



Research paper

Using digital technology to evaluate heart coherence in craniosacral therapy as an indicator of spiritual leadership

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ABSTRACT

Introduction: There is no evidence supporting the importance of heart coherence in spiritual leadership (which describes a transformation process increasing adaptability). The study aimed to evaluate heart coherence in students studying craniosacral therapy. Heart coherence was used as an indicator of spiritual leadership and was determined by an Inner Life and Coherent Interaction between its variables. Heart coherence denotes the degree of order, harmony and stability in the numerous physiological rhythms within the human body.

Methods: A multilevel, quantitative, within-subjects, experimental research design was used in a convenience sample of 11 craniosacral therapy students. Students had different levels of experience, low (group 1) and high (group 2). Spiritual leadership was measured using a questionnaire, while a heart sensor captured its coherence.

Results: Group 2 exhibited higher Spiritual Leadership (+18%) and higher outcomes for Spiritual Well-Being (+9%), with similar scores for Coherent Interaction. At the personal level, participants from the same group had higher Spiritual Leadership (+31%), higher Coherent Interaction (+14%), and higher Spiritual Well-Being (+11%). Individual Inner Life was 5% higher for Group 1 participants. A repeated measure ANOVA on the pre and post means did not produce any significant difference in heart coherence for both groups.

Conclusion: Findings support the hypothesis that Inner Life and Coherent Interaction can be usefully deployed to evaluate the emergence of Spiritual Well-being. The study could not provide evidence that heart coherence could be considered as an indicator of spiritual leadership, but results indicated a measurable variation and synchronization of heart coherence among participants during a craniosacral therapy session.

1. Introduction

The underlying phenomenon guiding this study is entrainment, defined as a synchronization process whereby two or more independent and naturally occurring rhythms interact with each other in such a way that they eventually lock-in to a common phase and/or periodicity [1]. The word *entrainment* originates from the French verb “*entraîner*” (to drag, to pull) and it was the Dutch mathematician, Christiaan Huygens who first noted it in the 17th century [2,3]. Meanwhile, entrainment has already been studied in a variety of disciplines – such as physics, neurosciences, physiology, biology – before researchers in organization theory started using entrainment to emphasize the importance of time, pace, and business cycles in organizations, because naturally occurring rhythms exist within individuals, groups, organizations, and environments [4,5]. Borrowing a phenomenon initially developed in other fields is not uncommon for organizational scholars to enrich “the study of organizations by enabling a more sophisticated understanding of various phenomena explaining organizational dynamics” [5:785]. Furthermore,

studies argue that entrainment is positively related to organizational outcomes [5–8]. However, perceiving these rhythms and paces is crucial for entrainment to happen [9–11], as well as the skills to manage rhythmic strategic choices over time [5,7,10,11], or the ability to take part in that process [12,13].

Sandra & Nandram [14] contend that applying the model of spiritual leadership to oneself, the team and the organization can drive entrainment in organizations. Spiritual leadership theory originates in the organizational sciences and describes a transformation process, based on intrinsic motivation, combining vision, altruistic love, hope/faith, to create an organization that is able to adapt to the continuously changing environment [15]. Its outcome is an increase in one’s sense of spiritual well-being, i.e., “they experience meaning in their lives, have a sense of making a difference, and feel understood and appreciated” [16:836]. Vision refers to a picture of the future created from the organization’s mission or reason for existence, while hope/faith is the hidden driver for the fulfilment of that vision [15,16]. Having faith is demonstrated through action, anchored in values, attitudes and behaviors, such as trust, be-

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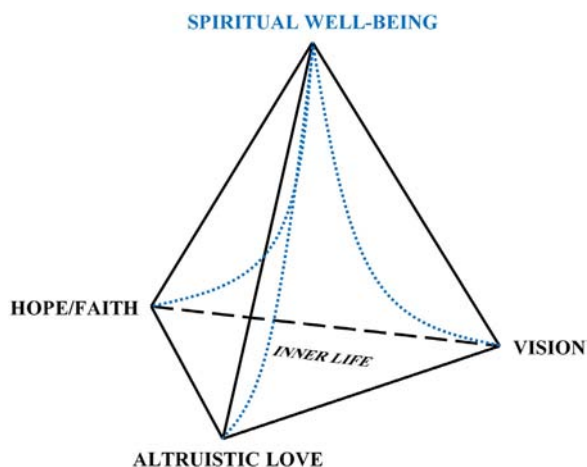


Fig. 1. Emergent resonant outcome of spiritual leadership [14].

lief, endurance, perseverance, and a willingness to maximize one's potential and personal best in one way or the other [15,17]. Altruistic love is defined as "a sense of wholeness, harmony, and well-being produced through care, concern, and appreciation for both self and others" [15:712]. Meanwhile, spiritual leadership has been extensively tested and validated in a variety of settings, and support a significant positive influence of spiritual leadership on employee life satisfaction (in terms of joy, serenity and peace), organizational commitment and productivity, and sales growth [18–21]. Spirituality in this model concerns "those qualities of the human spirit – such as love and compassion, patience, tolerance, forgiveness, contentment, a sense of responsibility, a sense of harmony – which bring happiness to both self and others" [22]. The theory of spiritual leadership was revised arguing that an inner life or spiritual practice (e.g., meditation, prayer, journaling, spending time in nature) is a fundamental source for spiritual leadership which positively influences the development of its variables [23]. Based on the theory of entrainment, Sandra & Nandram [14] argue that spiritual leadership occurs through a coherent interaction between the vision, altruistic love, hope/faith, and its environment, while an effective inner life positively influences this interaction process towards a higher degree of coherence. As a result, spiritual well-being is considered as the resonant outcome of such coherent interaction (Fig. 1).

Because the heart is considered as the strongest biological rhythm in the human system pulling other systems into entrainment [24–26], Sandra & Nandram [14] argue that coherence of the heart rate variability (HRV) is an indicator of spiritual leadership. Individual HRV coherence is related to personal spiritual leadership (PSL), while group HRV coherence is related to the group's spiritual leadership (GSL). HRV coherence or, also called, 'heart coherence' (HC), describes the degree of order, harmony and stability in the numerous physiological rhythmic activities within living systems during a specific period [24]. "An harmonious order signifies a coherent system that has an efficient or optimal function directly related to the ease and flow in life processes" [25,55]. HRV is the variation of the time intervals between two consecutive heartbeats and reflects the regulation of several physiological systems in the human body, such as cardiovascular, central nervous, endocrine, and respiratory system. An optimal level of HRV implies a healthy functioning and an inherent self-regulatory capacity, adaptability, or resilience [25,26].

Furthermore, Sandra & Nandram [14] contend that personal spiritual leadership is a prerequisite for spiritual leadership at the group level. This implies that an individual in a coherent state can help others to shift into a more coherent state as well. Studies of Morris [27], Childre & Cryer [28], McCraty & Childre [29], amongst others, have shown that such higher HRV coherence enhances people's cognitive performance, sensitivity, and mental clarity as well as increased emotional stability

and well-being. It is seen as a source of wisdom that fosters mental and emotional intelligence [30–33].

The theory and assumptions lead to the following hypotheses researched in this study using an experimental, mixed methods research design:

- H1 At the individual level: Inner life moderates the coherent interaction among the spiritual leadership variables (vision, hope/faith, altruistic love), which mediates the level of spiritual well-being.
- H2 At the group level: Spiritual well-being of each group member together moderates the coherent interaction among the spiritual leadership variables (vision, hope/faith, altruistic love) of the group, which mediates the level of spiritual well-being of the group.
- H3 HRV coherence (HC) is an indicator of spiritual leadership, through which spiritual well-being emerges.

2. Methods

2.1. Study design

When people come together – whether they know each other or not – they entrain to one another and to the environment [4]. Sandra & Nandram [14] argue that the level of spiritual leadership has an influence on this entrainment process, and that HRV coherence (HC) might be an indicator of spiritual leadership. Hence, this study required the following: the forming of a new team; working closely together during a distinct period of time; where HRV capturing is possible and under best circumstances (see 2.8 for more details); and where entrainment is fostered and not obstructed. Although different activities or events might also meet these requirements, a training in Craniosacral Therapy was selected because it deliberately works with rhythms in the human body, and because of the prior experience of the author with this therapy.

2.2. Recruitment strategy

Due to the complex nature of HRV, this study has a within-subjects design, as recommended by Quintana & Heathers [34]. Participants were not selected or recruited beforehand, but an opportunity to participate in this study was given to all students at the beginning of the craniosacral therapy training modules *Talking to the Heart* (24–27 May 2018) and *Know Your Brain - level 3* (15–18 Nov 2018) of the accredited Peirsman CranioSacraal Academie (Bussum, The Netherlands). The latter is an advanced course for graduates only. A brief explanation of the study was given to all students, including procedure and wearing of a heart sensor during the whole training.

2.3. Ethics

Ethical approval was waived by the Medical Ethics Committee of the University of Antwerp and from the Dutch Central Committee on Human Research (CCMO; 14 May 2018). This study focuses on variables in spiritual leadership theory, hence, outside the scope of the definition of a *medical experiment* as provided by the Belgian law and outside the scope of the *Medical Scientific Research Act with people* in The Netherlands, also referred to as *WMO* or *Wet Medisch-Wetenschappelijk Onderzoek met mensen*. All participants were given information about the research, including the guarantee of confidentiality, the right to withdraw from this research at any stage, and the right to see their data being collected throughout the research process. Each participant provided written consent regarding the use of their information.

2.4. Craniosacral therapy

Craniosacral therapy (CST), a term coined by research professor John Upledger in the 1980s at the Michigan State University. It originates from cranial osteopathy and works with the craniosacral system, a coherent physiological system including the meningeal membranes within

the skull and spine, the bones to which these membranes adhere and the cerebrospinal fluid. The cerebrospinal fluid circulates and pulses continuously through these membranes, about 10 cycles per minute, between the skull (cranium) and the sacrum, and is also called the craniosacral rhythm [35,36]. Craniosacral therapy is a complementary treatment approach where craniosacral therapists first palpate this rhythm for pace, amplitude, symmetry, and quality to identify where restrictions may exist, and then they apply sensitive methods for releasing them [35,37]. Several studies [38–41] indicate that CST may improve pain and general well-being. However, evidence in this field is still scarce. In this study, it is assumed that craniosacral therapy fosters the process of entrainment, hence, coherent interaction.

2.5. Apparatus and HRV data extraction

ElectroCardioGraphic (ECG) signals are continuously monitored by the ePatch ECG monitor. According to Saadi et al. [42], this device is specifically designed to limit wearing discomfort and impairment of normal daily life activities, and is approved by both the European CE and US Food & Drug Administration (FDA). Furthermore, it consists of a single-use adhesive ePatch electrode placed on the chest of the participant and a reusable ePatch sensor. Unlike regular telemetry equipment, this system design is less intrusive, and as a result, can be deployed in large-scale screening programs to monitor new populations of people wearing such a system [42].

Data recording starts automatically after mounting the system and is stored in a proprietary ePatch File System format. After removal from the chest, the raw sensor data was retrieved. The raw data was extracted by IMEC, a Belgian non-profit R&D organization specialized in nanoelectronics and digital technologies. A quality assessment of the ECG signal was performed using the quality indicators from Orphanidou et al. [43]. The HRV variables were calculated within a 10 min window with no overlap.

2.6. Measures

Besides socio-demographic variables – including age, sex, years of craniosacral practice, and years of inner life practice(s) – the following measures were selected based on Sandra & Nandram [14]:

2.6.1. Personal spiritual leadership and spiritual well-being

The level of personal spiritual leadership and well-being were assessed using the Personal Spiritual Leadership Survey (Rev 4/2018), rated on a scale from one (“strongly disagree”) to five (“strongly agree”). Included questions are “I have the courage to stand up for what I believe in.”; “I have a personal vision that is clear and compelling to me.”; “I always do my best because I have faith in myself.”

2.6.2. Group spiritual leadership and spiritual well-being

To assess the level of spiritual leadership and well-being in the group, participants were asked to fill in the revised Spiritual Leadership Survey (Rev 1/2018), also rated on a scale from one (“strongly disagree”) to five (“strongly agree”). Example questions are “My class’s purpose inspires my best performance.”; “I set challenging goals for my work because I have faith in my classmates and want us to succeed.”; “The members in my class are honest and without false pride.”

2.6.3. Inner life

The Mindful Attention Awareness Scale (MAAS) [44] was used at the start of the study to measure levels of dispositional mindfulness. It is a single factor scale which uses 15 items rated from one (“almost always”) to six (“almost never”). Higher mean scores indicate greater dispositional mindfulness. Included questions are “I find myself doing things without paying attention.”; “I rush through activities without being really attentive to them.” Studies provided evidence that “MAAS not only predicts well-being outcomes but also has value in the study of the

temporal and situational dynamics of self-regulated behavior and well-being.” [41:843] The findings of MacKillop & Anderson [45] largely support the validity of the MAAS and its measure is not related to gender. Hence, in this study, the MAAS score is considered as an adequate indicator for the level of inner life.

2.6.4. Heart rate variability

Although HRV was recorded continuously, only the measurements during a treatment session are taken into account to control for respiration and physical movement [34]. From those measurements, the heart coherence is calculated and taken into account.

2.6.5. Heart coherence

Heart coherence is assessed “by identifying the maximum peak in the 0.04–0.26 Hz range of the HRV power spectrum, calculating the integral in a window 0.030 Hz wide, centered on the highest peak in that region, and then calculating the total power of the entire spectrum. The coherence ratio is formulated as: (Peak Power/[Total Power - Peak Power])” [25:55]. An approximate measurement for Heart Coherence, HC2, is the ratio LF/(VLF + HF) [24,29]. Kim et al. [46] found a positive correlation between a similar proxy of MF / LF + HF and the accumulated coherence score (i.e., a score representing the length of a coherent state attained by a subject). In their study, the frequency bands were defined differently (LF: 0.01-0.08 Hz; MF: 0.08-0.15 Hz; HF: 0.15-0.5 Hz).

2.7. Data collection

After signing up for this study and before the start of the training, participants were asked to fill in the first self-reported questionnaire (i.e., personal spiritual leadership and inner life) and to wear the heart sensor during the whole duration of the training. A qualified person mounted the sensor on each participant. No further instructions were given, nor were any needed. Training could proceed as normal. Immediately after the end of the training and before leaving, participants were asked to fill in the second self-reported questionnaire about team spiritual leadership and to remove the heart sensor.

A craniosacral therapy training module typically consists of a combination of theory and practice, where students give and receive a treatment session. Students are encouraged to work with different students. This multi-therapist approach is beneficial for a higher generalizability of the therapeutic (entrainment) effect, and not to assess the therapist effect. This implies that data is collected from participants in the role of client and of practitioner. The whole training was voice recorded for analysis purposes only (see Section 2.8 for more detail).

2.8. HRV analysis

Quintana & Heathers [34:2] presented recommendations for HRV assessment highlighting the influence of respiration and external factors on HRV, such as time of day, physical activity, caffeine, levels of alcohol and age. For respiration, they note that “Denver et al. [47] have argued against the need to control for respiration for resting state recordings, given the important influence of breathing on HRV.”

To limit the influence of those factors, only a subset of the data was used to assess HRV, based on the following controls:

- Data is filtered on signal quality ($>=0.8$) and physical movement ($<=0.40$), recommended by IMEC, based on experience with other studies (not published).
- Only data during treatment sessions were taken into account to control for respiration and physical movement. This implies that for each day, those sessions were identified using the voice recordings.

RStudio (Version 1.1.463) was used to apply these filters to the data and to calculate means with standard deviation. Statistical tests were run using JMP Pro 14.0.0.

2.9. Qualitative comparative analysis approach

Qualitative comparative analysis (QCA) techniques allow a systematic comparison of cases, with the use of formal tools and theoretical foundations or conception of cases [48,49,]. It is built on the exploration of set-theoretical relationships between causally relevant conditions and its outcome [50]. There are several reasons why this approach is suitable to analyze the research question in this study. First, each case is seen as a complex combination of properties [51]. The small number of cases would render insufficiently reliable results using regression analysis. QCA, on the other hand, was developed primarily for small-to-medium N approach. “It can be said that QCA techniques strive to meet advantages of both the ‘qualitative’ (case-oriented) and ‘quantitative’ (variable-oriented) techniques.” [51:6]. Next, QCA makes it possible to have a rich discourse with theory [48,49]. Furthermore, the use of a formal Boolean language facilitates this discourse and can be applied at several levels of analysis at the same time [34]. Finally, QCA does not ask to specify a particular causal model but leaves room for complexity to determine causal models that exist among the cases being compared [52].

The hypotheses put forward in this study can be translated in Boolean terms where two necessary conditions are jointly sufficient (i.e., IL: Inner Life, and CI: Coherent Interaction) to foster coherent interaction – through the process of entrainment – among the spiritual leadership variables out of which spiritual well-being (SWB: Spiritual Well-Being) emerges. Heart Coherence (HC) is considered as an indicator for this level of SWB.

At the individual level:

$$IL \times CI \rightarrow SWB_{ind} \sim HC_{ind}$$

At the group level:

$$\frac{\sum_i^n (IL \times CI)_i}{n} \rightarrow SWB_{grp} \sim HC_{grp}$$

For this study, the fuzzy set QCA (fsQCA) approach is used to explore the conditions (IL and CI) for the emergence of spiritual well-being. This implies that data are calibrated in fuzzy set membership scores between 0 and 1 according to the degree of presence of the condition in a specific case. This study opted for a continuous fuzzy set scale, as shown in Table 1, where interval-scale variables are converted into fuzzy set values, using packages QCA v3.4 and SetMethods v2.4 [53] within RStudio v1.1.463. Unlike standard interval measures, fuzzy sets assign a quality to the variation. Membership has to be “purposefully calibrated” [49:30].

In this study, it is suggested that the MAAS score is an indicator for Inner Life. Brown & Ryan [44] examined the MAAS scores among students of Zen meditation because one way of cultivating mindfulness is engaging in meditation. They found a significant difference between the Zen practitioner group (M = 4.29, SD = 0.66) and the comparison group (M = 3.97, SD = 0.64). Moreover, the scores within the Zen group correlates positively with the number of years of practice. To calibrate the MAAS score into fuzzy sets, values are assigned according to the score, as shown in Table 2.

As discussed earlier, Sandra & Nandram [14] contend that spiritual leadership occurs through a coherent interaction between the vision, altruistic love, hope/faith, and its environment (i.e., the variance among these variables is minimal). Since this study was conducted in the same

Table 1
Continuous fuzzy set scale.

1	Fully in
0.50	More “in” than “out” Cross-over: neither in nor out More “out” than “in”
0	Fully out

Table 2
Fuzzy set construction.

Variable	Code	Set construction break-points
Inner Life	IL	Fully in: 4.29 Cross-over: 3.97 Fully out: 1.0
Coherent Interaction	CI	Fully in: 0.80 Cross-over: 0.60 Fully out: 0.0
Spiritual Well-Being	SWB	Fully in: 4.0 Cross-over: 3.0 Fully out: 1.0

place, it assumes the same interaction of the environment with the two groups. Then, the coherent interaction can be expressed using the standard deviation of the spiritual leadership scores for each variable. To make the measure a coefficient, it is divided by the maximum score (=5) of the survey scale. The coherent interaction (CI) is calculated as follows:

$$\text{Coherent Interaction} = CI = 1 - \frac{2\sigma}{5}$$

Spiritual well-being is the outcome of spiritual leadership. Scores below 3 indicate the need for improvement, while scores above 4 indicate areas that are satisfactory (based on PSL Rev 4/2018).

The final step in this approach is to calibrate the findings in fuzzy sets by applying Table 2 to the data. Two additional measures are particularly important for fuzzy set relationships: consistency and coverage. Consistency percentage evaluates the degree of support among the cases of a subset. Consistency is to set relationships, as p-value is to statistical inference. The higher the consistency, the stronger the set-theoretical relationship. Rule of thumb is to look for relationships with consistencies greater than 90% [48]. The coverage percentage, on the other hand, evaluates the proportion of the membership scores in an outcome that a particular configuration explains.

3. Results

The measures of spiritual leadership are examined first using fsQCA to explore the conditions for entrainment, through which spiritual well-being emerges, both at the individual and group level. Then, using HRV analysis, the conditions are explored under which heart coherence emerges, as an indicator for spiritual well-being.

3.1. Participants

In total, 11 students (all female) volunteered to take part in this study, age range 50-66 (M = 55.4, SD = 4.6) years.: six participants were in the first group (out of eleven), and five participants were in the second group (out of fifteen). Participation rate was 55% and 33% respectively. There were no inclusion or exclusion criteria, nor were there any benefits of participating in this study. Each student was given the chance to participate. Table 3 gives a detailed overview.

Table 3
Study participation.

	I	II	Total
Participants (all female)	6	5	11
Age (y)	51-56	50-66	50-66
Average age (y)	53.1	58.3	55.4
SD (y)	1.5	5.4	4.6
Cranio practice (y)	1.5	11.0	5.8
Meditation practice (y)	17.1	5.1	12.3
Yoga practice (y)	26.4	5.7	18.6

I: Module Talking to the Heart.

II: Module Know Your Brain - level 3.

Table 4
Results spiritual leadership measures.

	Group 1						Group 2					Grp1	Grp2
	1.1	1.2	1.3	1.4	1.5	1.6	2.1	2.2	2.3	2.4	2.5		
SL	3,00	3,67	3,33	3,67	3,11	4,00	5,00	4,56	4,44	4,67	4,11	3,73	4,40
sdev	0,87	0,87	0,71	0,50	0,33	0,50	0,00	0,53	0,53	0,50	0,33	0,62	0,66
IL	4,27	5,40	4,27	4,87	4,53	4,93	4,47	4,60	4,80	4,00	4,60	4,71	4,49
CI	0,65	0,65	0,72	0,80	0,87	0,80	1,00	0,79	0,79	0,80	0,87	0,75	0,74
SWB	3,67	4,67	3,67	3,83	3,50	4,33	5,00	4,50	3,83	4,50	4,17	4,23	4,63

SL: spiritual leadership; sdev: standard deviation; IL: inner life (MAAS); CI: coherent interaction; SWB: spiritual well-being.

Table 5
Fuzzy set spiritual leadership measures.

Case	preHC	IL_fs	CI_fs	ILxCI	SWB_fs
2.1	0,17	0,99	1,00	0,99	1,00
1.2	0,37	1,00	0,68	0,68	0,99
2.2	0,19	1,00	0,94	0,94	0,99
2.4	0,11	0,57	0,95	0,57	0,99
1.6	0,42	1,00	0,95	0,95	0,98
2.5	0,25	1,00	0,98	0,98	0,97
1.4	0,05	1,00	0,95	0,95	0,92
2.3	0,10	1,00	0,94	0,94	0,92
1.1	0,68	0,94	0,68	0,68	0,88
1.3	0,23	0,94	0,85	0,85	0,88
1.5	0,13	0,99	0,98	0,98	0,81
Grp1	0,31	1,00	0,90	0,90	0,97
Grp2	0,16	0,99	0,89	0,89	0,99
Consistency		97%	93%	90%	
Coverage		95%	98%	98%	

preHC: HeartCoherence (before start study; see 5.3.2 for more details).
IL: inner life; CI: coherent interaction; SWB: spiritual well-being.

3.2. Spiritual leadership

Table 4 gives an overview of the findings for each participant and group. As a reminder, Spiritual Leadership (SL) is the average of the scores vision, hope/faith and altruistic love, for which the standard deviation (sdev) and coherent interaction (CI) are calculated. Inner life (IL) is the MAAS score of each participant, and the average of the participants in the group. Spiritual Well-Being (SWB) is the average of the scores calling and membership from the SL survey.

At the group level, the second group exhibits higher Spiritual Leadership scores than the first group (3,73 vs. 4,40; +18%) with similar Coherent Interaction (0,75 vs. 0,74). Inner Life scores are slightly higher (+5%) for the first group (4,71 vs. 4,49). The outcome, Spiritual Well-Being, is about 9% higher for the second group (4,23 vs. 4,64).

At the personal level, on average the participants in the second group had higher Spiritual Leadership scores (3,46 vs. 4,56; +31%), higher Coherent Interaction scores (0,85 vs. 0,75; +14%), and higher Spiritual Well-Being scores (4,40 vs. 3,95; +11%). Individual Inner Life levels were about 5% higher for the participants in the first group.

As shown in Table 5, the consistency of the set-relationship IL x CI is 90%, while coverage is 98%, across all cases (individual and group). The necessary conditions IL and CI also had consistency scores higher than 90% indicating that these are necessary for the outcome. In other words, there are cases where the relationship does not apply (i.e., cases 1.4 and 1.5; 2.3 and 2.5).

3.3. Heart coherence

In total, about 4 500 data points were collected in 10-minutes windows of ECGs recordings. For the first group, 440 data points were collected on average per participant, while 384 data points for the second group. However, only 200 the data points were suitable for the first group (34 per participant on average) and 230 for the second group (47

per participant on average). Table 6 gives an overview of the frequency domain means (pre- and post- per group; during the first and last treatment session, i.e., ECGs recordings of more than 10 minutes). Frequency domain metrics are used to calculate heart coherence (HC and HC2).

Table 7 shows the heart coherence for each participant during the first 10 min of the first recorded treatment session, and during the last 10 min of the last recorded treatment session. A repeated measure ANOVA on the pre- and post-means did not produce any significant difference for each group (Group 1: F test value: 0,2026; Prob>F: 0,36; Group 2: F value: 0,00; Prob>F: 0,97).

Fig. 2 shows the heart coherence variation during the longest recording of a treatment session (i.e., day 3 from 14:30 until 15:30 UTC - group 2). It shows the seven consecutive data points per participant.

4. Discussion

Participants and groups may differ in (1) inner life; (2) coherent interaction; and (3) spiritual well-being. First, the high Inner Life (IL) scores among all participants (Table 4) outperform Zen meditation practitioners by 7,5%. This might be explained by the many years practice of meditation, yoga and craniosacral therapy (see Table 3). For example, the first group has on average 17 years of meditation practice and 26 years of yoga, with limited cranio practice (1.5 years). The second group, on the other hand, has more years of cranio practice (11 years) but less years of meditation and yoga practice (5 years), which might explain the slightly lower IL score (-5%).

Second, the variance among the spiritual leadership variables (i.e., vision, altruistic love, hope/faith) determines the coherent interaction. Group scores (Table 4) do not differ much, resp. 0,75 and 0,74. Individual scores, on the other hand, do differ per group by 13%, resp. 0,75 and 0,85. The difference in years of cranio practice (11 vs. 1,5 years) might have contributed to this.

Next, spiritual well-being is the outcome of spiritual leadership. On the individual level and group level, the first group exhibits lower scores, resp. 3,94 vs. 4,40 (-11%), and 4,3 vs. 4,63 (-9%). The individual scores are consistent with the lower levels of coherent interaction. The familiarity with the school, its student and/or alumni, and the years of cranio practice might explain a higher score of spiritual well-being for the second group. Harrison et al. [58] noted a positive influence of familiarity on the entrainment process. Using the fsQCA approach, the results in Table 5 support the hypotheses (H1 and H2) that inner life and coherent interaction can be usefully deployed in a consistent way to understand the emergence of spiritual well-being through coherent interaction, both at the personal and group level. In Boolean terms, IL x CI → SWB, with a 90% consistency. It shows that a high level of spiritual well-being emerges with inner life levels ≥ 4.29 and with coherent interaction levels ≥ 0.8, across the individual and group level.

There is no significant change in heart coherence among participants (Table 7), hence, the hypothesis that heart coherence is an indicator of spiritual leadership cannot be assessed. Several reasons might explain this lack of significance. First, calculating the heart coherence mean during a longer period averages out higher scores. Metrics in this study were calculated using a window of 10 min, as used by other studies [54,55,]. A window of one minute or shorter might show more accurate

Table 6
Pre and Post means per group (frequency domain).

	Group 1				Group 2			
	Pre		Post		Pre		Post	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
HR (BPM)	69,1	9,7	76,2	9,8	73,8	13,1	65,5	16,2
LF (ms ²)	860	823	752	555	383	345	463	350
HF (ms ²)	419	499	421	536	327	462	482	443
LF/HF	4,55	5,40	3,44	2,77	1,75	1,15	1,11	0,48
HC	0,24	0,15	0,22	0,11	0,13	0,05	0,09	0,05
HC2	0,62	0,56	0,80	0,42	0,33	0,23	0,24	0,11
Accelerometer	0,01		0,01		0,02		0,01	
Signal quality	0,96		0,97		0,95		0,92	

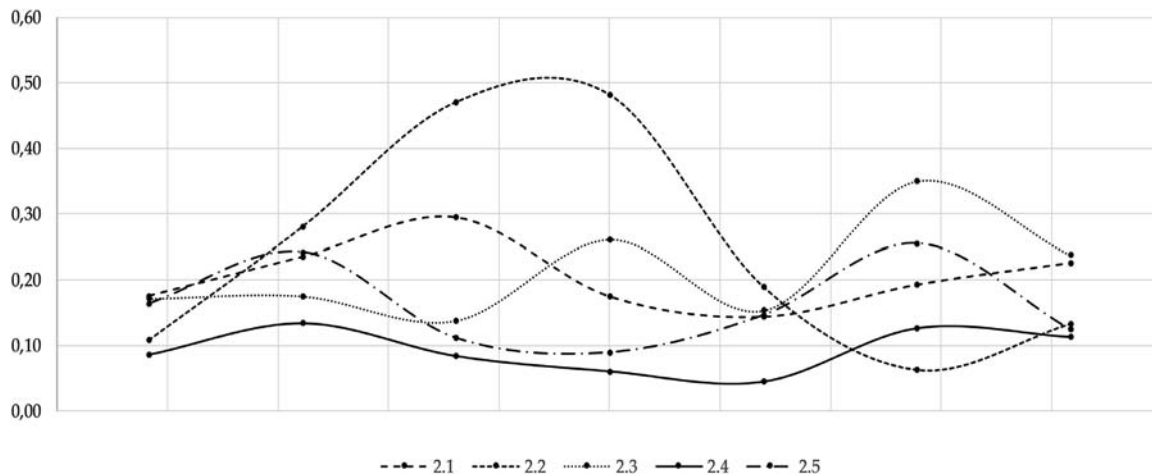


Fig. 2. Heart coherence variation during 60' CST session (group).

Table 7
Heart Coherence: Pre and Post results.

Group 1	HC		HC2	
	Pre	Post	Pre	Post
1.1	0,68	0,21	1,67	0,25
1.2	0,37	0,14	1,17	0,47
1.3	0,23	0,18	0,12	0,65
1.4	0,05	0,36	0,10	1,50
1.5	0,13	0,10	0,26	0,53
1.6	0,42	0,25	0,96	0,75
Mean	0,31	0,21	0,72	0,69
Sdev	0,23	0,09	0,65	0,43
Group 2	Pre	Post	Pre	Post
2.1	0,17	0,23	0,26	0,21
2.2	0,19	0,13	0,30	0,42
2.3	0,10	0,24	0,23	0,36
2.4	0,11	0,11	0,84	0,45
2.5	0,25	0,12	0,81	0,40
Mean	0,16	0,17	0,49	0,37
Sdev	0,06	0,06	0,31	0,09

results. Instead of averaging the metrics, one could also count the number of times a participant has entered into a coherent state level [56]. Another reason for this insignificance may be found in the role of the participant (i.e., therapist or client), which has not been investigated in relation to heart coherence. Although no generalization can be made on the recordings shown in Fig. 2, it is clear that heart coherence can vary in different ways per person, probably also as a function of the participant's role (i.e., therapist or client). This was not taken into account in the current study design.

For a better understanding of this variation in heart coherence between therapist and client, an additional experiment was done with a

client (with no previous experience with craniosacral therapy). Fig. 3 shows such variation during a CST session (per 5 min window of ECGs recordings). Typically, a craniosacral therapist tune into the craniosacral rhythm for its quality [35,37], which might explain the fluctuations in heart coherence during the session, as shown in the figure. Moreover, every therapist has his own way of tuning in, and every session is focusing on different parts of the body. All these elements might explain the high variation and lack of significant change in heart coherence during the whole training. Nevertheless, this study illustrates that heart coherence does play a role in the process of entrainment (i.e., tuning into craniosacral rhythm), but further research is needed to understand its role.

5. Limitations

The lack of experience with using heart sensors during a long recording period has limited this study in a number of ways. First, the results show that for certain participants the signal quality deteriorated the longer the sensor was worn. Future studies could pay more attention to the state of the skin before mounting the sensor to increase signal quality and adhesiveness of the patch (e.g., no skin lotion). Next, if data collection is not needed during the night, then it is highly recommended to use a new patch each day. Mounting of the sensor is easy and participants could do this for themselves in the following days. This approach will most likely increase participation rate as well (next to signal quality) if data collection is limited to working hours only. Although wearing the heart sensor is not uncomfortable, it does limit them in specific daily activities and hygiene routines.

Spiritual leadership theory has been extensively tested and validated in a variety of settings [18,19,57]. This study, however, uses the MAAS score (Mindful Attention Awareness Scale) [44] as an indicator for inner

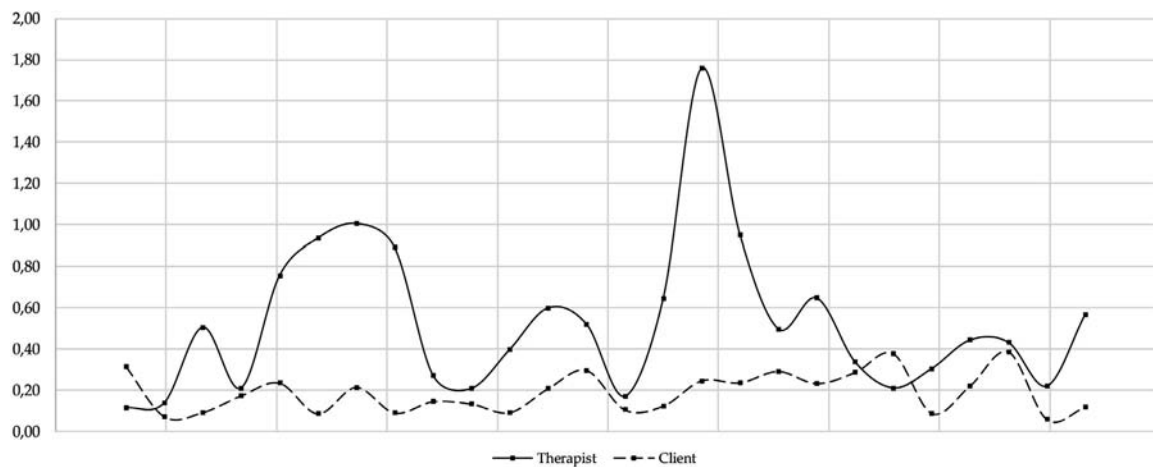


Fig. 3. Heart coherence variation during CST session (therapist-client).

life because it is more extensive and its role in psychological well-being has been validated separately. As such, it combines two questionnaires that have not been validated together. Future research could validate this further. In addition, other questionnaires or theories could be considered to assess (the effectiveness of) inner life practice in future studies.

The limited number of cases in this study restricts the conclusion and generalization of its findings. Fuzzy set qualitative comparative analysis techniques were used based on two necessary conditions with spiritual well-being as outcome. With higher number of cases, the generalization could be increased, but this novel analysis approach to spiritual leadership could also be extended with additional conditions to take into account other types of entrainment. For example, a condition related to the place (physical or geographical location), or a condition related to familiarity, which influences interpersonal entrainment. Harrison et al. [58] demonstrate that a priori familiar teams have a positive impact on such entrainment.

This study is also subjected to the author's bias towards the use of craniosacral therapy and its effect on the entrainment process. As a consequence, this implies a risk of unwitting selectivity and interpretation of evidence in a such a way that it fits the researcher's existing beliefs, expectations, or hypotheses [59]. Although this kind of bias can never be mitigated completely, the following elements attempted to limit its impact. First, the heart sensors captured the data from the participants autonomously without any possible manipulation of the researcher. Second, data from these sensors was processed independently from the researcher, including the heart coherence for each participant. Finally, the QCA approach does not ask to one particular causal model but leaves room for complexity to determine causal models that exist among the cases being compared [48].

6. Conclusion

Spiritual leadership theory describes a transformation process for increased adaptability to the ever changing environment. The outcome is an increase in one's sense of spiritual well-being achieved through a coherent interaction between vision, altruistic love, and hope/faith, fueled by an inner life. The limited findings in this study support the hypothesis that inner life and coherent interaction among the spiritual leadership variables can be usefully deployed to evaluate the emergence of spiritual well-being, both at the individual and group level. In Boolean terms, $IL \times CI \rightarrow SWB$ (90% consistency). It shows that a high level of spiritual well-being emerges with inner life levels ≥ 4.29 and with coherent interaction levels ≥ 0.8 .

Furthermore, the study revealed that measuring synchronized heart data during several days among participants is possible, but did not

show a significant change in heart coherence. As such, the study could not provide evidence that heart coherence could be considered as an indicator of spiritual leadership. However, results indicate a measurable variation and synchronization of heart coherence among participants during a craniosacral therapy session. A similar approach could be used in different healthcare settings.

This study contributes to the literature of spiritual leadership in several ways. First, it applies a fuzzy set QCA approach to spiritual leadership theory. A similar approach could be applied to existing data (of other spiritual leadership theory studies) to explore these and alternative conditions for the emergence of spiritual well-being and other outcomes, such as organizational performance. It also stimulates a different discourse by looking through this methodological lens. Next, it provides a definition of coherent interaction – not examined before in spiritual leadership – and an initial target level that can be challenged in future research.

In addition, for studies in craniosacral therapy, this study shows that heart coherence is influenced in many different ways at the same time during a treatment session. Foremost, it suggests that heart coherence does play a role in the entrainment process and most likely it depends on the role the person fulfills (i.e., therapist or client). Future research could take into account the role of each participant in a similar study. Other research could verify whether people with higher levels of heart coherence are able to tune into rhythms easier or not. Alternatively, research could capture the necessary data during a different activity or training, e.g., residential team building.

This experimental research design can be refined in several ways. One way is to recruit earlier in the process which gives the researcher the possibility to work with a multiple base line for one or more measures, such as personal spiritual leadership and inner life. Collecting data of specific measures at the end of each training day might give insights into the evolution of that measure. Assigning the role of client or practitioner to each participant beforehand is another way to refine this design. Finally, the QCA approach enables the researcher to easily add other measures to be evaluated as additional conditions.

Authors contribution

All research done by author.

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Declaration of Competing Interest

The study was conducted in collaboration with the Peirsman Cranio Sacraal Academie (PSCA) in The Netherlands and with IMEC, a Belgian non-profit R&D organization specialized in nanoelectronics and digital technologies, who provided the heart sensors and support in processing the data from the sensors. These partners had no control over the conduct of the study.

The author declares that there is no competing interest the publication of this manuscript. This research was part of the author's doctoral program at the University of Antwerp, Belgium.

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Data availability

All data necessary to produce the results in this article can be obtained from the author on request.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.eujim.2021.101329.

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