Archival Report

Biological Psychiatry

The Speed of Visual Attention and Motor-Response Decisions in Adult Attention-Deficit/Hyperactivity Disorder

Fernando Cross-Villasana, Kathrin Finke, Kristina Hennig-Fast, Beate Kilian, Iris Wiegand, Hermann Joseph Müller, Hans-Jürgen Möller, and Thomas Töllner

ABSTRACT

BACKGROUND: Adults with attention-deficit/hyperactivity disorder (ADHD) exhibit slowed reaction times (RTs) in various attention tasks. The exact origins of this slowing, however, have not been established. Potential candidates are early sensory processes mediating the deployment of focal attention, stimulus response translation processes deciding upon the appropriate motor response, and motor processes generating the response.

METHODS: We combined mental chronometry (RT) measures of adult ADHD ($n = 15$) and healthy control ($n = 15$) participants with their lateralized event-related potentials during the performance of a visual search task to differentiate potential sources of slowing at separable levels of processing: the posterior contralateral negativity (PCN) was used to index focal-attentional selection times, while the lateralized readiness potentials synchronized to stimulus and response events were used to index the times taken for response selection and production, respectively. To assess the clinical relevance of event-related potentials, a correlation analysis between neural measures and subjective current and retrospective ADHD symptom ratings was performed.

RESULTS: ADHD patients exhibited slower RTs than control participants, which were accompanied by prolonged PCN and lateralized readiness potentials synchronized to stimulus, but not lateralized readiness potentials synchronized to response events, latencies. Moreover, the PCN timing was positively correlated with ADHD symptom ratings.

CONCLUSIONS: The behavioral RT slowing of adult ADHD patients was based on a summation of internal processing delays arising at perceptual and response selection stages; motor response production, by contrast, was not impaired. The correlation between PCN times and ADHD symptom ratings suggests that this brain signal may serve as a potential candidate for a neurocognitive endophenotype of ADHD.

Keywords: ADHD, Decision-making, Electroencephalography, Neuro-cognitive endophenotypes, Psychophysics, Stimulus-response translation

http://dx.doi.org/10.1016/j.biopsych.2015.01.016

Attention-deficit/hyperactivity disorder (ADHD) frequently persists into adulthood (1–3). Due to developmental changes in symptom expression, however, the diagnosis of adult ADHD remains challenging (1–10). Latent neurocognitive traits might, thus, constitute endophenotypes of ADHD that 1) differentiate between affected and unaffected individuals, 2) are more closely related to the neurobiological changes associated with adult ADHD than the overt symptoms, and 3) might provide specific information about target functions for interventions (11). In this regard, various attention tasks have been used to study ADHD, with the general finding being that children and adults with ADHD exhibit slowed response times (RTs)[1] (except for the most basic response tasks) (5,13–20). However, the exact contributions of the respectively engaged internal processes—which might be the source(s) of the overt RT slowing—are not specified unequivocally (4,5,7,10,13–16). Candidate processing levels are early sensory processes that guide the deployment of focal attention (4,10,21), stimulus-response translation processes that decide upon the correct motor response, and motor-response production processes (5,22–24).

Event-related potential (ERP) waves of the electroencephalogram (EEG) allow the assessment of the timing and magnitude of neural activity underlying several distinct processes during task performance (25–27). Thus, a systematic decomposition of potential perceptual and response-related sources underlying overt behavioral slowing is possible when combining ERPs with behavioral measures. This opens the potential for identifying latent internal traits of ADHD-related slowing that bear candidacy for neurocognitive endophenotypes (26–29). Of note, the few previous ERP studies of ADHD patients that investigated early sensory components provide some evidence

[1]These findings indicate that behavioral slowing is a reliable finding across the life span. In the clinical symptomatology, this is reflected by inattention symptoms (i.e., sluggish orienting and responding to social and cognitive stimuli and difficulties to direct and maintain selective attention to motivationally relevant tasks) being more enduring than hyperactivity symptoms (6,12).

ISSN: 0006-3223

for alterations of sensory processes that mediate attentional (21) as well as subsequent response selection (22–24). However, none of these studies or those in children with ADHD (26) used a design capable of disentangling the respective potential contributions of the three distinct, consecutive substages of information processing to overt task performance.

Here, we assessed lateralized brain electrical activity in combination with RTs during a compound search task (30) in which the pop-out target to be detected (31,32) contained an additional feature that had first to be identified (e.g., vertical versus horizontal orientation) before a decision about the appropriate motor response could be reached (e.g., left versus right index finger) (32,33). This way, the feature that defined the target from its surroundings (e.g., color) was dissociated from the feature that determined the response (e.g., orientation), permitting target selection, response selection, and response production processes to be examined independently in terms of their respective ERP signatures both within the same participant and in the same task (Figure 1).

In particular, our analyses focused on the posterior contralateral negativity (PCN, also called N2pc) (34,35)—a negativity elicited over parieto-occipital areas contralateral to the location of an attended stimulus—as a marker of focal-attentional selection (36). Second, the lateralized readiness potential (LRP)—a negative-going deflection over the motor areas contralateral to the side of a unimanual response—was examined to index the activation and execution of effector-specific motor responses (37,38). When synchronized relative to stimulus onset (stimulus-locked LRP [sLRP]), its onset latency marks the speed of motor-response decisions, that is, the time it takes to select one out of several possible response alternatives (39). When synchronized relative to response onset (response-locked LRP [rLRP]), its onset reflects the time between response selection and response execution [e.g., (40,41)].

All behavioral and neural measures were compared between adult patients with ADHD, diagnosed in a comprehensive procedure, and matched healthy control participants. We expected to replicate behavioral slowing of RTs in adults with ADHD (10,13–20). Since both perceptual (4,10,21) and response-related (5,22–24) processes have been suggested as candidate sources of overt RT slowing, we further expected to observe delays in at least one of the analyzed ERPs. Moreover, to assess the clinical relevance of affected ERPs, we further correlated ERP measures with symptom ratings of disease severity. First, we used the Conners Adult ADHD Rating Scales (CAARS) (42) as an index of the severity of subjective current ADHD symptoms. Second, we used the Wender Utah Rating Scale (WURS) (43) sum score as an index of the subjective retrospective severity of childhood symptoms.

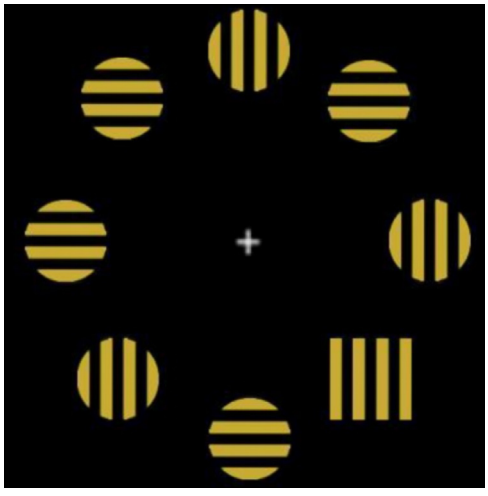

Figure 1. Example of stimulus displays used in the present study. Each display contained a pop-out target, defined in the feature dimension shape (square) or color (red circle), among distracters (yellow circles). The task was to indicate the target's (grating) orientation (horizontal vs. vertical) via pressing the respectively assigned mouse button (left vs. right).

METHODS AND MATERIALS

Participants

Fifteen adult ADHD patients (6 male patients; mean age 32.93 ± 10.36 years)[2] diagnosed at the Department of Psychiatry (Ludwig-Maximilians-University Munich) participated in the study. In the diagnostic procedure, two psychiatric interviews (according to DSM-IV) were conducted either by psychiatrists of the ADHD outpatient clinic or by psychiatrists in clinical practice and by experienced neuropsychologists. Patients were only included in the study when both psychiatrists and neuropsychologists rated them as ADHD patients. A psychologist trained in ADHD assessment collected collateral information from different sources. Elementary school reports or prior diagnoses during childhood and adolescence had to confirm childhood onset according to the obligatory DSM-IV symptoms for childhood ADHD. Patients were only included if descriptions of the respective symptoms were reported at an age <7 years and persisted for a long-term period in the subsequent developmental reports. In Germany, elementary school reports contain comprehensive descriptions of learning performance, social behavior, and daily structure, differentiated according to cognition, emotion, and motor behavior. Furthermore, prior psychiatric diagnoses or third-party informants (siblings, parents, and/or spouses) had to confirm that these symptoms were also displayed at home and that there had been no alternative suspected diagnosis.

Neuropsychological Testing

Current ADHD symptoms were assessed using the long version of the CAARS and retrospective childhood symptoms were assessed using the WURS. Average current ADHD symptom ratings in patients (Table 1) indicated significant subjective impairment in all subscales (mean t scores > 60), except for hyperactivity/restlessness (mean t score = 57),

[2]The relatively high rate of female participants in our study is consistent with a generally more balanced gender distribution of prevalence rates in adulthood compared with childhood ADHD studies (44). It has been argued that while in childhood, referrals from teachers and parents are biased toward male subjects; self-referrals in adulthood are more common and lead to diminishing differences in prevalence rates between male and female subjects (45).