

APPENDIX C

AXIOMATIC MODELS OF WORKLOAD

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A. A SIMPLE STEADY STATE MODEL OF WORKLOAD

1. Workload is a meaningful concept only in the context of a well-defined task which must be performed to a stipulated criterion.
 - a.-def. a 'well-defined task is one for which specific actions on the part of a human operator can be identified and quantitative criteria for each action stated.
 - b.-def. workload is a non-accessible, hypothetical undimensional, internal variable over the range of 0.0-1.0 in any human operator.
2. Workload increases as the demand of the task increases.
 - c.-def Demand of a task is the list of actions and their performance criteria.
3. Workload decreases as the capacity of the human operator increases with respect to that task.
 - d.-def Capacity of a human operator is the limiting level of performance on any action which is part of a task.
4. By 2. and 3. workload may be considered to be the ratio of Demand to Capacity with respect to action. Thus $L_i = \frac{D_i}{C_i}$ or the workload of action is the ratio of the demand of action i to the capacity to perform action i .

5. Actions required by a task may be classified into elemental types.

e.def. An elemental type is a non-reducible action.

6. All actions required by a task are either elemental types or are reducible into elemental types.
7. The non-reducibility of elemental types implies independence of elemental types.
8. By 7., the demand of a task can be mapped into an N-dimensional space whose orthogonal axes are the elemental types of the task and are also the capacities associated with each elemental type by def. d.
9. The N-dimensional space of elemental type demands and capacities may be transformed into an N-dimensional space of elemental type workloads. The axes of the new space are not limited to the range 0-1.0; the mapping consists of dividing elemental type demands by elemental type capacities.
10. The total workload of the task may be considered to be the vector sum of the elemental type workloads.
11. If a task demand consists exclusively of a repetitive elemental type, the load placed on the human operator will be $N.L_i$ where N is the number of actions of type i . In all other cases the total workload $L = \sum_{i=1}^N (M_i L_i)^2$ $^{1/2}$ which is the length of the vector composition of the elemental type work loads. N is the number of elemental types and M_i the number of each elemental type i .
12. If any elemental type workload exceeds 1.0, the human operator cannot meet the demand of the task. If the vector task workload exceeds 1.0, the human operator cannot meet the demand of the task.
13. Summary of simple steady state model.

Workload of a well defined task is the length of a vector in a space defined by N elemental type workload axes. On each axis is plotted the workload corresponding to that elemental type. Each such elemental workload is computed by taking the ratio of elemental type demand to elemental type capacity.

B. SIMPLE NON-STEADY STATE MODEL OF WORKLOAD

1. In any real task the numbers and type of elemental type actions which compose the demand of the task vary as a function of time.
2. As a consequent the vector sum of the elemental workloads varies in time in both length and angle relative to each elemental type axis.

3. In any real human operator the capacity to perform any elementary action varies as a function of time.
4. As a consequent, the vector sum of the elemental type workloads varies in time in both length and angle relative to each elemental type axis.

C. THE LOAD COMPONENT GENERATED BY INTERNAL SWITCHING

1. Subjective report strongly indicates the existence of a workload component generated internally to the human operator.
2. The internally generated workload component may be considered to be orthogonal to and similar to the elemental type workloads demanded by the task.
3. The internally generated workload increases monotonically with increasing number of elemental type workloads demanded by a task.

Hypothesis: The workload generated internally is $L_N + 1 = K.N$, where N is the number of elemental type workloads and K is the workload associated with the switching from one elemental type to another

4. It follows that the workload vector is in a space of $N+1$ dimensions and will increase with increase in N .

D. THE LOAD COMPONENT GENERATED BY EXTERNAL SWITCHING

1. Subjective report and direct observation require that a workload component is generated by switching of attention from place to place and from signal to signal.
2. Switching of visual directions of attention requires some minimum time τ_1 .
3. Switching from sensory mode to sensory mode requires some minimum time τ_2 .
4. From the task description the number of loci of visual attention can be calculated and the number of intersensory switchings can be estimated.
5. The time lost in switching is then $T_L = k_1\tau_1 + k_2\tau_2$ where k_1, k_2 are the numbers of switchings which the human operator must perform.

Hypothesis: Total capacity but not elemental type capacity is reduced by T_L/T when T is the total time available to perform the task.

E. SWITCHING LOADS AND TIME COST

1. In external switching as in an extended monitoring task, the principal demand is for the switching act itself.

2. Therefore Time Demanded is the measure of demand and Time to Perform is the measure of capacity.
3. The workload for an externally limited task is $\frac{T_d}{T_c}$ where T_d is the time demanded and T_c is the time required by the human operator to perform.
4. The relationship of timing of elemental type demands relates to workload.
5. If actions are demanded independently, two or more actions may be required simultaneously. There are two consequences.
 - 1) Priorities accumulate and force uneconomic switching.
 - 2) Human operators will fail to perform required actions until after an undersirable delay.
6. A totally self-paced task can never have a workload greater or less than 1.0. No overload can exist in either transient or steady-state conditions.
7. Because of the load cost of internally generated switching load, the adaptive human operator will minimize the switching load by aggregating demanded actions into groups of the same elemental type if priorities permit.
8. Two identical streams of actions, one self-paced and the other externally-paced will generate different load levels and different physiological response levels. A behaves in a self-paced mode. B receives as demanded action whatever A has done and is therefore externally paced.
9. Some elemental capacities are single channel in nature. The elemental type load is therefore always 0 or 1.0 with the average load reflecting the relative proportion of time the load is 1.0.
10. For such elemental types queueing models are required for the calculation of load as a function of time and for the estimation of the probability of transient overload.

F. MOTIVATION AND EFFORT

1. Motivation (Effort) controls the fraction of capacity (total) which a human operator will commit to a task.
2. Differing payoff systems and task designs will alter capacity and, therefore, the load imposed by a task.
3. High motivation allows a high fraction of capacity to be used. This results in improved performance. Low motivation produces low available capacity and permits overload to occur at low levels of demand.

Hypothesis: Available capacity is product of

Motivation and Capacity $C_A = M \cdot C_T$ where M is a 0-1 variable.