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Commentary

On the assessment of (mental) workload and other subjective qualifications

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1. Introduction

With increasing traffic density, mainly after the Second World War both in the air and on the ground, concern arose over human error, effort, fatigue, stress, comfort, etc. and the call for measurement was heard everywhere. *Ceteris paribus* the same happened in industry and the basis for the science of ergonomics was born. A host of research followed, dividing the scientific world in hard-liners with respect to objective measurements and those that felt the need for and saw the value of subjective measurements. Annett analyses this dispute appositely, elaborating on the pros and cons of subjective rating scales. A large number of problems are put in perspective by Annett, among which the almost inherently ordinal character of subjective measurements is perhaps most prominent.

In some areas such as traffic and transport research, subjective measures and scales are rather common. It is hard to imagine research in this field without subjective measurement, although its ordinal character might suggest otherwise. Specifically in within-subjects designs, however, the ordinal character is not such a problem as it may seem compared with ratio or interval mea-

asures. We do not only want to know whether a newly developed system in a vehicle functions well; if the user does not understand or like it, the system will be ignored, misused, not bought, etc. By means of research with suitable with- and without system crossover designs, a fair view on both functional and qualitative aspects can be derived. The predictive validity may not be assured, but the sure pitfall of unsuccessful introduction of newly developed, gleaming but disliked techniques can be avoided. Annett stresses other important limitations, besides the ordinal character and predictive validity, such as timing and/or memory, context and consciousness (e.g. in the case of pleasure or pain). Certainly in an applied field, such as traffic and transport, where the measurements are carried out in dynamic situations under often extremely varying conditions, these limitations have to be seriously taken into account.

With respect to the observed dissociation, or discrepancy between subjective assessment and behaviour, we mainly disagree; we often do not see a problem *per se*, but rather an opportunity, a potentially very useful indication of the discrepancy between what people think/feel and actually do in practice.

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For instance, after medication with different medicinal drugs, people sometimes perceive very well that the drug affects their behaviour and capabilities, but occasionally they do not. In a driving test in actual traffic, after two different antihistamines, participants indicated correctly the negative effects on their driving behaviour, i.e. the correlation between driving parameters and subjective measures was relatively high (Brookhuis *et al.* 1993). However, this is not always the case, depending probably on the type of drug administered to ambulant patients. In a similar study with four types of antidepressants, participants did not have a correct sensation of incapacity with one of the four drugs (Louwerens *et al.* 1986). It goes without saying that this is not just interesting, but also highly relevant for physicians and other drug-prescribing authorities. For this reason it is often useful to include non-suspect measures like EEG as a 'verum' to check on drowsiness in this type of studies (Brookhuis and De Waard 1993), criterion variables as Annett indicates them.

Annett discusses the fitness of subjective ratings to different purposes within the field of ergonomics research and concludes that the choice of measures, whether subjective or objective, must be justified in terms of the purpose of the study. Although this is certainly true, it disregards an important limitation that was not explicitly discussed, i.e. the restriction of range of variables. This limitation and its consequences are connected with the earlier mentioned dissociation of measures, amongst others.

2. Model of operator performance, task demands and mental workload

Dissociation of measures is put in a different perspective in the 'region model of operator performance, task demands

and measurement of mental workload' (De Waard 1996). Vidulich and Wickens (1986) claimed that in ideal conditions *all* measures should reflect changes in mental workload during task performance. If one measure reflects an increase in workload and another measure does not, then measures are said to dissociate. Dissociation has usually been reported between self-reports and measures of performance, and sometimes between physiological and self-report measures (Myrtek *et al.* 1994). Viewed from the region-model perspective, parameters can very well 'dissociate'. Increased mental workload does not have to affect performance, and not all measures have to be strongly correlated. Figure 1 shows this principle. In Region A1, A3 and B, measures of performance and measures from the other categories are actually *expected* to be uncoupled, the variables are *restricted in the range in which they are indicative*! In the lower panel of figure 1 (Measure), the relationship (e.g. dissociation) between measures is illustrated.

The model is an extension of the model by Meister (1976) who related levels of increasing task demands to three regions of performance. In his Region A, the task demands are low and performance is high. In Region B, increasing task demands lead to decreased performance levels, while in Region C performance remains at a minimum level with increases in demand. However, the model turns out to be too simplistic. In optimal conditions, workload will be low, but if the operator has to exert effort to maintain this level of performance with time on task, then workload will increase. Effort, consciously protecting the level of task performance by 'trying hard', can counteract an impaired operator state as well as enable dealing with increased task demands (e.g. Hockey 1986). Region A should therefore be split into

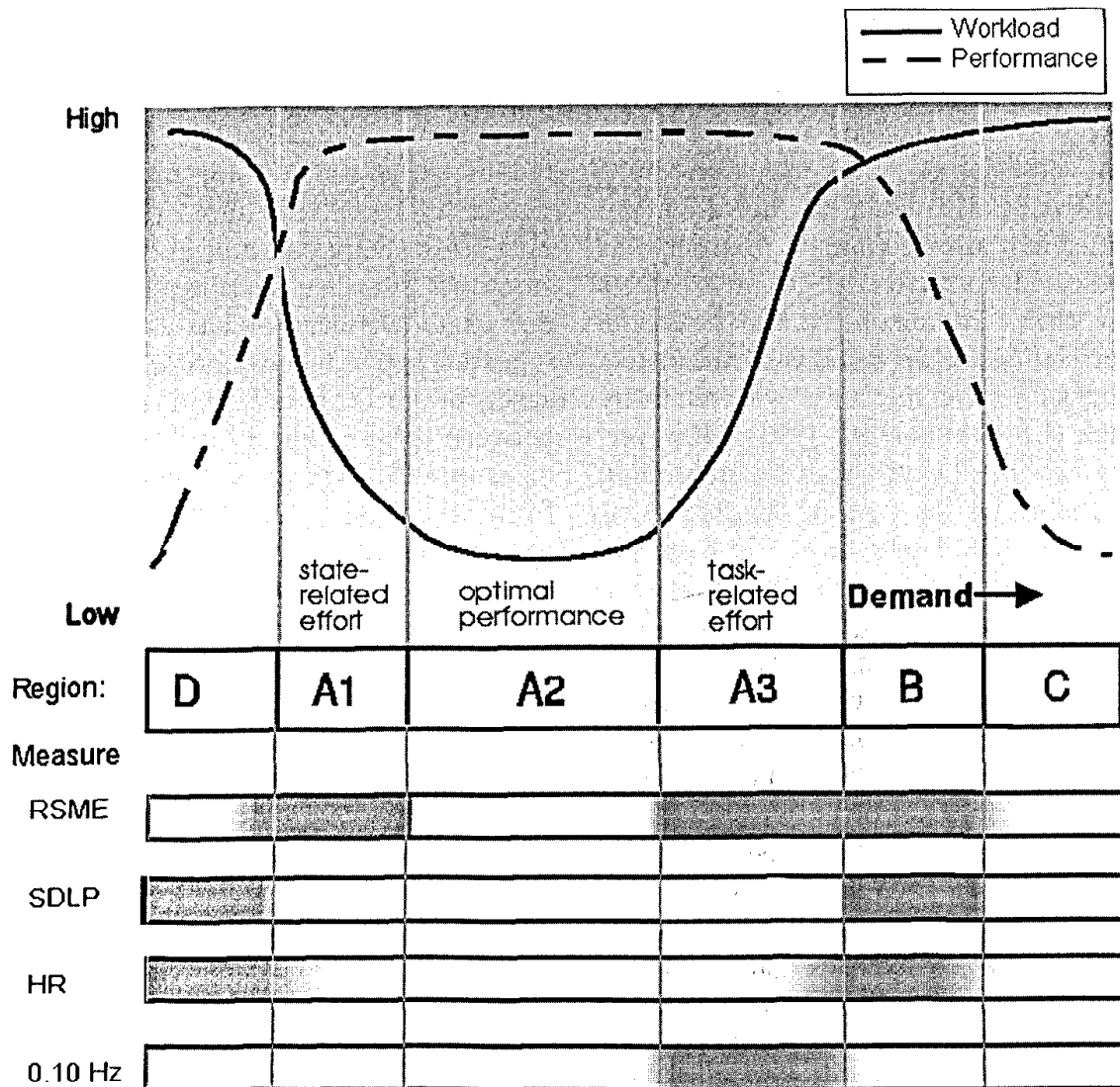


Figure 1. Relationship between task demands, workload and performance in six regions (upper panel). In Region D (D for deactivation) the operator's state is affected. In Region A2 performance is optimal, the operator can easily cope with the task requirements and reach a (self-set) adequate level of performance. In Regions A1 and A3 performance remains unaffected, but the operator has to exert effort to preserve an undisturbed performance level. In Region B this is no longer possible and performance declines, while in Region C performance is at a minimum level: the operator is overloaded. The lower panel shows the sensitivity of four measures to driver mental workload. RSME is a self-report scale (Zijlstra 1993), SDLP is a primary-task performance measure, while HR and 0.10 Hz are cardiac measures (also Brookhuis and De Waard 1993).

three subregions, Region A1, A2 and A3. In Region A2, performance is optimal and workload is low, analogous to Meister's model. In Region A3, increased task demands require effort compensation to maintain performance at a high level. In Region A1, the investment of state-related effort counteracts the negative effects on perfor-

mance of a reduced driver state. Adding a D region preceding Region A1 completes the model. In Region D the effects of driver deactivation can no longer be compensated by the exertion of effort, and reduced performance becomes apparent. The effects on the operator of, for example, monotonous tasks are situated in this D Region. These are

low demand tasks that can result in increases in task difficulty and workload by a reduction in capacity. In case of, for example, boredom, a reduction in capacity requires that a larger proportion of the capacity is used for performance of the same task, thus increasing mental workload (O'Hanlon 1981, Meijman and O'Hanlon 1984). The model is shown in the upper panel of figure 1. It is important to stress that 'demand' on the x-axis is not directly linked to 'region of performance'. Task demands are determined by the goals that have to be attained by task performance and cannot be linked directly to workload, which is subjective. Region merely indicates the interaction between performance and workload. The same task can result in performance in Region A2 for one individual, and may require effort compensation and thus Region A3 performance for another.

Explanations for the dissociation of subjective and other measures could be several; a higher sensitivity of subjective measures for peak loads (Verwey and Veltman 1996), the time lag between taking performance measures and subjective ratings (Hancock *et al.* 1995), or the uncertainty over which aspect or task in multiple tasks performance is to be judged (Vidulich and Wickens 1986). Whether the source is one of these, or a combination, is only part of the story, as the restriction of range determines whether measures will indicate any change at all. Most important is that the picture that emerges when subjective measures are taken together with performance and physiological measures, whether dissociating or not, reveals *more* about task performance and mental workload than any measure taken in isolation. Artistic illustrations like figure 1 may support the complex task of the ergonomist.

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