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TRADE-OFFS BETWEEN SAFETY-BUFFERS, EFFICIENCY, AND TASK-LOAD

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A new scaling approach for traffic situations in ATM assess the changes in and trade-offs between safety-buffers, efficiency and task-load in the work of air-traffic controllers. A computerised scaling tool was developed, which showed sufficient validity for simulated traffic situations (Vormayr, 2005). Results from a study of 23 Austrian air traffic controllers were presented, which could be grouped into controllers with a individual critical situation (ICS) (n=10) and (n=13) without an individual critical situation during a full shift are reported. Controllers were asked to rate the traffic situations after the shift during a reconstruction interview, based on these ratings individual critical situations were identified. In addition SET-ratings were obtained during the shift in regular intervals. The SET-Tool showed significant differences between situations of different impact, and a couple of typical profiles emerged, which reflect the working-strategies used by the controllers. The discussion addresses the options to use the SET tool to evaluate individual working strategies in different traffic situations and to evaluate and detect limits in sector capacity.

Keywords: Safety-buffers, Sector capacity, Task-Load, individual critical situations, Air Traffic Management

Introduction

In this paper, attention is focused on the basic principle of anticipation to explain spatial orientation in flight and thus the role of erroneous anticipation as cause for critical flight situations such as spatial disorientation.

Assessment of workload

The assessment of workload is a classical and well established way to depict the traffic situation in ATM from the controllers´ point of view. The stress-strain model triggered this approach. It allows to use a multi-level-multi-method approach from stress research to look at the controllers strain as a critical common end path of changing task load due to varying traffic density, traffic complexity, improved system tools or improved teamwork. The stress strain model considers the skills and the resources of the controllers as moderators, which determine how much strain will result from working on a certain task (c.f. Hilburn & Jorna, 1998). Well established scaling methods are used to assess change in workload like the NASA-TLX (Hart & Staveland, 1988), or the ISA-technique as used by EUROCONTROL or more classical procedures like multidimensional assessments of the psychological state. Psychophysiological assessment and/ or behavioral observations (cf. Backs & Boucsein, 1995) are used to supplement, extend and validate the workload measurement in many instances.

Determinants of workload

The basic determinants of workload for a given working position are the task load defined by traffic density and complexity, the required or desired efficiency, and the required or desired safety buffers. These determinants match well with the basic descriptors for a sector. These are capacity, efficiency and safety.

Capacity, efficiency and safety of the system depend on how the controllers manage these factors and their possible trade-offs. Task load will increase with increasing traffic and increasing traffic complexity. The limits of the capacity on the sector side equal the limits of task load on the controllers side. The limits of efficiency on the system level are directly dependent on the limits of efficiency on the controllers´ ide. The safety-buffers, which controllers use in their working procedures contribute essentially to the system safety in critical situations. On the system level there are multiple trade offs between safety-buffers, efficiency and capacity. Safety-buffers constitute of additional risk reducing factors, which are introduced in the system or inherent in the system to increase safety of the system beyond the tolerable risk levels. Safety buffers help to manage the system safely even in critical or in emergency situations. In many instances safety buffers are systematically increased in threat situations. An example is reduction of the maximum number of a/c in an approach sector during very stormy weather conditions. This is a first example of the interdependence of safety-buffers, capacity and efficiency. Increasing safety-buffers often reduces the capacity. The other way round reducing minimum separation standards allowed an increase of capacity. Efficiency gives the relation between resulting effect and necessary effort or invested resources. Thus increasing efficiency (e.g. by a new tool or an intelligent problem solving strategy) can increase capacity without affecting safety-buffers negatively. On the controllers side increased efficiency can reduce work-load with task-load and safety-buffers kept stable.

Simultaneous assessment of safety-buffers, task-load, and efficiency.

A task and workload analysis to study relevant factors of sector capacity from the controllers side with 16 controllers and four observations of each controller during a full sector periods (about 90 minutes each) revealed that workload, efficiency and safety-buffers reflect the state of the sector-controller-unit quite well. The results from post-observation interviews allowed to classify situations and the solutions for traffic situations reflecting the actual working-style of the controllers. Different form of trade-offs could be observed. Most frequent workload was increased in difficult traffic situations to hold efficiency constant and increase safety buffers. In some instances efficiency could be increased markedly by "intelligent solutions" like direct routing of an aircraft, which caused high traffic complexity. The effect was increased or constant safety-buffers and reduced workload. The observed "working styles" are flexible and vary according to the traffic situations (Hoffmann, Kallus, Pichler, Ehgartner, 2001). Based on these results the concept of a joint scaling of safety-buffers, efficiency and load of the controller emerged to characterize the sector-controller unit. It was decided to separate the objective and subjective side as it is done in psychophysical scaling to keep the scaling conceptually on the situation-related side. Thus, safety-buffers, efficiency, and task-load were rated as they can be viewed as objective factors or system characteristics. This scaling might be supplemented by a scaling of personal efficiency, personal safety-buffers and personal workload.

Symmetric, equal sided triangles can be used to visualize the balance or non balance between the factors "safety-buffers, efficiency and task-load. This visualization was the bases for a computer version of the scaling, which was supplemented by classical scales to allow different modes of data entry. The SET-Scaling is depicted in figure 1. A basic validation could be demonstrated by Vormayr in her master´s thesis (Vormayr, 2005). She used systematically varied traffic scenarios in an air traffic simulation and obtained highly significant effects on the scalings, corresponding to the changes in the scenarios (like number of a/c, dynamic density, ..).

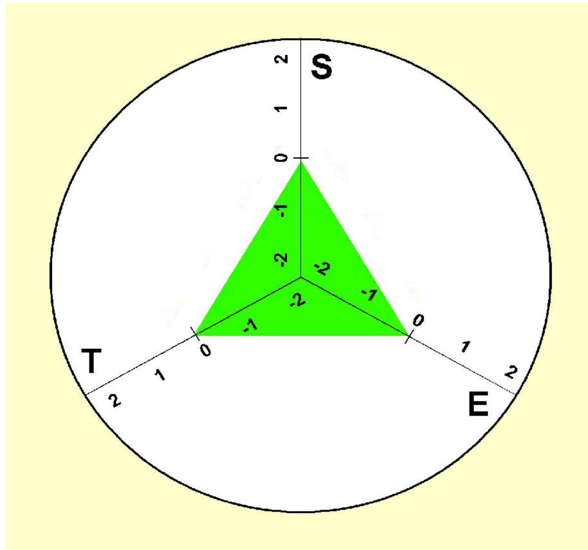

Figure 1. Screen dump of the computerized SET-Scaling procedure (Vormayr, 2005)

Individual Critical Situations

Modern concepts in safety management tend to have a look at threats and small scale human errors in everyday operations (Helmreich, 2000). Threats are deviations from normal operations without constituting a critical incident. To account for these situations in task analysis a scaling technique has been developed for traffic situations addressed during reconstruction interviews. Reconstruction interviews a constitutive part of Intergrated Task Analysis procedures ((ITA; Kallus, Barbarino, & Van Damme, 1998). For the situation at hand a two step scaling is obtained using the "subdividing categories" approach of psychophysical scaling. The resulting scale values range between 0 "absolutely routine" and 50 "critical incident". The values reflect deviations from standard, which need special attention, effort and/or active problem solving from the controllers.

In the current study the SET – scaling was used describe the changes of in safety-buffers, efficiency, and task-load and their trade off before, during and after individual critical traffic situations during normal operations.

Method

Detailed full shift task analyses were conducted in a sub sample of 24 out of 53 Austrian air traffic controllers. Task analysis was supplemented by physiological recordings. Controllers were asked to rate non-routine traffic situations after the shift during a reconstruction interview using the scaling for Individual Critical

Situations (ICS-Scaling). The traffic situations were scaled according to their impact using a 50-point categorical scaling method with the range between the extremes “routine situations without any risks” (zero) to “critical incidents” (50). 10 out of 24 controllers indicated a scale value above 29, which was selected as a cut off point for individually critical situations (ICS). Seven controllers from comparable working positions served as control group without ICS. Changes in safety-buffers, efficiency and task-load (SET-ratings) defined as deviation from routine work were obtained using the SET software. This allowed to indicate changes in the SET triangle by moving the endpoints via mouse or entering the scale values (5-point, -2 to +2) on the scales via keyboard. SET-ratings were obtained during the shift in regular intervals and additional SET-rating were obtained for the non-routine situations during the reconstruction interviews.

Results

The SET-Tool showed significant differences between situations of different impact, and a couple of typical profiles emerged, which reflect the working-strategies used by the controllers.

Task-load ratings are highly correlated with work-load ratings. Physiological data and ratings of monotony, tiredness and saturation show corresponding results.

Discussion

The SET tool offers options to monitor changes in safety-buffers, efficiency and task-load from the controllers´ side. In addition trade-offs can be analyzed, which reflect the way in which the traffic situations are managed. Thus, the SET tools allows to have a first look into the magic of controllers´ working styles, which is based on a large amount of training, expertise and situation specific intelligence, The results can be used to make normal operation safety surveys more efficient, to help supervisors monitor the situation in the center and to give the controllers feedback. SET scaling provides much more information than the “only” workload ratings obtained in most studies and simulations currently.

In combination with the ICS-ratings the research on stress on ATC might be drawn to the central focuses. This seems to be important as stress in ATM is not always obvious. Controllers are trained to cope with difficult traffic situations and non routine situation in a most professional way. Thus stress might be visible only in few critical situations.

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