The evaluation of non-literal language processing in schizophrenia

Ph.D. Thesis

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Introduction

Non-literal language (e.g. metaphors, irony, and conversational implicatures) is widely used in everyday verbal communication. The comprehension of the intended meaning of non-literal utterances requires pragmatic language skills.

Pragmatics investigates the social, cognitive and holistic aspects of language use, therefore, it studies language in social, interpersonal situations, and meaning in action. It studies language processing and its cognitive mechanisms where context contributes to the overall meaning of the utterance, and particularly aims to explain how utterances are interpreted. The successful interpretation of such content assumes the ability to go beyond strictly literal speech, so as to decipher the intention of the speaker. According to the relevance theory, it is widely accepted that successful communication depends on the inferring of beliefs and intentions of the speaker in conversation, and they also highlight the role of 'theory of mind' (ToM) ability in understanding utterances, especially when they involve non-literal meaning. The term 'theory of mind' refers to the ability to conceptualize other people's mental states, such as their beliefs, knowledge and intentions, and hence to explain and predict their behaviour.

Studies show that schizophrenic patients have problems understanding non-literal language, and such deficits can lead to social isolation. Furthermore there is now substantial evidence also for ToM deficit in schizophrenia. Recently, a number of studies have paid attention to the pragmatic competence of schizophrenic patients in several dimensions of non-literal language processing, such as metaphor, irony, and conversational implicatures.

Studies about the comprehension of conversational implicatures show rather congruent results about schizophrenic patients' impaired performance in social situations. However, research data on the comprehension of metaphor and irony in schizophrenia are not that consistent at all.

Compensatory effect of general cognitive skills on non-literal language processing in schizophrenia: A preliminary study

Schizophrenia is characterized by general cognitive impairment, and it is still a question how impaired nonliteral language comprehension is influenced by cognitive disturbances. In most of the studies about nonliteral language comprehension in schizophrenia, the IQ (reflecting general neurocognitive functions) differences between the schizophrenia groups and the control groups were significant. In some of the studies the IQ scores were taken into account in the statistical analysis, but still, the IQ scores of the patients were very low.

Our previous findings suggest that patients with higher IQ may be able to understand irony tasks better because they can rely on IQ-dependent problem solving skills and analogical reasoning.

Aims of the study

- Our aim was to give a preliminary overview about the pragmatic competence of schizophrenic patients with good general intelligence (measured by WAIS), in order to identify the influence of good general neurocognitive skills on non-literal speech construction in schizophrenia. As schizophrenia is a heterogeneous disorder, only patients with paranoid type of schizophrenia were recruited to increase the homogeneity of the experimental group.
- We hypothesized that patients with schizophrenia with relatively high IQ would make use of their good cognitive skills when performing in tasks on non-literal language comprehension.

Methods

A total of 19 Hungarian-speaking patients with paranoid type of schizophrenia fulfilling the diagnostic criteria of DSM-IV were investigated. The psychopathology was assessed using Positive and Negative Syndrome Scale (PANSS). The control group (CG) consisted of 19 Hungarian-speaking healthy individuals, recruited from the general community. They had no record of psychiatric (personal or family) and neurological morbidity, presence of dependence on psychoactive substances (excluding caffeine and tobacco). Age, ethnic origin, educational status and general intelligence were matched to the characteristics of the patients group.

Participants with normal range of IQ were selected for this study (schizophrenia group: 95-127, mean=109.00, S.D. ±9.35; control group: 95-122, mean=113.63, S.D. ±6.99) to exclude an effect of general cognitive impairment on the investigated issue. As the full scale IQ of patients and controls was calculated by the use of the Hungarian version of Wechsler Adult Intelligence Scale (WAIS) (Wechsler, 1986), patients and controls were matched for all subtests of WAIS, such as Information, Comprehension, Digit Span, Arithmetic, Similarities, Digit-Symbol Coding, Picture Arrangement, Block design, Picture Completion and Object Assembly.

We used four experimental conditions: metaphor, irony, conversational implicatures (including quality-, quantity-, manner-, relation- and control implicatures) and semantic condition. We presented 5 tasks (i.e. scenarios) in the metaphor condition, 5 tasks in the irony condition and 5 tasks in the semantic condition. 20 tasks were presented in the conversational implicatures condition, summing up to a total of 35 tasks in our study. The 35 tasks were randomly intermixed in order to present the different experimental conditions in an unpredictable order. The randomized tasks were presented verbally by an investigator in the form of an interview in one session for all participants individually. Each interview was recorded, and two independent investigators scored the recorded data.

The metaphor condition consisted of three conventional and two unconventional metaphor tasks, as generally used in Hungarian. After each task, two questions were asked about the figurative meaning of the metaphors serving as the target in the stories.

We presented 5 short scenarios as irony tasks for the participants. After each task two questions were asked to assess the speaker intended meaning.

The total of 20 tasks were presented to the subjects concerning the recognition of the infringement of the four Gricean maxims (4 tasks for each type), namely that so the maxim of

quantity, maxim of quality, maxim of manner, and maxim of relation. As for the control tasks in the conversational implicatures condition, we employed 4 control implicatures tasks that were intended to trigger the literal meaning of the utterance of the speaker. After each task the first question concerned the identification of the linguistic inappropriateness of the answers (called the linguistic part of the implicatures: e.g. 'Is this a strange utterance? Why is it strange to say something like this?') In the second question the subjects were asked about the understanding of the intended meaning of the speaker's answer (called the ToM part of the implicatures: e.g. 'What did the speaker really mean by the utterance?'). To examine each of the implicatures in detail, we scored the linguistic part of the implicatures (L-relation, L-manner, L-quality, L-quantity) and the ToM part of the implicatures (ToM-relation, ToM-manner, ToM-quality, ToM-quantity) separately. The semantic tasks were used to test schizophrenic patients' semantic competence (that is, their abilities in literal interpretation) with short scenarios based on physical causality of non-living entities, contained no implicatures, therefore, their interpretation did not required any pragmatic skills. After each task subjects were asked questions investigating the comprehension of the target sentences.

The SPSS version 20 for Windows was used for statistical analysis. In the statistical analysis, $P<.05$ was considered significant. The distribution of data was checked with the Kolmogorov-Smirnov goodness of fit. We used independent sample t-test in the case of parametric data (subtests of WAIS, IQ and age). As distributions did not prove to be normal, Kruskal-Wallis one-way analysis of variance (ANOVA) by ranks was performed to compare group medians across the experimental conditions. In the control- and in the schizophrenic group Spearman's rank correlation coefficients (ρ) were calculated to assess the relation between non-literal language tasks scores, and semantic tasks scores, IQ, as well as PANSS scores. Finally, we explored the effect of IQ by dividing the schizophrenia group into two subgroups using a median split (median IQ=106). The 'higher-IQ' subgroup included 9 patients with schizophrenia (mean=117.5; S.D. ±4.59), and the 'lower-IQ' subgroup included 10 schizophrenia patients (mean=101.2; S.D. ±3.94). The task performance of the two patients' groups ('higher-IQ' schizophrenia subgroup and 'lower-IQ' schizophrenia subgroup) were then compared again to the task performance of the control group using Kruskal-Wallis one way analysis of variance (ANOVA).

Results and discussion

Schizophrenic patients performed well in several non-literal language tasks, such as in the conventional metaphor tasks ($\chi2=0.641$; $p=0.423$, n.s.), in the irony tasks ($\chi2=1.62$; $p=0.202$, n.s.) and in the L-quality tasks ($\chi2=3.84$; $p=0.052$, n.s.).

Schizophrenic patients performed significantly less accurately than control subjects in the unconventional metaphor tasks ($\chi2=5.591$; $p=0.018$), and in the implicatures tasks (In details: in the L-relation tasks ($\chi2=18.36$; $p<0.001$), in the ToM-relation tasks ($\chi2= 5.30$; $p=0.021$), in the L-manner ($\chi2=8.45$; $p=0.004$) as well as in the ToM-manner tasks ($\chi2= 15.61$; $p<0.001$), in the L-quantity tasks ($\chi2=15.12$; $p<0.001$) and ToM-quantity tasks ($\chi2=19.85$; $p<0.001$) in the ToM-quality tasks ($\chi2= 15.42$; $p<0.001$)).

We found a strong significant correlation between the comprehension of conventional metaphors and the comprehension of semantic tasks ($\rho=0.631$, $p=0.004$). Furthermore, a strong significant correlation was found between the comprehension of unconventional metaphors and IQ ($\rho=0.727$, $p<0.001$). Irony interpretation revealed significant positive correlation with IQ ($\rho=0.542$, $p=0.02$). The response accuracy in the questions of L-implicatures by the patient group showed significant correlation with IQ ($\rho=0.523$, $p=0.022$) as well.

Full scale IQ was significantly lower in the low-IQ (mean=101.2; S.D.±3.94, $95\leq IQ\leq106$) schizophrenia subgroup ($t=5.177$, $p<0.001$) compared to the control group. However, the high-IQ (mean=117.5; S.D. ±4.59, $106<IQ\leq127$) subgroup and the control group did not differ with respect to IQ ($t=-1.771$, $p=0.090$ n.s.). Compared to the healthy control group, the lower-IQ schizophrenia subgroup's performance differed significantly in the unconventional metaphors (($\chi2=10.063$; $p=0.002$), irony ($\chi2=5.559$; $p=0.018$), ToM-implicatures ($\chi2=17.841$; $p<0.001$) and the L-implicatures ($\chi2=17.070$; $p<0.001$) tasks. However, the higher-IQ subgroup differed significantly from the control group only in the ToM-implicature ($\chi2=12.560$; $p<0.001$) and in the L-implicature ($\chi2=4.369$; $p=0.037$) tasks, and the significant difference disappeared in the case of the unconventional metaphors ($\chi2=0.354$; $p=0.552$) and in the irony ($\chi2=0.984$; $p=0.321$) tasks.

In the case of irony comprehension, we assume that our patients, especially in the 'higher-IQ subgroup', might rely on a compensatory strategy, which could enable them to interpret irony without ToM competence. On the other hand we cannot fully claim that our patients have a genuine ability to understand other minds, mainly due to the weak performance in the mentalization part of the conversational implicatures, irrespective of IQ, found in the present study.

In the schizophrenic group, as compared to healthy controls, good performance was detected in

the comprehension of conventional metaphors, which are commonly used in our everyday language and in our normal metaphorical concepts. However, in the case of the decoding of unconventional metaphors with unfamiliar meaning patients performed significantly worse than healthy subjects. Moreover, in the patient group, the comprehension of conventional metaphors showed significant positive correlation with semantic processing, and the ability to decode unconventional metaphors was in a significant positive relation with general IQ. We found that the higher-IQ schizophrenia subgroup did not show any dysfunction across conventional- and unconventional metaphor comprehension. This finding differs from the performance of the lower-IQ schizophrenia subgroup, which showed significant impairment in the comprehension of unconventional metaphors, while their conventional metaphor processing was intact.

This finding is in line with the 'graded salient hypothesis'. This hypothesis claims that the salient (conventional, more frequent, more familiar) meaning of an utterance is activated first, and not necessarily the literal meaning. On the other hand the interpretation of an unconventional metaphor is more demanding, thus it requires sequential processing, in which the salient meaning is rejected and reinterpreted in order to get the implied meaning.

In line with previous studies we found significant deficits in the comprehension of conversational implicatures in the schizophrenic group. As for the ToM questions of the conversational implicatures we found a strong impairment in schizophrenic patients, irrespective of IQ. This finding supports the assumption that ToM deficit does exist in both the lower- and the higher-IQ subgroups of schizophrenics.

According to our present data at hand, we believe that schizophrenic patients can compensate their impaired ToM skills at least to some degree with their good neurocognitive functions and intact semantic processing in order to understand metaphors and irony. Besides, in the case of more demanding dimensions of non-literal language comprehension, such as conversational implicatures, when higher-order ToM functions are required, good neurocognitive functions do not suffice to compensate their defected ToM capacity and the existing theory of mind deficit remains. Our finding proposes a possible compensatory effect of good general neurocognitive skills on deficits in metaphor and irony processing. We also argue that it is important to use higher-order ToM tasks in order to detect the potential ToM deficits of schizophrenic patients with good cognitive skills in a more sophisticated way, especially in the cases of more complex pragmatic tasks such as implicature comprehension embedded in social and cultural context. We also believe that it is fairly important to incorporate the monitoring and the enhancing of neurocognitive skills into the treatment plan of schizophrenic patients.

Irony comprehension and context processing in schizophrenia during remission – a functional MRI study

Functional brain imaging studies in schizophrenia are important and useful in order to find brain regions play a part in the psychopathology of schizophrenia, and to find specific and sensitive biomarkers of the disease.

As it was mentioned earlier, it is widely accepted – according to the relevance theory – that successful communication depends on the inferring of beliefs and intentions of the speaker in conversation, and the role of ToM ability is also highlighted in understanding utterances, especially when they involve non-literal meaning. In line with that, several findings show that the comprehension deficit of non-literal language in schizophrenia is the result of impaired ToM capacity.

Irony involves implicit communicative intent, where the implicit meaning is the opposite of what is explicitly expressed. Irony comprehension is a non-literal language use that requires not only semantic and syntactic decoding, but also the decoding of the speaker's non-linguistic inference. The integration of the literal meaning and social context is essential for irony comprehension, in order to be able to represent the speaker's mind, and to recognize that the actual intention expressed by the speaker is exactly contrary to the literal meaning of the ironic statement. Thus, irony understanding requires not only the correct interpretation of communicative intentions, but also the ability to construct a coherent narrative based on contradictory information.

To date, only a few brain-imaging studies have examined the neural basis of irony comprehension. During irony understanding, healthy subjects recruited some typical regions of the ToM network such as the medial prefrontal cortex, the temporal pole, the inferior parietal lobule, and the sulcus temporalis superior. However, so far no fMRI study has investigated the neural correlates of irony comprehension in schizophrenia.

Aim of the study

- Our aim was to investigate irony comprehension and the underlying brain activity in patients with schizophrenia during remission. To decrease the heterogeneity of the experimental group we decided to examine a clinically homogenous group of patients with paranoid type of schizophrenia. We examined various phases of irony comprehension separately (such as context phase, statement phase, as well as question on comprehension and answer phase). We also evaluated whether providing more explicit contextual information (by insertion of a short linguistic cue that described the speakers' emotional state) could modify the patients' performance in irony comprehension and the related brain activities.
- We hypothesized that patients with schizophrenia would perform worse and exhibit an abnormal brain activation pattern during irony comprehension. We assumed that linguistic cues depicting the speaker’s emotional state would improve patients’ performance, and modify the network activation. To model complex, real life situations, when irony is applied in conversational situations, we used short social scenarios presented as auditory stimuli in an event related design, and examined the differences in irony processing at various stages of the paradigm in patients and controls.

Methods

The schizophrenia group comprised 21 patients with paranoid type of schizophrenia fulfilling the diagnostic criteria of DSM-IV. The control group consisted of 24 healthy individuals recruited from various sources. They had no record of psychiatric and neurological morbidity, presence of dependence on psychoactive substances (excluding caffeine and tobacco).

We used three experimental conditions: irony (I), irony with linguistic help (IH) and a control (C) condition. During scanning participants listened to short tasks (i.e. scenarios). We used auditory stimuli – as opposed to reading – to minimize individual differences in the processing of the stimuli. We presented 15 scenarios in each condition summing up to a total of 45 tasks. All of them started with a two-sentence context phase followed by a statement and a yes/no comprehension question testing if the statement was correctly understood. In irony condition (I) the tasks consisted of a short context phase describing a social situation with two participants, this was followed by an ironic statement, i.e. one of the participants' ironic remark the literal meaning of which was the opposite of the intended one. In the irony with linguistic help condition (IH), the context part contained one additional word as a linguistic help describing the speaker's emotional state. The control condition (C) contained tasks based on physical causality, which entailed the representation of non-intentional causal links from the part of the participants. Each scenario was matched in syntactic structure, semantic complexity and length.

We used an event-related design. Each task started with a context phase (1), followed by a 2-4 s (jittered) inter-stimulus interval. The ironic statement phase (2) appeared next, and finally a comprehensive question (3) followed. Between tasks, inter-trial intervals of 5-7 s (jittered) were used. After the question, yes/no judgments were given by pressing a button with the thumb (yes) or index finger (no), as quickly as possible. The third phase of the tasks (question-answer phase) continued until participants pressed the answer button. The experimental protocol was administered in one session of 45 tasks.

The SPSS version 15 for Windows was used for statistical analysis of demographic and clinical data, as well as full scale IQ and ToM task performance. We used independent sample t-test for parametric, as well as chi-squared test for non-parametric data to determine between-group differences. As distributions proved not to be normal, Kruskall-Wallis one-way analysis of variance (ANOVA) by ranks was performed to compare group medians across the experimental conditions.

Functional data sets were analyzed using FSL 4.1.3. FEAT (FMRI Expert Analysis Tool) Version 5.98, part of FSL. Blood oxygenation level-dependent (BOLD) changes during the different phases of the tasks were modeled using separate regressors during context phase for I, C and IH conditions, during statement phase for I, C and IH conditions; as well as during question- answer phase for IH conditions. Questions were answered by defining contrasts of regressors: context phase: I>C, IH>C, statement phase: I>C, IH>C, question-answer phase: I>C, IH>C. Note, that we defined I>C, as well as IH>C contrasts of regressors, in order to eliminate the confounding factor of basic semantic processing. Moreover, significant activations in the I>IH, as well as in the IH>I contrasts were also calculated during each phase of the tasks.

Z (Gaussianised T/F) statistic images were threshold using clusters determined by $Z>2.3$ and a (corrected) cluster significance threshold of $P=0.05$. Images were rendered on a mean anatomical brain volume of all subjects in standard space for display purposes. As patients' full scale IQ was found significantly lower than healthy subjects' IQ (stat: $t=3.9$, $P<0.001$), our group-level general linear model included full scale IQ as an additional covariate modeling general intelligence scores for the schizophrenic and control groups (demeaned separately for each group). Thus, we modeled full-scale IQ scores as covariates of no interest to remove any potential contributions of general intelligence to the brain activations during task performance.

Results and discussion

The CG performed significantly more accurate in the irony (I) condition (Kruskal-Wallis ANOVA, $P<0.0001$, Kruskal-Wallis statistic =37.14; Dunn's Multiple Comparison Test: difference in rank sum=39.82, $P<0.01$; $median_{CG}$= 15, $range_{CG}$= 10-15; $median_{SG}$= 13, $range_{SG}$= 7-15) than the SG; however, this between-group difference disappeared in the IH, as well as in the C condition (Dunn's Multiple Comparison Test: difference in rank sum= 29.98; and 26, respectively, n.s.; IH condition: $median_{CG}$= 15, $range_{CG}$= 13-15, $median_{SG}$= 14, $range_{SG}$= 8-15; C condition: $median_{CG}$= 15, $range_{CG}$= 14-15, $median_{SG}$= 14, $range_{SG}$= 11-15).

Schizophrenic patients performed significantly worse in the irony comprehension task than healthy controls. During the sequential analysis of fMRI data, we found that the two groups had markedly different brain activation patterns.

After the insertion of a short linguistic help, which had reduced the implicit information content of the context, response accuracy of schizophrenic patients improved, and the statistically significant differences between the groups disappeared. Notably, there were no significant differences in the BOLD responses between the groups, when linguistic help was added to the context.

During the context phase of the irony tasks subjects had to take the characters' perspective, acknowledge the implicit emotional state and communicative intent in the scenarios. During the context phase the control group presented activity in the left TPJ and precuneus. Remarkably, processing of the complex social context of the scenarios appeared to be a substantial linguistic, cognitive, and emotional load to the schizophrenic patients, as the schizophrenic group recruited highly widespread areas encompassing not only the left IPL (reaching the TPJ), but also several prefrontal and temporo-parietal, as well as subcortical regions.

Between-group comparison: the schizophrenic group exhibited significantly stronger activations in the left IFG, and in the left IPL during the context phase of the irony tasks. These areas are responsible in language processing and are considered to be parts of the human 'mirror neuron system'. Stronger between-group activation of the left IFG and the left IPL in the schizophrenic group can be interpreted as a compensatory activity for vanquishing ToM and language deficits in schizophrenia. All these correspond with schizophrenic patients' difficulties in context processing.

In line with previous neuroimaging studies on irony understanding in healthy subjects, we registered activations of several regions of the ToM network: we found a widespread left temporal

lobe activation with a local maximum in the left posterior sulcus temporalis superior, activation in the posterior cingulate cortex/precuneus, in the anterior cingulate cortex extending into the right paracingulate cortex and the anterior medial prefrontal cortex, as well as in the right inferior parietal lobule in the control group. While the control group presented activations mainly in ToM related brain areas, and in regions associated with the non-literal language processing, the schizophrenic group activated regions associated with linguistic and auditory processing.

In the between-group comparison, the control group exhibited significantly greater BOLD responses than the schizophrenic group in three brain areas, right anterior dorsolateral prefrontal cortex, right temporal pole, and right inferior parietal lobule, during the ironic statement phase of the irony tasks. Considering schizophrenic patients' weaker activation of the anterior dorsolateral prefrontal cortex, we can speculate that this between-group difference may be a part of the "hypofrontality" phenomenon in schizophrenia. In conclusion, in line with poorer understanding of irony tasks, schizophrenic group's activation pattern was poorer and localized mainly in brain areas associated with semantic processing during the ironic statement phase of the irony tasks.

In the irony with linguistic help condition, a short linguistic cue made explicit the speaker's emotional state during the context which, decreased the context processing demand of the task. Due to this, neither the response accuracy, nor the registered BOLD responses differed statistically between the groups. Similarly to the activations of the control group during the context phase of the irony tasks, a significant activation of the left temporo-parietal junction and precuneus could be found in the control group. However, due to the inserted linguistic help the schizophrenic group also activated these regions. Furthermore, we suggest that linguistic help served as a cue activating higher-order cognitive functions such as working memory (dorsolateral prefrontal cortex activation) in both groups. The most unique finding of the present study was the schizophrenic group's engagement of the mentalizing network during the statement phase in the irony with linguistic help tasks.

Finally, we should consider how our results could be utilized in trainings aiming to improve the social cognitive and interactive skills of schizophrenic patients. Research on psychosocial interventions proved that patients with schizophrenia are able to improve their ToM strategies. These psychosocial trainings begin with emotion processing training (i.e. defining emotions, emotion mimicry), and continue with other social cognitive and interaction skills. The efficacy of trainings such as those mentioned above might correspond with our results, as we found that making explicit the speaker's emotional state (by means of a short linguistic cue) can substantially improve schizophrenic patients' performance during irony understanding.

Summary of new findings

- In our first investigation we found that schizophrenic patients can compensate their impaired ToM skills at least to some degree with their good neurocognitive functions and intact semantic processing in order to understand social situations including metaphors and irony.
- Besides, in the case of more demanding dimensions of non-literal language comprehension, such as conversational implicatures, when higher-order ToM functions are required, good neurocognitive functions do not suffice to compensate their defected ToM capacity and the existing theory of mind deficit remains.
- In our second study, we firstly investigated the neural background of irony comprehension in schizophrenia. We found that besides the impaired irony comprehension an abnormal brain function exists in schizophrenia.
- While during the ironic statement phase of the irony tasks we found brain activations specific for ToM function in the control group, the schizophrenic group did not activate brain regions associated with ToM functions during the same task.
- In the irony with linguistic help condition, a short linguistic cue made explicit the speaker's emotional state during the context which, decreased the context processing demand of the task. Due to this, brain activations of the schizophrenic group became similar to the brain activations of the control group. The most unique finding of our study was the schizophrenic group's engagement of the mentalizing network during the statement phase in the irony with linguistic help tasks.

This work is based on the following articles

1. **Varga, E.**, Tényi, T., Fekete, S., Herold, R. (2008). Mentalizációs deficit vizsgálata faux pas teszttel szkizofréniában. Neuropsychopharmacologia Hungarica, 10, 75-80.

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Impact factor: 8.234

This work is based on the following abstracts

1. **Varga, E.**, Simon, M., Hajnal, A., Tényi, T., Fekete, S., Herold, R. (2009). A magasabb szintű mentalizációs készségek deficitje szkizofréniában. Psychiatria Hungarica, 23, Suppl., 158.

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Further publications

1. Lőrintz, Z., Varga, A., Szabó, I., Mendel, K., **Varga, E.** (2008). Activities and practice at the Mental Health Centre in Székesfehérvár, Hungary. Psychiatria Hungarica. 23(4), 232-4.

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1. Hajnal, A., Herold, R., **Varga, E.**,Tényi, T., Fekete, S., Simon, M. (2009). Euthym bipoláris betegek mentalizációs teljesítményének vizsgálata. Psychiatria Hungarica, 24, Suppl.,70.

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5. Hajnal, A., **Varga, E.,** Schnell, Zs., Orsi, G., Tényi, T., Fekete, S., Simon, M. (2010). Az irónia megértése bipoláris zavarban – 3T funkcionális MR vizsgálat. Psychiatria Hungarica, 25, Suppl. 115.

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2. **Varga, E.**, Schnell, Zs., Perlaki, G., Orsi, G., Aradi, M., Auer, T., John, F., Dóczi, T., Komoly, S., Kovács, N., Schwarcz, A., Tényi, T., Herold, R., Janszky, J., Horváth, R. (2014). Hemispheric lateralization of sentence intonation in left handed subjects with typical and atypical language lateralization: an fMRI study. In: Campbell, Gibbon, Hirst (eds.) Speech Prosody 7, 1135-1138. Proceedings of the 7th International Conference on Speech Prosody.

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