

## HRV Regulation by Calligraphic Finger Writing and Guqin Music: A Pilot Case Study

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### Abstract

**Introduction.** Previous research shows that brush Chinese calligraphy handwriting (CCH) improves one's cognitive functions as well as emotional and mental health. Similarly, Guqin, the popular Chinese musical instrument, induces positive emotions and emotional stability. The present study tested the efficacy of using the index finger to achieve similar mind–body changes. **Methods.** We employed a heart rate variability (HRV) Calligraphy–Guqin biofeedback intervention that was implemented with a Zephyr HxM Bluetooth chest heart rate monitoring device and an Android smartphone. A web-based HRV big database app stored the data from three consecutive sessions: (1) 5 min of Guqin music listening; (2) 5 min of CCH finger writing of calligraphy; and (3) again 5 min of Guqin music listening. The second session was designed to explore additive effects of the finger-writing task. One subject participated with the index finger employed for the writing task. **Results.** The results showed that the first and third Guqin sessions elicited 55% and 68% HRV coherences, respectively, while the CCH finger writing in the second session elicited 31% of high HRV coherence. The increase in HRV coherence between the two Guqin sessions was attributed to the calligraphy finger writing training effect. The practice of finger writing contributed to increased HRV regulation through heightened attention and concentration.

**Keywords:** calligraphy; finger writing; Guqin music; emotion; HRV biofeedback; rehabilitation

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### Introduction

#### Background

Research in Chinese calligraphy handwriting (CCH) has produced interesting and highly significant findings in the nature, processing, and outcomes of the practice of Chinese script. It is established that the processing of Chinese characters exerts positive and beneficial effects on one's perceptual, cognitive, and brain activities during handwriting. The contributing factors relate to the interactions between the character's visual-spatial properties and its associated cognitive and neural activities of the practitioner (Kao, Lam, & Kao, 2018). Sustained practice of Chinese character writing has the function of perceptual and cognitive activation and has been

shown to contribute to functional plasticity in the human cerebral cortex.

Previous studies have also discovered that the cingulate cortex is involved in the process of visual stimulus, premotor planning, and memory operations, which are vital in CCH training. The finding of a smaller cingulate gyrus volume (CGV) in the CCH groups suggested that long-term CCH practice may reshape the brain structure by increasing the efficiency of neural activity (Chen, Chen, He, Wang, & Wang, 2016). Recent neuroimaging research also finds that CCH practitioners show better neural functions of updating and inhibition. The CCH group also shows stronger resting-state functional connectivity than the control group in the brain areas

involved in updating and inhibition. These outcomes suggest that long-term CCH training may be associated with improvements in specific aspects of the executive functions and the strengthened neural networks in related brain regions (Chen et al., 2017). At a deeper level of analysis, when processing the visual-spatial configurations of Chinese characters at the cortical level, the act of writing can initiate and facilitate cognitive activities and functions of related cortical substrates (Kao et al., 2018; Xu, Kao, Zhang, Lam, & Wang, 2013).

### The Theory

A conceptual framework has been advanced to account for the character's roles and practical impact on handwriting within a dynamic behavioral cybernetic system (Kao, 2006, 2010). Handwriting consists of three main components in the writing of script: the hand, the writing instrument, and the paper or surface of writing material. The theory of handwriting operation and skills training has its conceptual origin in the context of a cybernetic system of perception and motor performance (Kao & Smith, 1969; Smith & Smith, 1962, p. 341). The writing of script and the tool used during handwriting result in different forms of feedback: reactive feedback from the hand itself, instrumental feedback from the action of the writing instrument, and operational feedback from the resulting handwriting traces on the paper or writing surface (Smith, 1961; Smith & Smith, 1962; Smith & Smith, 1988). Moreover, skill learning such as handwriting occurs as a result of motor control mechanisms interfacing the motor displacements relative to the spatiotemporal coherence between mind–body movements and its instrumental sensory feedbacks during the task. This displacement control process is mediated by neuronal detector mechanisms (Smith & Smith, 1988) as well as a full spectrum of behavioral feedback mechanisms (Kao, 2000) underlying the writing motions with the characters.

The theoretical bases for calligraphy writing by brush are threefold (Kao, 2000; Zhu et al., 2014). First is the sensory feedback: the individual receives sensory feedback from the graphic record while practicing calligraphy. Second is the bioemotional feedback: the calligraphy involves the movement of the arms and the body as the guide to regulate their movements. Finally, the cognitive feedback: the subjective experiences of heightened attention, alertness, and quickened responses during the writing acts (Xu et al., 2013; Zhu et al., 2014). Our past research has been guided by these measures of brush handwriting.

As for the crucial role of the Chinese characters as the materials in brush handwriting, we have followed

a set of psychogeometric which states that characters with Gestalt and topological properties such as balance, closure, orientation, connectivity, etc. are space-structured, easily recognized, and speedily processed. The visual facilitating effect of each single property on processing the characters is formed upon the practitioner's response to the visual-spatial structure of Chinese characters or English letters that are relative to the practitioner's body and hand movements, taking place in the course of the writing tasks (Kao, 1999).

### The Applications

The positive effects of CCH practice at the fundamental behavioral level have included identified enhancements in one's attention and concentration, physical relaxation, and emotional stabilization, among others. Specifically, effective outcomes with CCH intervention have been obtained in a variety of disease and clinical applications as well as behavioral changes. These include significant results of (1) patients of strokes in palm strength of the affected hand and increased response facilitation in fine motor coordination (Chiu, Kao, & Ho, 2002); (2) the awakening of a coma patient after stroke with significantly enhanced focusing, alertness, visual scan and span, and quickened visual and motor responses (Kao, Lam, & Kao, 2018); and (3) Alzheimer's disease patients showing significant improvement in short-term memory tasks and verbal ability (Kao, 2010).

In addition, other clinical areas of CCH treatment include (1) Chinese cancer (nasopharyngeal carcinoma) patients with CCH training who demonstrated gradually lowered systolic blood pressure and respiration rate at pre- and posttreatment measures as the intervention proceeded, as well as elevated level of concentration and reduced mood disturbance (Yang, Li, Hong, & Kao, 2010); (2) our CCH training of post-earthquake PTSD children, which led to significant decrease in hyperarousal symptoms and salivary cortisol levels among the child survivors (Zhu et al., 2014); and (3) that CCH training plus Wenlafaxine drugs, which yielded better effects in treating patients of anxiety disorder that were measured by the Hamilton Anxiety Scale (HAMA), Self-Rating Anxiety Scale (SAS), and Clinical Global Impression (CGI) Scale (Dong, Jia, Wang, Cui, & Zhang, 2006). These results provide encouraging evidence on the strength of CCH intervention toward reducing certain neuropsychiatric symptoms and conditions (Chu, Huang, & Ouyang, 2018; Wagner, 2018).

The above studies and findings have all been conducted using the traditional Chinese brush as the

exclusive writing instrument. It is interesting to explore whether a shift to a newer and different writing instrument would yield the same or similar research outcomes. The purpose of the present study was to test this notion by resorting to the use of a finger for writing. This idea is significant in view of the current surge of interest and development of touch-screen writing technologies in the cyber age of innovation.

We designed this pilot study (1) to analyze finger writing as an efficacious writing tool, (2) to test its contributions to health enhancement, and (3) to examine its writing effectiveness on a new surface platform of a smartphone.

### **Finger Writing: The New Instrument**

Research results have suggested that repetitive movements on a smooth touchscreen reshape sensory processing from the hand and the thumb. It is proposed that cortical sensory processing in the brain is continuously shaped by the use of personal digital technology (Gindrat, Chyiris, Balerna, Rouiller, & Ghosh, 2015). Recent results indicate that a combination of motor training with mirrored visual feedback (MVF) therapy can induce significant neuroplasticity changes through multisensory integration. The findings of this finger movement therapy lend support to the application of finger calligraphy writing for inducing cortex plasticity in the course of treatment (Kumru et al., 2016). We have made initial attempts to develop finger writing as a new mode for calligraphy therapy. Pilot studies have included using finger writing with a tablet computer for calligraphy writing in treating an Alzheimer's patient as well as a coma patient (Kao, Lam, & Kao, 2018).

This initial experience prompted our interest in exploring finger writing in connection with a new smartphone platform with a touch-screen surface for handwriting. The present study is the first test of the efficacy of handwriting in a handheld mobile smartphone and represents a new tactile-motor feedback-based finger writing system.

### **The Guqin Music**

The Guqin (Chinese zither), also known as a seven-stringed Qin, is the most ancient plucked instrument of China with a history of over 3,000 years. It was a prerequisite subject for the ancient scholar, as well as an art for personal development and cultural cultivation in ancient China (Fung & Wang, 2011; Wang, 2006, p. 60).

Along with calligraphy training as a therapeutic system, Guqin has also been promoted recently as a method of relaxation therapy (Lam, Kao, & Fung, 2012; Yeh, 1991) and shown to be capable of

inducing a state of psychological quiescence that improves symptoms of insomnia (Fung & Wang, 2011). Guqin music was adopted in this study as a complementary intervention along with the act of finger writing characters.

### **The HRV Coherence**

The rhythm of a healthy heart—even under resting conditions—is actually irregular, with the time interval between consecutive heartbeats constantly changing, which is known as Inter-Bit-Interval (IBI) changes. The naturally occurring beat-to-beat variation in heart rate is called heart rate variability (HRV). Any generation of sustained positive emotions facilitates a body-wide shift to a specific, scientifically measurable state, which is termed psychophysiological coherence because it is characterized by increased order and harmony in both our psychological (mental and emotional) and physiological (bodily) processes. Psychophysiological coherence is a state of optimal function, which generates increased mental clarity and improved cognitive function. Simply stated, as our body and brain work better, we feel better, and we perform better herein (McCraty, Atkinson, Tomasino, & Bradley, 2009).

### **HRV and Behavior**

A review of literature suggests that heart rate oscillations can enhance emotion by entraining brain rhythms in ways that enhance regulatory brain networks. Because blood flow timing helps determine brain network structure and function, slow oscillations in heart rate have the potential to strengthen brain network dynamics, especially in medial prefrontal regulatory regions that are particularly sensitive to physiological oscillations. It supports that individuals with high HRV tend to have better emotional well-being than those with low HRV (Mather & Thayer, 2018). In addition, HRV is impacted by stress (Kim, Cheon, Bai, Lee, & Koo, 2018) and associated with level of anxiety (Chalmers, Quintana, Abbott, & Kemp, 2014). These studies provide a glimpse of the applications of HRV relative to emotion, stress and anxiety, and other disorders.

### **Inter-Bit-Interval (IBI) and CCH**

We have investigated some psychophysiological changes on the part of the CCH practitioner. Results showed a consecutive reduction in heart rate for the first 10 s during brush handwriting. This indicates that a significant increase in IBI means that the HRV is measured in the time domain (Kao, Lam, Guo, & Shek, 1984; Kao, Lam, Robinson, & Yen, 1989). Based on these findings we believe that the state of HRV coherence could be regulated as an index (Appelhans & Luecken, 2006) of the effects that are

induced by the Guqin listening as well as by finger-writing intervention in this study.

We introduce the smartphone in this study as an advanced alternative practice with calligraphy finger writing and Guqin music listening, forming a new system of HRV regulation for cognitive neural interventions.

### Aims of the Study

1. To investigate the complementary roles and effects of calligraphy training and Guqin listening in HRV regulation through using a smartphone as an active HRV biofeedback platform.
2. To develop the HRV regulation function of finger writing using a smartphone. It is expected that calligraphic finger writing can promote the effects of Guqin music listening with meditation toward a deeper and positive level of mind–body harmony (HRV coherence).

### Materials and Methods

#### Participant

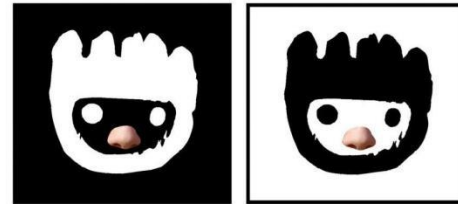
The case study subject was a 56-year-old male with treated hypertension and no history of psychiatric disorders or decline in cognitive functions. The trials were conducted in the home environment.

#### Selection of Guqin Music and Writing Protocols

In the first and third sessions, 5 min of Guqin music are selected from Li Xiangting's Guqin album "Heart".

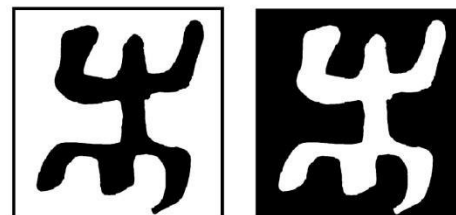
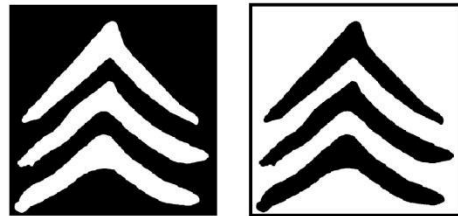
In the second session of 5 min of calligraphic finger writing, calligraphy graphic characters are selected from a newly developed "iPad calligraphy: fingering writing psychotherapy" design (Kao & Lam, 2011).

### Finger Writing Materials: The Graphic Characters

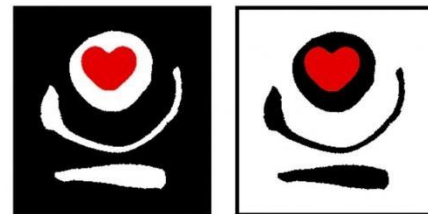


*Patterning the Breath*

*XY Kao and Henry Kao 2009*



*The Healing Characters*



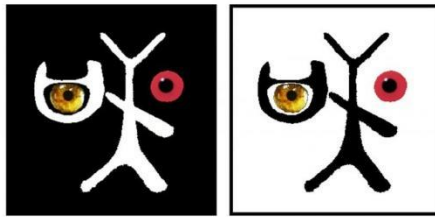
*Resting Emotions*

*Henry Kao and XY Kao 2009*

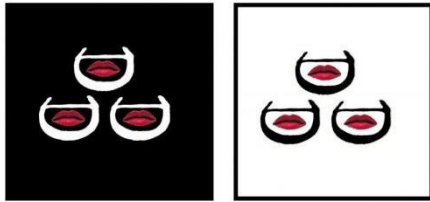


*Steady Hand*

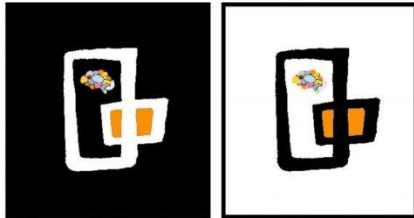
*Henry Kao 2009*



*Perceptive Eyes*  
Henry Kao-2009



*A Taste of Art*  
Henry Kao and Tintin Kao 2009



*Active Mind*  
Henry Kao and XY Kao-2009

### "Calligraphy–Guqin" HRV Biofeedback Design

"Calligraphy–Guqin" HRV is a system based on the "Biofeedback-based System of Calligraphy Therapy" (Lam & Kao, 2007) which was invented by our team and shown at the Innovation Expo 07 in Hong Kong in 2007; the Zephyr HxM Bluetooth chest heart rate monitoring device; the HTC EVO 3D Android smartphone; and the Heart-Love HRV Android app, an HRV Internet big database that is used to analyze and store the data collected from three 5-min sessions for HRV regulation.

An HTC EVO 3D Android smartphone in Figure 1 is used for Guqin music playback and the ongoing finger writing of the participant.

The Zephyr HxM Bluetooth chest heart rate monitoring device is set up for the participant, as illustrated in Figure 2.

1. First session: 5 min of meditation with Guqin music listening. See Figure 3.
2. Second session: 5 min of calligraphic finger writing intervention. See Figure 4.
3. Third session: 5 min of meditation with Guqin music listening. See Figure 5.

Instant analysis of recorded HRV through Internet cloud big databases as a remote and mobile healthcare platform is shown in Figure 6.

Improved process outcomes that regulate HRV coherence after intervention and the HRV are graphically displayed in Figure 7, while the HRV coherence for the control trial is graphically displayed in Figure 8.

### The Procedure

The design of this 15-min protocol of meditation with Guqin music listening and calligraphic finger writing intervention for HRV regulation is tested with a single trial case study to evaluate the efficacy of both the new protocol and the finger writing as an instrument for CCH therapy.

The HRV coherence app is installed, the Guqin music is recorded, and the graphic characters are all stored in the smartphone in advance of the display of Guqin music and the graphic characters in a predefined sequence. The conventional equipment setup and procedures are followed. Refer to separate descriptions under the respective figures.



**Figure 1.** The HTC EVO 3D Android smartphone.

Before wearing the Zephyr HxM Bluetooth chest heart rate monitoring device: (1) clip the Zephyr monitor to the chest strap, (2) put on the chest strap around the chest as shown in Figures 1 and 2, and (3) the Zephyr monitoring device will be turned on automatically. Note: In order to ensure a good connection, it might be necessary to sprinkle a small amount of water on the fabric sensors before wearing. The monitoring device is then paired with the HTC EVO 3D Android smartphone. The audio output of the smartphone is connected to a surround sound receiver for playback of the Guqin music and also for the tone for biofeedback of the Heart-Love's HRV coherence Android app.



**Figure 2.** The Zephyr Bluetooth chest heart rate monitoring device and setup illustration.

The subject sits comfortably in an armchair, turns on the smartphone, the monitoring device, and the surround sound receiver. For the first session (see Figure 3), initiate playback of the Guqin music and the HRV coherence app, pay attention, and enjoy the Guqin music; the higher tone for biofeedback will change as a higher HRV coherence is reached.



**Figure 3.** The first session: 5 min of meditation with Guqin music listening.

Save the HRV coherence result after 5 min of the first session of Guqin music listening. Then, proceed to the second session (see Figure 4), display the first graphic character, initiate the HRV coherence app, and then start tracing the graphic character with the index finger on the touch screen; the higher tone for biofeedback will change as a higher HRV coherence is reached.

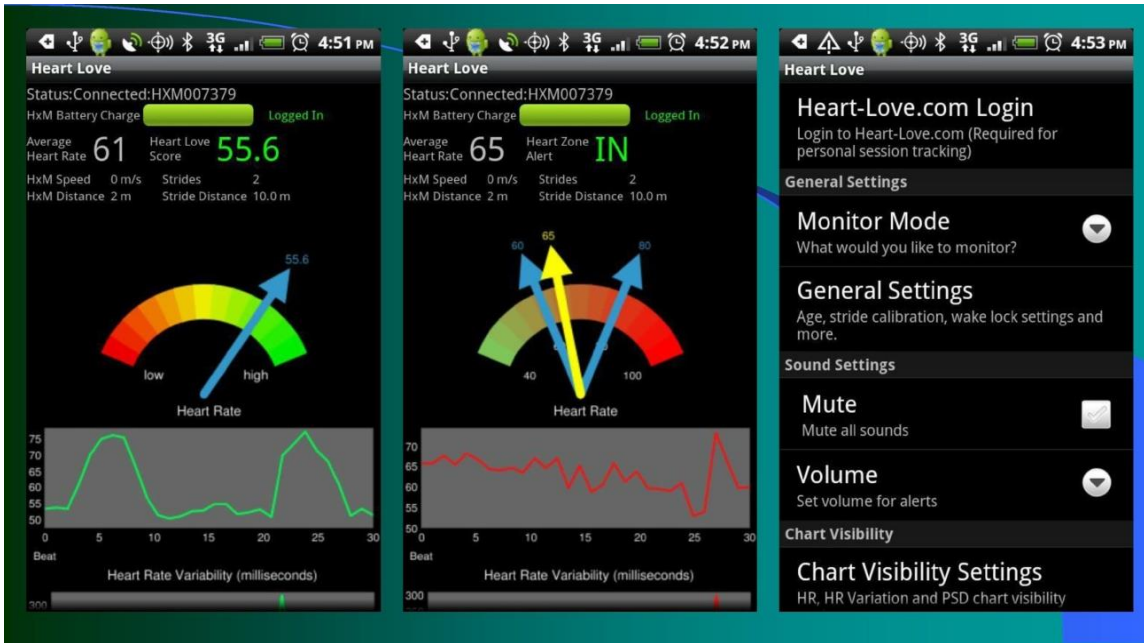


**Figure 4.** The second session: 5 min of calligraphic finger writing on the touch screen of an HTC smartphone.

After completing the first graphic character, display the second graphic character for tracing and so on for 5 min of the second session. Save the HRV coherence result after 5 min of the second session of CCH finger writing. Then, proceed to the third session as the procedure of the first session (see Figure 5). Save the HRV coherence result after 5 min of the third session of Guqin music listening. The three sessions of intervention are then completed.



**Figure 5.** The third session: 5 min of meditation with Guqin music listening.

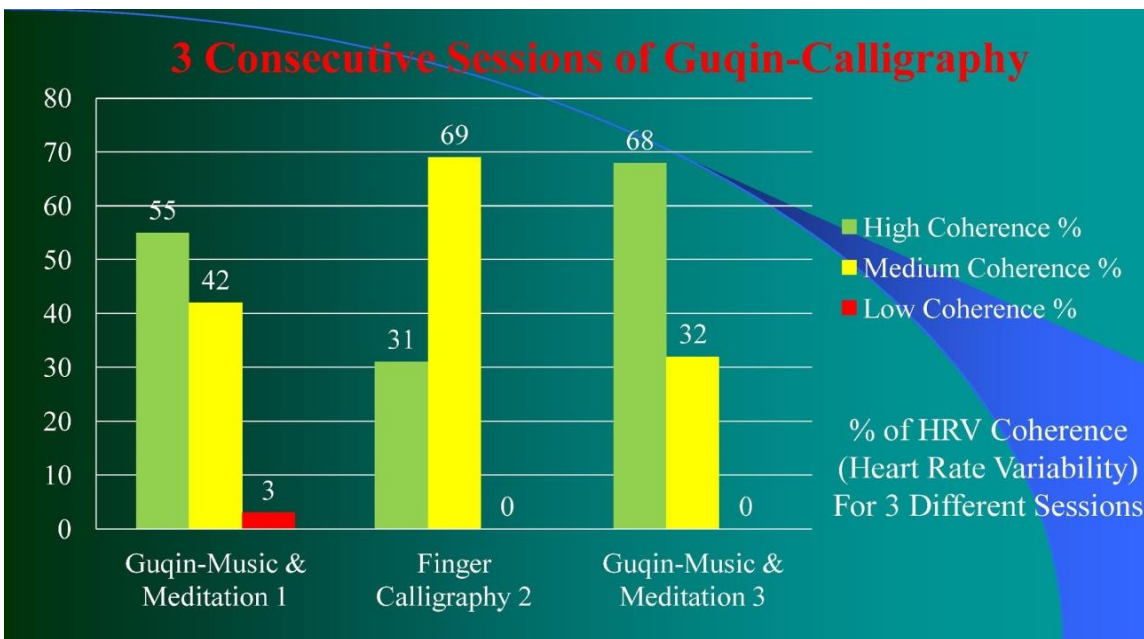


**Figure 6.** HRV graphic data icons on smartphone showing instant analysis of Internet big databases as remote and mobile healthcare platform.

**Results & Discussion**

The results of the percentage of HRV coherence of the three sessions of the saved test trial and control trial in the cloud database are plotted with Microsoft Excel in Figures 7 and 8, respectively.

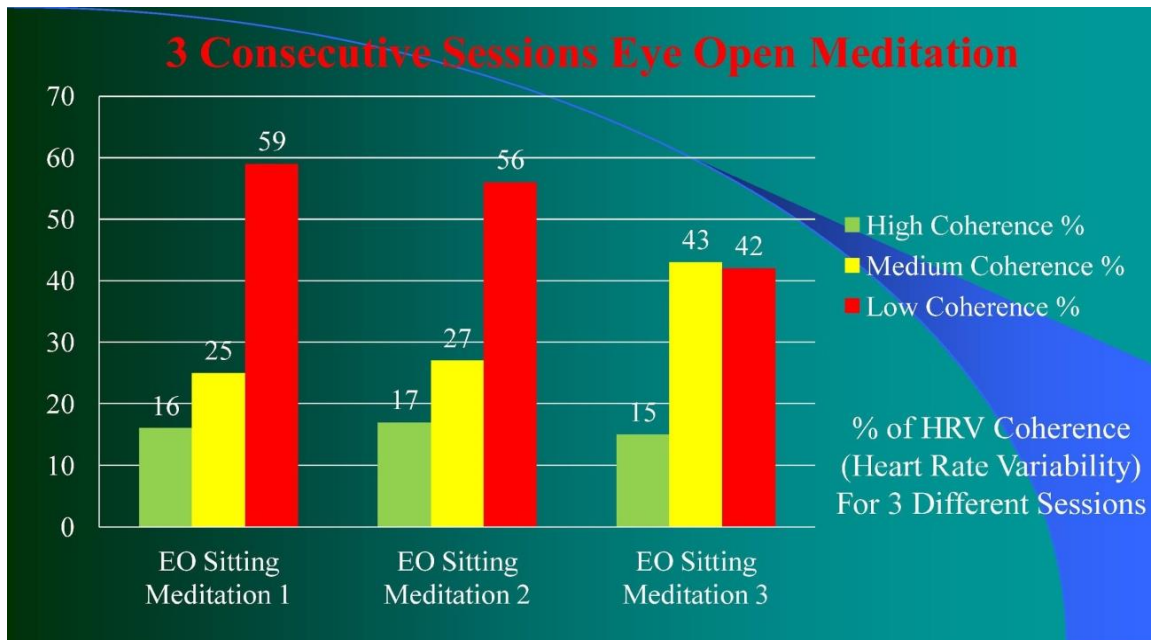
The video version of the biofeedback trial of application of the calligraphic finger writing and Guqin music listening process can be viewed online from YouTube (<https://youtu.be/eyr6ziNHHyw>).



**Figure 7.** HRV results plotted for three different sessions of Guqin music listening and finger writing.

Results in Figure 7 demonstrated that after the calligraphic finger writing intervention, the first and third sessions of meditation with Guqin music listening elicited 55% and 68% of high HRV coherence respectively, while the second session of calligraphic finger writing elicited 31% of high HRV coherence. This indicated a preliminary observation that calligraphic finger writing and Guqin music listening both improved one's HRV regulation, and

that this effect could mean a shortening of intervention duration as well as a potential application of both for treatment and rehabilitation with the use of a smartphone or a handheld tablet computer. It is noted that previous research on Guqin music listening for insomnia treatment elicited also a marginal significance ( $p = .055$ ) of HRV coherence after intervention (Fung, Han, & Lee, 2014; Fung, Kao, Lam, & Kao, 2019).



**Figure 8.** HRV results plotted for three consecutive sessions of eyes-open sitting meditation.

Results in Figure 8 showed that, as a control trial with three consecutive sessions of eyes-open sitting meditation, the first, second, and third eyes-open meditation sessions only elicited 16%, 17%, and 15% of high HRV coherence respectively with little differentiation. This demonstrated that, in Figure 7, the high HRV coherence result in the third session of Guqin music listening is solely due to the intervention effect of calligraphic finger writing. We believe that this practice contributed to increased HRV regulation from 55% to 68% of high HRV coherence through an increase in attention and concentration that are associated with the practice of calligraphic finger writing.

The third session of meditation with Guqin music listening has confirmatory data not only on the positive effect of Guqin music listening in the literature alone but also suggestive of an additive value of accompanying calligraphic finger writing during the process of dual factor intervention. This would suggest the likely value of combined treatment

system for behavioral intervention. A first implementation in this direction has seen a recent investigation of applying combined Guqin music and calligraphy in the successful treatment of symptoms of primary insomnia. The results have shown this joint intervention being effective in promoting heart rate coherence as well as optimum brain functions (Fung, Kao, et al., 2019).

In line with previous studies in which HRV is positively associated with stress decrease (Chalmers et al., 2014; Kim et al., 2018), anxiety reduction (Dong et al., 2006) as well as PTSD hyperarousal decrease (Zhu et al., 2014) reviewed in previous sections, we believe that the significant increase in high HRV coherence induced by calligraphic finger writing on the touch screen of the smartphone plus Guqin music listening can exert a curative and effective treatment for the emotional conditions of stress and anxiety.

The HRV and Emotion theory and research support the utility of HRV as a noninvasive, objective index of



the brain's ability to organize regulated emotional responses through the autonomic nervous system (ANS) and as a marker of individual differences in emotion regulatory capacity (Appelhans & Luecken, 2006) and the reviewed findings suggest that heart rate oscillations can regulate emotion by entraining brain rhythms in medial prefrontal regulatory regions. It supports that individuals with high HRV tend to have better emotional well-being than those with low HRV (Mather & Thayer, 2018). On the basis of such observations, we speculate that high HRV coherence induced by calligraphic finger writing on the touch screen of a smartphone plus Guqin music listening may also be able to regulate emotions.

This preliminary case study has provided valuable findings toward further development of systematic application of finger writing together with the smartphone toward a curative and effective platform of behavioral treatment. We conclude that Guqin music and calligraphic finger writing contributes to inducing the harmonious effect of "mind and body" coherence and emotional relaxation. Further testing and validation of the present system are warranted for broader clinical applications in the areas of brain health and treatment of neuropsychiatric diseases.

### Conclusion

This new, shortened 15-min protocol is designed in order to adapt to the busy style of modern life by using a smartphone to store and playback the graphic characters and Guqin music which can be completed either at home, school, or at work. The whole treatment protocol is automated using the smartphone in guiding the practitioner to work through the intervention processes with a light handheld indoor or outdoor calligraphy and Guqin finger writing intervention platform which may be limited to effective treatment for the emotional conditions of stress and anxiety.

Calligraphy treatment usually completes a psychotherapy intervention process with a 3-min sitting meditation—30 to 45 minutes of calligraphy handwriting intervention followed by 3 min of sitting meditation. Because calligraphy is written with a brush as the main tool, it requires a place and a relatively quiet environment, together with a longer intervention program that takes about 45 to 60 minutes including preparation work (Kao et al., 1984). To apply as a clinical trial in the future, a design of different graphic characters to target specific neuropsychiatric diseases (Chu, Huang, & Ouyang, 2018) with 30 to 45 minutes intensive treatment is required for calligraphy and Guqin finger writing.

For future development, cloud database is to connect to upload trials, and view Sessions, Goals and Achievement scores. Daily Coherence Ratio, Achievement Totals and Community Achievement Scores may be all visible to the clients and may also be visible to an assigned and authorized clinical therapist for coaching.

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### Author Disclosure

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