ELECTROPHYSIOLOGICAL CORRELATES OF EMPATHY

Sanja Tatalović Vorkapić

Department of Preschool Education, Teacher Education College, University of Rijeka

Meri Tadinac

Department of Psychology, University of Zagreb Faculty of Humanities and Social Sciences

Address for correspondence:
Sanja Tatalović Vorkapić, PhD
Department of Preschool Education, Teacher Education College, University of Rijeka
University Campus, Slavka Krautzeka bb, 51000 Rijeka, Croatia
E-mail: sanjatv@ufri.hr

Vorkapić, S.T. & Tadinac, M. (2011). Electrophysiological Correlates of Empathy.
The Romanian Journal of Psychology, Psychotherapy and Neuroscience, 1(1), 19-37

ABSTRACT

This study focused on examining whether there were any electrophysiological correlates of empathy, by analyzing the relationship between empathy and latencies/amplitudes of evoked potentials (N1, P2, N2, P3 & Sw). A sample consisted of N=54 female psychology students, within the age range 19-23 years, and all right-handers. Evoked potentials were measured by using the standard visual oddball paradigm in two trials with two occipital and two parietal electrodes. Empathy was measured by EPQ-IVE.

Correlation analysis showed a significant negative correlation between empathy and N2-amplitude in the first trial at one parietal electrode (r=-.36, p<.01). More empathetic students showed lower extraction of stimuli characteristics and target selection during task, probably due to fronto-central distribution of N2-component. This kind of distribution has been usually registered in participants experiencing empathy, as it was expected. Also, lack of other significant correlations could be explained by the very simple and neutral task that has been used.

Key words: Empathy, Evoked Potentials, Individual Differences, Students

INTRODUCTION

It is well-known that people are intrinsically social. The survival of humans critically depends on social interaction and therefore most of our actions are directed towards or are responses to others (Decety & Batson, 2007). Empathy refers to the capacity to understand and respond to the unique emotional experiences of another person. At the basic level of description, empathy is defined as an interaction between any two individuals, with one experiencing and sharing the feeling of the other, while being aware of the distinction between self and others (Decety & Jackson, 2004; Decety & Lamm, 2006). Also, even some researchers such as Hoffman (1981) who emphasized the emotional part of empathy and defined it as involuntary response to emotional cues perceived in others, and such as Batson et al. (1997) who emphasized cognitive part of empathy and defined it as intentional role-taking ability, today it is clear that empathy can be seen as a coin with two opposite sides. So, to conclude: despite the various definitions of empathy, there is a broad agreement on three primary components: a) an affective response to another person which often, but not always, entails sharing that person's emotional state; b) a cognitive capacity to take the perspective of the other person; and c) emotion regulation (Decety & Jackson, 2006). A traditional approach in studying the psychology of empathy relies on subjective ratings of empathic emotion (Batson, 1987) and self-report questionnaires that measure empathy as a trait (Bryant, 1987; Eysenck & Eysenck, 1994; Davis, 1996). Even though some researchers, such as Fan and Han (2008) criticized this way of measuring empathy in the context of their neural substrates, and emphasized the fact that the results of these studies could be influenced by intention of self-presentation and social desirability, besides the comprehension of subjective emotional reaction to others' feeling was obtained, this way of data collection is faster, cheaper and more economic than modern neuroimaging studies.

The human electrophysiological responses play an important role in a wide range of affective experiences, especially empathy. By combining biological and psychological approaches, social neuroscience sheds new light on the complex phenomenon of empathy. The capacity to have an emotional reaction to others' feelings of pain and intentionally adopt the subjective perspective of others requires that the individual to mentally simulate the other's perspective using one's own neural machinery (Decety & Chaminade, 2003). According to that, the neuroimaging studies, where participants were asked to put themselves in the shoes of the other, have shown that, regardless of the affective content of the situations depicted, activation was detected in the frontopolar cortex, the ventromedial prefrontal cortex, the medial prefrontal cortex, and the right inferior parietal lobule – congruent with the role of these regions in executive functions associated with the perspective-taking process (Ruby & Decety, 2004). Also, observing others' pain has been found to activate certain brain regions, such as insula and anterior cingulated cortex (ACC) (Wicker et al., 2003; Singer et al., 2004; Jackson et al., 2005; Lieberman & Eisenberger, 2009). Besides neuroimaging and fMRI studies, the ERP-method (method of using the evoked brain potentials) with its great temporal resolution and flexibility, has presented a valuable social neuroscience research tool in exploring the electrophysiological correlates of empathy (Decety & Keenan, 2006). For example, study of Saarela et al. (2007) determined the significant correlation between the magnitudes of insula and left frontal activities induced by painful faces and subjects' self-rated empathy. Overall, presented findings support the existence of a shared neural network for one's own affective experience and the perception of others' similar emotional states.

Taking into consideration the functional role of early and late components of evoked brain potentials, such as: N1, P2, N2, P3 and Sw, it would be very interesting to see the possible correlation between those EP-components and self-rated empathy. Evoked potentials (EPs) or event-related potentials (ERPs) presented the changes in the electrical activity of the nervous system recorded in response to physical stimuli, in association with psychological processes, or in preparation for motor activity (Picton, 1980). Considering the psychophysiology of the EPs relevant to this study, it is important to shortly describe so called Long Latency Exogenous Components (P1, N1, P2), which occur after visual stimulus, from 100 msec up to 200-300 msec, and they are called transient since they share some characteristics with the endogenous components, such as P3 and Sw. In the auditory modality, the P1 usually peaks at about 50 msec, N1 at about 80-100 msec, and P2 at about 170-200 msec (Hugdahl, 1995). N1 is related to selective attention, therefore not being an exclusively exogenous component. P2 is related to the early information processing, and together with N1 encodes the physical characteristics of stimuli. Visual Evoked Potentials (VEP) can be recorded in the visual modality, and they are generally grouped around the P1 component. This wave has been used for non-invasive assessment of functional state of visual fields and visual cortex (Dabić-Jeftić & Mikula, 1994). N2 component was placed at the group of late, cognitive components that have longer latencies (more than 100 msec) and higher amplitudes, and depend on the context in which a stimulus has appeared. It always occurs after the appearance of a rare and unexpected stimulus, so it represents automatic extraction and determination of stimulus' properties, and target choice. N2 consists of a negative deflection occurring about 200 msec after the stimulus, and its amplitude is reversely proportional to the probability of a stimulus occurrence. It is elicited by rare changes in stimulus, irrespectively of participant's focusing on the stimulus, and if the change is relevant for the task, it is followed by a P3 component (Donchin et al., 1988). In summary, N2 is related to the process of discrimination and stimulus novelty (Nätäänen, 1992), it has fronto-central distribution. P3 accompanies the cognitive processing including the activation of attention mechanisms and changes in working memory (Picton, 1980). It does not reflect the physical parameters of stimuli, is not always connected to the appearance of the stimulus, is being evoked by the unexpected stimuli and does not appear if the stimuli are not relevant for the subject (Polich, 1998), and as for its neural model, P3 shows a fronto-parietal activation (Polich & Kok, 1995; Polich, 2004). Finally, Slow Wave Activity follows P3-distribution with the latency of 1 sec and duration of 3-4 sec. The same variable effected P3, have the important impact on Sw, which has a rather different scalp distribution. Taking into account fine differences in psychophysiology of described EP-components, it would be interesting to analyze their different relationship with empathy.

So, the main objective of this study was to examine the relationship between empathy and amplitudes and latencies of evoked potentials: N1, P2, N2, P3 & Sw elicited by the visual oddball paradigm. According to the previous findings, it was expected that empathy would be significantly correlated with those components that have similar distribution on the head – fronto-central.

METHOD

Subjects

Fifty-four female subjects (*M*=20.5 years, *SD*=1.28, range: 19-23), all undergraduate psychology students from the Department of Psychology, Faculty of Philosophy, University of Rijeka, participated in this study. They are all right-handed, naive to electrophysiological studies, and reported no visual or neurological/psychiatric problems. At the beginning of study, all subjects were familiar with the fact that they will receive course credit for their participation in the study.

On the basis of their scores on the EPQ/IVE Empathy subscale, the subjects were divided by the Median criterion (C=14.2) in two groups: Low empathy group (E≤14, *N=28*) with the low results on the Empathy scale and High empathy group (E>14, *N=26*) with the high results on the Empathy scale.

Questionnaires

Empathy was self-rated using standardized Croatian version of Eysenck's Personality Questionnaire – Impulsivity, Venturesomeness and Empathy, EPQ-IVE (Eysenck & Eysenck, 1994), originally formed by Eysenck et al. (1985). It has total of 54 items and 19 items measured empathy (Item example: *"Are you interested for the problems of your friends?"*). Subjects had to answer the questions by choosing YES or NO. Item analysis in this study has also confirmed previous levels of reliability (r=.69): Cronbach Alpha for empathy r=.70.

Evoked potentials' measurement and procedure

After filling out the self-rated empathy questionnaire, students were informed about schedule of EP-measurement. Each subject underwent a measuring of previously described evoked brain potentials: N1, P2, N2, P3 & Sw in two repeated trials with the inter-trial interval of 2 minutes. All recordings were made in the course of four months, always on Wednesdays, in groups of 4-6 students, and always at the noon. EP-responses were elicited by the standard visual oddball paradigm using a Medelec/TECA Sapphire^{II} 4E device (1996) with five Ag/AgCl disc electrodes. The active electrodes were placed on O_1, O_2, P_3 and P_4 (according to 10-20 system), and referred to Fz. The electrode impedance was kept below 5kΩ and the filter bandpass was 0.1-50 Hz. A pattern reverse binocular full-field stimulation was performed in a dark, quite room. Also, 16x16 checkerboard patterns were used and it was away from the nasion 70 cm, with 1Hz frequency and 100% contrast. 75% of stimuli were frequent (nontarget) checkerboards (consisting of the big quadrangles), presented in the random order, whereas 15% of stimuli were rare (target) checkerboards (consisting of the small quadrangles). Subjects were instructed to look at the red circle in the centre of the monitor and to react to the target stimuli by pressing the pen. The EP-marking of two parameters: latency and amplitude was performed manually, using a cursor, by the same medical technician for both trials. To avoid the effect of the latency jitter (Coles, Gratton, Kramer, & Miller**,** 1986; Hoormann, Falkenstein, Schwarzenau, & Hohnsbein, 1998), and to make EPs more stable over trials, in the second trial the EPs were marked by the same latencies as the ones from the first trial. Therefore, for each subject there were the same EP-latencies (as measured only in one trial) in both trials and two different EP-amplitudes.

RESULTS AND DISCUSSION

Descriptive statistics for empathy and evoked potentials

The group average for the EPQ/IVE Empathy (*M*=14.18; *SD*=3.09) did not substantially differ from the one obtained on the Croatian standardization group (*M*=14.39; *SD*=2.87). Although it was expected that the sample of psychology students would show higher levels of empathy in comparison to students from other faculties, this finding does not support the assumption. Nevertheless, this finding can be explained in two ways. First, the questioned sample of this research was relatively small if we have on mind just self-rated personality characteristics. Second, since empathy presented the social desirable ability, it is possible that psychology students are more aware of social desirable biased answers during self-rated researches, so it could be that their answers are more honest than those collected within the English sample of students of other faculties in the research of Eysenck and his colleagues (1985). Using the Kolmogorov-Smirnov test of conformity, it was determined that the empathy distribution results were normal (Table 1, Picture 1).

Table 1. Means and standard deviations for empathy and EPs: N1, P2, N2, P3 and Sw (amplitudes and latencies) measured in the first and the second trial block for the whole sample (*N*=54)

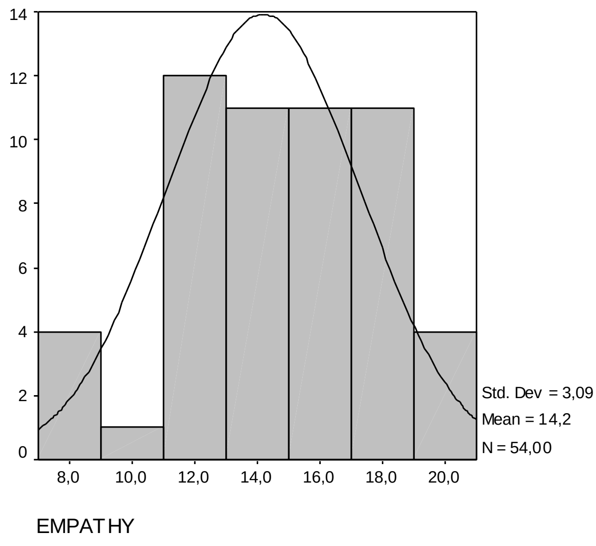
Electrode	Mean (Standard Deviation)					
	EP	**N1**	**P2**	**N2**	**P3**	**SW**
O_1	**latency**	143,3(29,5)	220,8(20,1)	300,6(36)	412,8(42,9)	495,8(58,2)
	amplitude1	10,2(5,3)	9,2(5,1)	4,5(4,2)	4,5(2,9)	
	amplitude2	10,4(5,4)	8,9(4,6)	4,6(4,8)	3,7(3,2)	
O_2	**latency**	143,3(29,5)	220,4(19,9)	300,6(35,9)	413,7(44,3)	499,2(58)
	amplitude1	12,4(6,4)	10,8(6,1)	4,9(5,3)	4,6(3,2)	
	amplitude2	12,1(6,3)	10,4(5,6)	4,9(5)	3,5(2,7)	

P_3	**latency**	138,1(30,1)	209,4(24,7)	291,5(51,5)	389,1(65,5)	480,6(77,6)
	amplitude1	13,4(7,5)	13,6(8)	8,9(6,1)	9,2(7)	
	amplitude2	13,1(7,2)	11,7(8,3)	8,5(6,3)	8,9(6,8)	
P_4	**latency**	137,7(30,3)	209,9(24,9)	291,4(51,5)	388,8(65,7)	480,9(78,3)
	amplitude1	15,4(8,5)	14,7(9,1)	8,1(5,2)	9,2(7,3)	
	amplitude2	14,7(7,8)	13(8,3)	7,7(5,7)	9(7)	
	EMPATHY	M=14,18 SD=3,09 Range=7-19 K-Sz=.94 p=.33				

Legend: *p<.05 **p<.01
Electrode sites: two occipital (O_1 and O_2) and two parietal (P_3 and P_4)
EP (evoked brain potentials): N1, P2, N2, P3 & SW
Amplitude1: amplitude measured in the first trial
Amplitude2: amplitude measured in the second trial
M: Mean, SD: Standard Deviation;
K-Sz: Kolmogorov-Smirnov test of distribution normality

This finding enabled use of parametric statistics, so Pearson's coefficients of correlation were calculated. Also, as it could be seen in Table 1, all determined latencies and amplitudes of measured EPs were within the expected range, what has confirmed their assumed topographical distribution.

Picture 1. Distribution of Empathy results on the whole sample (N=54)



The relationship between evoked potentials and empathy

As it could be seen in Table 2, correlation analysis showed only one significant finding, and that is the significant negative correlation between empathy and N2-amplitude in the first trial at one parietal electrode ($r=-.36$, $p<.01$).

Table 2. The correlations (r) between Empathy and EPs: N1, P2, N2, P3 and Sw (latency in the one and amplitude two trial blocks) on 4 electrodes (O_1, O_2, P_3 & P_4) on the whole sample (N=54)

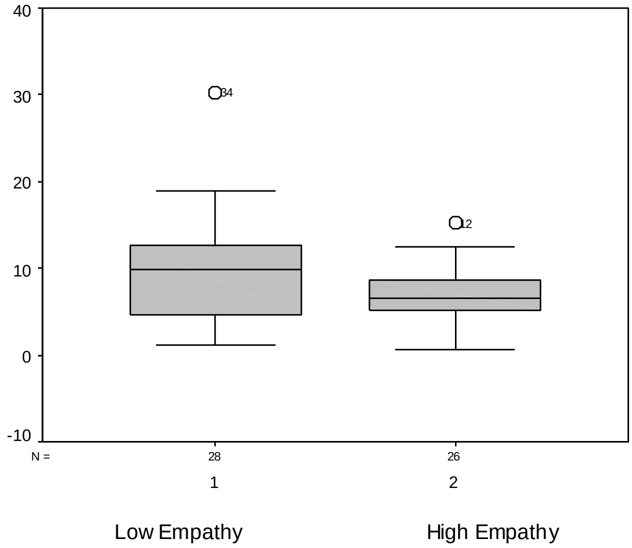
		Correlations with empathy				
Electrode	**ERP**	**N1**	**P2**	**N2**	**P3**	**SW**
O_1	**latency**	.05	-.16	-.12	-.08	-.08
	amplitude1	.06	.14	.24	.13	
	amplitude2	.14	.17	.07	-.17	
O_2	**latency**	.05	-.16	-.14	-.06	-.06
	amplitude1	.11	.04	.08	-.01	
	amplitude2	.07	.02	.04	-.15	
P_3	**latency**	-.01	.11	-.06	.00	.03
	amplitude1	-.04	-.08	-.18	.16	
	amplitude2	-.03	-.08	.00	-.16	
P_4	**latency**	-.01	.09	-.06	.02	.04
	amplitude1	-.02	-.21	**-.36****	.12	
	amplitude2	.01	-.25	-.15	-.15	

*p<.05 **p<.01

Legend:
Electrode sites: two occipital (O_1 and O_2) and two parietal (P_3 and P_4)
Amplitude1: amplitude measured in the first trial
Amplitude2: amplitude measured in the second trial

Also, calculated one-way ANOVA showed a significant difference between Low and High Empathy Group ($F_{(1,52)}=4.792$, $p=.033$) in measured N2-amplitude from the first trial on P4 electrode. Thid significant difference between two empathy groups could be seen in Picture 2.

Picture 2. Stem-an-Leaf Plot of N2-amplitude measured in the first trial block at P_4 electrode determined in Low Empathy Group (N=28) and High Empathy Group (N=26) – the significant difference could be observed



In other words, correlation analysis determined that with the lower empathy level, N2-amplitude increased. So, more empathetic students showed lower possibility of the stimuli characteristic extraction and target selection during visual discrimination task. Looking at the Table 2, it can also be seen that all other correlations were not significant. Overall, one significant finding and the lack of the others, could be explained by the fact that N2-component had the fronto-central scalp distribution, what could be often seen within previously mentioned imagining studies of evoked empathy in subjects (Ruby & Decety, 2004; Saarela et al., 2007). So, N2-component showed a fronto-central distribution, partially similar to the one usually registered in participants experiencing empathy (Decety & Chaminade, 2003), which is in accordance with the hypothesis. According to that, it was expected that some other EP-components with the similar scalp distribution, such as P3-wave, would gain significant correlation with the self-rated empathy. So, the lack of other significant correlations could be explained by the fact that very simple, and monotonous task has been used within this study. Also, the used task was neutral and the visual stimuli used have not contained empathy-relevant pictures which have been often used in other studies (Wicker et al., 2003; Singer et al., 2004; Jackson et al., 2005; Lieberman & Eisenberger, 2009).

Besides that, two technical limitations of this study should be emphasized because the findings could be explained partially by them. First of all, since only two occipital and two parietal electrodes have been used in this study, there were no any information about fronto-central activation of measured EP-components. And second, the use of Medelec/TECA Sapphire[II] 4E device (1996) in this research which is old type of EP-device and the subjectivity of manually EP-marking presented the factors that definitely limited the quality of this research. Finally, within the question of the gained significant negative correlation with the amplitude of N2-wave could be explained by the fact that empathy had the significant positive correlation with neuroticism measured by the EPQ/R ($r=.33$, $p<.01$), which also showed significant negative correlation with EP-amplitudes (Tatalovic Vorkapic, 2010). So, in future studies, since empathy was closely connected with the neuroticism trait, we could expect that its electrophysiological correlates would be more correlated with the amplitudes of evoked potentials rather than latencies, and with those EP-amplitudes that mainly showed fronto-central scalp distribution.

CONCLUSION

So, it can be concluded that the main study hypothesis is partially confirmed. The determined significant negative relationship between N2-amplitude measured on one parietal electrode only in the first trial and self-rated empathy was interpreted within its similar scalp distribution to the one determined in the neuroimaging studies, which measured brain activity while subjects observed others' pain. Also, the lack of other significant correlations has been explained by certain technical limitations of this study, such as type of used task, type of used stimuli, manual EP-marking and used electrodes, that should be definitely taken into consideration for any future studies. Finally, this data argumentative implied at the great possibility of existing biological foundations of human's empathy that support the most findings of other relevant empathy studies.

REFERENCES

Batson, C.D. (1987). Physiological indices of empathy. In: Eisenberg, N., J. Strayer (Eds.), *Empathy and its development,* 356–360. New York: Cambridge University Press.

Batson, D.C., Early, S., Salvarani, G. (1997). Perspective taking: Imagining how another feels versus imagining how you would feel. *Personality & Social Psychology Bulletin, 23,* 175–178.

Bryant, B.K. (1987). Critique of comparable questionnaire methods in use to assess empathy in children and adults. In: Eisenberg. N., J. Strayer (Eds.), *Empathy and its development,* 361–373. New York: Cambridge University Press.

Coles, M.G.H., Gratton, G., Kramer, A.F., Miller, G.A. (1986). Principles of signal acquisition and analysis. In: Coles, M.G.H., E. Donchin, S.W. Porges (Eds.), *Psychophysiology: Systems, Processes and Applications,* 183-221. New York: The Guilford Press.

Dabić-Jeftić, M., Mikula, I. (1994). *Evocirani potencijali kore mozga – Osnovne postavke i klinička primjena (Evoked cortical potentials – Basic assumptions and clinical use).* Zagreb: Školska knjiga.

Davis, M.H. (1996). *Empathy: A Social Psychological Approach.* Westview Press, Madison, WI.

Decety, J., Chaminade, T. (2003). Neural correlates of feeling sympathy. *Neuropsychologia, 41*, 127-138.

Decety, J., Jackson, P.L. (2004). The functional architecture of human empathy. *Behavioral and Cognitive Neuroscience Reviews, 3,* 71–100.

Decety, J., Jackson, P.L. (2006). A social-neuroscience perspective on empathy. *Current Directions in Psychological Science*, *15(2),* 54-58.

Decety, J., Keenan, J.P. (2006). Social Neuroscience: A new journal. *Social Neuroscience, 1(1),* 1-4.

Decety, J., Lamm, C. (2006). Human empathy through the lens of social neuroscience. *The Scientific World Journal, 6,* 1146–1163.

Decety, J., Batson, C.D. (2007). Social neuroscience approaches to interpersonal sensitivity. *Social Neuroscience, 2(3-4),* 151-157.

Donchin, E., Coles, M.G.H. (1988). Precomentary: Is the P300 component a manifestation of context updating? *Behavioral and Brain Sciences, 11(3),* 355-372.

Eysenck, H.J., Eysenck, S.B.G. (1994). *Priručnik za Eysenckove skale ličnosti: EPS-odrasli (The Handbook for use of Eysencks' personality scales: EPS-adults).* Naklada Slap, Jastrebarsko.

Eysenck, S.B.G., Pearson, P.R., Easting, G., Allsopp, J.P. (1985). Age norms for Impulsiveness, Venturesomeness and Empathy in Adults. *Personality and Individual Differences, 6(5),* 613-619.

Fan, Y., Han, S. (2008). Temporal dynamics of neural mechanisms involved in empathy for pain: an event-related brain potential study. *Neuropsychologia 46,* 160–173.

Hoffman, M.L. (1981). Is altruism part of human nature? *Journal of Personality and Social Psychology, 40,* 121–137.

Hoormann, J., Falkenstein, M., Schwarzenau, P., Hohnsbein, J. (1998). Methods for the quantification and statistical testing of ERP differences across conditions. *Behavior Research Methods, Instruments, & Computers, 30(1),* 103-109.

Hugdahl, K. (1995). An overview of psychophysiology: Introduction. In: Hugdahl, K. (Ed.) *Psychophysiology: The Mind-Body Perspective,* 3-31. Cambridge, MA: Harvard University Press.

Jackson, P.L., Meltzoff, A.N., Decety, J. (2005). How do we perceive the pain of others? A window into the neural processes involved in empathy. *NeuroImage 24,* 771–779.

Lieberman, M.D., Eisenberger, N.I. (2009). Neuroscience: Pains and pleasures of social life. *Science, 323(5916),* 890–891.

Näätänen, R. (1992). *Attention and brain function.* Lawrence Erlbaum Associates, Inc. Hillsdale, New Jersey, USA

Picton, T.W. (1980). The use of human event-related potentials in psychology. In: Martin, I., P.H. Venables (Eds.), *Techniques in psychophysiology*, 357-395. New York: Wiley.

Polich, J. (1998). P300 clinical utility and control of variability. *Journal of Clinical Neurophysiology, 15(1),* 14-33.

Polich, J. (2004). Neuropsychology of P3a and P3b: A theorethical overwiev. In: Arikan, K., N. Moore (Eds.), *Brainwaves and mind: Recent developments,* 15-29. Wheaton, IL: Kjellberg.

Polich, J., Kok, A. (1995). Cognitive and biological determinants of P300: an integrative review. *Biological Psychology, 41,* 103-146.

Ruby, P., Decety, J. (2004). How would you feel versus how do you think she would feel? A neuroimaging study of perspective taking with social emotions. *Journal of Cognitive Neuroscience, 19,* 989-999.

Saarela, M.V., Hlushchuk, Y., Williams, A.C.deC., Schürmann, M., Kalso, E., Hari, R. (2007). The compassionate brain: Humans detect intensity of pain from another's face. *Cerebral Cortex*, *17*, 230–237.

SapphireII User Manual 003W009A (1996). Medelec, Vickers Medical & Teca Vickers Medical. Medical Device Directive, Medelec Ltd, England.

Singer, T., Seymour, B., O'Doherty, J., Kaube, H., Dolan, R.J., Frith, C.D. (2004). Empathy for pain involves the affective but not sensory components of pain. *Science, 303,* 1157–1162.

Tatalovic Vorkapic, S. (2010). Odnos između temperamenta, temeljnih dimenzija ličnosti i evociranih mozgovnih potencijala (The relationship between temperament, basic personality dimensions and evoked brain potentials). *Doctoral Dissertation,* Department of Psychology, Faculty of Humanities and Social Sciences, University of Zagreb.

Wicker, B., Keysers, C., Plailly, J., Royet, J.–P., Gallese, V., Rizzolatti, G. (2003). Both of us disgusted in my insula: The common neural basis of seeing and feeling disgust. *Neuron, 40*, 655–664.