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Measurement of Beta and Theta Brain Wave Coherence with Cardiac Wave Rhythm in Managers with Rational Decision-Making Style Based on Emotional Intelligence through ERT Cognitive Task

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ABSTRACT

Objective: Since human life and society depend on brain functions, our understanding of the brain and mind can significantly impact all dimensions of human life. Therefore, the main objective of this study was to assess the coherence of brain waves (EEG) and cardiac wave rhythms (HRV) based on neuroscientific and neurocardiology principles.

Methods and Materials: This research utilized an experimental design, specifically a quasi-experimental approach without a control group, and was applied in nature. The statistical population consisted of managers (90 individuals) from both public and private sectors in Gilan Province in 2022. From this population, 30 individuals were randomly selected. Their brain waves and cardiac rhythms were simultaneously recorded in both resting and decision-making states from the CZ region of the brain and triangular regions around the heart using the ProComp 2 neurofeedback tool while performing the emotional intelligence assessment test. The research instrument included the ERT cognitive test (Emotional Recognition Task) designed by Cambridge University in 1980 and administered through the Cantab software and BioGraph Infiniti version 0.6 software. For the purposes of this study, the cognitive task was provided to participants via software. The data were analysed using analysis of variance and mean comparison test via SPSS-26.

Findings: The correlation test of brain waves and cardiac waves in resting and cognitive task states showed significant differences. No coherence between EEG and ECG was observed in the resting state compared to the cognitive task state.

Conclusion: The results indicate that changes in brain waves and cardiac waves, and the coherence between these waves, vary among managers with similar decision-making styles. These variations depend on the environmental, mental, and emotional conditions of the individuals.

Keywords: *coherence, EEG and ECG signals, decision-making, emotional intelligence.*

1. Introduction

Neuroscience, through the study of biological and chemical processes in the brain, provides the potential for excellence in leadership and managerial processes such as decision-making and coordination. The scope of neuro-brain leadership studies has even extended into the realm of brain-computer interface research (da Motta et al., 2021). In addition to leadership as a critical role and function in management, other management functions have not been deprived of cognitive sciences to the extent that traces of cognitive sciences can be observed in most classical functions. One of the management functions that has attracted the attention of cognitive sciences is decision-making. Two significant areas where cognitive sciences have entered this function to optimize decision-making are mental models (Elsawah et al., 2015) and cognitive maps (Tolman, 1948).

Scientists have established a conventional classification for this spectrum of frequencies, which are respectively delta (1-4 Hz), theta (4-8 Hz), alpha (8-12 Hz), beta (13-30 Hz), and gamma (30-70 Hz). The electroencephalogram (EEG), by showing stable individual differences in brain function, can be a powerful method for exploring biological bases (Jauk et al., 2012). Neurocardiology or cardiac neuroscience studies the neurophysiological and neurological aspects of the cardiovascular system, particularly cardiac disorders of neurological origin (Natelson, 1985).

In addition to neural networks, there is an extensive communication system in the heart that interacts with the brain and body such that the heart transmits information throughout the body via magnetic field interactions. The heart produces one of the most potent and extensive electromagnetic fields (Shirzad et al., 2019). In physics, the concept of coherence describes the interactions or linkages between different oscillating systems where synchrony is the key idea. Synchrony describes the degree of phase or frequency alignment between two or more waves or when connections between systems or states occur without obstruction (McCraty et al., 2004; McCraty et al., 1995; McCraty et al., 2009). The more stable the frequency, amplitude, and waveform, the greater the coherence. When coherence in a single system (which is linked to other systems) increases, it draws other systems towards coherence, leading to increased cross-system coherence in activities, even across different timescales of activities. Similar to the increased brain-heart synchrony observed during heart coherence, heart rate variability (HRV) results from the dynamic interactions of many body systems. Short-term (beat-to-beat) heart rate changes are largely produced and enhanced by interactions between the heart and brain. The signal flow between these systems occurs through afferent and efferent pathways of the sympathetic and parasympathetic branches of the autonomic nervous system (ANS). Therefore, HRV is a measure of neuro-cardiac function reflecting the interactions between the heart and brain and the dynamics of the ANS. Establishing and increasing heart rhythm coherence (a stable and sine-wave-like pattern in HRV) is a key indicator of psychophysiological coherence. Heart rhythm coherence manifests as a significant increase in power in the low-frequency (LF) band (around 0.1 Hz) and a decrease in power in the very-low-frequency (VLF) and high-frequency (HF) bands in the HRV power spectrum. Therefore, coherent heart rhythm is defined as a relatively balanced (sine-wave-like) signal with a very narrow and high-amplitude peak in the low-frequency region of the HRV power spectrum, without any large peaks in the very-low-frequency or high-frequency regions. Hence, coherence is approximately equal to the ratio: LF/(VLF + HF) (Hansen et al., 2003; McCraty et al., 2004; McCraty et al., 1995; McCraty et al., 2009; Singer, 2010).

In humans and many animals, the resonance frequency of the system is around 0.1 Hz, corresponding to a 10-second rhythm (McCraty et al., 1995). During coherence, there is more synchrony between the heart and brain, particularly with brain alpha rhythms showing more synchrony with heartbeats (Armour, 2003). It is now widely accepted that afferent neural signals sent from the heart to the brain have a regulatory effect on many ANS signals flowing from the brain to the heart, blood vessels, and other glands and organs. However, less attention has been paid to the fact that these afferent cardiovascular signals involved in physiological regulation also travel to higher brain centers and affect their activity and functioning. One of the most important impacts is the effect of heart inputs on the cerebral cortex, the brain region housing thinking and reasoning capabilities (Natelson, 1985; Shirzad et al., 2019). The complex heart-brain circuits, with over 40,000 neurons, provide the heart with the ability to sense, regulate, and remember. Additionally, the heart's brain processes information and independently of the central nervous system makes decisions about controlling the heart (Armour & Kember, 2006; Armour, 2003). The very-low-frequency (VLF) range (0.0033-0.04 Hz) is primarily an indicator of sympathetic activity, while the high-frequency (HF) range

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(0.04-0.15 Hz) reflects faster, moment-to-moment changes in heart rhythm due to parasympathetic activity. The 0.1 Hz range, termed the low-frequency (LF) range (0.04-0.15 Hz), reflects activity in feedback loops between the heart and brain, controlling short-term blood pressure changes and other regulatory processes. The physiological factors contributing to VLF range activity are complex, indicating a combination of afferent and efferent sympathetic and parasympathetic activity and vascular system resonance. An increase in power at 0.1 Hz indicates a significant increase in heart rhythm coherence (da Motta et al., 2021; Jauk et al., 2012; Natelson, 1985).

Some studies related to this research include Bohlouli and Ghaffari (2020), which indicate that decision-making is influenced by determinants such as the health and efficiency of the decision-maker's brain cells, the health of neural information receptors, and ultimately the decision-maker's level of self-awareness and their interconnections (Bohloli & ghafari, 2020). Shirzad et al. (2019) showed in their research that changes in alpha wave intensity across all cortical areas were significant compared to other wave changes (Shirzad et al., 2019). Regarding the necessity of this research, it should be noted that although studies have been conducted, the main difference in this research lies in addressing the brain-heart theory, focusing on which among the multiple physiological measures (such as heart rhythm, EEG, and electromyographic activity, respiration, skin conductance, etc.) according to the HeartMath Institute's research, rhythmic heart activity patterns are directly related to mental activation and distinct emotional states. These heart rhythm patterns reflect changes in emotional states and change concurrently with existing emotions and feelings. This research aims to examine the coherence of brain waves and cardiac waves in managers during decision-making. Therefore, the main objective of this study is to measure the coherence of beta and theta brain waves with cardiac rhythms in managers with a rational decision-making style based on emotional intelligence through the execution of a cognitive task.

2. Methods and Materials

2.1. Study Design and Participants

This research employed an experimental design, specifically a quasi-experimental approach without a control group. The statistical population included managers (90 individuals) from public and private sectors in Gilan Province in 2022, from which 30 individuals were randomly selected. The inclusion criterion for the sample was managers with physical health and no prior brain or heart disorders. The exclusion criterion was regular participation in sessions. Brain waves and cardiac rhythms were simultaneously recorded in two situations—resting and decision-making—from the CZ region of the brain and triangular regions around the heart using the ProComp 2 neurofeedback tool while performing the emotional intelligence assessment test.

Participants had at least 8 hours of sleep the night before the test and self-reported no significant stress or anxiety events in the week preceding the test. Participants arrived at the organization based on the pre-arranged schedule (six participants per day). Despite providing a brochure to explain the research's purpose and testing procedures and teaching the Anapana breathing technique before recording, the research's goal and the safety of the device were re-explained on the test day. Participants were asked to sit comfortably in a designated chair. Brain wave sensors were attached to the CZ area of the head and ears, and cardiac sensors were placed on the chest. After performing the Anapana breathing technique for 15 minutes and playing relaxing music for meditation, brain waves and cardiac rhythms were recorded for 10 minutes in a complete rest state using the ProComp 2 device. Immediately after this stage, participants were presented with a monitor placed half a centimeter away.

2.2. Measures

The research instruments included the ERT cognitive test (Emotional Recognition Task) designed by Cambridge University in 1980. For the study's objectives, the cognitive task was provided to participants via software. All stages of simultaneous recording of brain waves and cardiac rhythms were conducted using the ProComp 2 biofeedback device, Thought Technology's SA7400 model, along with BioGraph Infiniti version 0.6 software. The cognitive task was administered using Cantab software.

2.3. Data analysis

The data were analysed using analysis of variance and mean comparison test via SPSS-26.

3. Findings and Results

In the research sample, out of 30 selected participants, there were 20 men (67%) and 10 women (33%). Regarding

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educational levels, there were 10 bachelor's degree holders (33%), 19 master's degree holders (65%), and 1 Ph.D. holder (2%), with the highest percentage of participants holding a master's degree. Concerning work experience, there were 6 individuals (20%) with 6 to 10 years, 7 individuals (23%) with 11 to 15 years, and 17 individuals (57%) with over 15 years of experience, the latter being the largest group. Age-wise, there were 6 participants (20%) aged 38 to 40, 15 participants (50%) aged 41 to 50, and 9 participants (30%) over 50, with the majority being aged 41 to 50. Regarding job type, 20 participants (67%) were employed in the private sector and 10 participants (33%) were employed in the public sector.

Table 1

The Role of Emotional Intelligence in the Impact of Brain Wave and Cardiac Wave Frequency Coherence on Rational Decision-Making Style (REST)

Emotional Intelligence	Cardiac Waves	DELTA	THETA	LOW ALPHA	HIGH ALPHA	SMR	BETA 1	BETA 2	BETA 3	BETA 4	BETA 5	BETA MEAN	GAMMA	THETA/THETA
Emotion Regulation	ECG.LF	-0.463	0.683	-0.577	0.429	0.757	-0.327	0.641	0.984	0.094	-0.039	0.087	-0.122	-0.294
	ECG.HF	0.170	-0.777	-0.491	0.226	0.736	-0.228	0.744	0.976	0.139	-0.271	0.292	0.027	-0.127
	ECG.VLF	-0.340	0.255	-0.706	0.482	0.460	-0.073	0.661	0.997	0.045	-0.014	0.036	-0.117	-0.005
	LH/HF	-0.307	0.605	-0.525	0.164	0.561	0.026	0.860	0.987	0.173	-0.092	0.181	-0.097	-0.118
	LF/VLF+HF	0.197	-0.550	-0.540	0.295	0.707	0.018	0.796	0.988	-0.037	-0.175	0.178	-0.168	-0.021
Emotion Assessment	ECG.LF	0.323	-0.068	0.059	0.626	0.779	-0.155	0.693	0.982	0.066	0.092	0.058	0.004	-0.161
	ECG.HF	-0.131	0.320	-0.469	0.360	0.709	0.376	0.790	0.980	0.122	-0.179	0.252	-0.060	-0.006
	ECG.VLF	-0.204	0.376	-0.599	0.276	0.818	0.431	0.555	0.984	-0.041	0.045	0.032	-0.179	-0.005
	LH/HF	-0.212	0.572	-0.483	0.352	0.688	0.025	0.805	0.980	0.158	-0.090	0.088	-0.045	-0.215
	LF/VLF+HF	-0.311	0.344	-0.587	0.349	0.841	0.168	0.516	0.981	0.250	-0.050	-0.048	0.005	-0.038
Emotion Application	ECG.LF	-0.217	0.534	-0.391	0.723	0.717	-0.071	0.596	0.971	0.005	0.051	-0.346	-0.220	-0.117
	ECG.HF	0.012	0.807	0.839	-0.210	-0.378	0.784	-0.535	0.978	0.237	0.060	0.052	0.076	-0.046
	ECG.VLF	-0.240	0.698	-0.292	0.599	0.659	0.170	0.770	0.981	0.109	0.116	-0.181	-0.124	-0.133
	LH/HF	-0.344	0.293	-0.641	0.285	0.672	0.365	0.672	0.990	-0.016	-0.066	0.138	-0.161	-0.032
	LF/VLF+HF	-0.154	0.539	-0.231	0.413	0.803	0.667	0.784	0.980	0.247	0.041	0.020	0.064	-0.030
Communication Skills	ECG.LF	-0.667	0.418	-0.719	0.078	0.504	0.244	0.749	0.993	-0.048	0.020	-0.045	-0.150	-0.044
	ECG.HF	-0.032	0.655	-0.569	0.041	0.661	-0.183	0.775	0.983	0.125	-0.184	0.295	-0.046	-0.083
	ECG.VLF	0.242	-0.043	-0.552	0.518	0.662	0.067	0.710	0.988	0.093	-0.048	-0.035	-0.039	0.008
	LH/HF	-0.110	0.806	-0.635	0.327	0.721	-0.340	0.645	0.984	0.209	-0.138	0.082	-0.182	-0.174
	LF/VLF+HF	0.406	-0.460	-0.363	0.638	0.755	-0.660	0.669	0.985	0.057	-0.170	-0.074	-0.161	-0.091

The results of Table 1 indicate that the correlation coefficient of brain waves with each of the cardiac wave rhythms shows a significant difference in each manager's coherence of these waves.

Table 2

Multiple Comparisons: Tukey's Post Hoc Test for Brain Waves Based on Rational Decision-Making Style and Emotional Intelligence Components (REST)

Emotional Intelligence	Index	DELTA	THETA	LOW ALPHA	HIGH ALPHA	SMR	BETA 1	BETA 2	BETA 3	BETA 4	BETA 5	BETA MEAN	GAMMA	THETA/BETA
Emotion Regulation	Mean difference	0.756	0.168	0.566	0.712	0.455	0.156	0.489	0.178	0.266	0.511	0.158	0.189	0.450
	Std. Error	0.217	0.344	0.289	0.589	0.218	0.290	0.326	0.232	0.478	0.266	0.590	0.411	0.289
	sig	0.212	0.544	0.324	0.511	0.266	0.278	0.366	0.411	0.289	0.411	0.675	0.216	0.344
	Lower Bound	0.477	0.155	0.266	0.217	0.545	0.343	0.266	0.454	0.547	0.434	0.266	0.656	0.687
	Upper Bound	0.343	0.214	0.233	0.266	0.436	0.554	0.367	0.434	0.277	0.214	0.454	0.411	0.455
Emotion Assessment	Mean difference	0.233	0.323	0.677	0.325	0.267	0.411	0.577	0.324	0.477	0.367	0.677	0.566	0.486
	Std. Error	0.233	0.215	0.544	0.344	0.343	0.365	0.544	0.165	0.436	0.456	0.216	0.165	0.565
	sig	0.367	0.326	0.367	0.266	0.435	0.211	0.233	0.231	0.327	0.277	0.437	0.611	0.277

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	Lower Bound	0.455	0.546	0.255	0.476	0.366	0.277	0.656	0.127	0.366	0.878	0.656	0.127	0.291
	Upper Bound	0.234	0.176	0.435	0.611	0.234	0.176	0.435	0.216	0.576	0.232	0.478	0.277	0.657
Emotion Application	Mean difference	0.767	0.218	0.655	0.455	0.231	0.657	0.342	0.344	0.546	0.121	0.287	0.326	0.440
	Std. Error	0.546	0.676	0.367	0.566	0.676	0.232	0.576	0.465	0.277	0.343	0.658	0.277	0.216
	sig	0.436	0.266	0.218	0.435	0.231	0.217	0.325	0.270	0.433	0.325	0.221	0.267	0.512
	Lower Bound	0.435	0.476	0.236	0.156	0.435	0.266	0.366	0.375	0.488	0.412	0.238	0.325	0.232
	Upper Bound	0.756	0.168	0.566	0.712	0.455	0.156	0.489	0.178	0.266	0.511	0.158	0.189	0.450
Communication Skills	Mean difference	0.217	0.344	0.289	0.589	0.218	0.290	0.326	0.232	0.478	0.266	0.590	0.411	0.289
	Std. Error	0.212	0.544	0.324	0.511	0.266	0.278	0.366	0.411	0.289	0.411	0.675	0.216	0.344
	sig	0.477	0.155	0.266	0.217	0.545	0.343	0.266	0.545	0.547	0.434	0.266	0.656	0.687
	Lower Bound	0.343	0.214	0.233	0.266	0.436	0.554	0.367	0.434	0.277	0.214	0.454	0.411	0.455
	Upper Bound	0.233	0.323	0.677	0.325	0.267	0.411	0.577	0.324	0.477	0.367	0.677	0.566	0.486

According to the contents of Table 2, for managers with a rational style based on the emotion regulation component, the mean theta brain wave was 0.168 with a std. error of 0.344. Beta 2 wave had the highest mean of 0.489 with a std. error of 0.326, and Beta 1 wave had the lowest mean of 0.156 with a std. error of 0.290. Based on the emotion assessment component, the mean theta brain wave was 0.155 with a std. error of 0.214. Beta 4 wave had the highest mean of 0.547 with a std. error of 0.277, and Beta 2 wave had the lowest mean of 0.266 with a std. error of 0.367. Based on the emotion application component, the mean theta brain wave was 0.323 with a std. error of 0.215. Beta 2 wave had the highest mean of 0.577 with a std. error of 0.544, and Beta 3 wave had the lowest mean of 0.324 with a std. error of 0.165. Also, based on the emotion regulation component, the mean theta brain wave was 0.218 with a std. error of 0.676. Beta 1 wave had the highest mean of 0.657 with a std. error of 0.232, and Beta 5 wave had the lowest mean of 0.121 with a std. error of 0.343.

Table 3

Multiple Comparisons: Tukey's Post Hoc Test for Cardiac Waves Based on Rational Decision-Making Style and Emotional Intelligence Components (REST)

Cardiac Waves	Emotional Intelligence	Mean Difference	Mean Difference	Std. Error	Std. Error	Std. Error	sig	sig	sig	Lower Bound (95% CI)	Upper Bound (95% CI)
ECG.LF	Emotion Regulation	0.455	0.112	0.112	0.465	0.215	0.000	0.000	0.000	0.300	0.767
ECG.HF		0.411	0.165	0.165	0.544	0.165	0.000	0.000	0.000	0.338	0.685
ECG.VLF		0.344	0.216	0.216	0.675	0.216	0.000	0.000	0.000	0.413	0.641
LH/HF		0.477	0.217	0.217	0.266	0.155	0.000	0.000	0.000	0.361	0.700
LF/VLF+HF		0.455	0.122	0.122	0.498	0.214	0.000	0.000	0.000	0.412	0.622
ECG.LF	Emotion Assessment	0.477	0.156	0.156	0.677	0.166	0.000	0.000	0.000	205/0	840/0
ECG.HF		0.343	0.165	0.165	0.544	0.215	0.000	001/0	0.000	0.317	721/0
ECG.VLF		0.435	0.231	0.231	0.455	0.277	0.000	0.000	0.000	501/0	0.509
LH/HF		0.291	0.127	0.127	0.656	0.155	0.000	0.000	0.000	0.568	0.546
LF/VLF+HF		0.234	0.213	0.213	0.345	0.176	0.000	0.000	0.000	0.121	0.566
ECG.LF	Emotion Application	0.546	0.178	0.178	0.655	0.121	0.000	0.000	0.000	0.327	0.588
ECG.HF		0.411	0.121	0.121	0.499	0.156	0.000	0.000	0.000	0.413	0.641
ECG.VLF		0.566	0.121	0.121	0.611	0.143	0.000	005/0	0.000	0.566	0.121
LH/HF		0.435	0.156	0.156	0.555	0.266	0.000	0.000	0.000	0.546	0.145
LF/VLF+HF		0.455	0.112	0.112	0.465	0.215	004/0	0.000	0.000	0.611	0.533
ECG.LF	Communication Skills	0.411	0.165	0.165	0.544	0.165	0.000	0.000	0.000	0.435	0.326
ECG.HF		0.344	0.216	0.216	0.675	0.216	0.000	0.000	0.000	0.688	0.216

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ECG.VLF	0.477	0.217	0.217	0.266	0.155	0.000	0.000	0.000	0.436	0.219
LH/HF	0.455	0.122	0.122	0.498	0.214	0.000	0.000	0.000	0.478	0.355
LF/VLF+HF	0.477	0.156	0.156	0.677	0.166	0.000	0.000	001/0	871/0	435/0

The results of the analysis of variance in **Error! Reference source not found.** show that the mean difference in the correlation between brain waves and cardiac waves for each sample in rational decision-making style based on each emotional intelligence component is significant. Multivariate analysis of variance results showed that the variable of brain waves and cardiac waves had a value of 0.434 and F = 23.43 with a Sig. value of 0.000. The decision-making styles variable had a value of 0.276 and F = 12.53 with a Sig. value of 0.000. The emotional intelligence variable had a value of 0.587 and F = 15.76 with a Sig. value of 0.000. Therefore, the Sig. value is less than the alpha value (0.05), indicating significance. Thus, it can be concluded that the effect of brain wave and cardiac wave coherence based on decision-making styles and emotional intelligence components differs significantly.

Table 4

The Role of Emotional Intelligence in the Impact of Brain Wave and Cardiac Wave Frequency Coherence on Rational Decision-Making Style (ERT)

Emotional Intelligence	Cardiac Waves	DELTA	THETA	LOW ALPHA	HIGH ALPHA	SMR	BETA 1	BETA 2	BETA 3	BETA 4	BETA 5	BETA MEAN	GAMMA	THETA/BETA
Emotion Regulation	ECG.LF	0.165	0.411	0.165	0.544	0.165	0.411	0.165	0.544	0.165	0.411	0.165	0.544	0.165
	ECG.HF	0.216	0.344	0.216	0.675	0.216	0.344	0.216	0.675	0.216	0.344	0.216	0.675	0.216
	ECG.VLF	0.217	0.477	0.155	0.266	0.217	0.477	0.155	0.266	0.217	0.477	0.155	0.266	0.217
	LH/HF	0.122	0.455	0.214	0.498	0.122	0.455	0.214	0.498	0.122	0.455	0.214	0.498	0.122
	LF/VLF+HF	0.156	0.477	0.166	0.677	0.156	0.477	0.166	0.677	0.156	0.477	0.166	0.677	0.156
Emotion Assessment	ECG.LF	0.165	0.411	0.165	0.544	0.165	0.411	0.165	0.544	0.165	0.411	0.165	0.544	0.165
	ECG.HF	0.216	0.344	0.216	0.675	0.216	0.344	0.216	0.675	0.216	0.344	0.216	0.675	0.216
	ECG.VLF	0.217	0.477	0.155	0.266	0.217	0.477	0.155	0.266	0.217	0.477	0.155	0.266	0.217
	LH/HF	0.122	0.455	0.214	0.498	0.122	0.455	0.214	0.498	0.122	0.455	0.214	0.498	0.122
	LF/VLF+HF	0.156	0.477	0.166	0.677	0.156	0.477	0.166	0.677	0.156	0.477	0.166	0.677	0.156
Emotion Application	ECG.LF	0.165	0.411	0.165	0.544	0.165	0.411	0.165	0.544	0.165	0.411	0.165	0.544	0.165
	ECG.HF	0.216	0.344	0.216	0.675	0.216	0.344	0.216	0.675	0.216	0.344	0.216	0.675	0.216
	ECG.VLF	0.217	0.477	0.155	0.266	0.217	0.477	0.155	0.266	0.217	0.477	0.155	0.266	0.217
	LH/HF	0.122	0.455	0.214	0.498	0.122	0.455	0.214	0.498	0.122	0.455	0.214	0.498	0.122
	LF/VLF+HF	0.156	0.477	0.166	0.677	0.156	0.477	0.166	0.677	0.156	0.477	0.166	0.677	0.156
Communication Skills	ECG.LF	0.165	0.411	0.165	0.544	0.165	0.411	0.165	0.544	0.165	0.411	0.165	0.544	0.165
	ECG.HF	0.216	0.344	0.216	0.675	0.216	0.344	0.216	0.675	0.216	0.344	0.216	0.675	0.216
	ECG.VLF	0.217	0.477	0.155	0.266	0.217	0.477	0.155	0.266	0.217	0.477	0.155	0.266	0.217
	LH/HF	0.122	0.455	0.214	0.498	0.122	0.455	0.214	0.498	0.122	0.455	0.214	0.498	0.122
	LF/VLF+HF	0.156	0.477	0.166	0.677	0.156	0.477	0.166	0.677	0.156	0.477	0.166	0.677	0.156

The results from Table 4 show that the correlation coefficient of brain waves with each of the cardiac wave rhythms shows a significant difference in each manager's coherence of these waves based on emotional intelligence components during the ERT cognitive task.

Table 5

Variance Ratios for Mean Theta Frequency Band in REST and ERT Conditions

Index	Theta	Sample Size	Variance	DF	F	P(F <= f)	Critical F
REST	7.47	30	0.344	29	16.77	0.000	1.23
ERT	7.18	30	0.132	29	10.54	0.000	4.55

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Table 6

Variance Ratios for Mean LF/HF Ratio in REST and ERT Conditions

Index	LF/HF	Sample Size	Variance	DF	F	P(F <= f)	Critical F
REST	1.93	30	0.116	29	11.23	0.000	11.34
ERT	2.43	30	0.189	29	21.56	0.000	10.23

Table 7

Variance Ratios for Mean LF/VLF+HF in REST and ERT Conditions

Index	LF/VLF+HF	Sample Size	Variance	DF	F	P(F <= f)	Critical F
REST	0.58	30	0.176	29	26.77	0.001	11.57
ERT	0.17	30	0.280	29	12.88	0.001	12.98

The results in Table 5 show that the variance of the theta frequency band in participants (n=30) during the ERT cognitive task was lower compared to the REST condition. The theta frequency band is associated with creativity and impulsivity, as well as distraction, inattention, daydreaming, depression, and anxiety. According to neurotherapy principles, training to increase theta in the frontal lobe should not be conducted because a slow frontal lobe is not desirable. Theta in the front of the head should always be trained to decrease.

The results in Table 6 show that the variance of the LF/HF ratio increased during the ERT cognitive task compared to the REST condition, with the highest ratio observed during the ERT task. This ratio indicates the balance of the autonomic sympathetic and parasympathetic nerves and reflects the relative power of LF to HF. A decrease in HF and VLF power and an increase in the LF/HF ratio indicate a reduction in vagal nerve activity. The vagus nerve is a critical communication pathway between the brain and heart, exerting inhibitory effects on the heart. It is expected that in the REST state, with increased HF and VLF, the LF/HF ratio decreases, and during the ERT cognitive task, the LF/HF ratio increases. The increase in the LF/HF ratio for participants (n=30) during cognitive tasks indicates a sympathetic-vagal balance. In a healthy individual, the LF/HF ratio is typically between 1.5 and 2. If this ratio exceeds 2, it indicates that the person is highly mobilized. Such arousal is natural during work (or physical exertion), but it is not beneficial if a person is always excited. When the LF/HF ratio is less than 1, it is normal for a tired person, indicating the body is transitioning to rest. In this study, the LF/HF ratio was less than 2 in the REST state and within the normal range, but it exceeded 2 during cognitive tasks, indicating the impact of emotion on individuals.

The results in Table 7 show that the variance of heart rhythm coherence in participants (n=30) increased during the ERT cognitive task compared to the REST condition. Heart rhythm variability is influenced by sympathetic and parasympathetic nerves. Coherence of heart rhythm is not accompanied by a decrease in variability but rather by the emergence of organized and regular variability. It is important to note that these are not fixed states but are highly dynamic and variable. Psychophysiological coherence occurs when an individual can maintain positive emotions during cognitive tasks and in response to challenging and stressful conditions, accompanied by a highly organized, smooth, and sine-wave-like heart rhythm (coherence). Thus, coherence is not necessarily associated with changes in heart rhythm or heart rate variability but is characterized by a shift towards a distinctive heart rhythm pattern. Psychophysiological coherence occurs at a lower frequency, often with a higher amplitude.

4. Discussion and Conclusion

This study aimed to examine and study the coherence of brain waves and cardiac waves of managers during decision-making activities based on emotional intelligence components. Given the importance of managerial decision-making and its impact on achieving organizational goals, this research used patterns of brain activity and heart rate, as well as the measurement of simultaneous changes in brain and cardiac wave frequencies, to decode managers' decision-making algorithms as a cognitive behavior based on Scott and Bruce's decision-making styles. What is especially relevant for psychotherapists is that heart rate not only acts as an index of brain regulatory systems but also affects brain and emotional functions (Armour & Kember, 2004).

The results showed that in managers with a rational decision-making style and the emotional intelligence

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component of emotion regulation, it was expected that during decision-making in the cognitive task stage, the correlation of heart rhythms with one of the brain waves (e.g., alpha brain wave) would be similar. However, by examining the frequency of brain waves and cardiac waves and the correlation coefficient between waves in individual managers, even those with similar decision-making styles, no similarity in brain wave activity was found. Each manager exhibited higher frequency brain waves based on physiological structure and the type of emotion and feeling management during decision-making. The results showed that the correlation of brain waves and cardiac waves in rational, intuitive, spontaneous, avoidant, and dependent decision-making styles based on emotional intelligence components (emotion regulation, emotion assessment, communication skills, and emotion application) showed significant differences.

These differences indicate that changes in brain waves and heart rhythm in individuals depend on their ability to manage emotions and feelings and to respond logically to emergency and stressful conditions. It is suggested that new technologies such as biofeedback and neurofeedback, and protocols related to each brain wave from the recorded brain wave region (e.g., recording brain waves from the CZ region in this study), can be used to regulate and enhance brain waves. Additionally, through training to familiarize managers with neuroscience and neuroleadership and applying it in management, particularly during decision-making and coping with change and emergency conditions, favorable conditions can be created in terms of brain wave regulation and its coherence with heart rhythms, leading to positive effects on managers' work efficiency (Hansen et al., 2003).

Like many studies on managerial decision-making, this research examined decision-making at the individual level. However, the significant difference in this study is that it examines the brain-heart theory, addressing the subject that among multiple physiological measures (such as heart rhythm, electroencephalographic and electromyographic activity, respiration, skin conductance, etc.), the rhythmic heart activity pattern has a direct relationship with mental activation and distinct emotional states, reflecting changes in emotional states that change simultaneously with individuals' emotions and feelings. This study examines the role of emotional intelligence in the impact of brain and cardiac wave coherence in managers. For example, Shirzad et al. (2019) in their study as a preliminary study in a laboratory research, examined strategic thinking and presented their results. Additionally, no similarity was observed in the intensity changes of brain waves and their coherence with heart rhythm during cognitive tasks in managers with different decision-making styles. Coherence of heart waves according to the formula (LF/VLF+HF) and the ratio of LF to HF (LF/HF) showed differences in correlation with brain waves in individuals with different decision-making styles. In comparing the resting state and cognitive tasks, no similarity was observed between the coherence of brain waves and cardiac waves in participants with different decision-making styles (Shirzad et al., 2019).

5. Limitations & Suggestions

One limitation of this study is that it was conducted only on managers, excluding other employees, so the results are not generalizable. Another limitation was the inability to consider a control group due to the extended duration of the test and multiple returns. It is suggested that future studies examine the coherence of brain waves and cardiac waves in managers during decision-making from a neuroscience perspective and other physiological body measures. Future researchers should also include a control group. Another suggestion is to include other employees and occupations as samples and compare the results.

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Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethics Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants. This research received ethical approval from the Human Research Committee of the Faculty of Nursing, Islamic Azad University, Rasht Branch (Ethics Code:

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IR.IAU.RASHT.REC.1401.001), and consent and voluntary participation forms were obtained from all participants.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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Authors' Contributions

All authors contributed equally.

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