus on the spatial aspects of the interaction over the dynamic or temporal characteristics. In some sense, this is to be expected, after all in mathematics and engineering itself, it is easier to work from first from statics (a timeless, momentary representation) and extend this to dynamics, rather than the other way around. Also, there is little to wonder at in this strategic approach since the world appears to us as a three-dimensional construct and only becomes dynamic by virtue of the apparently linear and immalleable flow of time about which we appear to be able to do little. The present work seeks to expose the flaws in such conceptions. First, all behavior is temporal, since non-temporal behavior is a logical contradiction. Second, time is neither immalleable nor linear, since these are constructs from the convenience of physics not the reality of experience. As a consequence, we have ample opportunities to design time. However, I will argue that our present largely unconscious and intrinsic efforts are clumsy, uninformed, and unsystematic. Indeed, I would go so far as to say that we have destroyed previous tried and tested rhythmic designations and replaced them with a temporal *ganzfeld* that has much to do with the ennui of modern-day experience. My exposition will address these issues and express what opportunities presently exist to structure a meaningful temporal world.

Timely and Accurate Decisions

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A long history exists in decision research in which the criterion for good decision making is defined largely by the quality of decision outcomes, disregarding when the outcomes are achieved. When people are making decisions interacting with technology in dynamic environments, however, the timeliness of a decision can be a crucial factor in overall decision effectiveness. We will present the results of a study in which we modelled the decision strategies used by commercial aviation pilots to make both timely and accurate navigation decisions during (surface) taxi navigation. We found that in order to meet the severe time constraints associated with navigating a 60,000 kg vehicle in low visibility conditions, pilots appeared to resort to "quick & dirty" heuristics that were surprisingly effective and robust, yet were nevertheless defeated in rare instances by atypical combinations of ATC clearances and taxiway geometry. This research highlights the need for a reformulation of the concept of a speed- accuracy trade-off in decision making, since in dynamic tasks, the accuracy of a decision is often inseparable from its timeliness.

Time-related Considerations in Adaptive Collision Warning Systems

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New technology is moving into cars and with it comes the demand to design for a variety of time-related considerations that have substantial safety consequences. The timing of collision warnings is an important example. Collision warning systems use radar and laser range finders to estimate the proximity of surrounding vehicles and algorithms combined these data to assess the threat of collision. Early warnings give drivers more time to respond, but are also prone to sensor noise and may be viewed as not very useful by drivers. Recently, researchers have advocated that these safety systems adapt to the driver state. For example, the warning threshold might be adjusted downward if the driver is detected to be distracted or drowsy. Estimating driver state introduces another set of time-critical considerations that must be integrated with the collision warning system. Unfortunately the time constants of these estimation processes differs by approximately two orders of magnitude: 200msec for the collision warning system and 200 seconds for some estimates of driver workload and fatigue. Reconciling these time-related considerations depends on innovations in algorithm design and information presentation.

Time as Information

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Time between events serves in many cases as an information source for operators. Typical examples are the time between actions in a task that requires periodic activities, such as the scanning of instruments or the observation of time between events as an indication for the functioning of a process. Research on duration estimates has shown two main properties of subjectively experienced time. First, the content of the time interval will affect the experienced duration. Second, the person's actions during the time interval, including her or his monitoring of the events, affect the experienced duration of the event. Some of the implications of these properties of time perception for the use of time as an information source, especially in critical tasks, will be discussed.

Guidelines for Coordinating Complexity in Ambiguous Environments over Time

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The complexity of large-scale technical and collaborative work-systems requires significant effort for coordination, with system status at any given time often containing a large degree of intractable ambiguity and uncertainty. The process of coordinating a suite of surgical operating rooms

(ORs) is one example of such as complex system. Examining the information usage in this setting can provide functional requirements for technology to support these coordination activities, and elucidate the role of and tolerance for ambiguity as a function of time. Observations provided evidence that, to provide necessary functionality, any new technology system must (a) serve as a common referent for communication, (b) provide a communal memory tool for planning (c) serve as catalyst for collaborative and distributed cognition (d) allow parallel manipulation for multiple user-groups, (e) allow flexible content-reconfiguration. We additionally propose a model describing ambiguity-tolerance as a function of time to explain specific information-seeking behaviors.

Interruption Scheduling

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At first glance it seems absurd that busy people doing important jobs should want their computers to interrupt them. However, successful job performance also frequently depends on people's abilities to (a) constantly monitor their dynamically changing information environments, (b) collaborate and communicate with other people in the system, and (c) supervise background autonomous services. Automated notification systems can perform the constant monitoring, but they induce alerts that may interrupt other activities. People do not perform sustained, simultaneous, multi-channel sampling well; however, they have great capacity to manage concurrent activities when given specific kinds of interface support. Our findings reject the hypothesis that the temporal delivery of human interruptions can be fully automated. Timing issues are often very complex and it is usually either prohibitively expensive or technically impossible to construct a reliable algorithm. We present practical design results that have been proven in the Aegis Weapon System to maximize human performance during interruptions.

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