Theses of Doctoral (PhD) Dissertation

The electrophysiological correlates of visual automatic change detection

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I.   The aim of the thesis, general background

Some recent study (see review Stefanics et al., 2014) have provided the evidence of automatic change detection in various aspects of environmental events. Non-attended stimuli violate regularities in both auditory and visual modality, elicit characteristic components, the (auditory) mismatch negativity (MMN), and visual mismatch negativity (vMMN), respectively, even if the irregular (deviant) stimuli are non-attended (for reviews on MMN see e.g. Näätänen et al., 2007; Fishman, 2014; for vMMN see Czigler, 2007; Stefanics et al., 2014). Emergence of the mismatch components is an indirect evidence about the registration of regularities (frequent standards), otherwise deviation cannot be identified. Visual mismatch negativity (vMMN) event related potential (ERP) is elicited by violation of sequential regularity established by environmental stimulation. VMMN is an error signal to the discrepancy between representation of regularities and deviant events, vMMN is generally investigated with passive oddball paradigm: a frequently presented type of stimuli (standards) acquires the representation of regularity, and another, infrequently presented type of stimuli (deviants) violates this regularity. The difference between the ERPs to the deviant and standard is the vMMN component. The vMMN polarity is typically negative, it has parieto-occipital maximum and peaks at around 110-400 ms after the onset of the rare, deviant events.

VMMN emerges to deviant features like orientation (Astikainen et al., 2008), movement (Pazo-Alvarez et al., 2004). Additionally, the system underlying vMMN is sensitive to complex deviant events, like the change of emotional categories, and the laterality of human hands (see review, Czigler, 2014).

More recent data (Näätänen et al., 2001) suggest that the sensory memory (first described by Näätänen et al., 1978) underlying mismatch negativity is capable to registrate the environmental events without attentional processes. These perceptual achievements are mainly based on processes of a cognitive nature ("primitve system of intelligence") of the perceptual system (in acutsic modality Näätänen et al., 2001; in vision: Czigler, 2010). Even higher cognitive processes than previously thought (such as those that organize the sensory input, extract the common invariant patterns from acoustically varying sounds and anticipate the incoming events of the immediate future) occur at the level of sensory system (even if attention is not directed towards the sensory input). This „primitive system of intelligence" organizes input and anticipates the events of future. The main function of the system is to update a predictive model, which represent the earlier events. The vMMN is an ERP correlates of the automatic detection

of unpredictable events. It is important to emphasize that the unpredictable event is based on probability learning.

According to Friston et al. (2010) the predictive model of the mechanisms of vMMN reflects continuous interaction between top-down and bottom-up processes. The „internal" model is updated through prediction and prediction errors. The predictive coding theory indicates a complex hierarchical organization of neural network.

In the thesis we examined event-related potential correlates of categorization of task-relevant and task-irrelevant complex, natural stimuli. We supposed that this sensory system is capable to generate implicit category formation (e.g. symmetry, gender faces or homogeneous/ heterogeneous patterns) even if the stimulation is not related to the ongoing behavior. The other main question is whether the vMMN processes connected to the higher order perceptual categorization processes. The automatic perceptual categorization is a basic function of the visual perception. This general principle carries out of the formation of the perceptual categories from different visual objects (maximal information with the least cognitive effort, see review: Rosch, 1999; Pothos and Wills, 2011).

The thesis reviewed the category-related vMMN processes and provided evidence that the visual sensory memory can represent complex stimuli characteristics, well beyond the individual features like faces or symmetrical patterns.

II.   Methods

It is worth to mention that we used similar methods during the experimental procedure and data analysis. In the four studies the EEG was recorded with DC-100 Hz filter, 500 Hz sampling rate from 64 electrodes (according to extended 10-20 system) with nose reference. The participants were paid, healthy students. The age, gender and number of participants were counterbalanced across studies.

In the thesis, we used common vMMN protocol termed as oddball paradigm, where the identical frequently presented type of stimuli were infrequently interchanged with rare, different type of stimuli (with 0.1 or 0.2 probability). Additionally, the difference between the experiments was only related to the task. In active two-stimulus oddball paradigm (active attending) the infrequent stimuli were the target. The participants were instructed to identify the rare category

and to respond with button press. Before each block (the block order was randomized) the participants were informed about the current target category: we measured reaction time response and accuracy of the responses. The other type of experiment design was passive paradigm where the sequences of stimuli were similar to the active vMMN sequences, however, the stimulus categories were unrelated to the participant's task. In passive paradigm stimuli built up automatic prediction without attention and the rare deviants were task-irrelevant also. The participants had to continuously fixate to the central task to achieve proper performance. Event-related potentials were averaged separately for the frequent and infrequent stimuli. To identify change-related activities, ERPs elicited by standard stimuli were subtracted from ERPs elicited by deviant stimuli.

In the first study we investigated the sensitivity of vMMN to the violation of categorical relationship: symmetry. Considering the perceptual organization principle, the visual system is especially sensitive to various forms of symmetry. As an obvious cue of living objects, the vertical mirror symmetry has biological significance ((Treder, 2010), and this type of symmetry is automatically detected (Machilsen et al., 2009). Such properties are characterized by patterns that form object by perceptual organization and separates figure from the background. Symmetry is described as a prominent grouping principle of perceptual organization (Wagemans, 1995).

The aim of the study is to demonstrate the bilateral vertical symmetry is a salient stimulus category, and stimuli violating the rule of successive appearance of such patterns elicit visual mismatch negativity, even if the stimulus patterns are unrelated to the ongoing behavior.

In the second and third study we examined event-related potential correlates of task-relevant and irrelevant gender face categorization. In the task-relevant case the gender faces were delivered in active oddball paradigm i.e. the infrequent target stimuli were embedded within sequence of frequent standard faces. The participant were instructed to identify the rare gender face (either female or male in various sequences; 20 per cent of target within a sequence) and respond with button press. In the sequence of stimuli there was no repetition along physical appearance of gender faces. In the task-irrelevant experiment participants had to identify the change of a foveal presented stimulus (passive oddball condition). Appearance of the faces was identical to the active experiment: stimuli were 80 cropped faces with neutral emotional expression, 40 from each gender. The successive stimuli were never physically identical. In the present studies concentrated to categorical aspects of gender face processing. The aim of the

study is to demonstrate that the perceptual system is capable to encoding the changes of gender faces in both cases of task-relevant and task-irrelevant paradigms. In social interactions of everyday life face recognition is a fundamental function. The human perceptual system can identify faces (Bruce and Young, 1986); the well-investigated event-related potential correlate of the face recognition is a negative component with 170 ms post-stimulus latency (N170) that reflects the neural mechanisms of face detection (for a review see Bentin & Allison, 1996). The majority of studies concentrated on emotion and familiar aspects while the gender-related categorical perception is investigated less frequently. On the basis of the results of category-related vMMN studies (Czigler, 2014), we investigated that the representation and encoding of gender information of the faces would be automatic.

In the fourth study we observed that the attribute of the automatic processes underlying vMMN is similar to the visual search effect. This fundamental finding of visual attention is well demonstrated (Wolfe, 2011) by results of visual search task studies. The main finding is faster to identification of certain target stimuli among certain distractors than vice versa. The stimuli in this study were Q and O characters, i.e., a type of stimuli frequently used in studies of search asymmetry. In general this kind of asymmetry is due to low-level perceptual differences, i.e. the presence vs. absence of a line within one of the objects. In this study we hypnotized that the stimuli elicited asymmetric search performance elicit also vMMN asymmetry, and asymmetry cannot be attributed to low-level perceptual differences.

III.   Results of thesis

1. The electrophysiological data showed that the random deviant elicited two posterior negativity with 116 ms and 288 ms peak latency relative to the symmetrical standard. This components are regarded as a valid vMMN components that are generated by automatic detection of category change. We consider the two negative differences as two subcomponents of error signals (vMMN) originated from difference between a model predicting characteristics of ongoing stimulation and the bottom-up processes elicited by the actual stimulation. However when deviant symmetrical patterns were rarely embedded in sequence of random patterns than no vMMN emerged. Frequent presentation of members of symmetry category establishes sequential regularity while repetition of non-categorical random patterns does not. Consequently memory representation underlying vMMN encodes symmetry category.

2. We recorded N170 component, that neural correlate of face stimuli recognition (see Bentin & Allison, 1996; structural encoding unit). Additionally, stimuli elicited gender category change-related component (vMMN with 300 ms peak latency) and P3 component (reflect attentional and categorization processes). In an active experiment we assessed the gender-related discriminability of the stimuli.

3. The results of third study is demonstrated that the perceptual system can encode two gender categories along various faces without attention. The main finding is that the vMMN processes are sensitive to gender category changes even if the changing are unrelated to ongoing behavior. In active experiment we obtained an enhanced N170 component and additionally, the amplitude difference appeared to deviants and standards with 350 ms peak latency i.e. a category- related vMMN component. We suppose, the two vMMNs of the two studies (active and passive), to reflect identical perceptual and cognitive processes.

4. As the main result of this experiment, both deviants (Q and O) elicited posterior negativities. Moreover we obtained latency and amplitude difference on ERPs to the Q and O stimuli (Exp1. 210 ms vs. 254 ms; Exp2. 254 ms and 286 ms). That is the deviant Q elicited vMMN component earlier than deviant O. The study was an example of visual search asymmetry: it is faster to find additionally visual feature, than the absence of the same feature of visual object. We suggest that the access to representation of regular events consisting of plus feature of stimuli is faster, and the vMMN latency difference is due to the more efficient memory access.

In the thesis studies we investigated robust vMMN effect. The appearance of the vMMN is sensitive to perceptual categorization processes because the implicit memory registered the categorical propriety and detected the violation of propriety. In conclusion, the doctoral thesis studies demonstrate connection between automatic change detection system and automatic perceptual categorization processes.

IV. Author's publications

Candidate: Krisztina Kecskés-Kovács
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List of publications related to the dissertation

Hungarian scientific article(s) in Hungarian journal(s) (1)

*1. **Kecskés-Kovács K.**, Czigler I.: Arcok nemi kategorizációs folyamatainak elektrofiziológiai
   korrelátumai.
   Pszichológia. 34 (3), 207-224, 2014. ISSN: 0230-0508.
   DOI: http://dx.doi.org/10.1556/Pszicho.34.2014.3.1

Foreign language scientific article(s) in international journal(s) (3)

2. Czigler, I., Sulykos, I., **Kecskés-Kovács, K.**: Asymmetry of automatic change detection shown by
   the visual mismatch negativity: An additional feature is identified faster than missing features.
   Cogn Affect Behav Neurosci. 14 (1), 278-285, 2014. ISSN: 1530-7026.
   DOI: http://dx.doi.org/10.3758/s13415-013-0193-3
   IF:3.209 (2013)

3. **Kecskés-Kovács, K.**, Sulykos, I., Czigler, I.: Is it a face of a woman or a man? Visual mismatch
   negativity is sensitive to gender category.
   Front. Hum. Neurosci. 7 (532), 1-11, 2013. ISSN: 1662-5161.
   DOI: http://dx.doi.org/10.3389/fnhum.2013.00532
   IF:2.895

*Correction in: Pszichológia (2014) 34, 4, p. 457. DOI: 10.1556/Pszicho.34.2014.4.9

4. **Kecskés-Kovács, K.**, Sulykos, I., Czigler, I.: Visual mismatch negativity is sensitive to symmetry as a perceptual category.
Eur. J. Neurosci. 37 (4), 662-667, 2013. ISSN: 0953-816X.
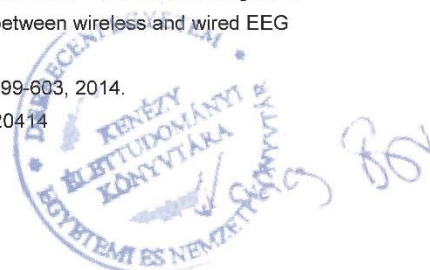DOI: http://dx.doi.org/10.1111/ejn.12061
IF:3.669

List of other publications

<u>Foreign language scientific article(s) in international journal(s)</u> (2)

5. Sulykos, I., **Kecskés-Kovács, K.**, Czigler, I.: Asymmetric effect of automatic deviant detection: The effect of familiarity in visual mismatch negativity.
Brain Res. Epub ahead of print (2015) ISSN: 0006-8993.
DOI: http://dx.doi.org/10.1016/j.brainres.2015.02.035
IF:2.828 (2013)

6. Sulykos, I., **Kecskés-Kovács, K.**, Czigler, I.: Mismatch negativity does not show evidence of memory reactivation in the visual modality.
J. Psychophysiol. 27 (1), 1-7, 2013. ISSN: 0269-8803.
DOI: http://dx.doi.org/10.1027/0269-8803/a000085
IF:1.425

<u>Foreign language conference proceeding(s)</u> (1)

7. Török, Á., Sulykos, I., **Kecskés-Kovács, K.**, Persa, G., Galambos, P., Kóbor, A., Czigler, I., Csépe, V., Baranyi, P., Honbolygó, F.: Comparison between wireless and wired EEG recordings in a virtual reality lab: Case report.
Cognitive Infocommunications (CogInfoCom) 1 (1), 599-603, 2014.
DOI: http://dx.doi.org/10.1109/CogInfoCom.2014.7020414

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Foreign language abstract(s) (2)

8. Czigler, I., Sulykos, I., **Kecskés-Kovács, K.**: Refractory issue and visual mismatch negativity: A skeleton in the cupboard.
Int. J. Psychophysiol. 94 (2), 155-, 2014. ISSN: 0167-8760.
DOI: http://dx.doi.org/10.1016/j.ijpsycho.2014.08.689

9. **Kecskés-Kovács, K.**, Sulykos, I., Czigler, I.: The female is a real oddball between males: a vmmn study to automatic gender face category changing.
Psychophysiology. 50 (1), 25, 2013. ISSN: 0048-5772.
DOI: http://dx.doi.org/10.1111/psyp.12120

Total IF of journals (all publications): 14,026
Total IF of journals (publications related to the dissertation): 9,773

The Candidate's publication data submitted to the iDEa Tudóstér have been validated by DEENK on the basis of Web of Science, Scopus and Journal Citation Report (Impact Factor) databases.

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VI.   References

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