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Differential topographic pattern of EEG coherence between simultaneous and successive coding tasks

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Abstract

The concept of two types of information coding, simultaneous and successive processing, is now well supported by extensive studies with factor analysis. However, few EEG evidence on processing types have been reported. In the present study we investigated whether varying demands on simultaneous or successive processing are reflected by different pattern of EEG coherence change from the passive condition to the active condition. We computed EEG coherence during simultaneous and successive processing tasks in both passive and active conditions. Under the passive condition, participants were just to perceive the presented stimuli. In the active condition, participants were required to remember the presented stimuli and then reproduce or recognize the remembered stimuli. Our result revealed the different topographic patterns of coherence change from the passive to the active condition between the simultaneous and the successive task. In the successive processing task, bilateral frontal–left temporal coherence in beta showed a significant decrease during the active condition, supporting Luria's model of the two information coding types. The condition effect of coherence in the simultaneous processing task was rather unclear. Our data also indicated that more task related cognitive processes, rather than the task-independent processes such as attentional demand, were reflected in EEG coherence of higher frequency bands. The different EEG coherence patterns seen in the simultaneous and successive tasks suggested the first step evidence that EEG coherence pattern may differentiate two distinctive types of information coding.

Keywords: Coherence; Electroencephalogram; Simultanesou and successive processing; Infromation coding; Das-Naglieri Cognitive Assessment System (DN-CAS)

1. Introduction

Among the approaches to understand human intelligence, a new view that defines intelligence by how to process the information, rather than by what to be processed, has been developed in the context of cognitive psychology. In this view, there are several dichotomies of human information processing styles, including parallel and sequential (Neisser, 1967; Sternberg, 1966), holistic and analytic (Levy, 1972; Brown, 1983), and simultaneous and successive processing (Luria, 1966; Das et al., 1975).

Luria (1973) proposed three principal functional units of the brain based on clinical observation of patients with brain damage. These are (a) the first functional unit for regulating tone and waking and mental states, (b) the second functional unit for receiving, analyzing, and storing information, (c) the third functional unit for programming, regulation and verification of activity. In the second unit of the brain, Luria (1966) described two basic forms of integrative activity of the cerebral cortex, simultaneous and successive information coding. Simultaneous coding involves an immediate apprehension and integration of various elements of experience. Successive coding, on the other hand, involves the sequential integration of stimuli into an organized temporal or serial order. Luria (1966) showed that the higher cortical processes in patients with a lesion of the posterior (parieto-occipital) and anterior (fronto-temporal) regions of the cortex revealed profound differences in the character of the disturbances. Disturbance of simultaneous coding was observed in patients with parieto-occipital lesion of the cortex, and disturbance of successive coding was observed in patients with lesion of the fronto-temporal regions of the left hemisphere. The

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former had problems in understanding logico-grammatical relationships and spatial associations, while the latter had problems in reproducing the presented serial order either auditory or visually.

The concept of two processing types is often discussed regarding the intricate relationship among such content dimensions as verbal–nonverbal or auditory–visual. In the context of verbal processing, Luria (1966) emphasized that both successive and simultaneous coding are important and that each contributes a different component to language comprehension. Successive coding is evident in understanding the syntax of a sentence because such coding involves the apprehension of the serial relation of one word to the next. Simultaneous coding is apparent in constructing meaning in a spatial configuration. In the context of the auditory–visual dichotomy, Languis and Miller (1992) suggested that as the nature of simultaneous coding is the grasping of the totality of experience all at once, it is often characterized as having spatial features. However, as Das et al. (1994) stated, an important point to recognize is that code content (what is to be processed) is not exactly the same as the coding type itself (how it is to be processed). Verbal codes may be simultaneous (as in the referent of a word or the relationship between two words), and spatial codes may be successive (as in recognizing a sequence of actions or remembering a series of pictures). Thus, we posited the existence of three different but interrelated dimensions: visual–auditory, verbal–nonverbal for code content type, and simultaneous-successive processing for coding type.

According to Luria (1973), the second unit's functions are regulated by the occipital, parietal, and temporal lobes posterior to the central sulcus. Within the second unit, the parieto-occipital region of the cortex is associated with simultaneous processing and the fronto-temporal region is associated with successive processing (Luria, 1966). Levy and Trevarthen (1976) proposed the hemispheric specialization hypothesis, derived from study with split-brain patients, for the two processing types, holistic and analytic processing. According to the hypothesis, the left cerebral hemisphere processes information using an analytic, logical, and sequential style for which words are an excellent tool. The right hemisphere, on the other hand, processes information in a holistic, simultaneous, or parallel manner that is particularly suitable for processing spatial relations (Bogen et al., 1972). Kaufman and Kaufman (1983) suggested that their tasks in the Kaufman Assessment Battery for Children (K-ABC, 1983) whose cognitive loads on simultaneous and sequential coding may refer either to Luria's processes or to the left brain–right brain distinction. However, evidence from experimental studies with both healthy participants and brain damaged patients supports that both hemispheres can process verbal and visuospatial information analytically and holistically (Arrigoni and De Renzi, 1964; Sergent, 1982).

The phenomenon of evoked potential can be used not only to indicate a direct response to specific sensory stimuli, but also to objectively record changes in the reception and analysis of information arising through the mobilization of active attention (Luria, 1966). A number of EEG studies suggested that EEG measures have successfully captured the brain activities of the three distinctive functional units and have also supported Luria's view that all three functional units cooperate to fulfill the variety of complex human brain activities (Languis and Miller, 1992).

In line with Luria's (1973) theory of the first functional unit, studies of event related potentials (ERPs) suggested that the brain stem and midbrain structures may be involved in attentional processes (Mirsky, 1987). ERP studies also suggested multiple sources contribute to the selective attention ERP and thus multiple sources are functionally closely interrelated (Klorman, 1991; Woods, 1990). More recently, studies with neuroimaging corroborate this view, suggesting multiple areas of activation including the frontal cortex during attentional tasks (Brass and von Cramon, 2004; Gruber and Goschke, 2004; Milham et al., 2003). Based on the involvement of frontal cortex in planning behavior (Newman et al., 2004; Morris et al., 1993), these results support the close interaction between the first functional unit (attnetional control) and the third functional unit (programming and planning). On another front, the well-known ERP component P300, which is known to be related to the selective attention process, is related to more than selective attention. Research with depth electrodes has demonstrated that a primary source of P300 is the hippocampus (Kuroiwa et al., 1997), which has a major role in memory encoding. Thus, the attentional discrimination component of P300 is also related to stimulus encoding and integration in Luria's second functional unit (Languis and Miller, 1992).

The second functional unit of the brain is responsible for receiving, analyzing, and storing information (Luria, 1973). Various tasks such as short-term memory task, spatial task and semantic coding task are relevant to the second functional unit. Studies with these tasks consistently reported the contribution of the parietal cortex. In the Sternberg short-term memory paradigm (Sternberg, 1966), the subject views a set of serially presented single-symbols and is asked to recall if a subsequent target digit was in the previously presented set or not. A distinctive ERP component during the Sternberg task is a waveform that has a peak over the parietal region of the brain. Also, the right parietal area of the brain is well established as a center for the encoding and integration of spatial information (Languis and Miller, 1992). In an EEG study with two pictorial tasks, Raven's Progressive Matrices (Raven, 1938) and Space Relations Test (Mitrushina and Stamm, 1994) reported consistent, strong interaction between the left parietal area and the right frontal area across all the task conditions. Semantic coding tasks require primary use of successive and simultaneous integration process of Luria's second functional unit of the brain (Languis and Miller, 1992). Kutas and Hillyard (1980) showed an ERP peak approximately 400–600 ms after stimulus onset over parietal brain areas. It was elicited when semantically incongruent words were presented at the ends of otherwise meaningful sentences. It is important to note that although each study reviewed above used various verbal–nonverbal and auditory–visual stimuli showed consistent results indicating the contribution of parietal area of the brain during the task performance. These results may correspond to Luria's second functional unit. However, the investigation of the different patterns during the two types of information coding task is yet to be done.