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The HeartMath coherence model: implications and challenges for artificial intelligence and robotics

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Abstract
HeartMath is a contemporary, scientific, coherent model of heart intelligence. The aim of this paper is to review this coherence model with special reference to its implications for artificial intelligence (AI) and robotics. Various conceptual issues, implications and challenges for AI and robotics are discussed. In view of seemingly infinite human capacity for creative, destructive and incoherent behaviour, it is highly recommended that designers and operators be persons of heart intelligence, optimal moral integrity, vision and mission. This implies that AI and robotic design and production should be continuously optimized through vigilant and appropriate human and material quality control procedures. Evidence is provided for some value and effectiveness of the HeartMath coherence model in this context.

Keywords HeartMath · Coherence · Artificial intelligence · Robotics

1 Introduction

Intelligence may be variously viewed as concept, gift, art and science. It may be contrasted with intellect, that uniquely human capacity that develops through experience. Artificial intelligence implies human creation, e.g. robots, which were developed to simulate human behavior. Heart intelligence refers to physical, emotional and spiritual forms of intelligence, known to many cultures through the ages and recognized anew through interdisciplinary research pioneered by the HeartMath Institute. Heart intelligence is a specific form of intelligence, including and transcending other psychometrically measured forms of intelligence such as the intelligence quotient (IQ), emotional quotient (EQ) and other multiple forms such as Platonic and Taoist tripartite (*tan tien*) divisions, and correlated biological oscillators in the head, heart and gut (Gardner 2011; McCraty et al. 1995). For example, one recent finding providing mathematical and physiological foundations for various meditative and wisdom traditions including Hinduism, Buddhism, Taoism, Christianity and Islam, is of a relatively autonomous "heart brain" with hormonal, biophysical, neurochemical and electromagnetic communication patterns (Childre et al. 2016). It has been hypothesized that such patterns could be associated with a vital neurological shift in the mechanics of perception from binary dualistic to unitive, non-dual consciousness (Bourgeault 2016). Implicit in this hypothesis is coherent alignment with other dynamic, physiological, subsystems, not only including the prefrontal cortex of the "head brain", with its associations with supposedly uniquely human forms of creativity, moral reasoning and executive action, but also wider personal, transpersonal, social, ecological and global systems (Childre et al. 2016). The aim of this paper is to review heart intelligence with special reference to the HeartMath coherence model and it implications for artificial intelligence and robotics.

2 HeartMath

HeartMath is a contemporary, scientific model of heart intelligence. The HeartMath system was specifically created by Doc Childre to develop heart focused intelligence, health and wellbeing. Working with a small group of professionals, with similar heart-based values, who represented a wide spectrum of experience and expertise, Childre and Martin (2000) established a non-profit research and educational organization, the HeartMath Institute, in Boulder Creek, California in 1991. Coherence became a key orientation

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concept, in both general terms, as in logical argumentation, or systemically related parts, as well as specific meanings, as in phase relationships in the mathematical and physical sciences. In pursuit of a central vision and mission to facilitate personal, social and global coherence, the institute rapidly pioneered integral, heart focused research in neuroscience, cardiology, physiology, biochemistry, bioelectricity, physics and psychology. Major findings related to heart communication of electromagnetic, neurochemical, biophysical and hormonal information (McCraty et al. 2009). Also pioneered were a system of practical, heart based tools and techniques for people of all ages to use in the moment to relieve stress and promote health, creativity, intuitive insight and zoned performance, as well as biofeedback technology to facilitate heart rate variability (HRV) coherence feedback training (Childre et al. 2016).

2.1 Independent HeartMath research

At website: https://scholar.google.com/citations?user=frIB6zgAAAAJ&hl=en, google scholar lists 327 independent studies conducted by researchers not employed by or attached to the HeartMath Institute, which provide consistent evidence for the natural, human and social scientific value, validity and effectiveness of the HeartMath system, tools and techniques. This is not surprising when it is considered that these tools and techniques usually involve various procedures based on established physical, biological and psychophysiological evidence related to (a) the physical law of resonance (b) electromagnetic and cardiorespiratory activity, (c) the vagus nerve, with its mainly afferent, heart to brain neural communication system including systemic brainstem, limbic, amygdala and prefrontal neural communication networks, (d) respiratory sinus arrhythmia (RSA), the naturally occurring physiological mechanism whereby heart rate increase during inhalation and decreases during exhalation, mechanism, (e) heart rate variability and related adaptive function of varying intervals between heart beats as well as coherent and incoherent heart rhythms and their correlations with negative emotions and positive emotion, respectively, with the latter heart rhythms resembling coherent sine wave type activity, (f) biofeedback principles.

3 Coherence model

Coherence is a core concept in HeartMath research, psychotherapy and meditation techniques. Coherence implies harmony, interconnectedness and consistency and typically including a global order where the whole is greater than the sum of the parts (McCraty 2017). At the natural scientific level, auto-coherence or auto-correlation implies stability in a single wave form as in the sine-wave and cross-coherence, phase locking and resonance reflect harmony in various rhythmic activities. At the psychophysiological level, coherence may occur between positive emotions, cardiovascular, respiratory, and immune and nervous systems (McCraty et al. 2009). At the human, interpersonal, team and social levels, coherence refers to dyads, couples, groups, organizations and communities, where harmonious relationships promote efficient energy flow, communication, synchronization and collective action, as in a rowing team or group working towards shared goals. At the global level, groups, nations and countries working co-operatively could promote optimal ecological and planetary peace and harmony, which is one goal of the HeartMath Global Coherence Initiative (GCI) as will be discussed later.

3.1 Psychophysiological coherence

Psychophysiological research continues to provide evidence that the vital role of the heart transcends physics and metaphor. The importance of bidirectional communication between the heart and the brain has been known for over 100 years (MacKinnon et al. 2013). In addition to its sensory, organic functions, the heart has become recognized as a sophisticated information processing centre, with an intrinsic nervous system, capable of making autonomous, functional decisions (McCraty et al. 2009). Through its transmission of dynamic patterns of information to the brain and throughout the body, the heart possesses a more extensive communication system with the brain than other organs (McCraty et al. 2009). Heart rate variability (HRV) performs a vital communicative function in this regard. HRV is generated largely by interaction between the heart and brain via neural signals flowing through pathways of the sympathetic and parasympathetic (vagal) branches of the autonomic nervous system (ANS). These neural pathways, often, respectively, likened to the accelerator and break in a motor car, have different heart rhythm oscillatory patterns associated with their varying frequency bands, as discussed below in very simplified form.

Heart rate variability (HRV) is considered as a measure of neurocardiac function that reflects heart-brain interactions and ANS dynamics. It has great value as an index of adaptation, resilience and general health, owing to its resonant interconnections with psychophysiology in particular and the cosmos in general. HRV oscillations are typically dived into frequency bands, which include the high frequency (HF) from 0.15 to 0.4 Hz, low frequency (LF) between 0.04 and 0.15 Hz and very low frequency (VLF) band between 0.0033 and 0.04 Hz. The HF band reflects vagal parasympathetic activity. It is often referred to as the respiratory band because it corresponds to heart rate variations related to the respiratory cycle. The LF band has been called the baroreceptor band as it reflects resting blood pressure related

stretch receptor activity. The heart produced VLF band, which relates to heat and hormone regulation, appears to be fundamental to health (Lehrer and Gervitz 2014; McCraty and Shaffer 2015).

Heart rhythm coherence, a stable, sine-wave-like pattern in the heart rate variability waveform, is the key marker of the psychophysiological coherence mode. This appears in the HRV power spectrum as a large increase in power in the low frequency (LF) band (typically around 0.1 Hz) and a decrease in the power in the very low frequency (VLF) and high frequency (HF) bands. "A coherent heart rhythm can, therefore, be defined as a relatively harmonic (sine-wave-like) signal with a very narrow, high-amplitude peak in the LF region of the HRV power spectrum and no major peaks in the VLF or HF regions. Coherence thus approximates the LF/(VLF + HF) ratio"… (McCraty et al. 2009, p. 23). To quantify heart rhythm coherence, the maximum peak is identified in the 0.04–0.26 Hz range (the frequency range within which coherence and entrainment can occur). The peak power is then determined by calculating the integral in a window 0.030 Hz wide, centered on the highest peak in that region. The total power of the entire spectrum is then calculated. The coherence ratio is formulated as: (Peak Power/(Total Power − Peak Power))2. This method provides an accurate measure of coherence that allows for the nonlinear nature of the HRV waveform over time (McCraty et al. 2009, p. 23).

The HeartMath coherence model is supported by three complementary HRV related psychophysiological theories. First, resonance theory, based on collaborative heart rate variability biofeedback (HRVB) research has indicated that maximal increases in amplitude of heart rate oscillation are produced when the cardiovascular system is rhythmically stimulated by paced respiration at a frequency of about 0.1 Hz (about 5–7 breaths per minute). Second, polyvagal theory postulates the "vagal brake" as a key, functional, social evolutionary mechanism, advocates the measurement and enhancement of respiratory sinus arrhythmia and high amplitudes of HRV for health and well-being. Third, the neurovisceral integration model describes a central autonomic network (CAN), extends polyvagal theory as to the importance of the "vagal brake" operating in relation to higher level social, cognitive, affective, and physiological regulation (McCraty et al. 2009). Independent HeartMath research as well as that of Childre et al. (2016) provide consistent evidence to support the psychophysiological, social, and global consequences of the HeartMath model and its application in collective heart focused activity, including meditation and prayer.

The HeartMath system includes various scientifically validated tools and techniques, with a practical energetics approach and biofeedback functions. Emphasis is on awareness of energy depletion, renewal and resilience in preparing for challenges and sustained reliance through regular HeartMath practice. Physiologically, changes in afferent information that occurs with HeartMath techniques represents the addition of a key "bottom up" process in terms of self-regulation—this combined with a "top-down" cognitive approach is what accounts for their effectiveness. First, energy expenditure is required to better self-regulate, as techniques are practised and anchored. Adherence is facilitated by mentoring for sustaining practice and improved self-regulation. In the second phase, the process become less effortful, more automatic and intuitive. Finally, continued practice lifts consciousness and brings more consistent, intuitive alignment with the moment to moment intuitive guidance of the deeper Self (McCraty and Zayas 2014). Specific psychophysiological coherence promoting techniques include Heart focussed breathing, Quick Coherence, Freeze-Frame and Heart Lock-In (Childre and Martin 2000). Tools include emWave2, emWave pro and Inner Balance (Institute of HeartMath 2014).

3.2 Social coherence

The HeartMath psychotherapy is supported by the research of Pribram (2011) and Schwartz and Russek (1997). HeartMath studies consistently indicate that the heart transmits various, dynamic, energetic patterns through moment to moment, beat-to-beat heart rate variability (HRV) communications. For example, signal averaging research techniques have provided evidence of one person's electrocardiogram (ECG) signals registered in another person's electroencephalogram (EEG) and electrocardiogram (ECG), in both physical contact and non-contact situations (McCraty 2017). A bioenergetics communication system apparently also exists in highly coherent group contexts. Laboratory studies have provided evidence that people trained in achieving high states of heart coherence can facilitate coherence in other people (Leskowitz 2008; Morris 2010; McCraty 2017).

The study by Morris (2010), which used a randomized experimental and control group design, warrants detailed discussion. The specific objective was to assess whether groups of three participants trained to achieve high states of heart rate variability coherence (HRVC) could facilitate higher levels of HRVC in an untrained subject seated at the same table. Fifteen adult volunteers were trained to increase HRVC. Six different experimental protocols were used in 148 10-min trials. Untrained receivers either practiced (a) quick coherence technique (QCT) or (b) relaxed. Trained senders used one of three protocols, (a) high coherence with intention to send this to the receiver, (b) high coherence with no intention to send this, (c) relaxation alone. Data analysis included two sophisticated research techniques. One technique, originally developed for analysing relationships between geophysical time series data, was customized for

transforming heart rate time series into continuous wavelet transforms (CWT) and for analysing relationships between individual heart rate time series through cross wavelet transforms (XWT) and wavelet coherence (WTC) tests of significance. Another technique, originally developed for use in determining causal relationships in neural populations, was used for conducting a Granger causality analysis between heart rate rhythms of multiple pairs of subjects. Results indicated that the HRVC of the untrained subject was found to be higher in approximately half of all matched comparisons and was highest in cases where all four participants focused on achieving increased HRVC. Significant relationships were found between participants' comfort with each other and trial success. Greater levels of inter-group comfort were positively linked to increases in HRVC.

Finally, higher levels of HRVC correlated with higher levels of heart rate synchronization between participants. Morris (2010) concluded that findings indicate that: (a) a coherent energy field can be generated and/or enhanced by the intentions of small groups of participants trained to send coherence-facilitating intentions to a target receiver, (b) the field is made more coherent with greater levels of comfort between group members, (c) The heart rhythm synchronization evidence across participants points towards heart-to-heart bio-communications. Such research thus provides a plausible mechanism for energy exchanges between healer and client, which McCraty (2003: 17) explicates as follows:

> Coherence-building approaches may also help health care practitioners increase their effectiveness in working with patients. In self-generating a state of physiological coherence, the clinician has the potential to facilitate the healing process by establishing a coherent pattern in the subtle electromagnetic environment to which patients are exposed. Since even very weak coherent signals have been found to give rise to significant effects in biological systems, it is possible that such coherent heart fields may provide unsuspected therapeutic benefits. Furthermore, by increasing coherence, clinicians may not only enhance their own mental acuity and emotional stability, but may also develop increased sensitivity to subtle electromagnetic information in their environment. This, in turn, could potentially enable a deeper intuitive connection and communication between practitioner and patient, which can be a crucial component of the healing process.

These HeartMath social coherence studies extend a body of psychotherapeutic evaluation findings, initiated many years ago by Rogers and others who pioneered the development of accurate measurement scales for essential therapeutic variables (Rogers 1980). For example, Carkhuff (1969) provided convincing evidence that if helpers are functioning at a high level with regard to important facilitative conditions, constructive changes will take place in helpees. The Carkhuff scales present five facilitative levels for such variables as empathy, respect, genuineness, self-disclosure, concreteness, confrontation, immediacy, and helpee self-exploration. Facilitative characteristics range from level one, where helper expressions are typically unhelpful or destructive, to level five, where helper communications are very effective and creative. For example, in the case of empathic understanding, level five involves helper responses that add significantly to the feeling and meaning of helpee expressions, first so as to accurately express feelings below what the helpee is able to express and, second, to be fully with the helpee in the event of ongoing deep self-exploration (Carkhuff 1969). The scales are still widely used today. There much scope for research and intervention studies on therapist- client or doctor patient relationships, monitoring and promoting coherence.

McCraty (2017) summarized HRV and social coherence research with special reference to physiological synchronization in social interactions and as measure of interaction synchrony. Endorsing the importance of early mother–child relationships, Feldman's (2009) findings suggest that mother heart rate and HRV synchrony form the foundation of socialization processes. Findings consistently point to the magnetic field of the heart as most likely physical mechanism that can continuously provide information exchange between living systems and the larger ecosystem. In recent study (McCraty 2017), 12 participants, including 6 preassigned pairs, were, respectively, asked to close their eyes, use the Heart Lock-In technique for 5 min and radiate feelings of appreciation to their partner only. Findings revealed significant HRV synchronization between pairs only, indicating the power of intentionality when coherently focused. These findings and other ongoing HeartMath studies have important implications for interpersonal and group psychotherapy.

3.3 Global coherence

A given for advanced meditators, for others the apprehension of interconnectedness may emerge as an eternal, infinite moment breaking into everyday awareness. Such transpersonal psychotherapeutic events are typically associated with contexts such as sleep, dreams, birth, death, sex and/or communal ceremonies, heightened consciousness, insights, morality and ethical behaviour (Wilber 2016). Such consciousness facilitated the founding of the Institute of Noetic Sciences, by Apollo 14 astronaut Edgar Mitchell in 1973. More recently, several independent lines of evidence have provided support for the existence of an interconnecting global information network facilitated through the earth's magnetic field (László 2007; McCraty 2017; Nelson 2011). The Institute of HeartMath, Global Coherence Initiative (GCI) is conducting pioneering researching into

interconnectedness to promote social and global coherence, consciousness and health through heart-focused care (Institute of HeartMath 2014).

HeartMath psychotherapy advances time honoured indigenous practices that have existed for centuries. As mentioned in the introduction to this article, integral healing forms of heart focused practice are found in ancestral reverence, Hinduism, Judaism, Buddhism, Taoism, Christianity and Islam (Wilber 2000, 2006, 2016). From a physiological perspective, the brain, heart and intestines contain biological, oscillating pacemaker cells, whose rhythms can be altered through conscious intentionality and/or volition. HeartMath postulates that the heart generates the most powerful, comprehensive, rhythmic, electromagnetic field, whose information patterns form coherent networks with various environmental energy fields (McCraty et al. 2009; McCraty 2017).

In practical healing terms, positive emotions and heart focussed breathing at about six breath cycles per minute facilitate vast interconnectivity (Childre et al. 2016). In 2008, the GCI was launched to promote global health and well-being through heart-focused care. In pursuit of this mission, a global network of ultrasensitive magnetic field detectors are being installed strategically around the planet to provide data on relationships involving physical, animal, human, planetary and cosmic ecologies. At present five sites are operational in California, Saudi Arabia, Lithuania, Canada, New Zealand and South Africa. Information on live data can be found at http://www.heartmath.org/research/global-coherence/gcms-live-data. From a cosmological perspective, the global coherence initiative resonates with findings from the Global Consciousness Project (Nelson 2011) and other emerging interdisciplinary fields, for example, linking life science, neuroscience and cosmology.

In addition to empirical outcomes, HeartMath research provides further physical evidence for phenomenological intuitions relating to interpersonal, group and community psychotherapy. Findings support many evidence based studies with regard to propensity to facilitate consciousness, particularly moral consciousness and behaviour, creativity and health promotion (Alexander 2005; Horan 2009; Nidich et al. 2000). For example, well controlled, transcendental meditation collective consciousness research, using sophisticated, time series methodology, has indicated significant correlations between size of meditation group, reductions in war deaths and/or intensity, as well as improvement in broad quality of life indices (Orme-Johnson 2000). In simple terms, the great value of such studies is their support for what many people know intuitively, that good intentions, quality dialogue, genuine care and related actions, make a beneficial difference in the quality of life in society.

There are many thousands of GCI ambassadors from over 150 countries practicing heart focussed care, compassion and love towards improving global coherence (Childre et al. 2016). Many have become members after successfully transforming negative into positive feelings. Anyone motivated to promote planetary health and welfare can become GCI ambassadors at no financial cost. As more individuals, families, communities and nations transform negative into positive experiences, build resilience and raise coherence levels, this can lead to improved personal, social and global coherence, heart intelligence, planetary consciousness and general collaborative work to make the world a better place. Conceptual and practical implications of this initiative with special reference to global healing can be found on the websites: http://www.Heartmath.org and http://www.glcoherence.org. These websites also contain information on various online courses, for example, for person's needing HeartMath Coach/Mentor training.

4 Conceptual issues for AI and robotics

Is HeartMath a form of AI? If psychometric measures of cognitive and emotional intelligence are generally considered as forms of AI, in their specific facility to promote heart intelligence, through optimal heart rate variability derived mathematical and psychophysiological measures of coherence, HeartMath tools such as Inner Balance and emWave2 certainly qualify as forms of AI, as do, to lesser extent, the scientific designed techniques such as Freeze Frame, Cut Thru, Heart Lock In and Quick Coherence (Institute of HeartMath 2014). The latter raise conceptual and definitional issues as to where to draw boundary lines to the extent that any humanly designed intelligence measures, tools and techniques can be viewed as form of AI. Similar issues arise in the case of heart transplants, particularly in the case of artificial hearts. Here further issues arise in the following more specific questions: What types of heart intelligence will an artificial heart be able to simulate? Given measurable interconnectedness between the human heart, brain and general environment, what types of heart intelligence and associated behaviours will robots be able to simulate? How can robots be programmed to improve various types of coherence, psychophysiological, social, global and, if so, in what contexts? How will heart holograms improve cardiac care? (Khader et al. 2018). How will meditation be advanced by AI and vice versa in that AI may not have the ego, desires or fears of humans? (). At more subtle levels, research continues on the neuroscience of meditation as promoted by Buddhist, Hindu, Christian, Islamic and other wisdom traditions (Bourgeault 2016; Lama et al. 2016; Louchakova-Schwartz 2013; Travis et al. 2005). What implications does this have for AI and robotics?

Heart intelligence is associated with dynamic systemic brain behaviour relationships. Moral actions inevitably involve perennially controversial notions of determinism,

free will and related philosophical and ethical issues involving vocation, volition, agency and decision making processes. Brain imaging techniques such as functional MRI have facilitated objective measurement of introspective data. For example, building on an earlier *what, when*, and *whether* (*WWW*) model (not to be confused with computer science WWW) of intentional action or decisions, Brass et al. (2013) have postulated an anterior-posterior gradient within the medial frontal cortex (mPFC), whereby (mPFC) based intuitions become funnelled into more specific behaviours associated with the rostral cingulate zone (RCZ), and pre-supplementary motor areas (SMA/preSMA), respectively. These specific behaviours include intentional suspension of volitional control, with regard to which humans seemingly have the ability to veto movements preceded by early brain signals up to 200 ms before movement onset (Schultze-Krafta et al. 2016). At least, such research provides some physical basis of hope for discerning intuitions, responsible decisions and effective actions by AI and robot designers of sound moral integrity.

5 Implications and challenges for AI and robotics

It seems that HeartMath offers opportunities for explorations in heart intelligence, AI and robotics. The supreme challenge seems to be the design of AI systems, models or robots that will simulate those uniquely human, personal and transpersonal experiences, behaviour, realities or phenomena (nous) that will allow further realization, and planetary advancement of the greatest good, moral qualities and general excellence, as well as ensuring survival and flourishing for all sentient beings, through furthering intelligence, humanity, art, science and optimizing interconnectedness. It is equally important that human destructiveness and violence, that most basic unrecognized source of illness, incoherence, disorder and disease, which is typically transmitted through such contexts characterized by power, greed, conflict, rivalry and domination, is not somehow programmed and propagated. This implies programming optimal moral and ethical behaviour to encourage and advance such contexts as love, peace and harmony and such related relationship variables as empathy, respect, coherent communication and coherent therapy (Ecker and Hulley 2015). The HeartMath Coherence model provides theory and praxis in this regard. Such initiatives need promotion. For example, it is worth mentioning that various studies have indicated that mass meditation, prayer and contemplation focused on positive outcomes may have measurable beneficial effects (Orme Johnson 2000). There is converging scientific evidence for vast, energetic, interconnectivity at human, planetary and solar systemic levels (Childre et al. 2016).

In the short term special focus should be on planetary threats of nuclear war, international terrorism, global warming, overpopulation, unemployment, poverty, illness, injustice, corruption, crime and endemic violence to promote humanity and other inhabitants of planet earth and beyond. Properly programmed robots could assist humanity design such systems, choose most needed options and basic moral imperatives. These and the following are examples of immediate challenges. Just as HeartMath has the facility to promote various meditation and contemplation methods that have been empirically validated to advance health and well-fare, AI could assist promote subtle energetic reality, positive emotions and altruistic behaviour following contemplation. Alternatively AI contemplating mechanisms could be designed to further explicate processes whereby positive emotional feelings are encoded electromagnetically, and in other ways, to further explicate non-local energy communication. AI challenges could include programming computer holographic images and testing functions of the "heart brain" including relationships with computerized graph of planet earth's torus fields and heart resonance patterns, tracking the fluid machinery of the body in biofeedback, blood pressure reductions, creativity, ethics, intuition and other functions of the superconscious. Evidence advanced in this paper provides argument for the need, study and practice of heart intelligence to promote \coherence, creativity, moral reasoning and executive action, in the personal lives of AI robotic designers and their productions.

6 Conclusion

HeartMath is viewed as a scientific, coherent model of heart intelligence, which includes various physical, emotional and spiritual forms of intelligence that have been recognized by many perennial, wisdom traditions. A review of the HeartMath coherence model reveals various conceptual issues, implications and challenges for AI and robotics. Although the physiological coherence model may be readily amenable to operational design involving binary and holographic, dynamic systemic functioning, greater challenges are envisaged with regard to uniquely human, personal, transpersonal, ethical and moral behaviour. In view of seemingly infinite human capacity for creative, destructive and inconsistent behaviour, it is highly recommended that designers and operators be persons of optimal moral integrity, vision and mission. This also means that AI and robotic design and production should be continuously optimized through vigilant and appropriate human and material quality control procedures. This paper provides evidence for the need, value and effectiveness of heart intelligence in this context.

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