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Event-related potentials during individual, cooperative, and competitive task performance differ in subjects with analytic vs. holistic thinking

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ABSTRACT

It has been presented that Western cultures (USA, Western Europe) are mostly characterized by competitive forms of social interaction, whereas Eastern cultures (Japan, China, Russia) are mostly characterized by cooperative forms. It has also been stated that thinking in Eastern countries is predominantly holistic and in Western countries analytic. Based on this, we hypothesized that subjects with analytic vs. holistic thinking styles show differences in decision making in different types of social interaction conditions. We investigated behavioural and brain-activity differences between subjects with analytic and holistic thinking during a choice reaction time (ChRT) task, wherein the subjects either cooperated, competed (in pairs), or performed the task without interaction with other participants. Healthy Russian subjects ($N = 78$) were divided into two groups based on having analytic or holistic thinking as determined with an established questionnaire. We measured reaction times as well as event-related brain potentials. There were significant differences between the interaction conditions in task performance between subjects with analytic and holistic thinking. Both behavioral performance and physiological measures exhibited higher variance in holistic than in analytic subjects. Differences in amplitude and P300 latency suggest that decision making was easier for the holistic subjects in the cooperation condition, in contrast to analytic subjects for whom decision making based on these measures seemed to be easier in the competition condition. The P300 amplitude was higher in the individual condition as compared with the collective conditions. Overall, our results support the notion that the brains of analytic and holistic subjects work differently in different types of social interaction conditions.

1. Introduction

Humans differ with respect to their preferred mode of perception, thinking, and problem solving along a holistic to analytic dimension. The key feature of individuals with holistic thinking is a propensity to evaluate events and objects in the context in which they are presented. Holistic subject view the world as a complex structure of interactions, relationships and trade-offs, and pay attention to links between events. Analytic individuals, to the contrary, tend to consider events and objects as invariant in time, primarily changing according to their own rules, rather than due to interaction with the environment (Nisbett, 2003). Nisbett et al., 2001 selected four domains as constructs of the analytic-holistic thinking: locus of attention (inclusion or ignorance of a context), causal attribution (account of situational causes or dispositionism), perception of change (cyclic or linear), and attitude toward contradictions (compromised middle ground between components of the whole or formal logic without compromises). The differentiation to holistic and analytic subject can be traced back to history in philosophy. Aristotelian logic serves as an example of analytic, and Confucianism of holistic, thinking (Nisbett, 2003). Cultural differences between the analytic and holistic thinking styles are presently studied intensively (Kitayama and Uskul, 2011; Talhem et al., 2014; Nisbett and Miyamoto, 2005; Henrich et al., 2010).

Analytic-holistic thinking styles are assessed with either questionnaires or various experimental approaches (Norenzayan et al., 2002) where analytic individuals use clear pre-set criteria, while holistic individuals classify objects on the basis of their general similarity. Previous studies of the thinking styles have focused mostly on cross-cultural differences. For example, participants in South-East Asia were characterized by higher degree of holistic thinking than subjects in USA or Western Europe (Henrich et al., 2010; Norenzayan and Nisbett, 2000). However, the thinking styles have been shown to vary within cultures as a function of, e.g. professional activity, area of residence, and social class (Apanovich et al., 2014; Grossmann and Varnum, 2010; Henrich et al., 2010; Talhem et al., 2014).

Analytic and holistic thinking styles have been examined in both

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psychological and cognitive psychological cross-cultural studies (Pask, 1976; Davies and Graff, 2006; Gutchess et al., 2010). However, methods that are effective in cross-cultural comparisons are not always successful in distinguishing the analytic and holistic thinking styles of individuals within the same culture (Na et al., 2010). The Analytic-Holistic Scale (AHS) is a questionnaire that measures analytic-holistic thinking based on a four component model (Nisbett et al., 2001). The AHS can be used to measure both cross-cultural and within-cultural differences (Choi et al., 2007). It is worth noting that the phenomena studied in cross-cultural experimental designs can be influenced by a variety of other differences between the cultures. In our research we study analytic/holistic thinking inside one culture.

Cooperation and competition exist in all cultures with different degrees of manifestation (Basabe and Ros, 2005). It has been documented that competition occurs in different forms in collectivistic and individualistic cultures (Fülöp, 2009). The proportion of competitive and cooperative forms of social interactions in individualistic and collectivistic cultures is still an open question. It has been noted that combinations of individualistic and collectivistic tendencies exist in all cultures (Green et al., 2005).Based on extensive analyses of empirical and theoretical publications, Alexandrov and Kirdina (2013) suggested that analytic and holistic thinking should be addressed across different forms of social interactions, linking these thinking styles to the institutionality of a given society. Drawing parallels between these two thinking styles, the authors distinguished two types of "institutional matrices" based on commonality/non-commonality of material and technological environment: X-type, which dominates in Asia and Latin America, as well as in Russia, and Y-type, which dominates mainly in Europe and North America. The X-matrix (paralleling holistic thinking) was characterized by a predominance of cooperative relations, collectivism, and communality (Kirdina, 2014). Conversely, the Y-matrix (paralleling analytic thinking) was characterized by a predominance of competitive relations, individualism, and non-communality (Alexandrov and Kirdina, 2013). Since cooperation and competition (which are evolutionarily old forms of interaction (Griffin et al., 2004)) are the key factors of formation, functioning, and differentiation of social communities (Durkheim, 1997; Kirdina, 2014), we hypothesized that competitive and cooperative relationships are the candidate social interaction forms associated with analytic and holistic thinking.

This point of view is supported by others' work that has, for example, highlighted Western and non-Western cultures as syndromes with specific characteristics, moreover, holistic thinking has been associated with collectivistic cultures, and analytic thinking with individualistic ones (Henrich et al., 2010). Talhem et al. (2014) compared personal traits in different Chinese regions and found that analytic/holistic thinking correspond to individualistic/collectivistic forms of manufacturing prevailing in a region (Talhem et al., 2014). Finally, Fu et al. (2009) showed that whereas competition during training cultivated analytic skills in students, cooperation cultivated holistic thinking.

The neural mechanisms underlying social interactions has been studied extensively (for a review see Hari et al., 2015, Rilling et al., 2002), including competitive-cooperative and individualistic-collective interactions (Kitayama and Uskul, 2011). In particular, it has been observed that neural mechanisms supporting the same behavior in individuals characterized by analytic and holistic thinking are different (Henrich et al., 2010). However, even though the association of analytic and holistic thinking with collectivism-individualism has been hypothesized (see, for example, Henrich et al., 2010, Spencer-Rodgers et al., 2010; Alexandrov and Kirdina, 2013), the brain mechanisms supporting competitive and cooperative behavior in individuals with analytic and holistic thinking remains unexplored.

The P300 component of event-related potential (ERP) is a positive-polarity response in scalp-recorded EEG time-locked to stimuli and peaking roughly at about 350 ms from onset of task-relevant stimuli (Sutton et al., 1965). P300 has been considered to reflect active goal-directed processing of the stimulus. The systems-evolutionary approach (Shvyrkov, 1990; Alexandrov et al., 2000; Aleksandrov, 2015), building on the theory of functional systems (Anokhin, 1973), postulates that any goal-directed behavioural act is supported by the actualization (retrieval) of a set of functional systems formed during life, (i.e., neural representations of past experiences). Our previous studies demonstrated that P300 component of ERP is related to decision making in choice tasks (Bezdenezhnykh, 2013, 2014) involving a discrimination of two stimuli with a speeded response (e.g., pressing either one of two buttons). The P300 has been associated with organization of a system and interpreted as dynamic actualization of experienced-based processing during behaviors (Aleksandrov and Maksimova, 1985; Alexandrov et al., 2007). It is known that holistic and analytic subjects use different experienced-based behavioural strategies during the same problem solving (Choi et al., 2007; Norenzayan et al., 2002). On this basis it can be hypothesized that P300 differs between analytic and holistic subjects.

The purpose of the present study was to test two hypotheses linking individual differences in thinking, social context, and the mode of social interaction. First, we hypothesized that subjects with analytic and holistic thinking would exhibit differences in both task-performance and brain physiology as measured with P300 amplitude and latency. Second, we hypothesized that these group differences are moderated by social context, i.e., depend on whether subjects perform the task alone or in pairs with other subjects. We further hypothesized that group differences are moderated by the mode of social interaction (cooperation versus competition). We hypothesized that these differences can be caused by the number of neural systems related to different forms of social interaction and estimated by the amplitude of P300. We specifically hypothesized that subjects with holistic thinking within one culture make decisions faster when cooperating, whereas subjects with analytic thinking make decisions faster when competing.

2. Materials and methods

2.1. Participants

Data of 78 participants (37 males, 41 females, median age 20 years, mean 24.6 years) were included in the analysis, after exclusion of 12 participants because of artifacts. All participants were paid for their participation. Prior to participation, an informed consent was obtained from each participant. The experimental procedures were approved by the Ethics Committee of Federal State-Financed Institution, Institute of Psychology, Russian Academy of Sciences, Moscow. The subjects were further divided into two contrast-groups, holistic and analytic, by selecting 20 percentile of the most analytic and holistic subjects based on their AHS scores. The analytic contrast-group included all subjects with AHS score below the 20th percentile ($N = 15$), and holistic contrast-group included all subjects with scores above the 80th percentile ($N = 16$). Such division criteria was based on the assumption that the thinking-related difference between the groups will increase, or at least remain on the same level, when the groups are more different in terms of holistic-analytic thinking, despite the smaller sample size. Earlier we performed a pilot study with full groups and obtained the same results (Apanovich et al., 2016a, 2016b). We suggested that if as ample size is a half reduced, but a significance level is higher or unchanged, it additionally testifies about validity and shows that the used division based on this construct is fundamental for the studied forms of social interactions and conditions. Methods for contrast group selection for statistical analyses are described earlier (Furr and Bacharach, 2013; Anastasi and Urbina, 1997). Two contrast group division (and also two task division immanent for these two groups) was transferred from cross-cultural studies and implemented for the intra-cultural study based on the reasons supported in Introduction.

2.2. Questionnaires

Analytic-holistic thinking of the subjects was assessed by means of the AHS scale (Choi et al., 2007), based on the four component model (Nisbett et al., 2001). We used the Russian language version previously adapted for the Russian population (Apanovich et al., 2016a, 2016b). The scale consists of 24 statements, which are assessed by subject on a 7-step Likert scale ("completely disagree" to "completely agree" with a middle point of "difficult to answer"). The test provides a total score of analytic-holistic thinking, and four subscores of the individual components of the analytic-holistic thinking type. The detailed description of the subscales was given earlier (Apanovich et al., 2017). The highest score for each scale represents a holistic pole, and the smallest – the analytic pole. Subjects who provided 6 or more "difficult to answer" responses were excluded from subsequent analyses (4 subjects).

2.3. Experimental procedure

After taking the AHS test, subjects participated in the sensorimotor choice reaction time task (Bezdenezhnykh, 2012) during which their brain activity was measured with ERP. In four experimental condition subjects were presented with two alternative visual stimuli, vertical bars of different heights, which they had to respond (Fig. 1) to by pressing the corresponding button as soon as possible. The order of the stimuli was randomized, and they were presented with equal probability. A bright square served as a preparation stimulus before the start of the trial, and was presented with equal probabilities for either 750 ms or 900 ms prior to one of two alternative visual stimuli which was presented either a long (3sm) or short (2sm) bright vertical bar (Fig. 1). The subject was instructed to press the corresponding button as fast as possible with the index finger of dominant hand. The left button is to be used for the first signal (the shorter bar), and the right button – for the second signal (the longer bar). The starting position of the finger was located equidistantly from both buttons at a distance of 3 cm. Feedback on the response (speed and correctness of the pressing) was provided to subjects 2 s after the button press with either "+" or "−" symbols. Preparation stimulus of each subsequent trial was delivered 1.5 s after feedback in the previous trial. Thirty trials were presented in randomized order.

Subjects always performed the task in pairs, however in training sessions (and also in one of the experimental sessions) they were informed that they were working alone. The experiment consisted of 4 conditions. In the 1st (training) condition, the subjects were trained to quickly and accurately respond to the presented stimulus (level of training was measured by the stabilization of reaction time). Then the subjects participated in three experimental conditions, the order of which was counterbalanced. The subjects were positioned in such way that each subject saw only his/her own monitor; subjects could not observe each other (Fig. 2).

We used within-subject experimental design. In the "solitary" condition, the subjects performed the task alone, were instructed to be as quick and accurate as possible, and were informed that performance of the second subject (present in the room as in Fig. 2) would bear no

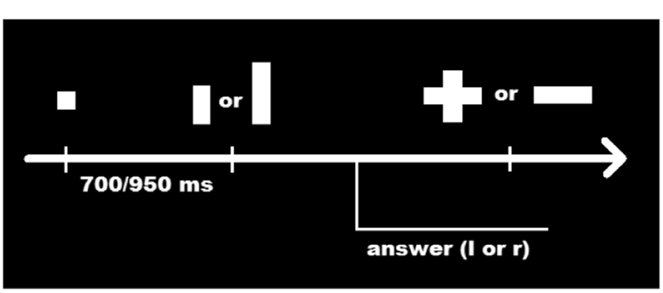

Fig. 1. The order of presentation of stimuli in a single trial. l – left button, r - right button.

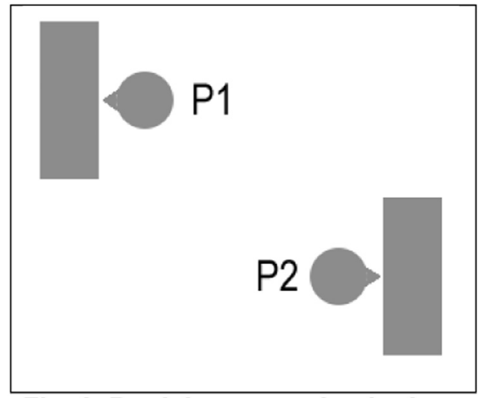

Fig. 2. Participants setting in the experimental room.

relevance on his/her own performance. In two other conditions the subjects were informed that they performed the task in pairs with the other subjects in the room. In the cooperation condition, feedback was presented to both subjects simultaneously and in random order, i.e., not related to the quality of task performance, however, the subjects were not informed about the random nature of the feedback. The subjects were instructed that if "+" was shown, then both subjects performed the task successfully, while "−" meant that one or both subjects had failed. In the competition condition, both subjects received the same feedback after the response. Each subject was instructed that if "+" was shown, he/she had reacted faster and more accurately than the opponent, and "−" indicated a slower or incorrect response relative to the opponent.

The main factor which induced subjective differences in social interactions between these experimental conditions was the instruction given to subjects, according to which subjects had to be involved in cooperative, competitive, or independent task performance. In the instructions, the subjects were explicitly pointed out which form of social interaction will be used in a particular series: competition, cooperation or independent from performance of someone else.

Despite that cooperation and competition cannot be regarded as a full dichotomy (Fülöp, 2009), in each activity one aspect might be prevailing. In our study we implemented so-called parallel type cooperation (Thompson, 2003).

2.4. Electrophysiological measures

EEG was recorded with non-polarizing silver chloride electrodes using unipolar F3, F4, Cz, P3, P4 electrode positions of the international 10–20 system with linked earlobes electrodes serving as the reference. Eye movements were registered with two vertical EOG electrodes attached above and beneath the left eye. Electrode impedance did not exceed 5 kΩ for EEG electrodes, and 10 kΩ for EOG electrodes. The sampling rate for EEG and EOG was 250 Hz and the acquisition bandwidth 0.1–70 Hz, with the time constant of 10 s.

2.5. Analysis of the results

Reaction times and artefact-free EEG segments (epochs) time-locked to visual stimuli presentation were averaged separately for the three conditions. In order to reject artifacts we used an expert evaluation of raw data, which eliminated fluctuations associated with oculomotor activity with amplitude higher than 20 μV. Each ERP consisted of maximum of 30 trials (in the absence of artifacts).The baseline was defined as − 100 to 0 ms before visual stimuli onset. We focused on the P300 component elicited by visual stimuli, because this component and the frontal (positive) slope of P300 is associated with decision-making process (Bruder et al., 2002; Nandrino and Massioui, 1995;

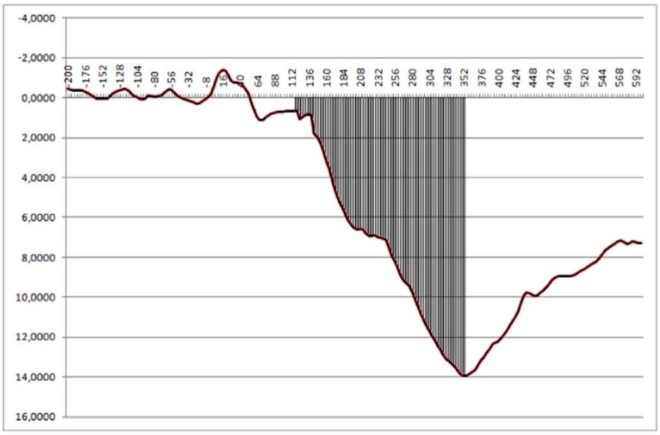

Fig. 3. The IDS-P300.

Bezdenezhnykh and Gulina, 2016 As previously reported (Aleksandrov and Maksimova, 1985), P300 characteristics might be associated with many empirically selected variables, but it was argued earlier based on empirical and theoretical studies that P300 characteristics reflect dynamics of how multiple processes based on previous experiences are recruited in processing the task-relevant stimuli, i.e., we interpret P300 as indicator of recruitment of memory-based task-relevant schemas. It can be argued that alternative views of P300 are in fact describing this process from other vantage points. WequantifiedtheP300 in the following way:

a) Initial descending slope of P300 (IDS-P300) (i.e., average of all points in the ERP range between N200 and P300 peaks, Fig. 3).
b) The P300 latency.
c) The amplitude of the P300 peak (i.e., the difference between the peaks of the negative N200 and positive P300 peaks).

We also averaged the reaction time (RT) for three conditions: individual, competition and cooperation. Medians and between-subject variances were also calculated for all the parameters.

Statistical analyses were performed using SPSS 17.0 software. Since distributions of physiological and behavioural metrics were significantly different from the normal distribution, we used nonparametric tests (Mann-Whitney and Wilcoxon). The variances were analysed using Levene's test, which doesn't make normality assumptions (Glass and Stanley, 1970). Bonferroni-Holm Correction for Multiple Comparisons was used for pair-wise comparisons between the series.

3. Results

3.1. Comparison of behavioural and physiological parameters of holistic and analytic groups

We compared physiological and behavioural measures (Table 2) and their dispersions (Table 3). For descriptive statistics see Fig. 4.

Analytic subjects responded faster than holistic subjects in Individual condition ($U = 783.5$, $z = -2.267$, $p = 0.023$).In competition condition the IDS-P300was larger in holistic than in analytic subjects ($U = 628$, $z = -2.834$, $p = 0.005$). In cooperation condition, the P300 amplitude was significantly higher in holistic than in analytic subjects ($U = 496.5$, $z = -1.99$, $p = 0.046$). The holistic group showed larger variance in the IDS-P300 ($F = 4.911$ $p = 0.030$), but significantly less variance compared to analytic group in response time ($F = 5.510$, $p = 0.021$) in cooperation condition. In the competition condition, holistic group showed significantly higher variance in amplitude of the P300 peak ($F = 17.040$, $p = 0.00008$). Fig. 5 shows an example of ERP in competition condition (a) and cooperation condition (b) for subjects with holistic and analytic thinking.

3.2. Effects of the social interaction mode on behavioural and electrophysiological parameters within analytic and holistic groups

We addressed the decision making process in the holistic and analytic groups independently of each other in three experimental conditions: individual, competitive and cooperative. We compared the behavioural and electrophysiological parameters in three conditions using pairwise comparisons with Wilcoxon test (see Table 4).

We found the following differences both in analytics and holists: reaction time in the competitive condition was significantly shorter than in the cooperative or the individual condition ($p < 0.001$ for all cases). P300 amplitude was significantly higher in the individual condition as compared to both the competitive condition ($p = 0.023$ for analytists; $p = 0.014$ for holists) and the cooperative condition ($p = 0.006$ for analytists; $p = 0.0001$ – for holists). The P300 latency was significantly lower in competitive vs cooperative conditions in the analytic group ($p = 0.011$). The P300 latency was significantly lower in individual vs competitive conditions in the holistic group ($p = 0.086$, at the level of tendency). P300 latency distribution for subjects with holistic and analytic thinking styles are represented in Fig. 6.

Next, we analysed homogeneity of the groups by comparing the variances of parameters in three experimental conditions (Table 5). For analytic group we did not find significant differences in variability of the parameters. For holistic group, however, variability of RT ($F = 11.973$, $p < 0.001$), the IDS-P300 ($F = 3.988$, $p = 0.021$), and P300 amplitude ($F = 4.873$, $p = 0.009$) were found to be significantly different; variability of amplitudes in the individual and the competitive condition of holists was higher as compared to the cooperative condition.

4. Discussion

Our study revealed significant differences in behavioural and electrophysiological indicators of decision making between individuals with holistic and analytic thinking. Furthermore, as expected, these differences varied as a function of the social context in which the cognitive task was performed (independent, cooperative, and competitive). These findings suggest that brain mechanisms subserving decision making are modulated by individual differences in thinking styles. Notably, the same reaction-time task performance was associated with both different behavior and different brain activity in the experimental conditions, that differed only in terms of being independent, cooperative, and competitive social situations. All other factors were stable.

4.1. Comparing individual and collective behavior

We observed that P300 amplitude was higher in individual condition, compared to cooperation or competition. Previous research suggests that the P300 amplitude is associated with the number of neural systems activated in the decision making process (Bezdenezhnykh, 2014; Alexandrov et al., 2007; Aleksandrov and Maksimova, 1985). It was shown that P300 amplitude in the individual condition was higher for both groups. One possible explanation is that in individual behavior neuronal systems of social interactions are reactivated (Di Paolo and De Jaegher, 2012; Hari et al., 2015, of P. 181; Hari et al., 2016) in a less selected manner than in concrete forms of social interactions, i.e., cooperation and competition. Therefore, for each of these forms of interactions the number of actualized systems, or elements of individual experience, might have been less (De Jaegher et al., 2016).

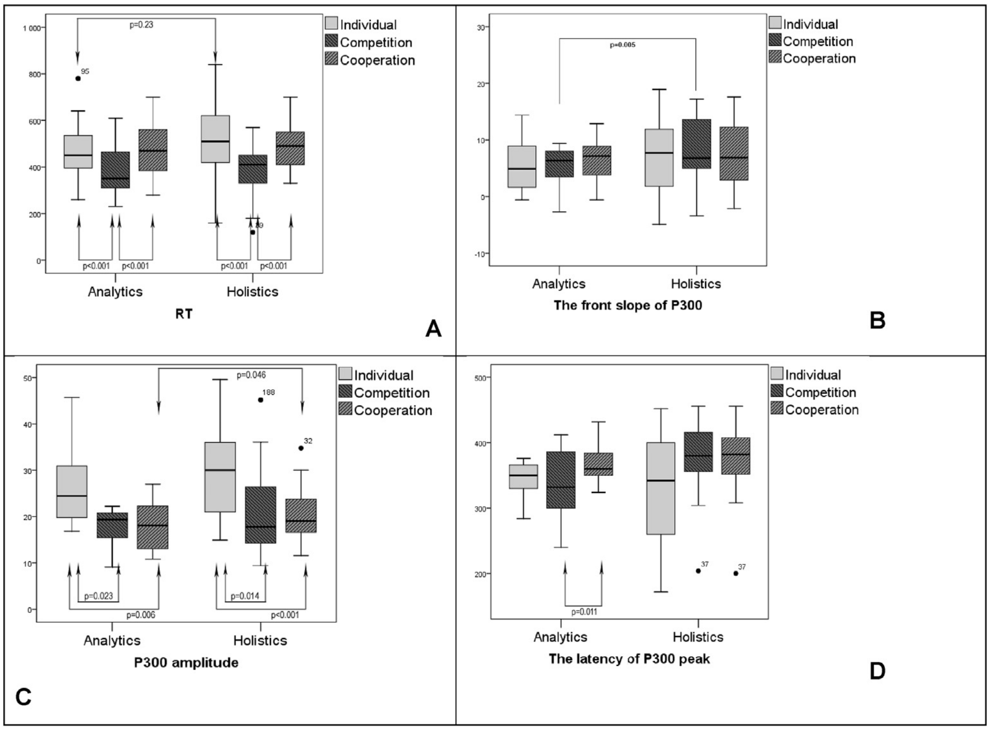

Fig. 4. A. The RT for analytic and holistic groups in different experimental conditions. B. The IDS-P300. C. Amplitude of P300 peak. D. P300 latency. Response time and P300 latency are plotted in milliseconds, the IDS-P300 and P300 amplitude are plotted in μV. The data are presented in Table 1 of supplementary materials.

4.2. Comparing the individual and collective behavior in "analytic" and "holistic" groups

The special importance of joint forms of interaction for holistic group is empathised in differences in amplitude parameters between holistic and analytic subjects in cooperation and competition (with P300 amplitude higher), yet not in the individual, condition. Together, these findings suggest, in light of theoretical thinking of (Bezdenezhnykh, 2014, Alexandrov et al., 2007, Aleksandrov and Maksimova, 1985) that holistic subjects possess more systems that are actualized during both collective forms of social interaction. As a cautionary remark, P300 amplitude might be also related to working memory capacity (Fabiani et al., 1986; Mecklinger et al., 1994), the number of predicted alternatives (Munson et al., 1984), subjective probability and stimulus meaning (Johnson, 1986)and activity level (Polich and McIsaac, 1994), yet these alternative interpretations need not be seen as mutually exclusive but, rather, different descriptions of the number of activated systems. There are different views on the explanation of the amplitude of slow potentials, including P300. Detailed substantiation of our position (including the substantiation of the connection of the amplitude of EEG slow potentials with the number of actualized systems - memory elements) and comparison with other authors' views have been described by us in previous papers (Alexandrov et al., 2007, Aleksandrov and Maksimova, 1985).

4.3. The variance of the amplitude parameters in "analytic" and "holistic" groups

The present findings suggest that group differences in variability of behavioural and amplitude parameters depend on the form of social interaction only in the holistic group. We did not observe similar results in the analytic group, i.e., the variability of physiological parameters in the analytic group never changed across the conditions.

Together, these data suggest that for analytic subjects the process of solving the problem itself is important, with less consideration for the contextual factors. In contrast, holistic subjects consider the environmental context, as well as the form of social interaction, in their decision making process. The data are consistent with the basic characteristics of the two types of thinking, i.e., holistic individuals view the environmental, "background" factors as important, while the focus of

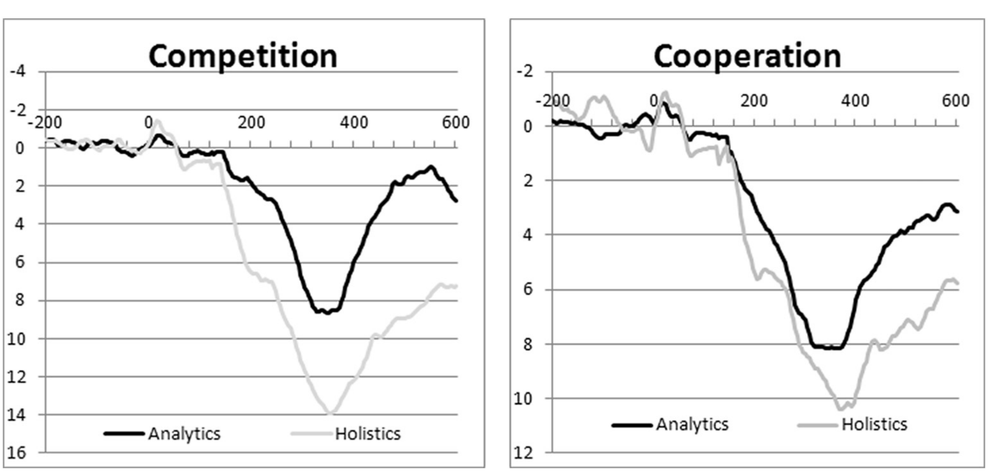

Fig. 5. Comparison of the ERPs in competition and cooperation conditions. Time is plotted in milliseconds, amplitude is plotted in μV.

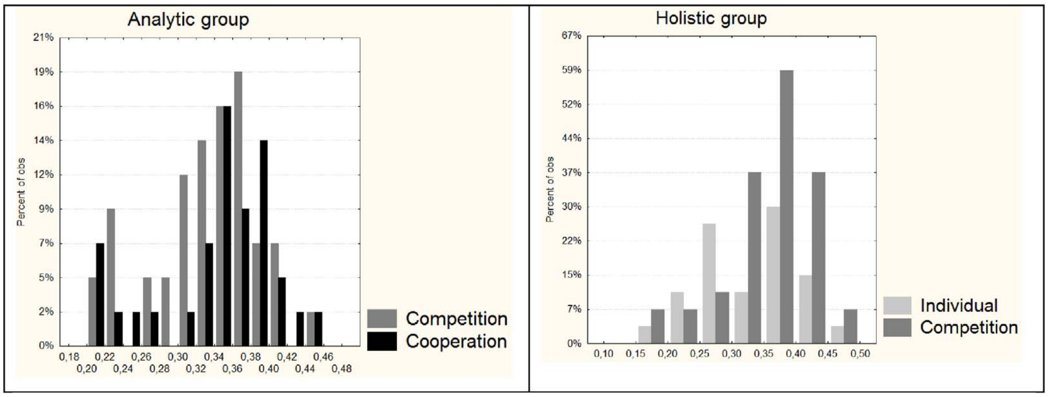

Fig. 6. Distributions of the P300 latencies in "analytic" group (left) and "holistic" group (right) for different experimental conditions. Peak of inter-individual latency distribution in analytic group is shifted to the right in cooperation vs. competition, while peak of inter-individual latency distribution in holistic group is shifted to the right in competition vs. individual, condition.

attention of analytic subjects is on the object itself, outside of the context. This also corroborates previous findings on that in cultures characterized by prevalence of holistic thinking, the inter-individual relationships and interactions are especially important (Nisbett, 2003).

4.4. The P300 latency as a marker of decision making difficulty

We considered the P300 latency as a possible indicator of the complexity of the decision making process. Specifically, the longer the P300 latency, the more difficult the task (i.e. the longer is the process of actualization, the search for and interaction of systems, or recruitment of experience-based elements needed for the decision; Fabiani et al., 2000; Stanzione et al., 1991; Bezdenezhnykh, 2013). Our results suggest that for holistic individuals the decision making process is more difficult in competitive forms of social interaction (compared to cooperative), and for analytic subjects, the cooperative form of social interaction is more difficult (compared to individual). As we mentioned in introduction, any behavior, including "individual", is in its essence collective. For holistic individuals, the difficulty of decision making in individual condition was the same as in cooperative and competitive forms of social interaction, suggesting that for holistic subjects the individual behavior to a greater extent involves using the experience of both forms of collective interaction. On the other hand, for analytic subjects, in the individual condition the difficulty of decision making was the same as in the competitive condition but different from the cooperative condition, suggesting that for analytic subjects the individual behavior is more associated with using the experience of competitive interactions.

The shorter P300 latency in analytic subjects in competition condition, as well as different sensitivity to social interaction forms in analytic and holistic subjects requires additional explanation. Previous cross-cultural research have shown that holistic and analytic thinking are inherent to collectivistic and individualistic communities, respectively, and associated with different types of economic interactions (Alexandrov and Kirdina, 2013; Kirdina, 2014). Holistic thinking corresponds to cooperation (competition is less pronounced and is only optional), and analytic thinking is associated with competition (cooperation is optional). Here we addressed the intra-cultural differentiation; however, similar associations between holistic-analytic thinking and types of economic activity were found for groups representing specific subcultures: more pronounced holistic thinking in individuals and members of their families who are engaged in economic activities requiring greater level of cooperation (Henrich et al., 2010; Talhem et al., 2014). This is also in accordance with the notion that competition leads to development of analytical skills, and cooperation leads to development of synthetic (holistic) skills (Fu et al., 2009).

5. Limitations

Our study has limitations due to the fact that differences in subjects' social interactions (manifested in behavior and brain activity) were determined by different comprehension of the same task, induced by the instruction. Our further experiments will be constructed to overcome such limitations by preset objective differences in cooperation and competition during task performance in holistic and analytic subjects. Further, it should be noted that, even though analytic/holistic thinking has been observed as a key characteristic based on which subjects can be distinguished and relates to cross- and intra-cultural differences in mental activity, considering also other personality characteristics would have complemented the present results in an important way.

6. Conclusion

We found psychophysiological differences in the three experimental conditions, where the behavior of participants, characterized by analytic and holistic thinking, differed during independent, cooperative, and competitive tasks. We showed that variability of electrophysiological and behavioural parameters was significantly higher for holistic subjects in individual condition compared to cooperative, as well as in competition compared to cooperation. We observed that P300 amplitude is higher in the individual condition as compared to both collective conditions. Two main conclusions might be drawn from these study: (1) organization of behavior and underlying neural processes are different in people with analytic and holistic thinking styles; (2) brains of subjects with different thinking styles (holistic/analytical) work differently during different forms of social interaction, which imply that the holistic subjects make decisions easier in cooperative conditions, in contrast to analytic subjects who thrive in competitive conditions.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijpsycho.2017.10.001.

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