PART II: SAFETY ANALYSIS IN CRITICAL DOMAINS

This part is dedicated to the analysis and support of human functioning in safety critical and dynamic environments, such as air traffic management or warfare. Here incident models based on some case studies and a model of an adaptive display and are introduced and formally analyzed. Chapter 1 describes a model for information presentation developed for an adaptive display and its integration with a model of operator's functional state, such as for example stress or high workload etc. The focus of this ambient system lies in the operator's comfort and safety. The model described in this chapter corresponds to an intermediate (cognitive) level of process abstraction across the *process abstraction* dimension of the models classification framework and to local levels with respect to the *time* and *agent cluster* dimensions. Chapter 2 describes the formal analysis of an aviation incident based on a real life case study by means of formalization and dynamic simulations. The case study describes an incident that occurred in one European airport in 1995. The incident analysis is performed at local, intermediate and global levels of the temporal dimension and intermediate and global levels of the process abstraction dimension of the multi-agent system. With respect to the agent cluster dimension, all models described in this chapter refer to the local level. Chapter 3 contrasts agent-based analysis of aviation accidents with other popular accident analysis approaches in aviation, such as Event Trees, FRAM and STAMP. In this chapter four approaches were applied to one case study and a comparative analysis of the approaches is given. The models presented in this chapter correspond to local and intermediate levels across all three dimensions: process abstraction, time and agent cluster. In Chapter 4 a formal analysis of accident risk and conflict resolution events of a future TIPH (Taxiing into Position and Hold) air traffic operation is described. It was done by means of a definition of relevant events in a stochastic dynamic risk model and calculation events probabilities during Monte Carlo simulations of the model. The model can be positioned at an intermediate level of process abstraction dimension and at local levels of time and agent clustering. Chapter 5 presents an integration of three agent-based models and an application of the integrated model to a real life incident analysis. This complex integrated model occupies the same position in the cube as the models described in Chapter 4. Finally, in Chapter 6 two different modelling approaches are contrasted: a population-based approach at an aggregated agents cluster level and an agent-based approach at an individual level. Both models were applied in the context of Situation Awareness spread in a group. The models in Chapter 6 correspond to the intermediate and local levels of agents cluster dimension, to an intermediate (cognitive) level across the process abstraction dimension and a local level across the time dimension.

Chapter 1

An Integrative Agent Model for Adaptive Human-Aware Presentation of Information during Demanding Tasks

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An Integrative Agent Model for Adaptive Human-Aware Presentation of Information during Demanding Tasks

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Abstract. This paper presents an integrative agent model for adaptive human-aware information presentation. Within the agent model, meant to support humans in demanding tasks, a domain model is integrated which consists of a dynamical model for human functioning, and a model determining the effects of information presentation. The integrative agent model applies model-based reasoning methods to the domain model to analyze the state of the human and to determine how to adapt the presentation of information to this state.

1 Introduction

When a human is performing a demanding task, often support can be offered by presenting information that is relevant for the task. For example, a naval officer or air traffic controller may be offered visualized information on location and speed of several objects in the environment, and of the characteristics of such objects. Other cases are when information is presented on the workflow that is being followed, and on the status of the different tasks in a workflow, or relevant task information such as manuals for systems used. In all of such cases the human may take the initiative, for example, by activating certain options using menu structures. However, especially when tasks require a high level of attention and concentration, it is more beneficial when the human does not need to bother about such presentation aspects, by giving the system itself an active role in offering information of appropriate types and forms.

Adaptive information presentation can provide a useful type of support in a number of application contexts, varying from tourists in a museum (e.g., [17, 20]) and users in hypermedia and Web contexts (e.g., [22]), to students using educational systems (e.g., [13]) and humans in demanding tasks (e.g., [8, 10]). A main requirement for an adaptive information presentation system is that it presents information in types and forms that are strongly depending on these circumstances. Here circumstances may involve a number of aspects, for example (see also, e.g., [7, 19]): (1) the characteristics of the task, (2) the characteristics of the human involved, such as expertise level with respect to the task, (3) the state of the environmental context (4) task status and task progress, and (5) the cognitive, affective or functional state of the human. Here (1) and (2) may be considered static over longer time periods, but (3), (4) and (5) usually have a highly dynamic nature. To take such aspects into account an adequate presentation system has to be highly adaptive and has to be constantly aware of them.

Awareness of the state of the human, the task and the environment can in part be based on observation and sensoring information acquired. However, often awareness is required on aspects for which information cannot be acquired in a direct manner, for example, the level of anxiety, stress and exhaustion of the human, or the progress on the task. In such cases dynamical process models can be used to relate information that is directly acquired to information about aspects that are not directly accessible. In this paper an integrative agent model for an adaptive human-aware presentation system for humans in demanding tasks is presented that makes use of a dynamical model of human functioning, in particular to monitor the human's functional state (covering aspects such as exhaustion and experienced work pressure), combined with a model to determine the effects of information presentation. In Section 2 first the context is described in some more detail. A computational domain model is introduced in Section 3. Section 4 introduces the overall architecture of the integrative agent model. Section 5 presents simulation results based on one example scenario. Finally, Section 6 is a discussion.

2 On Adaptivity in Information Presentation

The context of the research reported in this paper is the domain of naval operations. An operator on a naval ship has to decide on and perform actions within limited time. The results of these actions can be critical for the result of the entire operation and can even be critical for self preservation, so besides timeliness, quality of human task performance is also essential.

Given this context and the inherent fallibility of human task performance, automated support for operators in strenuous situations is an interesting topic of research that is likely to be beneficial. This kind of support cannot only be provided at the team level, but also on an individual level. An example of support at the individual level is *adaptive information presentation*, in which information presented to an operator is personalized and adapted to his specific circumstances. This last kind of support is explored in this paper.

The main principles of design of information presentation in displays are extensively described in literature on human information processing and human factors; e.g., see [12, 25]. It is well established in this literature that a good display design can enhance information processing and improve human performance. However, this conventional display design is based on the general characteristics of human information processing and aims to serve an average person performing a particular type of a task. It usually does not consider personal characteristics and dynamic, constantly changing environments and human functional states. The goal of the research reported here is to incorporate principles of information presentation in a dynamic model along with such factors as operator's functional states, environmental and task characteristics. The integrative model presented in this article will represent the relations between these factors and human functioning while performing a task.

Cognitive performance is affected by the human's activation state, or alertness. Alertness is a physiological state that affects the attentional system and varies depending on internal and external factors [23]. Besides alertness, cognitive performance is also influenced by human information processing aspects, such as perception and working memory [25]. It is well-established that bright light rapidly increases alertness [18]. Therefore one of the assumptions underlying the work reported here is that the level of brightness, or *luminance*, may have an effect on alertness of an operator. Another characteristic of a display that may affect alertness is the *background colour* [21]. The *time of the day* is an environmental aspect that can also influence alertness according to numerous findings that relate alertness and performance to circadian rhythms. It is found that the activation of central nervous system passes through different stadia during the day according to the inner clock in a brain [25]. Fatigue, the physiological and psychological state of tiredness and dislike of present activity, is one of the aspects that influence a person's functioning [23]. It may be assumed that *exhaustion* has also negative influence on the alertness level as exhaustion is placed on a higher level of tiredness-fatigue-exhaustion continuum. Exhaustion as a factor that affects a person's functioning while performing a critical task is also mentioned in the functional state model presented in [2]. It is also found that motivation and alertness are correlated [11]**.**

The findings below describe the relations between different factors of information presentation and processing demands. Display *luminance* affects visual search performance with monitor displays without affecting detection performance significantly [14]. According to Badderley's theory about the working memory, if the visuo-spatial sketchpad buffer of working memory is totally occupied by the processing of visuo-spatial information during the execution of a task, no more visual information can be perceived and processed [1]. In this case presenting information in another modality, auditory for instance, will lead to less processing demand if a task being performed requires predominately visuo-spatial resources, but will lead to more processing demand if a task is predominantly auditory. This principle is applied in the PACE (Performance Augmentation through Cognitive Enhancement) system architecture developed for the conditions of high stress and workload and presented in [16]. The *grouping* of numerous objects imposes less processing demand because attention resources are applied on the groups of objects at certain locations rather than on the whole field of a display with the isolated objects [25]. Symbol size plays a role in processing demand too. The larger the symbols are, the easier it is to process them, but after a certain threshold there is no gain in processing anymore [6]. It may be hypothesized that the processing of objects is performed in the same way: the larger the objects, the easier it is to process them. On the other hand, it is obvious that the more objects occur in a display and the larger they are, the more processing demand may be imposed as the objects become less distinct and more difficult to perceive.

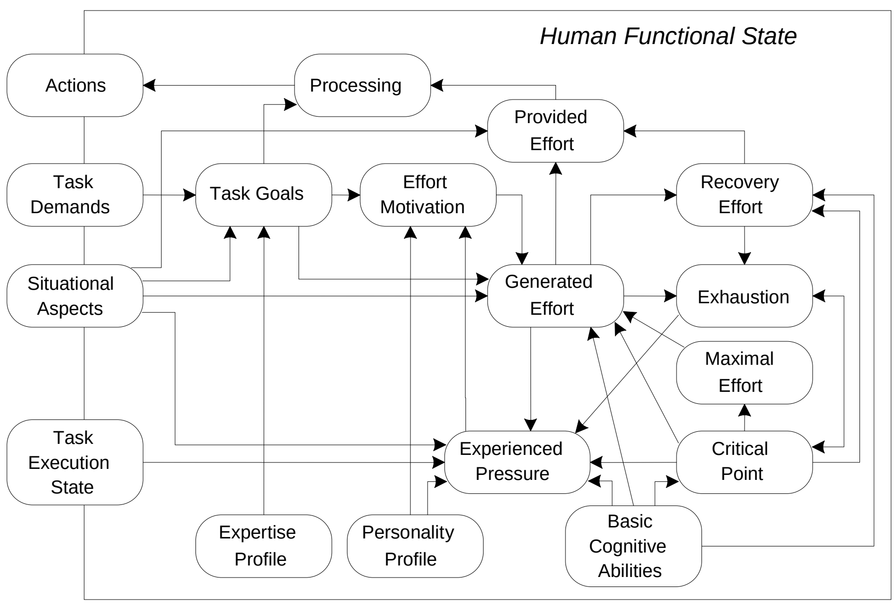

Figure 1. Functional state domain model.

3 A Domain Model for Functional State and Presentation Aspects

In this section the domain model used is presented, which consists of two interacting dynamical models, one to determine the human's functional state and one to determine the effects of the chosen type and form of information presentation. The approach used to specify the domain model is based on the hybrid dynamical modeling language LEADSTO [4]. In this language, direct temporal dependencies between two state properties in successive states are modeled by *executable dynamic properties*. The LEADSTO format used here is defined as follows. Let α and β be state properties. In the LEADSTO language the notation $\alpha \twoheadrightarrow_D \beta$, means:

If state property α *holds at some time t, then state property β will hold at time t+D*

Here, state properties can have a qualitative, logical format, or a quantitative, numerical format, and may consist of conjunctions of atomic state properties.

The dynamic model for the functional state used was adopted from [2]; for a global picture, see Figure 1. Here the functional state is defined as the combination of exhaustion (fatigue), motivation, experienced pressure, and effort. These are determined by external factors such as task demands and the state of the environment, and by personal factors such as experience, cognitive abilities and personality profile. Originally the model was implemented in MatLab. For the work reported here it was remodeled in LEADSTO and integrated within the agent model, as discussed in Section 4. On the one hand this model is based on the (informal) cognitive energetic framework [9], that relates effort regulation to human resources in dynamic conditions. On the other hand, the model is based on literature on fatigue in exercise and sports as formalised by a computational model in [24], in particular on the concept *critical power*, which is the maximal effort level a person can (constantly) maintain over a longer time period without becoming (fully) exhausted.
The arrows in Figure 1 denote causal dependencies; note that cycles occur. For example, generated effort is affected by the person's motivation level (*effort motivation*), the amount of effort the task requires (*task level*) and the effort the human is able to contribute (*critical point* and *maximal effort*). When generated effort is above the critical point, the exhaustion is increased. When generated effort is below the critical point, some recovery takes place (*recovery effort*), thus decreasing *exhaustion*. Effort contributed to cope with noise in the environment (*noise effort*) is extracted from the generated effort, so that the effort that can effectively be contributed to the task (provided effort) is less. The motivation is taken proportional to the task level, but also depends on the *experienced pressure*. An *optimal experienced pressure* is assumed which depends on the *personality profile*. The dynamical model has been formalised as a system of differential equations. For more details of this model, see [2].
The interaction from the model for information presentation to the model for functional state takes place by affecting the task demands. Conversely, a number of aspects of the functional state are used as input by the information presentation model: effort motivation, exhaustion, experienced pressure and provided effort. Figure 2 shows an overview of the information presentation model.
The general paradigm of the relations within the presentation model is partially based on the existing models on workload that consider the fit between individual factors, such as coping capacity, effort, motivation, on one side and work demands on the other side. One example of such a model can be found in [15]. This paradigm has been applied to the fit between the effort that a human is willing to invest while performing a task and demand. Effort is determined by internal and external factors while demand is imposed externally.
Presentation format aspects can be seen as a part of task demands that are imposed on a person because a form of a presentation may change processing demands. On the other hand, some presentation aspects, for example, background colour and luminance, can be seen as available resources that help a person to perform a task. Luminance is regarded both as a part of demands and as a part of resources in this model. All types of aspects are converged into two more global internal factors that influence the task performance: physiological state of *alertness* and mental *information processing* state of an operator.

Among these concepts a distinction is made between the states of available and used recourses of alertness and information processing, *alertness utilization* and *provided effort* respectively, and the states of demand for alertness and information processing, *alertness demand* and *processing demand*. The fit between the usage of these capacities and the demands determines the functioning of a human while performing a task, the *functioning fit*. Two specific types of fit are considered: *alertness fit* and *processing fit*.
If the usage of capacities and demands are at the same level, the fits will be high. If the levels of capacities and demands differ much, then the fits will be low. If both *alertness fit* and *processing fit* are high, then the *functioning fit* will be high.
All inputs for the model are represented by numbers between *0* and *1*. The same holds for the concepts *objects distinctness*, *visual demand*, *phonological demand*, *alertness demand*, *alertness utilization*, *processing demand*, and *available effort*. The concept *alertness fit* indicates the difference between alertness demand and alertness utilization and is represented by a number between *-1* and *1*. The same holds for *processing fit* which is the difference between available effort and processing demand. This was expressed in LEADSTO as can be found in Appendix A.

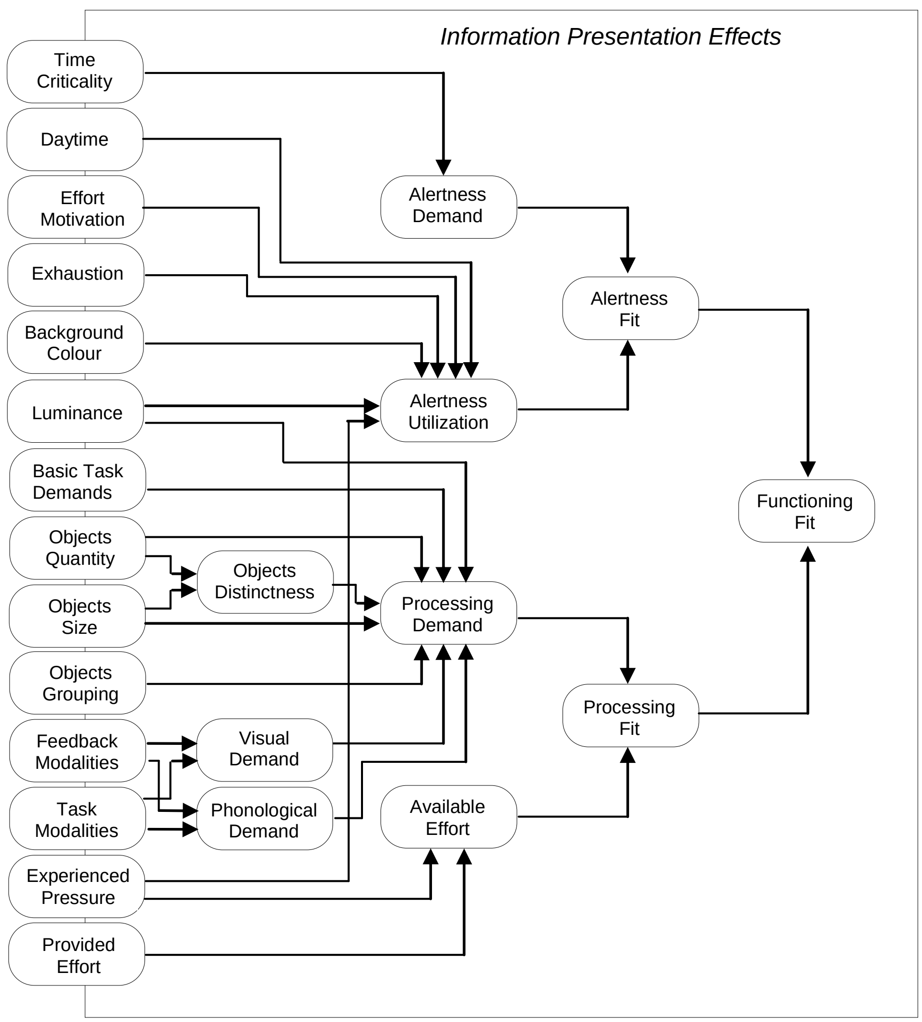

Figure 2. Information presentation effect domain model.

4 Overall Architecture of the Information Presentation System

For the overall architecture of the integrative agent model, principles of component-based agent design have been followed, as, for example, used within the agent design method DESIRE; cf [5]. Within the agent model two main components have been distinguished: the analysis component and the support component (see Figure 3). Accordingly, two different ways to integrate the domain models within the agent model have been used; see Figure 3.

- *analysis component*

To perform analysis of the human's states and processes by (model-based) reasoning based on observations and the domain model.

- *support component*

To generate support actions for the human by (model-based) reasoning based on observations and the domain model.

Within these components of the agent model, the domain model has been integrated which by itself consists of two (dynamical) models, as described in Section 3: a model for the functional state of the human and a model for the effects of information presentation. By incorporating such domain models within an agent model, an integrative agent model is obtained that has an understanding of the processes of its surrounding environment, which is a solid basis for knowledgeable intelligent behaviour. Note that here the domain model that is integrated refers to one agent (the human considered), whereas the agent model in which it is integrated refers to a different agent (the ambient software agent).

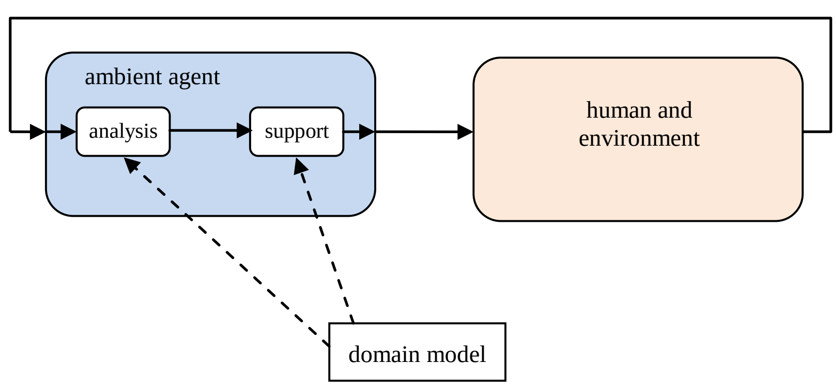

Figure 3. Overall design of the ambient agent and the integration of the domain model. Here solid arrows indicate information exchange (data flow) and dotted arrows the integration of the domain model within the agent model.

Analysis Component

Within the analysis component, by model-based reasoning forward in time based on the domain model, predictions are made about future states of the human and the environment. The integration of the domain model relationships within such an analysis model for model-based reasoning forward in time is done in a systematic manner by replacing the atoms in a domain model relationship, for example

has_value(a, V_1) & has_value(b, V_2) $\twoheadrightarrow_D$ has_value(c, f(V_1, V_2))

> with f(V_1, V_2) a function of V_1 and V_2 by predictions of the ambient agent about them:

predicted_value_for(a, V_1, t) & predicted_value_for(b, V_2, t)
$\twoheadrightarrow$ predicted_value_for(c, f(V_1, V_2), t+D)

An example of a function f(V_1, V_2) is a weighted sum function with weights w_1 and w_2:
$f(V_1, V_2) = w_1 * V_1 + w_2 * V_2$.
A more detailed description of the analysis component is given in Appendix B.

Support Component

Within the support component model-based reasoning based on the domain model takes place in a goal-directed manner, backward in time starting from desired (adjusted) future states. Within the support component this model-based reasoning can be done in a qualitative manner or in a quantitative manner. The former case is shown in Appendix C, where based on the causal graph as depicted in Figure 2, desires to increase or decrease values are derived (from right to left, against the direction of the arrows), in a heuristic manner without specifying numerically how much the increases or decreases should be. Below it is shown how a quantitative approach can be used, based on the more precise numerical relations of the information presentation model. In this case the integration of a domain model relationship within a support model for model-based reasoning backward in time can be done in a systematic manner by embedding some atoms in a domain model relationship in adjustment desires and some in beliefs and reversing the order, for example,

has_value(a, V_1) & has_value(b, V_2) $\twoheadrightarrow_D$ has_value(c, f(V_1, V_2))

for the case that the attribute b is kept fixed (not adjusted) is transformed into:

desire_for(c, V_3, t+D) & belief_for(b, V_2, t) $\twoheadrightarrow$ desire_for(a, g(V_2, V_3), t)

where g(V_2, V_3) is a function of V_2 and V_3 that inverts the function f(V_1, V_2) with respect to its first argument: $f(g(V_2, V_3), V_2) = V_3$ and $g(V_2, f(V_1, V_2)) = V_1$. For the example of a function f(V_1, V_2) as a weighted sum with weights w_1 and w_2 the inverse function is found as follows:

$f(V_1, V_2) = w_1*V_1 + w_2*V_2 \Leftrightarrow V_3 = w_1*V_1 + w_2*V_2 \Leftrightarrow w_1*V_1 = V_3 - w_2*V_2 \Leftrightarrow V_1 = (V_3 - w_2*V_2)/ w_1$
$\Leftrightarrow g(V_2, V_3) = (V_3 - w_2*V_2)/ w_1$.

It is also possible to distribute a desire for adjustment over adjustment desires for multiple attributes. Suppose as a point of departure an adjustment Δv_1 is desired, and that v_1 depends on two variables v_{11} and v_{12} that are adjustable (the non-adjustable variables can be left out of consideration). Then by elementary calculus the following linear approximation can be obtained:

$$\Delta v_1 = \frac{\partial v1}{\partial v11}\, \Delta v_{11} + \frac{\partial v1}{\partial v12}\, \Delta v_{12}$$

This is used to determine the desired adjustments Δv_{11} and Δv_{12} from Δv_1, where by weight factors μ_{11} and μ_{12} the proportion can be indicated in which the variables should contribute to the adjustment: $\Delta v_{11}/\Delta v_{12} = \mu_{11}/\mu_{12}$. Since

$$\Delta v_1 = \frac{\partial v1}{\partial v11}\, \Delta v_{12}\, \mu_{11}/\mu_{12} + \frac{\partial v1}{\partial v12} \Delta v_{12} = \left(\frac{\partial v1}{\partial v11}\, \mu_{11}/\mu_{12} + \frac{\partial v1}{\partial v12} \right) \Delta v_{12}$$

then the adjustments can be made as follows:

$$\Delta v_{12} = \frac{\Delta v1}{\frac{\partial v1}{\partial v11} \mu 11/\mu 12 + \frac{\partial v1}{\partial v12}} \quad \Delta v_{11} = \frac{\Delta v1}{\frac{\partial v1}{\partial v11} + \frac{\partial v1}{\partial v12} \mu 12/\mu 11}\, \frac{\Delta v1}{\frac{\partial v1}{\partial v11} + \frac{\partial v1}{\partial v12} \mu 12/\mu 11}$$

Special cases are $\mu_{11} = \mu_{12} = 1$ (*absolute equal contribution*) or $\mu_{11} = v_{11}$ and $\mu_{12} = v_{12}$ (*relative equal contribution*: in proportion with their absolute values). As an example, consider again a variable that is the weighted sum of two other variables: $v_1 = w_{11}v_{11} + w_{12}v_{12}$. For this case, the partial derivatives are w_{11} respectively w_{12}; therefore

$$\Delta v_{11} = \frac{\Delta v1}{w11 + w12\, \mu 12/\mu 11} \qquad \Delta v_{12} = \frac{\Delta v1}{w11\, \mu 11/\mu 12 + w12}$$

When $\mu_{11} = \mu_{12} = 1$ this results in $\Delta v_{11} = \Delta v_{12} = \Delta v_1/(w_{11}+ w_{12})$, and when in addition the weights are assumed normalized, i.e., $w_{11} + w_{12} = 1$, then it holds $\Delta v_{11} = \Delta v_{12} = \Delta v_1$. Another setting is to take $\mu_{11} = v_{11}$ and $\mu_{12} = v_{12}$. In this case the adjustments are assigned proportionally; for example, when v_1 has to be adjusted by *5%*, also the other two variables on which it depends need to contribute an adjustment of *5%*. Thus the relative adjustment remains the same through the backward desire propagations:

$$\frac{\Delta v11}{v11} = \frac{\Delta v1}{w11 + w12\, v12/v11} / v_{11} = \frac{\Delta v1}{v1}$$

This shows a general approach on how desired adjustments can be propagated in a backward manner using a domain model. For a detailed description of the support component see Appendix C.

5 Simulation Results

In order to analyse the behaviour of the integrative agent model, a number of simulations have been performed using the LEADSTO software environment; cf. [4]. The model exhibits behaviour as expected: after the assessment of alertness and/or processing fit as inadequate, the agent performs the relevant manipulations of information presentation aspects. As a result of the manipulations, both alertness and processing fits that are constituents of functioning fit are improved. As a consequence of alertness and processing fit improvement, functioning fit that represents general task performance becomes also better. For example, in the simulation depicted in Figure 4, it can be seen that after the manipulations of the ambient agent functioning fit, alertness fit and processing fit have improved. Time flow is represented on the horizontal axis and the values of alertness fit, processing fit and functioning fit are represented on the vertical axis. Dark bars in the figure represent the time intervals when a certain statement is true.

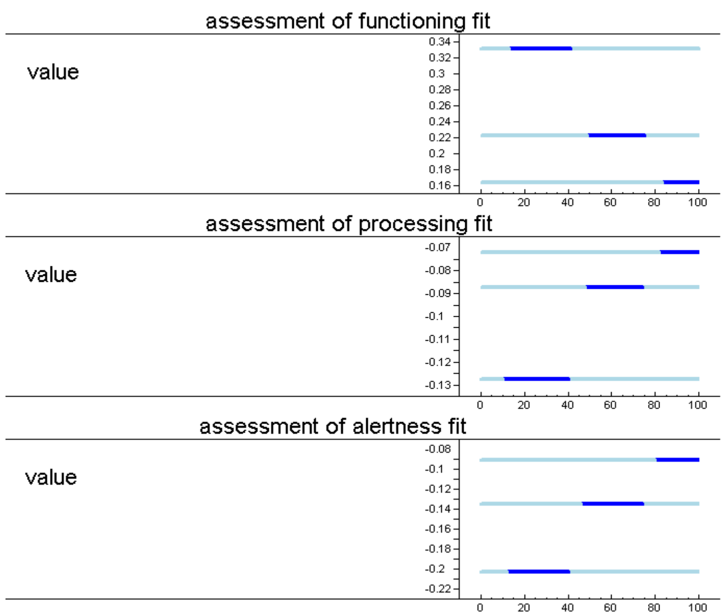

Figure 4. Simulation trace: alertness fit assessment ‘demand dominance’, processing fit assessment ‘demand dominance’.

6 Discussion

Adaptive information presentation involves presenting information in types and forms that are strongly depending on circumstances, which may comprise a number of aspects (e.g., [7, 19]). Some of these aspects are considered constant over longer time periods (e.g., personality characteristics or preferences), and often can be estimated in an accurate manner progressively over time, using some type of (machine) learning method. Other aspects may be more dynamic: they may change all the time. Such a moving target is not easy to estimate in an accurate manner at each point in time. One way that is sometimes exploited assumes that there are attributes (e.g., by sensors) observable at each point in time that directly relate (in a non-temporal manner) to the aspect to be estimated. For example, in [10] the human's anxiety state is determined in a non-temporal knowledge-based manner from monitor information. However, such attributes are not always available. A more general case is that there are relevant observable attributes, but they do not directly relate to the aspect to be estimated in a non-temporal manner, but instead, temporal, dynamic relations are available. This is the case addressed in the current paper. Model-based reasoning methods have been exploited by applying them to a dynamic model relating a human's functional state to information presentation aspects and task performance.

Other approaches to adaptive information presentation often address the human's characteristics and preferences; e.g., [17, 20, 22]. Such approaches usually do not address the human's cognitive, affective or functional state, which within one session may show much variation over time. For use within educational systems the learner's actions and progress can be monitored to get an estimation of the learner's cognitive load (e.g., [13]). Especially for humans in demanding tasks monitoring the human's cognitive, affective or functional state, and adapting information presentation based on this monitoring information may be crucial. As already mentioned, in [10] the human's anxiety state is determined in a non-temporal knowledge-based manner from monitor information. In contrast to such approaches, the approach presented in the current paper makes use of causal, dynamical domain models for the human's functional state and the information presentation aspects, and generic model-based reasoning methods applied to these models.

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Appendix A Detailed Specification of the Domain Model

If alertness utilization has value V_1 and alertness demand value V_2,
then alertness fit has value V_1-V_2

has_value(alertness_utilization, V_1) & has_value(alertness_demand, V_2)
$\twoheadrightarrow$ has_value(alertness_fit, V_1-V_2)

If available effort has value V_1 and processing demand value V_2,
then processing fit has value V_1-V_2

has_value(available_effort, V_1) & has_value(processing_demand, V_2)
$\twoheadrightarrow$ has_value(processing_fit, V_1-V_2)

If alertness fit has value V_1 and processing fit has value V_2,
then functioning fit has value $|V_1|+|V_2|$

has_value(alertness_fit, V_1) & has_value(processing_fit, V_2)
$\twoheadrightarrow$ has_value(functioning_fit, $|V_1|+|V_2|$)

If the basic task demand has value V_4, luminance V_6, visual demand V_1, phonological demand V_2, objects grouping V_8, objects size V_9, objects quantity V_{12} and object distinctness value V_3,
then processing demand has value
$\alpha_9*V_4+\alpha_{10}*(1-V_6)+\alpha_{17}*V_1+\alpha_{18}*V_2+\alpha_{12}*(1-V_8)+\alpha_{13}*(1-V_9)+\alpha_{14}*V_{12}+\alpha_{16}*(1-V_3))$

has_value(basic_task_demand, V_4)
& has_value(luminance, V_6)
& has_value(visual_demand, V_1)
& has_value(phonological_demand, V_2)
& has_value(objects_grouping, V_8)
& has_value(objects_size, V_9)
& has_value(objects_quantity, V_{12})
& has_value(objects_distinctness, V_3)
$\twoheadrightarrow$ has_value(processing_demand,
$\alpha_9*V_4+\alpha_{10}(1-V_6)+\alpha_{17}*V_1+\alpha_{18}*V_2+\alpha_{12}*(1-V_8)+\alpha_{13}*(1-V_9)+\alpha_{14}*V_{12}+\alpha_{16}*(1-V_3))$

If provided effort has value V_{15} and experienced pressure value V_3,
then available effort has value $\alpha_1*V_1+\alpha_2*(1-V_2)+\alpha_{19}*V_3+\alpha_3*V_5+\alpha_4*V_6+\alpha_5*V_{10}$

has_value(provided_effort, V_{15})
& has_value(experienced_pressure, V_3)
$\twoheadrightarrow$ has_value(available_effort, $\alpha_{20}*V_{15}+\alpha_{21}*(1-V_3)$)

If the effort motivation has value V_1, exhaustion V_2, experienced pressure V_3, background colour V_5, luminance V_6, and daytime value V_{10},
then alertness utilization has value $\alpha_1*V_1+\alpha_2*(1-V_2)+\alpha_{19}*V_3+\alpha_3*V_5+\alpha_4*V_6+\alpha_5*V_{10}$

has_value(effort_motivation, V_1)
& has_value(exhaustion, V_2)
& has_value(experienced_pressure, V_3)
& has_value(background_colour, V_5)
& has_value(luminance, V_6)
& has_value(daytime, V_{10})
$\twoheadrightarrow$ has_value(alertness_utilization, $\alpha_1*V_1+\alpha_2*(1-V_2)+\alpha_{19}*V_3+\alpha_3*V_5+\alpha_4*V_6+\alpha_5*V_{10}$)

If time criticality has value V,
then alertness demand has value V

has_value(time_criticality, V) $\twoheadrightarrow$ has_value(alertness_demand, V)

Appendix B Detailed Specification of the Analysis Model

If agent A predicts that at T the alertness utilization has value V_1
and agent A predicts that at T the alertness demand has value V_2
then agent A will assess that at T the alertness fit has value V_1-V_2

prediction(agentA, has_value_for(alertness_utilization, V_1, T)
& prediction(agentA, has_value_for(alertness_demand, V_2, T)
$\twoheadrightarrow$ assessment(agentA, fit_value_for(alertness, V_1-V_2, T))

If agent A predicts that at *T* the available effort has value V_1
and agent A predicts that at *T* the processing demand has value V_2
then agent A will assess that at *T* the processing fit has value V_1-V_2

prediction(agentA, has_value_for(available_effort, V_1, T))
& prediction(agentA, has_value_for(processing_demand, V_2, T))
$\twoheadrightarrow$ assessment(agentA, fit_value_for(processing, V_1-V_2, T))

If agent A assesses that at *T* the alertness fit has value V_1
and agent A assesses that at *T* the processing fit has value V_2
then agent A will assess that at *T* the functioning fit has value $|V_1|$-$|V_2|$

assessment(agentA, fit_value_for(alertness_fit, V_1, T))
& assessment(agentA, fit_value_for(processing_fit, V_2, T))
$\twoheadrightarrow$ assessment(agentA, fit_value_for(functioning, $|V_1|+|V_2|$, T))

If agent A assesses that at *T* the fit for *F* has value *0*
then agent A will assess the fit for *F* at *T* as perfect

assessment(agentA, fit_value_for(F, 0, T))
$\twoheadrightarrow$ assessment(agentA, fit_for(F, T, perfect))

If agent A assesses that at *T* the fit for *F* has value *V*
and $0<V$ and $V\leq 0.1$
then agent A will assess the fit for *F* at *T* as good

assessment(agentA, fit_value_for(F, V, T))
& $0< V$
& $V\leq 0.1$
$\twoheadrightarrow$ assessment(agentA, fit_for(F, T, good))

If agent A assesses that at *T* the fit for *F* has value *V*
and $-0.1\leq V$ and $V<0$
then agent A will assess the fit for *F* at *T* as good

assessment(agentA, fit_value_for(F, V, T))
& $-0.1\leq V$
& $V<0$
$\twoheadrightarrow$ assessment(agentA, fit_for(F, T, good))

If agent A assesses that at *T* the fit for *F* has value *V*
and $-1\leq V$ and $V<-0.1$
then agent A will assess the fit for *F* at *T* as demand dominance

assessment(agentA, fit_value_for(F, V, T))
& $-1\leq V$
& $V<-0.1$
$\twoheadrightarrow$ assessment(agentA, fit_for(F, T, demand_dominance))

If agent A assesses that at *T* the fit for *F* has value *V*
and *0.1<V* and *V≤1*
then agent A will assess the fit for *F* at *T* as effort dominance

assessment(agentA, fit_value_for(F, V, T))
& 0.1< V
& V≤1
↠ assessment(agentA, fit_for(F, T, effort_dominance))

If agent A assesses the fit for *F* at *T* as demand dominance
then agent A will assess the functioning fit at T as poor

assessment(agentA, fit_for(F, T, demand_dominance))
↠ assessment_of(agentA, fit_for(functioning, T, poor))

If agent A assesses the fit for *F* at *T* as effort dominance
then agent A will assess the functioning fit at T as poor

assessment(agentA, fit_for(F, T, effort_dominance))
↠ assessment_of(agentA, fit_for(functioning, T, poor))

Appendix C Detailed Specification of the Support Model

If agent A desires that functioning has an adequate fit
and agent A assesses the functioning fit at *T* as poor
and agent A assesses the alertness fit at *T* as demand dominance
then agent A will desire an increased alertness fit

desire (agentA, adequate_functioning_fit)
& assessment(agentA, fit_for(functioning, T poor))
& assessment(agentA, fit_for(alertness, T, demand_dominance))
↠ desire(agentA, increased(alertness_fit))

If agent A desires that functioning has an adequate fit
and agent A assesses the functioning fit at *T* as poor
and agent A assesses the alertness fit at *T* as effort dominance
then agent A will desire a decreased alertness fit

desire (agentA, adequate_functioning_fit)
& assessment(agentA, fit_for(functioning, T poor))
& assessment(agentA, fit_for(alertness_fit, T, effort_dominance))
↠ desire(agentA decreased(alertness_fit))

If agent A desires that functioning has an adequate fit
and agent A assesses the functioning fit at *T* as poor
and agent A assesses the processing fit at *T* as demand dominance
then agent A will desire an increased processing fit

desire(agentA, adequate_functioning_fit)
& assessment(agentA, fit_for(functioning, T, poor))

& assessment(agentA, fit_for(processing, T, demand_dominance))
↠ desire(agentA, increased(processing_fit))

If agent A desires that functioning has an adequate fit
and agent A assesses the functioning fit at *T* as poor
and agent A assesses the processing fit at *T* as effort dominance
then agent A will desire an decreased processing fit

desire(agentA, adequate_functioning_fit)
& assessment(agentA, fit_for(functioning, T, poor))
& assessment(agentA, fit_for(processing, T, effort_dominance))
↠ desire(agentA, decreased(processing_fit))

If agent A desires an increased alertness fit
then agent A will desire an increased alertness utilization

desires(agentA, increased(alertness_fit)) ↠ desires(agentA, increased(alertness_utilization))

If agent A desires a decreased alertness fit
then agent A will desire a decreased alertness utilization

desires(agentA, decreased(alertness_fit)) ↠ desires(agentA, decreased(alertness_utilization))

If agent A desires an increased processing fit
then agent A will desire a decreased processing demand

desires(agentA, increased(processing_fit))
↠ desires(agentA, decreased(processing_demand))

If agent A desires a decreased processing fit
then agent A will desire an increased processing demand

desires(agentA, decreased(processing_fit))
↠ desires(agentA, increased(processing_demand))