Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
International Journal of Psychophysiology 53 (2004) 71–73
INTERNATIONAL JOURNAL OF PSYCHOPHYSIOLOGY
www.elsevier.com/locate/ijpsycho

Letter to the editor

Decoupling of midfrontal delta–beta oscillations after testosterone administration

Sir: In June 2003 issue of the *International Journal of Psychophysiology*, an intriguing evolutionary based interpretation of brain oscillations in relation to the personality trait of behavioral inhibition was postulated by Knyazev and Slobodskaya (2003). This electrophysiological interpretation is derived from the triune brain concept, originally put forward by MacLean (1990), which states that the human brain is comprised of three loosely coupled systems. The reptilian complex and the limbic system are involved in affective processing and considered as representatives of the subcortical part of the brain. The neo-cortex encompasses the youngest evolved brain structure and is superimposed on the first two systems. The pronounced expansion of the frontal cortex is argued to have made a crucial contribution to the evolvement of conscious aspects of affective processing. Brain oscillations in specific frequency bandwidths furthermore epitomize diverse aspects of information processing on different neuroanatomical levels. Whereas the lower frequency ranges (i.e. 1–8 Hz) are implicated in the evolutionary older subcortical systems, higher frequencies (i.e. >8 Hz) would originate from thalamo–cortical and cortico–cortical interactions. Nowadays, it is widely accepted that the frontal cortex fulfills a modulatory role in subcortical information processing. For example, Knyazev and Slobodskaya (2003) have provided evidence that descending cortical inhibition of subcortical structures is positively linked to affective processing such as behavioral inhibition. Interestingly, reductions in behavioral inhibition and anxiety have been found after administrating the steroid hormone testosterone (Svensson et al., 2003). Testosterone arguably exerts these anxiolytic effects through receptor binding in steroid responsive networks located in subcortical structures (Wood, 1996; Tuiten et al., 2000; Van Honk et al., 2001). Since increases in delta (1–3 Hz) synchronization predict reduced anxiety (Hotz et al., 2000), testosterone might in particular influence delta synchronization specifically and thereby affect the coupling between the subcortical lower (i.e. delta (1–3 Hz) range) and the cortical higher frequencies (i.e. alpha (8–12 Hz) and beta (13–30 Hz) range). Sixteen healthy, right-handed volunteers were enrolled in a placebo controlled double-blind, within-subjects, cross-over design. On two testing days, which were separated by three weeks, between 09:00 and 10:00 h, participants received a single sublingually administration of 0.5 mg testosterone (with cyclodextrine as carrier) or placebo. Three hours after intake, see Tuiten et al. (2000) for the rationale behind this strategy, a 4-min electroencephalographic (EEG) baseline recording from the frontal, Fp1, Fp2, F3, F4 and Fz electrode sites was obtained (impedance: <5 kΩ, sampling rate: 250 Hz, amplification: 20 000). Raw EEG data were corrected for horizontal and vertical eye movements using linear regression. EEG signal containing residual muscle movements, or other forms of artifacts, greater than -50 μV and $+50$ μV were rejected prior to further analysis. The designation of an artifact in one of the leads resulted in removal of that epoch for all channels in order to ensure that the remaining data were identical for all sites in time. Next, 1024-s chunks of averaged artifact-free EEG were extract-

0167-8760/04/$ - see front matter
doi:10.1016/j.ijpsycho.2003.12.012

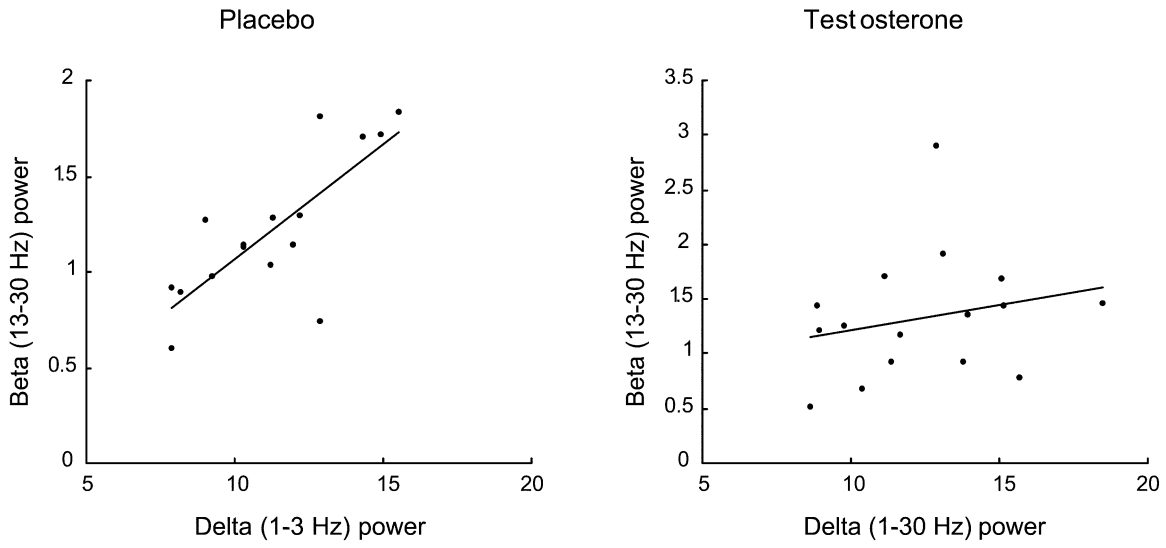

Fig. 1. Significant loss of midfrontal delta–beta coupling after testosterone compared to placebo administration in healthy human volunteers.

ed through a Hamming window (length 10%) to reduce spurious estimates of spectral power (μV^2) in the 1 Hz frequency bins for each electrode site. For each frontal electrode spectral power, values were averaged across all epochs within a single baseline and were then transformed to power density values for the delta (1–3 Hz), alpha (8–13 Hz) and beta (13–30 Hz) frequency bands. Paired-samples *t*-tests revealed a significant increase in delta power after testosterone administration over the midfrontal (Fz) electrode site [$t(16) = 2.13$: $P = 0.05$]. Furthermore, whereas a significant Pearson's correlation was observed for delta and beta oscillations in the placebo condition [$r(16) = 0.773$: $P = 0.0001$, the latter coupling was completely abolished after testosterone administration [$r(16) = 0.230$: $P = 0.4$]. The difference between the two correlations was statistically significant [$Z(16) = 2.55$: $P = 0.01$]. Fig. 1 depicts the coupling of midfrontal delta–beta oscillations after *T* and placebo administration.

From the viewpoint advocated by Knyazev and Slobodskaya (2003), it can be suggested that the currently observed sortical-cortical (beta–delta) decoupling after testosterone administration is due to increases in subcortical generated delta power. Furthermore, the present decoupling is in line with the behavioral disinhibitory properties of testosterone, suggesting the motivational stance of the brain shifts from behavioral inhibition towards behavioral activation. In sum, relationships between the different frequency bandwidths seem to provide important insights into functional and dysfunctional affective processes in the brain. The approach of Knyazev and Slobodskaya is thus both scientifically stimulating and clinically relevant.

Acknowledgments

This work was sponsored by an Innovational Research Grant (# 016-005-060) from the Netherlands Organization for Scientific Research (NWO).

References

Hotz, M.A., Ritz, R., Linder, L., Scollo-Lavizzari, G., Haeffel, W.E., 2000. Auditory and electroencephalographic effects of midazolam and a-hydroxy-midazolam in healthy subjects. Br. J. Clin. Pharmacol. 49, 72–79.

Knyazev, G.G., Slobodskaya, H.R., 2003. Personality trait of behavioral inhibition is associated with oscillatory systems reciprocal relationships. Int. J. Psychophysiol. 48, 247–261.

MacLean, P.D., 1990. The Triune Brain in Evolution: Role in Paleocerebral Functions. Plenum, New York.

Svensson, A.I., Akesson, P., Engel, J.A., Soderpalm, B., 2003. Testosterone treatment induces behavioral disinhibition in adult male rats. Pharmacol. Biochem. Behav. 75, 481–490.

Tuiten, A., Van Honk, J., Koppeschaar, H., Bernaards, C., Thijssen, J., Verbaten, R., 2000. Time course of effects of testosterone administration on sexual arousal in women. Arch. Gen. Psychiatr 57, 149–153.

Van Honk, J., Tuiten, A., Hermans, E., Putman, P., Koppeschaar, H., Thijssen, J., Verbaten, R., Van Doornen, L., 2001. A single administration of testosterone induces cardiac acclerative responses to angry faces in healthy young women. Behav. Neurosci. 115, 238–242.

Wood, R.I., 1996. Functions of the steroid-responsive neural network in the control of male hamster sexual behavior. Trends Neuroendocrinol. Metab. 7, 338–344.

Dennis J.L.G. Schutter*
Jack van Honk

*Corresponding author.
Affective Neuroscience Section, Department of Psychonomics, Helmholtz Research Institute, Utrecht University, Heidelberglaan 2, 3584 CS Utrecht, The Netherlands
Email address: d.schutter@fss.uu.nl

Received 9 December 2003
Available Online February 20 2004