BRAIN RESEARCH 1186 (2007) 194–202

available at www.sciencedirect.com

ScienceDirect

www.elsevier.com/locate/brainres

BRAIN RESEARCH

Research Report

Fractional anisotropy correlates with auditory simple reaction time performance

Stefan Böhr[a], *Daniel Güllmar*[a,b,*], *René Knab*[c], *Jürgen R. Reichenbach*[b], *Otto W. Witte*[d], *Jens Haueisen*[a,e]

[a]*Biomagnetic Center, Department of Neurology, Friedrich-Schiller-University Jena, Erlanger Allee 101, 07747 Jena, Germany*
[b]*Medical Physics Group, Institute of Diagnostic and Interventional Radiology, Friedrich-Schiller-University, Philosophenweg 3, 07743 Jena, Germany*
[c]*Core-Unit MR Methods, Friedrich-Schiller-University, Philosophenweg 3, 07743 Jena, Germany*
[d]*Department of Neurology, Friedrich-Schiller-University Jena, Erlanger Allee 101, 07747 Jena, Germany*
[e]*Institute of Biomedical Engineering and Informatics, TU Ilmenau, POB 100565, 98684 Ilmenau, Germany*

ARTICLE INFO

Article history:
Accepted 11 October 2007
Available online 17 October 2007

Keywords:
DTI
Fractional anisotropy
SRT
Cerebellum
Pyramidal tract
Handedness

ABSTRACT

During the last two decades, modern imaging studies focused intensively on the broad field of reaction time paradigms and significantly enhanced the understanding of behavioral performance. However, interindividual variations of simple reaction time (SRT) have been barely investigated. In this study, we intended to identify neural correlates of interindividual variation in auditory SRT (aSRT) employing the Poffenberger paradigm with auditory stimuli, in order to investigate neural processing speed performance. We conducted a whole-head voxel based morphometry analysis of fractional anisotropy (FA) in 19 healthy, right handed subjects. Simple regression analysis between FA and interindividual aSRT measures was performed for each voxel. Significant positive correlation (R^2: 0.44/0.78 min/max) for FA vs. individual mean aSRT was found in the right central cerebellum dorso-cranial of the dentate nucleus. A significant correlation (R^2: 0.453/0.633 min/max) was also detected between FA and the hand performance index, which characterizes the intraindividual RT difference between left and right hand, within the precentral portion of the pyramidal tract in the left hemisphere. Fast right handed response correlated with high local FA values located within neural structures participating in right hand control. Against the background of only right handed participants in our study, the hypothesis of local myelination as one basic condition influencing reaction time performance is strongly supported. The presented results identify brain areas involved in the processing speed of the aSRT tasks. We propose that the presented findings are due to an influence of participants' right hand preference on both FA and aSRT measures.

* *Corresponding author.* Medical Physics Group, Institute of Diagnostic and Interventional Radiology, Friedrich-Schiller-University Jena, Philosophenweg 3, 07743 Jena, Germany. Fax: +49 3641 935373.
E-mail address: daniel.guellmar@med.uni-jena.de (D. Güllmar).

0006-8993/$ – see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.brainres.2007.10.013

1. Introduction

Since the beginning of the 20th century, simple reaction time tasks (SRT) have provided insights into neurophysiologic and psychological functions of humans (Poffenberger, 1912). For a long time, SRTs are known to be influenced by a variety of extrinsic and intrinsic factors, e.g., caffeine, alcohol, arousal, physical activity, stimulus duration, stimulus intensity, warning signal, daytime, fatigue, age or IQ (see e.g., Welford, 1980; Luce, 1986; Taimela, 1991). In all SRT test paradigms, interindividual variability is reported and still not fully understood, even though strong correlations to both co-variables level of intelligence (Choudhury and Gorman, 1999) and age (Fozard et al., 1994) have been shown. For the intraindividual variance of SRT, a number of hypotheses and computer models exist (Reed, 1998; Miller and Ulrich, 2003), whereas for interindividual variability, an evident corresponding model is still under debate. Yet, it has been proposed that interindividual differences in reaction time (RT) may be due to white matter (WM) differences; especially with respect to myelination (Reed et al., 2004), since the interdependence between myelination and nerve conduction speed is well established (Jack et al., 1983).

Despite these findings, a direct proof for the interrelation of interindividual RT differences and myelination is still missing. Therefore, identification of neural correlates of differences in interindividual RT would provide important information for the understanding of the performance in neural processing speed and behavioral measures. Until recently, no method for the evaluation of such neuromorphologic microstructural WM properties was available *in vivo*. A turning point in the last decade has been the establishment of diffusion tensor imaging (DTI) (Basser et al., 1994; Le Bihan et al., 1993; Pierpaoli et al., 1996), which is even sensitive for WM abnormalities in clinical routine (Nguyen et al., 2005). Using DTI, the diffusion anisotropy can be mapped voxel by voxel. Thereby, direction of maximum diffusivity is assumed to coincide with the WM fiber tract orientation (Moseley et al., 1991). Fractional anisotropy (FA), which is based on the standard deviation of the three eigenvalues of the diffusion tensor (see Le Bihan, 2003 for a technical review), has been shown to be of clinical relevance in a wide range of various conditions including schizophrenia (Hoptman et al., 2004), sensory neural hearing loss (Chang et al., 2004), multiple sclerosis (Filippi et al., 2001) and others.

Only few reports on the correlation between FA and RT performance measures exist. Madden et al. (2004) reported a moderate correlation in young adults between FA and RT in the splenium of the corpus callosum ($r = -0.54$) by using a visual target detection oddball task. Tuch et al. (2005) demonstrated correlations between visual choice reaction tasks and FA in the visual projection and association pathways of healthy young adults. In the latter study, significant correlations were found in the right thalamus, right medial precuneus and left superior temporal WM, but not in the posterior internal capsule representing motor pathways nor in the interhemispheric connections, as represented by the corpus callosum.

Analyzing the time flow of aSRT processing (from stimulus to response) leads to a subdivision into different sections. Some of these sections are included in established neurophysiological test paradigms (Table 1). A comparison of aSRT results with average brainstem acoustic evoked potentials (BEAP), auditory middle latency response (AMLR) and corticomotor latency (CmL) measures in healthy subjects (see Table 1) shows that the involved brain areas are not very likely to account for the main part of latency across individuals in aSRT. Therefore, the complex structures involved during central processing time still remain as crucial influencing factors on interindividual aSRT differences. In imaging studies analyzing SRT responses, a single neuroanatomic substrate for motor preparation, independent of the movement information context was suggested (Deiber et al., 1996). In this PET study, which investigated visual RT tasks, different conditions of motor preparation were associated with increased regional cortical blood flow in a common set of cerebral regions, including contralateral frontal cortex, contralateral parietal association cortex, ipsilateral cerebellum, contralateral basal ganglia and thalamus.

The aim of the present study was to investigate whether variation across individuals in white matter FA of human brain structures was associated with auditory simple RT measures. We suppose a DTI detectable brain area or network along aSRT signal processing structures with crucial influence on human stimulus–response measures. To reduce the influence of complex covariables on RT (e.g., decision making, attention) due to task demanded central processing, we implemented a SRT paradigm. We calculated FA maps in 19

Table 1 – Duration and SD of aSRT compared to functional measures linking anatomy and timing of motor performance and central auditory pathway activation

Test modality	Mean (SD) in ms	Study/ source	Method	Location
BAEP	5.5 (0.5)	Büttner et al. (1983)	Click stimuli, electrodes	Stimulus to colliculus inferior
AMLR	17.1	Inui et al. (2006)	MEG study, auditory stimuli	Stimulus to PAC
	16–19	Yvert et al. (2005)		
Central processing time				Auditory processing to M1
CmL	19.9 (1.9)	Lyu et al. (2004)	TMS and APB-EMG	M1 to muscle activation
	19.0 (3.3)	Ludolph et al. (1989)		
SRT	194.2 (25.9)	Present study	aSRT task	Stimulus to response

BAEP: brainstem acoustic evoked potentials, AMLR: auditory middle latency response, MEG: magnetoencephalography, PAC: primary auditory cortex, M1: primary motor area, CmL: corticomotor latency, TMS: transcranial magnetic stimulation, APB: abductor policis brevis muscle, EMG: electromyography.