Interpreting P300 amplitude changes with adaptation level theory

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It is widely accepted that the P300 component of the event-related potential reflects integrative information processing in the brain that is often described as "endogenous." Task relevance and the probability of eliciting events are important

determinants of P300 amplitude. Both the target article (Verleger 1988t) and the Precommentary (Donchin & Coles 1988) acknowledged the importance of these consistently confirmed facts. The general object of discussion in both papers was the classical "oddball" paradigm using two categories of stimuli. In our view information processing in its full complexity can be investigated more adequately if in the P300 eliciting paradigm more than two task-relevant stimuli are used. Using several task-relevant categories of physical stimulus features appears to be a better approach to studying complex internal models of the environment and changes in it.

It is also important to note that the evaluation and categorization of events and their behavioral consequences has already been studied quantitatively in psychology using rating scale procedures and adaptation level theory (Helson 1964) or frame of reference theory (Lauterbach & Sarris 1980). Helson recognized that space-time averaging processes for acquainting the organism with changes in the environment are comparable to well-known processes of adaptation in sensory physiology. He suggested that all dimensions of objects and events contribute differentially to the formation of adaptation levels. Intensity of response can be described as a function of distance from the prevailing adaptation level or the ratio of stimulation to the prevailing level; the greater the magnitude of the ratio or distance, the steeper the excitation gradient and the greater the response.

In our laboratory we have recently found (Junghanns & Ullsperger 1989; Ullsperger & Gille 1988; Ullsperger et al. 1987) that with several kinds of task-relevant stimuli the behavior of P300 corresponds well with the principles of adaptation level theory. In one of these studies (Ullsperger et al. 1987) five categories of stimuli (strings of digits differing in length) were used. With increasing string length subjects reported greater difficulty in completing the visual search task. The probability of one of the five stimulus categories was varied to achieve three different adaptation levels near the short, long or medium length strings, respectively (for the calculation of adaptation levels, see Helson 1964). When short stimulus strings were highly probable P300 amplitude increased with increasing string length. In contrast, with the most probable long stimulus strings the P300 amplitude decreased with increasing string length. With stimuli from all five categories presented with identical probability, the smallest amplitude was elicited by medium length stimuli and the amplitude increased with a U-shaped trend toward short as well as long strings.

To illustrate our concept we refer to the "whirring noise" analogy of Donchin and Coles (1988). A whirring noise is generated as a byproduct of a data transmission process between the computer's memory and an external storage device. It occurs in the course of data transmission when the mechanical device used to whirl the diskette around or to move the reading head about is active. If the builders of external storage devices were to apply the concept of adaptation, a reading head would adjust to the areas that carry the currently relevant information most often needed (the adaptation level). To access less frequently needed information the reading head would have to move longer distances. The adaptation level established would depend on the user's specific informational requirements, say from different files. The frequency of using files would affect the adaptation level. Thus, the reading head would adjust adaptively to the file most often used in the near past. With increasing distance from the "adapted" location of the reading head the whirring noise would increase. In this sense the whirring noise analogy gives some idea of quantitative gradations.

In adaptation level theory it is assumed that the information about the environment is structured and categorized at different levels of abstraction according to certain relevant features. On this basis an inner neuronal model is established and currently updated. The adaptation level as a characteristic feature of the model adjusts to the probability of occurrence of relevant events. The dependence of P300 amplitude on probability (e.g., Duncan-Johnson & Donchin 1977) can also be seen in this context; probability affects the adaptation level and with increasing distance between the current adaptation level and incoming information the P300 amplitude increases. It should be further investigated whether the P300 reflects the output of a subroutine comparing the adaptation level of the neuronal model and incoming information, or, in addition, the instant change of the current adaptation level. The idea we propose is founded on basic processes of adaptation that could help us understand and explain the more general context updating mechanism. It provides ways of interpreting and predicting even quantitatively the changes in P300 amplitude occurring in various experimental paradigms.