

## EFFECT OF HEMISPHERIC ASYMMETRY ON PERFORMANCE IN AUDITORY VIGILANCE TASK

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### Abstract

*The study was aimed to determine whether both performance level and performance decrement differ across hemispheres in difficult signal detection task. Sixty-five subjects had to detect the threshold auditory signal presented to the left/right ears randomly. Both hits and false alarm rate were significantly higher, whereas reaction time was shorter in the right hemisphere (RH) than in left one (LH). The clear-cut effect of hemispheres on the slope of response time to hits was obtained: the temporal performance decrement for the RH was higher than for the LH. Results correspond to previous findings (see Parasuraman et al, 1998, for review) and suggest the predominant involvement of the RH into the processes of signal detection and sustained attention. Extraversion seems to be the personality variable mediating the way in which hemispheric performance strategies should be applied to the task. Introverts compared with extraverts seem to use the LH processing strategies more often than extraverts.*

A large body of lesion data supports that the right hemisphere (RH) is an important part of the circuitry, which implements both alertness and vigilance. Localization of damage in the right frontal lobes reduces signal detection performance [Wilkins et al. 1987]. One of possible mechanisms underlying this effect may be the impairment of processes sustaining the alertness state. Yokogama et al. (1987) found that the normal deceleration of heart rate response that occurs during the preparatory interval of a warned RT task was absent in RH-damaged patients not in LH-damaged ones. Posner & Petersen (1990) proposed that one of the three attentional subsystems – the vigilance system – was right lateralized. Auditory discrimination task is linked to increasing of glucose metabolism in the right middle prefrontal cortex [Cohen et al. 1992]. The involvement of the RH seems to be important not only for initial analysis of a signal but also for further processing of a stimulus in short-term memory. After binaural simultaneous presentation of two standard stimuli the subjects were presented a test signal with 1 sec delay and they had to respond whether there was a test signal among two standards or not. In this study the left ear/right hemisphere advantage was obtained [Bruder et al. 1991].

The RH superiority in visual vigilance tasks was found [Whitehead, 1991, Dimond, Beamont, 1973, 1979]. However this effect is less consistent than in auditory modality.

One of possible reasons might be that visual task requires cooperation between hemispheres whereas the auditory tasks are performed mostly via mechanisms and resources of the RH. This explanation is supported by split-brain studies data. The total commissurotomy patients demonstrated substantial decrement in detection of visual signals irrespective of stimulated hemisphere. When the same subjects completed auditory vigilance tasks, their detection efficiency was higher for the RH than for the LH [Dimond, 1979].

The predominance of the RH in dichotic listening task during hypnosis was obtained [Pagano et al. 1988]. This phenomenon suggests that RH is linked to the basic mechanism that regulates the auditory processing.

Nowadays the role of brain hemispheres in sustained attention is investigated mostly in visual tasks. Moreover, in most studies relatively simple vigilance tasks were used, in which both sensitivity index ( $d'$ ) and criterion ( $\beta$ ) changes could not be computed because of low false alarm rate [Koelega, 1992]. In contrast to the large body of results confirming a link between RH and the overall level of vigilance, the results demonstrating a link between RH and the vigilance decrement are much weaker [Parasuraman et al., 1998].

Our study was aimed to determine whether both performance level and performance decrement differ across hemispheres in difficult signal detection task. The task differed from common vigilance task [Koelega, 1992] in some substantial aspects: (1) a weak auditory signal nearing threshold level was used; (2) participants were trained until they reached fixed level of baseline performance; (3) both high target probability ( $P(S)=0.5$ ) and event rate (in average, 15 signals/minute) were applied; (4) the participants had to sustain their attention during a long period of time (more than 70 min), and (5) the subjects had to allocate their attention among their ears, as both signals and noises were presented to the left/right ears randomly.

## Method

Experimental design was analogous to one described in the article by Gusev, Schapkin (in this volume). Linear regression analysis was added in order to examine temporal trends of performance parameters for each hemisphere separately. The slopes ( $B_{lh}$ ,  $B_{rh}$ ) and intercepts ( $I_{lh}$ ,  $I_{rh}$ ) of regression curve were added to the ANOVA as dependent variables.

## Results and discussion

Our results correspond to previous findings (see Parasuraman et al, 1998, for review) and suggest the predominant involvement of the RH into the processes of signal detection and sustained attention. Both hits and false alarm rate were significantly higher in the RH than in the LH ( $P(H)_{lh} = .70$ ,  $P(H)_{rh} = .77$ ,  $F = 3.24$ ,  $p = .076$ ;  $P(FA)_{lh} = .24$ ,  $P(FA)_{rh} = .34$ ,  $F = 4.63$ ,  $p = .035$ ), whereas reaction time was shorter ( $RT_{lh} = 1294$  ms,  $RT_{rh} = 1202$  ms). It is important to note, that  $d'$  index did not differ across the hemispheres. Thus, the greater involvement of one hemisphere into the task did not automatically mean its efficiency in task implementation. No hemispheric differences in criterion shift were obtained. We suspect that large individual variability and non-linear changes in criterion over time are the reason of this phenomenon.

There is a body of findings supporting that information tends to be processed by those brain systems, which are capable to perform the task in most parsimonious way [Hellige, 1990]. It is widely assumed that the RH mechanisms implement mostly the holistic and shallow strategy of processing whereas the LH mechanisms provide the analytical and deep one. Our experimental conditions including discrimination of a weak target signal from noise, high event rate as well as equal probability for both types of stimuli require fast information processing. The parallel-holistic RH strategy appears to be more appropriate for this purpose than the sequential-analytical LH strategy. However, the overuse of the RH strategy by subjects had some negative effects: the shallow processing facilitated high rate of false alarms, which decreased the general performance level in the RH.

The problem whether the brain mechanisms subserving the vigilance level are different from those that underlie vigilance decrement is still discussed in the literature [Parasuraman et al., 1998]. The temporal trends of performance were examined to test this assumption. We found no hemispheric differences in both  $d'$  and criterion decrement. However, the clear-cut effect of hemispheres on the slope of response time to hits was obtained (RT:  $B_{rh} = -.002$ ,  $B_{lh} = .002$ ,  $F = 3.74$ ,  $p = .057$ ). Thus, the reaction time data demonstrated that both overall performance level and performance decrement for the RH was higher than for the LH.

This effect is in the line with results of Warm et al. (1980) who reported that reaction time to the RH signals was increasing alongside with the time on task, whereas reaction time to the LH signals remained stable, suggesting that only the RH showed a vigilance decrement. Warm et al. (1980) interpreted their findings in terms of a hemispheric cooperation model, in which the RH was postulated to show a greater initial level of performance and to show greater decrement over time. The LH is supposed to show lower initial performance but less decrement over time. The hemispheric cooperation model postulates that both hemispheres are involved into vigilance but the RH predominates. It may cause shortening of its resources and the vigilance decrement over time.

Extraversion seems to be the personality variable mediating the way in which hemispheric performance strategies should be applied to the task. Individual differences were obtained for LH only. Introverts showed both higher  $d'$  level ( $I$ ) and higher  $d'$  decrement over time ( $B$ ) than extraverts ( $I_i = 1.95$ ,  $I_e = 1.46$ ,  $F = 4.06$ ,  $p = .048$ ;  $B_i = -.02$ ,  $B_e = -.002$ ,  $F = 5.16$ ,  $p = .026$ ).

Individual differences in temporal trend of signal detection parameters are likely to be partly caused by the "initial level effect" mentioned above: introverts overperformed extraverts but introverts have less abilities to maintain the high level of vigilance over time. Introverts compared with extraverts seem to use the resources of the LH better and involve the analytical strategies into the processing more often. It might partly compensate both fast and shallow processing imposed by the task structure and be one of the reasons for better task performance by introverts (Gusev, Schapkin, in this volume). Eysenck (1971) who reported that introverts tended to implement the analytical strategies under conditions of information deficit provides support for this explanation. Future studies should explore the individual differences in the hemispheric strategies in detail.

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