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Indicators of Character Strengths in Individuals with Different Heart Rate Variability

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Abstract

Introduction. The problem of inter-coordination of systemogenesis processes in achieving a purposeful result is part of the problem of inter-coordination of individuals in achieving a collective result. The aim of the study was to assess the expression of indicators of 24 character strengths in individuals with different heart rate variability indicators. Since we previously showed that Heart Rate Variability (HRV) characteristics are related to the features of the structure and dynamics of actualized individual experience in achieving results, and also that the difference in ways individuals solve complex cognitive tasks and their character strength patterns correlate, we tested the hypotheses about different heart rhythm organization in participants with different patterns of 24 character strengths. **Methods.** Study participants (N=145; Med = 19 years old) completed the "Scale of Analyticity-Holism" and "24 Character Strengths" (VIA-24) methods, after which a cardiorhythmogram was recorded while they solved complex cognitive tasks. **Results.** A cluster analysis was performed on the heart rate variability indicators "Mean Heart Rate" and "Standard Deviation of Normalized RR-intervals", resulting in two clusters being identified. It was determined that these clusters differ in the dynamics of the indicators "Standard Deviation of Normalized RR-intervals" and "Sample Entropy": a cluster with high heart rate variability and its increasing complexity, and a cluster with low variability and its decreasing complexity. These same clusters differ in the pattern of character strengths. **Discussion.** Since the possibility of identifying groups of study participants with

differing ratios of heart rate variability indicators and character strength patterns has been established, it is concluded that substantive differences in the organization of the structure of individual experience, recorded by psychometric methods, are associated with the dynamic characteristics of the actualization of experience in behavior.

Keywords

structure of individual experience, systemogenesis, well-being, ways to achieve well-being, character strengths, heart rate variability, heart rate entropy

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Introduction

The present study addresses the problem of inter-coordination of systemogenesis processes in achieving a purposeful result and is part of the problem of inter-coordination of individuals in achieving a collective result. In relevant literature, problems similar to this are solved within the framework of interdisciplinary studies and are aimed at applying multivariate analysis to establish relationships between various properties of individuals, i.e., it allows for the identification of intersecting classes of equivalence and is achievable in quasi-experimental studies (in accordance with the modified typology of D. Campbell (Alexandrov, Maksimova, 2018; 2023), built on differing research objectives), which are distinguished by establishing contiguity relationships—syndromes are identified. This will allow linking the features of experience formation with their manifestations in the characteristics of both inter-individual interactions and general bodily systemic processes (including the organization of cardiac activity in ensuring the achievement of performance results) and will make it possible to formulate a more complete solution to the problem of individual variations in the learning process.

A special issue of the journal "Frontiers in Public Health", published in 2019, was titled "Heart Rate Variability, Health, and Well-being: A Systems Perspective" (Drury et al., 2019)

and was dedicated to the problem of assessing subjective well-being based on Heart Rate Variability (HRV). A variety of methods applied based on HRV were described, including the consideration of changes in variability during diseases, under conditions of acute stress and adaptive behavior in military personnel; HRV-based interventions such as resonant breathing, changing state through biofeedback methods, and improving quality of life after traumatic brain injury through acoustic stimulation and control of HRV change were also described.

In the article (Varfolomeeva et al., 2025), the significance, from the perspective of the systemic-evolutionary approach, of applying cardiorhythmogram analysis is considered, which allows for the reconstruction of "...the results of the processes of coordination of activity of various elements of the organism, which depends on the basic characteristics of the systemic organization of the behavior being implemented, including the degree of differentiatedness of the actualized set of systems..." (Bakhchina, Alexandrov, 2017, p. 117). At the same time, the dynamics of Sample Entropy (SampEn) of the heart rhythm during acute alcohol intoxication, as well as during changes in the complexity of cognitive tasks, emotionality, and stress level, are described. This indicator is standard in HRV studies, its magnitude describes the complexity of the heart rhythm, and its dynamics are related to the dynamics of the differentiatedness of actualized systems—elements of experience such that entropy increases with increasing differentiatedness (Alexandrov et al., 2017; Bakhchina, Alexandrov, 2017; Bakhchina et al., 2018; Bakhchina et al., 2021).

In S. B. Parin's studies, it is noted that individuals with a high expression of the characteristic "Self-Blame" show more pronounced stress activation when recalling a story publicly, and individuals with a high expression of the characteristic "Reflected Self-Attitude" show activation of the sympathetic division of the autonomic nervous system (Parin, Chugrova, 2017). Studies are conducted to assess the relationship between HRV and subjective well-being/quality of life. Some authors do not find such a relationship (Geisler et al., 2010). However, the work (Boman, 2018) established a relationship between a pronounced high-frequency spectrum of HRV and subjective well-being, and the work (Sommerfeldt et al., 2019) showed a connection between indicators of stress and anxiety, as well as HR.

The most important factor is not the actual "subjective assessment" of well-being, since this is a dynamic indicator and in clinical protocols such an assessment is limited to two-week intervals, but rather the way of achieving well-being (according to VIA), because it is a relatively stable indicator that relates to self-regulation. In previous studies aimed at operationalizing the construct "Ways of Solving" (WoS, see Tishchenko et al., 2021), a protocol was developed that allows for the identification of groups of study participants with differing WoS by grouping characteristics of problem-solving and establishing their correspondence to psychological characteristics. The assessment of the connectivity of the subjective report on the ways of achieving a result with the actual ways of achieving a result, as well as with the description from a third-party perspective (for example, by the researcher), is of fundamental importance.

Aim of the research: Assessment of differences in the ways of achieving psychological well-being in individuals differing in HRV indicators.

Research Hypotheses:

1. HRV indicators differ across the sample in such a way that it is possible to identify clusters representing groups of study participants with differing heart rhythm organization.
2. Study participants differing in heart rhythm organization possess differing expressions of the character strength pattern.

Methods

Sample

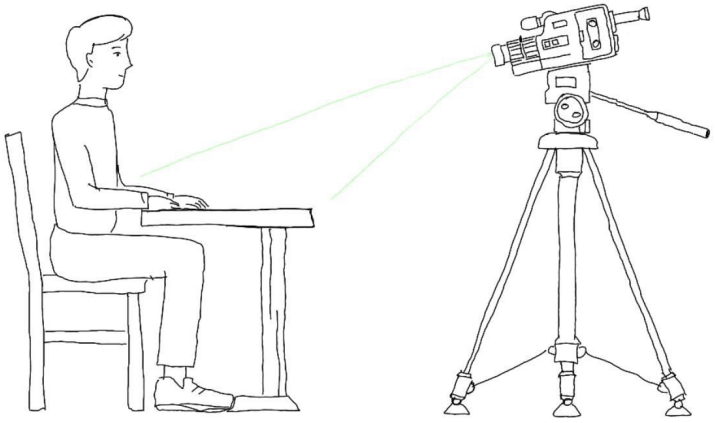
The study sample consisted of representatives of the student youth from Moscow (N=145) aged 18 to 35 years (Med=19 years).

Procedure

Before the main part of the study, participants completed the questionnaires: "24 Character Strengths" and "Scale of Analyticity-Holism". Also, before the main part, electrodes were placed on the study participants for ECG registration. The main part of the study consisted of a set of text tasks (N=30): "Knights and Knaves" (N=15) and "Moral Judgements" (N=15), which were presented in a quasi-random order and the time for solving them was not limited.

Figure 1

Schematic image of a study participant at a table while solving complex cognitive tasks and a video camera oriented towards the table surface and the participant's hands



Tests

1. The "Scale of Analyticity–Holism" questionnaire was constructed in 2007 in Korea (Choi et al., 2007) and validated in Russian (Apanovich et al., 2017). The scale includes 24 questions, 18 direct and 6 reversed. All questions are grouped into four subscales (focus of attention, causal attribution, tolerance for contradiction, perception of change), which reflect one of the indicators of analyticity/holism.
2. The "24 Character Strengths" (VIA-24) questionnaire is based on the model by C. Peterson – M. Seligman (Peterson, Seligman, 2004; Stavtsev et al., 2021), which describes 24 personality characteristics that can also be viewed as ways of achieving psychological well-being (Rean, Stavtsev, Kuzmin, 2024). Character strengths include: creativity (originality, ingenuity); love of learning; curiosity; broad-mindedness (wisdom); critical thinking; bravery (courage); perseverance (industry, diligence, grit); honesty (authenticity, integrity); zest (vitality, enthusiasm); love; kindness (generosity, nurturing, compassion); social (emotional) intelligence; prosocial activity; fairness; leadership; forgiveness (mercy); humility; prudence (caution); self-control (self-regulation); appreciation of beauty and excellence; gratitude; optimism (hope, future-mindedness); humour (playfulness); spirituality (faith, sense of purpose) (Stavtsev, Rean, Kuzmin, 2021).
3. Rosenberg Self-esteem Scale (Rosenberg Self-esteem Scale), in the adaptation by A. A. Bodalev, V. V. Stolin (Zolotareva, 2020).
4. General Self-Efficacy Scale by R. Schwarzer, M. Jerusalem in the adaptation by V. G. Romek (Schwarzer, Jerusalem, Romek, 1996).

Apparatus and Indicators

Electrocardiogram registration was performed using an autonomous telemetric electrocardiograph (MODEL ATÉK-1). The recorded cardiorhythmogram provided the values of RR-intervals, which are primary in heart rate variability analysis. The basis of HRV analysis is the isolation of the QRS complex of the electrocardiogram wave, where R—the point corresponding to the peak of this complex—acts as the beginning and end of the RR-intervals, the dynamics of which possess the properties of nonlinearity, fractality, and non-stationarity, which, in turn, allows calculating the values of entropy, i.e., the measure of scatter (distribution) of the heart rhythm. The duration of RR-intervals was measured programmatically, using the Pan-Tompkins algorithm, after which a recording of the sequence of RR-intervals was formed. These intervals are particularly significant in the analysis, since the beginning of the R wave is precisely the beginning of a new cardiac cycle, associated with the excitation of the sinus node, which allows studying the involvement of the heart cell population in ensuring purposeful behavior. The obtained sequence of RR-intervals was additionally cleaned manually for intervals invalid for analysis, outside the normative range of 550-1200 ms (see, for example, Galstyan, 2015). Then a matrix was compiled with the following variables: "Participant Number", "Interval Duration", "Task Number". The final matrix comprised 220 thousand rows. The prepared

matrix was loaded into the Python environment for calculating the main heart rate variability values (see Table 1).

Table 1
Heart rate variability indicators and their description

Indicator	Description
Mean-HR	Mean Heart Rate
SDNN	Standard Deviation (Root Mean Square) of Normalized RR-intervals
rMSSD	Root Mean Square of the Difference of Successive RR-intervals
LF	Absolute power of the Low-Frequency range (0.04-0.15 Hz)
HF	Absolute power of the High-Frequency range (0.15-0.4 Hz)
LF/HF	Ratio of Low-Frequency power to High-Frequency power
SampEN	Sample Entropy, describing the regularity and complexity of the time series

Data analysis

Only the values of HRV indicators and questionnaire scales were selected for analysis; task-solving characteristics were not included in the analysis described here. The analysis was conducted in SPSS 22.0 (IBM Statistics) software. The following statistical procedures were applied:

Two-step cluster analysis for identifying groups of study participants differing in HRV indicators (log-likelihood metric, Akaike criterion).

Mann-Whitney U-test and Kruskal-Wallis H-test for assessing the distribution of variables in the identified clusters.

The null hypothesis H_0 was rejected at $p<0.05$; tendencies were determined at $0.05 \leq p \leq 0.09$.

Results

The variables "Mean Heart Rate" and "Standard Deviation of Normalized RR-intervals" (hereinafter referred to as Mean-HR and SDNN, respectively; explanations in Table 1) were selected for clustering, as they were the most variable. Based on the results of the two-step clustering, two clusters were identified (Cluster 1 =20 individuals; Cluster 2 =20 individuals). This reduction in the number of study participants is due to the fact that only 40 participants solved all 30 tasks. Participants from Cluster 1 are characterized by higher values of Mean-HR and SDNN compared to participants from Cluster 2, as well as different expression of the pattern of 24 character strengths (see Table 2 for Mann-Whitney U-test results).

Table 2
Results of Assessing the Distribution of VIA-24 and AHS Variables in Two Clusters using the Mann-Whitney U-test

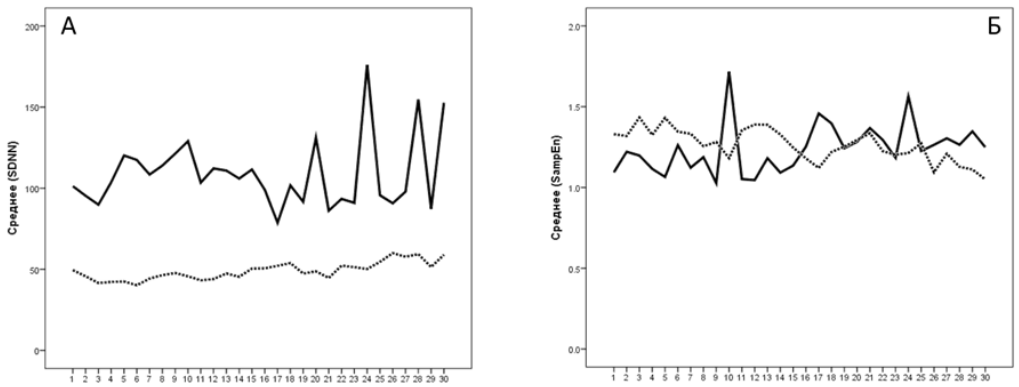
	Mean Rank		U	p-level
	Cluster 1	Cluster 2		
Critical Thinking	21,34	14,08	82,5	.032
Perseverance	22,34	13,19	66,5	.007
Fairness	20,81	14,56	91	.065
Gratitude	21,75	13,72	76	.018
Optimism	21,94	13,56	73	.014
Spirituality	20,91	14,47	89,5	.059
Causal Attribution	22,22	13,31	68,5	.009

Study participants from each cluster are characterized by different dynamics of the SDNN indicator from the 1st to the 30th task (see Fig. 2A). For participants from Cluster 1, no significant shift was found ($\chi 2$ = 23.653; p=0.746), whereas for participants from Cluster 2, an increase in SDNN magnitude is noted ($\chi 2$ =45.262; p=0.028). Study participants from each cluster are characterized by different dynamics of the Sample Entropy (SampEn) indicator from the 1st to the 30th task (see Fig. 2B). For participants from Cluster 1, a significant shift was found—entropy increases ($\chi 2$ =43.793; p=0.038), whereas for participants from Cluster 2, no significant changes in the magnitude of SampEn—entropy—are noted ($\chi 2$ =37.725; p=0.125).

Thus, the identified clusters can be characterized as follows: participants from Cluster 1 have high heart rate variability and its increasing complexity, while participants from Cluster 2 have low variability and its decreasing complexity.

Figure 2

Dynamics of the indicator (magnitudes are shown on the ordinate) SDNN (A) and SampEn (B) in two clusters from the 1st to the 30th task (on the abscissa). Solid line – Cluster 1, dashed line – Cluster 2.



A further clustering was conducted taking into account 15 solved tasks to check the partition on a larger part of the sample. Four clusters of study participants were identified: Cluster 1 (N=26), Cluster 2 (N=7), Cluster 3 (N=27) and Cluster 4 (N=27).

When assessing the dynamics of the SDNN and SampEn indicators, as was done in the first clustering, it was established that in participants from Cluster 2 there is a significant decrease in the SDNN indicator (Fig. 3A; χ^2 =73.758; p=0.000015) and a significant increase in the SampEn indicator (Fig. 3B; χ^2 =52.609; p=0.007). In participants from Cluster 4, there is a significant increase in the SDNN indicator (Fig. 3A; χ^2 =86.665; p=2.0845×10^{-7}).

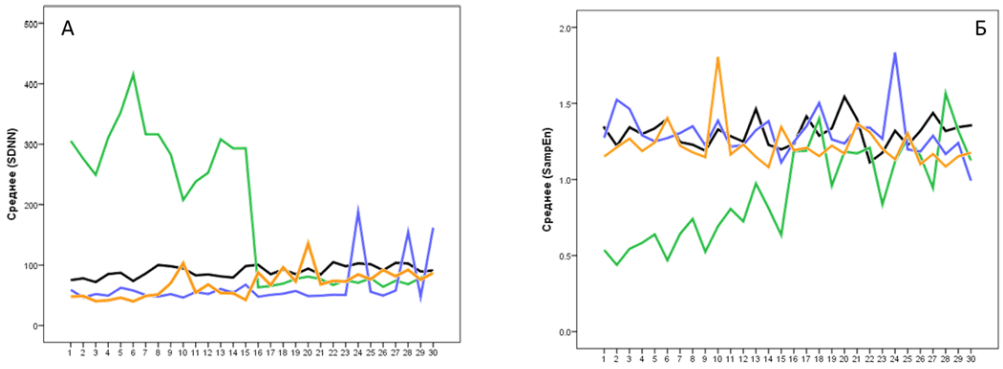
Table 3

Results of Assessing the Distribution of Variables in four Clusters using the Kruskal-Wallis H-test

	Cluster 1	Cluster 2	Cluster 3	Cluster 4	H	p-level
Curiosity	43,91	53,79	37,7	29,58	8,738	.033
Optimism	45	51,14	32,27	32,29	6,990	.072
Self-assessment	38,15	59,5	39,84	31,48	8,871	.031
Self-Efficacy	042,09	57,71	31,09	36,25	8,660	.034
Causal Attribution	43,07	51	29,61	38,63	6,818	.078

Figure 3

Dynamics of the indicator (magnitudes are shown on the ordinate) SDNN (A) and SampEn (B) in four clusters from the 1st to the 30th task (on the abscissa). Black – Cluster 1, Green – Cluster 2, Blue – Cluster 3, Orange – Cluster 4.



It should be noted that when clustering study participants based on HRV indicators for 15 tasks, the result is less pronounced and less stable. However, the four identified clusters can presumably be an intermediate result, i.e., with an increase in sample size, the final partition will be represented by two clusters. Therefore, considering the dynamic nature of the measured values and the nature of the tasks performed, both cluster solutions with the results of the distribution of psychometric variables in the identified clusters should be considered.

Discussion

The results obtained allow us to state that it is possible to identify clusters, representing groups of study participants with differing heart rhythm organization, based on HRV

indicators. The assessment of HRV indicators indicates their homogeneous nature across the sample for all tasks, which, considering the specificity of the two-step clustering procedure, does not allow for the isolation of brightly expressed clusters. This pattern was obtained, for example, for the indicators LF, HF, and LF/HF (which denote the power of the low- and high-frequency spectrum, as well as their ratio to each other). Since these indicators are mainly used in assessing the emotional state during task performance (Zaripov, Barinova, 2008), it can be concluded that the tasks used in the study were emotionally neutral.

The most variable indicators (within individual tasks and from the 1st to the 30th task) are Mean-HR and SDNN, which indicates a specific organization of the processes of coordination of activity of cells of different morphology, as well as its individual variability, which is manifested in the dynamics of the HRV entropy indicator (Varfolomeeva et al., 2025). An increase in the magnitude of entropy indicates an increase in uncertainty (unpredictability) of values in a numerical sequence or time series, while a decrease indicates an increase in certainty (predictability). From the perspective of the systemic-evolutionary approach, this points to differences in the degree of involvement of experience systems of different differentiatedness.

Character strengths make a significant contribution to the partitioning of study participant groups, who are characterized by different indicators of cardiac activity, which indicate a different structure and/or dynamics of their experience actualization during problem-solving. These groups differ in the indicators of the scales "Critical Thinking", "Perseverance", "Gratitude", "Optimism", "Spirituality", and "Causal Attribution"; the indicators of these scales are higher in the first cluster than in the second.

Moreover, such character qualities as "Critical Thinking", "Perseverance", and "Spirituality" can be viewed as ways of overcoming uncertainty, forming different solution strategies. "Critical Thinking" is considered as the ability and inclination for multilateral analysis, the ability to weigh arguments and change opinions based on evidence, making more effective decisions. "Spirituality" is characterized as having structured beliefs about a higher purpose. "Perseverance" is defined as the ability to voluntarily continue active work despite emerging obstacles and difficulties (Peterson & Seligman, 2004; Rean, Stavtsev, Kuzmin, 2024).

Such character qualities as "Gratitude" and "Optimism" are related to a positive perception of reality—in the first case, current and past, and in the second, related to the future. "Gratitude" as a character strength is defined as the ability to realize and be thankful for all the good that happens in life. "Optimism" is the expectation of the best from the future and the readiness to work towards achieving a high goal. These two character qualities frequently show the strongest connection with high indicators of life satisfaction, subjective resilience, and other indicators of high psychological well-being in both Russian and foreign studies. Furthermore, in the authors' empirical studies, "Gratitude" and "Optimism" are part of the "quartet of psychological resilience", along with "curiosity" and "zest" (Brdar, Kashdan, 2010; Gander et al., 2020; Rean, Stavtsev, Kuzmin 2022).

From the perspective of the "neurovisceral integration theory" (Thayer, Lane, 2000; 2009), which is leading in the study of the relationship between HRV and psychological well-being, it is substantiated that HRV acts as an "index of self-regulation strength" and is an indicator of the integration of the central nervous and autonomic nervous systems. Here, "self-regulation strength" is defined as "...the ability to exercise self-control, to cancel or change one's dominant response tendencies..." (Baumeister, Heatherton, 1996), and is a primary condition for adaptive behavior, such as regulating emotions, persistence in the face of failure, or positive health behavior (Schmeichel, Baumeister, 2004; Tangney et al, 2005).

Similar studies implement the logic of comparative (traditional or correlational) psychophysiology and directly relate "physiological" and "psychological" processes, arguing, in terms of influence, the connection between "nervous", "visceral", and "psychological" phenomena, focusing attention on the role of the autonomic nervous system and the vagus nerve.

The application of cluster analysis to HRV indicators allows assessing the joint dynamics of these indicators and, based on this assessment, comparing the expression of individuals' psychological properties. This approach to data analysis resolves the noted ambiguity in the results of studies examining the relationship between HRV and psychological well-being (or quality of life). The results of the present study indicate the relationship of HRV indicators during problem-solving, which in turn suggests a differing organization of the actualized systems of experience, manifested in HRV, in individuals implementing differing ways of problem-solving (Varfolomeeva et al., 2023).

Conclusion

1. It is established that, based on HRV indicators, it is possible to identify groups of study participants for whom the ratio of these indicators differs. Two stable groups are identified: a group with high heart rate variability and its increasing complexity and a group with low variability and its decreasing complexity.
2. Differences in the ratio of HRV indicators are associated with a differing expression of the character strength pattern: "Critical Thinking", "Spirituality", "Perseverance", "Optimism", and "Gratitude". These strengths are, on one hand, related to ways of overcoming difficulties ("Critical Thinking", "Spirituality", "Perseverance") and, on the other, provide psychological resilience and a positive attitude towards the world ("Optimism" and "Gratitude").

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Author Contributions

Anna V. Varfolomeeva: Literature analysis on electrocardiographic studies, analysis of heart rate variability, writing and preparation of the preliminary version of the manuscript.

Anton G. Tishchenko: Literature analysis on electrocardiographic studies, statistical analysis of heart rate variability indices and their associations with the psychological components of the VIA model.

Artur A. Rean: Scientific supervision; literature search, selection, and analysis; formulation of conclusions; preparation of the final version of the manuscript.

Andrey O. Shevchenko: Literature search, selection, and analysis; description of the socio-psychological components of the VIA model; formulation of conclusions.

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Conflict of Interest Information

The authors have no conflicts of interest to declare.