Chapter 9 – THE CONCEPT OF MODERATORS

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9.1 INTRODUCTION

The concept of moderators is based on the idea that there is a plausible 'datum' level of human behaviour that is modified by variations in internal state or the external environment. The modifications are frequently viewed as the primary source of human variability and, as such, have to be modelled in any nominally complete representation of human behaviour. The science of the impact of a range of environmental stressors has been the stock-in-trade of human science research for the past 60 years and some sophisticated models have been developed to explain human response to the stressful conditions. Even fairly simple cases can lead to considerable cost and complexity in implementation.

A barrier to the exploitation of Human Behaviour Representation in models for the analysis of systems and for supporting training applications is the cost of developing and validating the supporting elements. Developing a suite of models of moderators is a complex and expensive undertaking that involves a combination of physiological and cognitive models. Although many of the models are generic and can be reused, some components will be task specific and have to be tailored for each application, increasing the cost.

Do we have to be scientifically rigorous to develop models that are fit for purpose? Can we identify the number of internal states that we have to represent or can we approach the problem by using an argument that focuses on a single level of "arousal" to capture all stresses? Can we capture what we need by using a stochastic representation of human behaviour and rely on sensitivity analysis to draw our conclusions?

9.2 DISCUSSION

The term moderator is used to express any element in the simulation that can take different values on different occasions and that, through some route, affects human performance. To aid the analysis, moderators have been classified as external, internal or collective, defined as:

- ***External:*** Elements in the environment that can change the psychological or physiological state of an individual. Examples are temperature, clothing, imposed sleep/rest/work pattern, time of day, presence of a threat, or demand of an activity for work.

- ***Internal:*** Individual characteristics that can affect the psychological or physiological state of an individual, usually but not always in conjunction with an external moderator. Examples are height, weight, percentage body fat, gender, aspects of personality, experience, or level of training.
- ***Collective:*** Characteristics of the collective (or team) that can affect the state of interactions between the individuals who make up the team or collective. Examples are collective experience, nature of leadership.

The model of the action of external and internal moderators assumes that the moderating variable changes the psychological or physiological state of an individual and that this state change is what drives the change in behaviour or performance. State is therefore seen as dynamic within a simulation in that it changes with time. In general the internal moderators are viewed as "traits" and therefore fixed with time for a given simulation. There is a question of how many independent psychological or physiological states can be defined usefully. Early work on psychology identified a single state: arousal. For the purposes of modelling changes in performance or behaviour a number of states have been defined that relate to different moderators. Some states can clearly be affected by more than one moderator. Some examples are provided below.

Moderator	**State(s)**
Environmental temperature Clothing Height Percentage body fat Exercise level Drinking water	Core temperature Skin temperature Thermal comfort Hydration status Sweat rate
Exercise Food consumption	Blood glucose level Core temperature Skin temperature Thermal comfort Sweat rate
Time of day Prior sleep pattern Time zone history Work/rest pattern	Alertness
External threat Personality	Fear/Anxiety

A range of models has been developed that describe the effect of the environmental stressors on state. Examples are provided by sleep-loss fatigue models and alertness, or thermal models and body temperature. There is limited work describing the relationship between internal state and performance but some has been conducted (Belyavin & Spencer, 2004).

It is clearly possible to define physiological states that relate to external stressors. It is not as simple to isolate psychological states that relate to the "psychological" moderators such as personality, level of training, experience. Arousal has been used by psychologists for many years and appears to be a useful way of interpreting a number of effects. It is not clear whether fear or anxiety represents a distinct state or whether it drives arousal and affects performance by this route. A research requirement is the definition of the number of different states that need to be considered for the modelling of performance and behaviour and how these relate to the moderators of interest.

There is considerable discussion as to whether the problem of modelling more than one set of moderators simultaneously is more complex than modelling single moderators due to *interactions* between the associated states. An example would be the combination of the moderators that make up the thermal environment and those relating to sleep loss. If the sets of moderators do not interact, the effect of a change in alertness on performance or behaviour is not affected by current thermal status. Interaction implies that the different states affect the differing relationships between performance and behaviour. Preliminary investigation of a number of external moderators indicates that interactions of this kind may be present but are not large.

Andy Belyavin indicated that analysis at QinetiQ identified relatively few interactions between moderators, based on a review of the relevant literature. It was noted that interactions between internal and external moderators (flight strategy and fatigue) have been observed in basic research using computational cognitive models to study aircraft manoeuvring. Expert flight strategies, such as the control and performance concept for instrument flight, appear more fatigue resistant than novice strategies.

The challenge is to choose a minimally sufficient set of state variables and to model their impact on performance. There are a number of key questions.

- Could we use similar approaches to represent analytical physiological, cognitive and emotional processes?
- Are there valid models of individual states?
- What would be the potential interactions among the states?

Laurel Allender described how moderators are represented in IMPRINT (for more information, see: Allender, Salvi & Promisel, 1997). An engineering model is used based on performance data that defines a direct relationship between moderator and performance. The task is broken out over a taxonomy of lower level components such as gross motor movement, fine motor movement, visual perception, the components degraded and the outcome reconstructed from the components. The basis of the taxonomy is the mental or physical resource employed. For example in a decision making task the main resource would be the mental resource. It was observed that extrapolation from a data based model of this kind outside the range of the source data is not reliable and that more validity may be expected from a model that includes the intervening state and trait variables based on sound scientific relationships rather than mapping the moderator directly onto performance.

It was noted that the representation of moderators is linked to architecture because they form fundamental architectural constraints. Representing the effects of moderators in some architectures is difficult. The design of architectures should enable valid models of the effects of moderators to be incorporated.

There was a discussion of what was needed from modelling the effects of moderators. For training applications a view was expressed that plausible variation in behaviour was sufficient to meet the training need. The majority view of the meeting was that this is an ill-advised approach as it would result in TLAR (That Looks About

Right) validity that could easily fail for conditions only marginally different from the original design assumptions. Crude validity of this kind may be appropriate for narrowly focused applications, but for serious system analysis, general training or mission rehearsal where a broad spectrum of conditions could be anticipated, scientifically sound models and a higher level of validity are required.

9.3 CONCLUSION

Overall the meeting supported the argument that validated models of the effects of moderators are an essential component of all HBR applications. The approach involving external/internal/collective moderators related to internal states was endorsed in principle, although there was no agreement on an exhaustive list of either moderators or states. It was agreed that model architectures need to take account of modelling the effects of moderators explicitly.