GABA concentration in the superior temporal gyrus predicts gamma-band oscillations and multisensory perception

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Target Audience Neurologists, psychologists, psychiatrists

Purpose Multisensory perception requires the integration of different sensory streams into a coherent, conscious percept. In human brain, the superior temporal gyrus (STG) is an important region involved in multisensory perception. Recent studies have suggested that multisensory perception can be accompanied by condition-specific changes in oscillatory responses, which often, albeit not always, occur in the gamma band[1-3]. In addition, a recent magnetic resonance spectroscopy (MRS) study has shown a positive relationship between concentration of the inhibitory neurotransmitter GABA and gamma-band oscillations[4], which, however, did not remain undisputed[5]. Hence, it can be hypothesized that GABA concentration in the STG modulates gamma band oscillations, which in turn influences multisensory perception. In this combined MRS-electroencephalography (EEG) study, it was examined whether GABA concentration in the STG predicts gamma-band oscillations and multisensory perception in the sound-induced flash illusion (SIFI) paradigm[6]. In this paradigm the presentation of a single flash together with two rapidly succeeding tones can lead to the illusory perception of two flashes. Notably, the illusion rate, i.e. the number of perceived illusions relative to all trials, varies substantially between individuals in SIFI.

Methods N = 40 subjects (23 male, 17 female, age range 18-51) participated in this study. MRS and EEG data were acquired within 48 hours. All scans were performed on a 3T Verio system (Siemens Healthcare, Erlangen, Germany) using a 32 channel receive only RF coil. First- and second-order shims were adjusted using FAST(EST)MAP[7]. Single volume data from the left STG were acquired using the MEGA-PRESS sequence[8] with the following scan parameters: VOI = 20x30x20 mm^3, TR/TE = 3000/68 ms, number of averages = 256, T_{acq} = 512 ms, and editing pulse at 1.9 ppm. Metabolite quantification was performed using LCModel[9] with a measured basis set. EEG signals were recorded using a 128 channel active EEG system (EasyCap, Hersching, Germany). The setup of the SIFI and the analysis of gamma-band oscillations were conducted in analogy to previous studies[3,5]. The power and the peak frequency for a range of 40-80 Hz in response to the SIFI stimuli were calculated for a 200 to 600 ms post stimulus interval. This was done for 5 virtual electrodes that covered approximately the same volume as selected for the MRS measurement (i.e. left STG). Individual peak gamma power and corresponding frequency were correlated with GABA concentration and individual SIFI illusion rate.

Results Localized shimming resulted in water linewidths of 7.9 ± 0.7 Hz. Only quantification results for GABA from MEGA-PRESS spectra (Fig. 1) with Cramér-Rao lower bounds (CRLBs) < 25% were retained, yielding N = 34 participants with an average CRLB of (13.0 ± 4.0 %). As illustrated in Fig. 2, GABA concentration in the STG was positively correlated with the individual illusion rate in the SIFI paradigm (r = 0.469, p = 0.005), as well as with gamma-band power (r = 0.534, p = 0.001). In addition, there was a positive relationship between gamma-band power and the multisensory illusion rate in SIFI (r = 0.416, p = 0.012, Fig. 2).

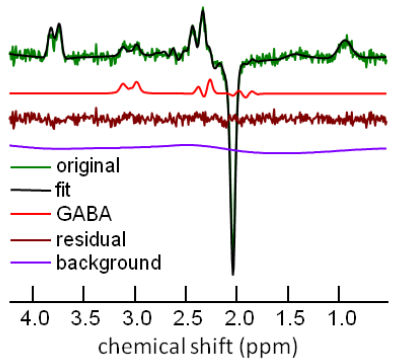

Fig. 1. ^{1}H difference spectra from the left STG of a healthy volunteer acquired with the MEGA-PRESS sequence together with LCModel fit, LCModel output for GABA, fit residuals, and background.

Discussion In the present study, it was demonstrated that GABA concentration in a key multisensory region predicts perception in a well-known multisensory illusion paradigm. In addition, it was shown that GABA concentration in the STG is highly correlated with the power of gamma-band oscillations in response to multisensory stimuli. Finally, providing further support for the notion that neural oscillations play an important role in multisensory processing[1-3], a highly significant positive association between gamma-band oscillations and the SIFI illusion rate across participants was found.

Conclusion This is the first study that demonstrates a tight triangular relationship between GABA concentration in the STG, gamma-band oscillations, and multisensory perception. The study revealed compelling evidence in support of the hypothesis that gamma-band oscillations play a crucial role in multisensory processing.

References 1. D. Senkowski et al., TINS, 31(8): 401-9, 2008; 2. J. Bhattacharya et al., Curr Microbiol, 45(2): 99-104, 2002; 3. J. Keil et al., Cereb Cortex, 24(5): 1278-88, 2014; 4. S.D. Muthukumaraswamy et al., Proc Natl Acad Sci USA, 106(20): 8356-61, 2009; 5. H. Cousijn et al., Proc Natl Acad Sci USA, 111(25): 9301-6, 2014; 6. L. Shams et al., Brain Res Cogn Brain Res, 14(1): 147-52, 2002; 7. R. Gruetter et al., MRM, 43(2): 319-23. 2000; 8. M. Mescher et al., NMR Biomed, 11(6): 266–272, 1998; 9. S.W. Provencher et al., MRM, 30(6): 672-79, 1993.

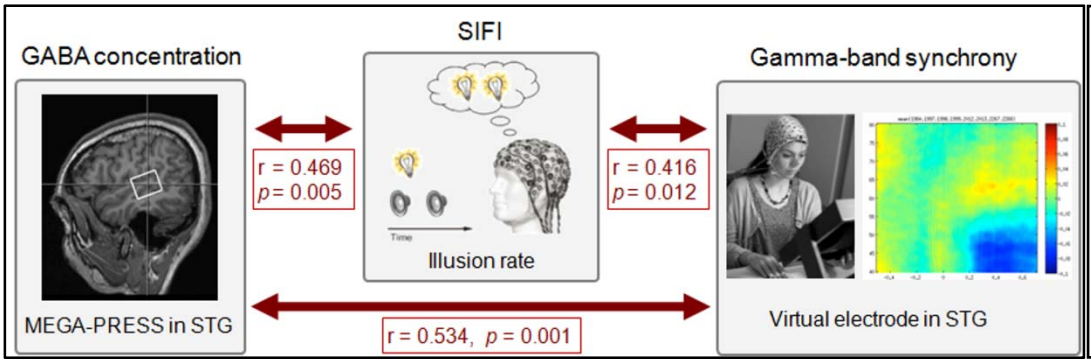

Fig. 2. Schematic of experimental setup where the GABA concentration in the STG using MRS (left), the illusion rate in the SIFI (center), and the power of gamma-band oscillations via EEG (right) are measured. Correlations between these three quantities are illustrated with arrows indicating a triangular relationship between the three measured quantities.