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PSYCHOPHYSIOLOGICAL CHANGES ASSOCIATED WITH CHINESE CALLIGRAPHY

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The present study attempted to extend the general findings of a reduction in physiological activity accompanying the writing of Chinese calligraphy. The first experiment investigated the effects of language experience, stimulus configuration and different writing instruments on heart rate (HR) and digital pulse amplitude (DPA). The second and third experiments examined the differential effects of stylistic variations of Chinese orthography on, respectively, adult's and children's HR and DPA, and normal's and schizophrenic's HR, DPA and blood pressure.

The results showed a reduction in HR during the commencement and progression of handwriting with a greater reduction during brush writing than felt pen writing. This was found for Chinese and non-Chinese subjects writing all three types of stimulus configurations, thus extending the effects of handwriting on HR reduction beyond ethnic and linguistic boundaries. The HR reduction was also found for adults and children and there was a trend for different stylistic variations of Chinese orthography to be differentially associated with cardiac activity in the adults and children. Finally, there was a HR reduction and DPA increase for normal and schizophrenic subjects during writing and resting periods. The implications of the writing of Chinese calligraphy leading to a relaxed physiological state were discussed.

1. INTRODUCTION

Recently a greater effort has been devoted to research on the effects of handwriting on physiological conditions and on identifying the psychophysiological components involved in handwriting. In particular, attention has focused on exploring the psychophysiological changes associated with the writing of Chinese calligraphy. Chinese calligraphy (*shu-fa*) has historically been believed to be able to induce a state of mental harmony, peacefulness, and equanimity to the practitioner. Yue Yong Hing, a famous Chinese scholar, said that 'when you want to write, you should withdraw your visual or auditory attention to outside stimuli, stop all your thoughts and concentrate, and make yourself as calm as possible; then you can understand the truth of handwriting.' Reflecting the traditional Chinese concept of mind and body which stresses a holistic integration of the two for the betterment of health and personal development, the act of Chinese calligraphy is believed to be capable of helping a person to reach a state of mental as well as physical harmony and tranquility.

From a psychological point of view, writing involves perceptual processes like visual pattern recognition of the characters and other cognitive/psycho-motor processes like coordination of the sequential movements. Certain factors distinguish the writing of Chinese calligraphy from the writing of English material. Firstly, owing to the differences in character size, and the thickness of strokes and variations in stroke formation, an effective and well-coordinated adjustment of sensori-motor movements of the fingers, wrist, arm and shoulder is essential for good brush writing. Secondly, control over other bodily functions (e.g. respiratory rate) is also needed to minimize disturbance of the writing movements. The motor control in writing calligraphy is further complicated by the pliability of the brush tip — slight deviation from the correct movement would lead to a much more serious error than using an ordinary pen. Thirdly, due to these factors, it is necessary that intensive attentional control be exercised during Chinese calligraphic writing, in order for motor control to be effectively executed. In fact, a rudimentary principle emphasized in the practice of calligraphic writing is to reduce both environmental and personal disturbances to a minimum. Furthermore, the exercising of such a high level of attentional involvement might, in certain respects, lead to or be reflected by certain activities of an individual's physiological system since it is widely believed that there is a two-way interaction between an individual's physiological state and complex motor movements. Ohkuho and Hamley,[1] for example, obtained measures of heart rate (HR) while individuals learned to drive a car (a complex motor performance requiring intense attentional involvement) and depicted a marked decrease in HR during both resting and driving periods. In addition, Kao, Lam and Shek[2] showed an HR deceleration during Chinese calligraphic writing, with the magnitude of deceleration varying according to the mode of handwriting control. Thus, these HR changes may possibly indicate different degrees of attentional allocation, which would then suggest that different degrees of attention are necessary during different modes of handwriting control. It is possible that such intensive attentional engagement and self-monitoring of physiological activities during Chinese calligraphic writing might possibly lead to a state of relaxation comparable to transcendental meditation (TM). In a review of articles, Dillbeck and Orme-Johnson[3] found that the research evidence indicated reduced somatic arousal during the TM technique compared with rest while other physiological changes simultaneously indicated increased alertness. It was thus suggested that the practice of TM leads to a 'restful alertness' state rather than only arousal reduction. Furthermore, there were extreme reductions in somatic arousal during periods of 'pure consciousness' (defined as an experience of consciousness without the activity of thought).[3]

A series of studies has provided the first scientific evidence of such a relaxed state as reflected by the indices of HR, respiration, blood pressure (BP), etc.[4,5,6] A general trend is found for these bodily functions which slow down as a function of the calligraphic writing act. For example, research on HR shows HR deceleration during the writing of Chinese calligraphy, indicating that relaxation or calmness develops, thus supporting the widely-held belief that the process of 'breath regulation possibly leads to the relaxed state'.[2,5,6] The results of research on HR and Chinese calligraphic writing have been summarized by Kao[5] as follows: (a) gradual beat-by-beat HR deceleration during the performance of calligraphic writing; (b) fluctuations in HR during the resting condition with a gradual beat-by-beat HR deceleration and regular HR during the process of calligraphic writing; and (c) long or short durations of calligraphy experience creating no special effects on the phenomenon of HR reduction.

Similarly, research on respiration shows that the respiration pattern during the writing of Chinese calligraphy differs from that of normal resting respiration. Kao and Shek[6] and Kao[5] found during Chinese calligraphic writing a per-cycle reduction in both the respiratory time and the interval between inhalation and exhalation and an increase in the ratio between inhalation and exhalation, when compared to normal respiration. This suggested that in order for the motor coordination in calligraphic writing to be executed smoothly, a voluntary control of patterns of respiration is practiced.

With respect to BP, there is evidence illustrating a trend toward lower BP while writing Chinese calligraphy[5]; however, further verification is needed. Kao[5] has found the BP level during the process of writing to be significantly lower than that at the short intervals between writing acts indicating that attention has a direct influence on BP.

Thus, in view of the above research, and our continuing effort to search and establish the components of handwriting behavior, the present study aimed at answering three major questions. It attempted to investigate the various physiological activities (HR and digital pulse amplitude (DPA)) of the writer during calligraphic writing associated (a) with different types of pen, namely brush and felt pen, and in different conditions, namely resting and writing of different forms of stimulus; (b) with children in comparison with those found for adults in previous studies; and (c) with schizophrenic subjects as compared with normal subjects found previously. Three experiments were conducted. Experiment 1 investigated the effects of language experience, stimulus configuration and different writing instruments on physiological activities. Experiments 2 and 3 examined the differential effects of stylistic variations of Chinese orthography on, respectively, adult's and children's physiological activities, and normal's and schizophrenic's physiological activities.

2. EXPERIMENT 1

2.1. Psychophysiological Changes Associated with Graphonomic Acts: Drawing, Calligraphy and Handwriting

This experiment was concerned with the effects of two different types of pen (brush and felt pen) and three different forms of stimulus (English words, Chinese characters, and geometric figures) on physiological activity, as measured by HR and DPA. The two types of pen were included to reflect different amounts of control; using a brush demands more motor control than a felt pen as a slight deviation from the correct movement results in a more serious mistake, as well as more control over other bodily functions (e.g. HR) to minimize disturbance of the writing movements. Furthermore, three types of stimulus were used to examine if the relationship between physiological activity and handwriting extends beyond linguistic boundaries.

Previous studies have illustrated a drop in HR and respiration as brush writing commences.[4,5] It has been suggested that as brush writing is a highly controlled motor-movement, the body will try to remain at a quiescent state as much as possible, such as by regulating the rate and depth of respiration, in order to avoid disturbances to writing. The inference from the general drop in physiological arousal during writing is that the writing state resembles that of relaxed wakefulness. Hence, it was expected in the present study that the writing of English words, Chinese words, and geometric figures would be associated with a relaxation effect. Thus, the physiological arousal level, as measured by HR and DPA, would be lower during writing than during normal resting.

Lacey, Kagan, Lacey and Moss[7] have distinguished between tasks involving attention to the external environment (e.g. instructions to note and detect external events) and tasks involving rejection of environmental inputs (e.g. mental concentration). They found that situations demanding sustained attentiveness to external stimuli are associated with cardiac deceleration whereas situations demanding mental concentration are associated with cardiac acceleration.

Furthermore, Lacey and Lacey[8] stress the importance of cardiac receptors in information processing. They postulated a mechanism which involves feedback from cardiac activity on cortical functioning such that a fall in HR and BP reduces the tonic inhibitory influence of the baroreceptors on the central nervous system (CNS) activity. As a result, this process prepares the organism for the intake of sensory stimuli. It is assumed that cardiac activity is related to cortical functioning through a negative afferent feedback mechanism (baroreceptor theory). This indicates that the frequency of impulses along visceral afferent feedback pathways (which is negative and inhibitory of motor behavior) from the baroreceptors of structures (e.g. carotid sinus) are determined by increases of BP and HR. This feedback loop provides input to the CNS, which should lead to a further drop in HR. Thus, the baroreceptor theory explains the bradycardia of attention. HR activity is viewed by Lacey and Lacey[8] as a 'psychological functional physiological variable'[9] in which HR activities regulate the attentional behavior involved. Thus, there is a close relationship between cardiac activities and information processing such that HR deceleration is the cause of attention. However, Obrist, Webb, Sutterer and Howard[10,11] base their theory on a somewhat different premise stating that HR change (especially HR deceleration) is a result of the psychological change taking place in the organism. According to their 'cardiac-somatic hypothesis' or 'somatic-cardiac coupling theory', HR changes are best understood as peripheral manifestation of some central processes that have already taken place. Thus, they suggest cardiac deceleration represents a 'somatic quieting' or 'motor inhibition' with a drop in metabolic requirements. Thus, consistent with Lacey *et al*,[7] they emphasize a close relationship between cardiac activities and information processing (especially attention); however, unlike Lacey *et al.*[7]; HR deceleration is viewed as the *result* of attention, and not the *cause* of attention. Owing to the pliability of the brush tip, more tight and precise control in hand movements is necessary for an exact trace of the words in brush writing. Therefore, looking from the viewpoint that the act of writing constitutes a negative feedback loop which helps maintain the quiescence of the body, it was expected that the feedback resulting from brush writing would be more efficient and exhibit lower physiological activity than during felt pen writing, which requires a far lesser degree of motor control.

2.2. Method

2.2.1. Subjects

A total of 20 subjects was used in this experiment. Five male and five female undergraduate students at the University of Hong Kong were recruited as Chinese-English bilingual subjects. The English monolinguals consisted of five non-Chinese males and five non-Chinese females. All were non-experienced in Chinese calligraphy and, with the exception of one non-Chinese female, all were right-handed. The mean ages of the two groups were 21.5 (SD = 11.05) for the bilingual group and 26.7 (SD = 18.61) for the English monolingual group.

2.2.2. *Apparatus and Recording Techniques*

Cardiac activities were measured by the EKG amplifier of the SLE-8 Micropore Tape, No. 2246.25) were used, with one placed on the sternum at the level of the second intercostal space and the other placed over the sixth rib on the anterior axillary line, (Modified Lead II Configuration). DPA was recorded via a photosensitive detector and emitting device attached to the tip of the middle finger of the subject's left hand (with the exception of the one left-handed non-Chinese female, in whose case it was attached to the right hand).

All measurements were taken throughout the experiment including the resting periods, and were shown immediately by an SLE-8 polygraph while simultaneously being recorded by the Hewlett Packard 3968A Instrumentation FM Tape Recorder. The portion of the signals required for analysis was digitized via the Lab-Master laboratory system with an IBM PCXT, and the digitized signals were sent to the server of the 3-Com Ethernet simultaneously. An IBM PCAT was used for signal analysis and manipulation. Reduced data were further arranged in a proper format and sent to the UNIVAC mainframe for statistical analysis via an RS-232 communication link.

2.2.3. *Stimulus Words and Writing Tasks*

The set of stimuli consisted of three sheets of paper with one containing five arbitrarily chosen Chinese words (馬 , 國 , 美 , 定 , 家) written in the Clerical Style of Chinese calligraphy, one including five English words matched to the meaning of the Chinese words (horse, nation, beau, stable, and family) and one containing five geometric figures (). Each of the Chinese characters and geometric figures was about 6cm × 6cm in size while each of the English words was about 11cm × 3 1/2cm. All Chinese and English stimuli were similar in meaning and stroke thickness. Brush writing tasks were done with a large-size brush on a special type of rice paper for Chinese calligraphy. For felt pen writing, a 'Pen Touch' 5mm felt pen and tracing paper were used. The stimulus sheet was placed under the paper and the stimuli were traced from left to right and from top to bottom.

2.2.4. *Experimental Design and Procedure*

The study included five independent variables consisting of three within-subject factors and two between-subject factors. The within-subject factors included type of stimulus (geometric figures, English words and Chinese words), type of pen (brush and felt pen), and second (ten one-second intervals). The between-subject factors were language experience (either Chinese-English bilinguals or English monolinguals) and sex (males and females). The order of presentation of stimuli was randomized for the subjects.

Each subject sat quietly in front of the writing table, where the purpose and procedure of the experiment were explained. Prior to the start of the investigation baseline recordings were made during a three-minute open-eye resting period followed by a three-minute closed-eye resting period. During these periods the subject was asked to relax and remain calm, as much as was possible. Then the three sheets each containing one type of stimuli were presented one by one in randomized order and the subject traced the five stimuli of each sheet with both a brush and felt pen — half of the subjects started with a brush while the other half started with a felt pen. After tracing each word or figure on the sheet the subject had to pause for about ten seconds to await instructions to begin the next word or figure. About three minutes elapsed between presentations of each stimulus sheet. Subjects were told to complete the whole word or figure before stopping or ink-dipping. After all of the stimuli had been traced with both the brush and felt pen, post-writing measurements were recorded in a similar manner to pre-writing measurements with the exception of closed-eye measurement which preceded open-eye measurement in the post-writing session.

For each subject, the brush was washed and cleaned before the experiment. For cardiac measures, the skin was cleaned before the placement of the electrodes. There was one experimenter throughout the experiment for the purpose of time-keeping, instruction-giving and the preparation of writing materials.

2.2.5. *Data Quantification and Analysis*

The changes of heartbeat were scored by the average reciprocal HR, that is, by the weighted (weighted according to the proportion of the second taken up by each individual interbeat interval (IBI)) average of all the intervals between heart beats within a one-second interval (average IBI).[12] The average of the two seconds of heartbeats immediately prior to writing each stimulus word or figure was used as the baseline to compare with the change in average heartbeat (average heartbeat is defined as the average heartbeat within one second for ten successive seconds) during writing of each stimulus word or figure. The subject's mean change in average heartbeat from these two seconds prior to writing each word or figure was then compared with those changes associated with writing each of the 15 stimulus words or figures. The difference between the mean changes in average heartbeat during the two seconds of pre-stimulus heartbeats and the average IBI of each of the average heartbeats (differential HR)[13] in the writing condition provided the data used in the statistical analysis.

In a similar manner, DPA was scored by the weighted average of the peak amplitude of pulses within a one-second interval. The average of the two seconds of peak amplitudes immediately prior to the start of each stimulus word or figure was used as the baseline to examine the amplitude during the writing of each stimulus within one-second for ten successive seconds. The subject's mean amplitude for these two seconds of amplitudes prior to the writing of each word or figure was then compared with those mean amplitudes associated with his writing of each of the 15 stimulus words or figures. The difference between the mean amplitudes in the two seconds pre-stimulus digital pulses and the mean amplitudes of each second of the writing of stimulus digital pulses in the writing condition was the basis of statistical analysis.

2.3. Results

The data were analyzed by ANOVAs using a conservative estimate of degrees of freedom.

In order to inspect the average HR over ten successive intervals, a four-way ANOVA was done with Language Experience (Chinese-English bilinguals and English monolinguals), Sex (male and female), Condition (pre-writing eye-open (EO); pre-writing eye-closed (EC); brush, Chinese words (BC); brush, English words (BE); brush, geometric figures (BF); felt, Chinese words (FC); felt, English words (FE); felt, geometric figures (FF); post-writing eye-closed (MC); post-writing eye-open (MO)), and Second (ten one-second intervals) taken as the independent variables. (It is a common practice and conceptually simpler to use seconds as an independent variable).[14] The results showed a significant effect of Condition ($F(1,16) = 9.013$, $p<0.01$). The mean number of beats associated with each of the conditions is shown in Fig. 1.

Graphic inspection of the data shows that the average IBI is greatest for the BF, BC and BE conditions followed by FC, FE, MC, FF, EC, EO and MO conditions, suggesting not only that writing is generally associated with a lower HR than the resting conditions, but also that brush writing produces less cardiac

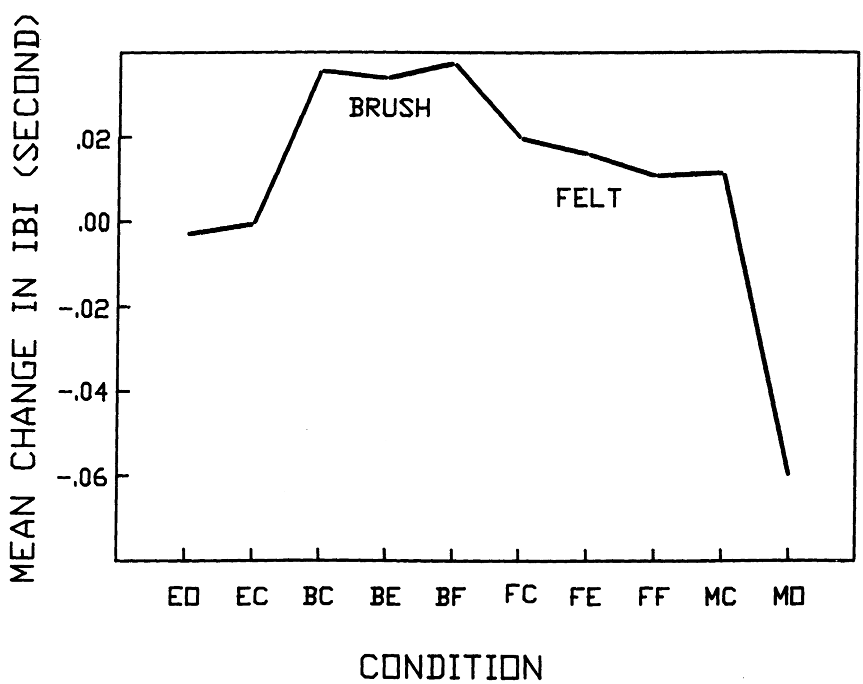

Fig. 1. Mean changes in IBI for all subjects under all 10 different experimental conditions.

activity than felt pen writing. The results also showed a significant effect for Second (lin) ($F(1,16) = 13.671, p<0.01$). The mean number of beats associated with each of the ten one-second intervals is presented in Fig. 2.

Graphic examination of the data reveals that the average IBI during writing (averaging Condition for each of the ten one-second intervals) increases for the first eight seconds after which it levels off for the remaining two seconds, suggesting the effects of attention. Thus, consistent with what was predicted, as writing commences there is less cardiac activity (as indexed by average IBI) and further, writing with a brush leads to less cardiac activity than writing with a felt pen. This suggests firstly that writing is associated with a relaxation effect (at a physiological level), and secondly, due to the far greater degree of control required in brush writing than felt pen writing, the negative feedback loop[8] resulting from brush writing is more efficient and produces lower physiological activity than during felt pen writing. No other significant main effects or interactions were revealed in the ANOVA.

Analysis of DPA using a four-way ANOVA with Language Experience, Sex,

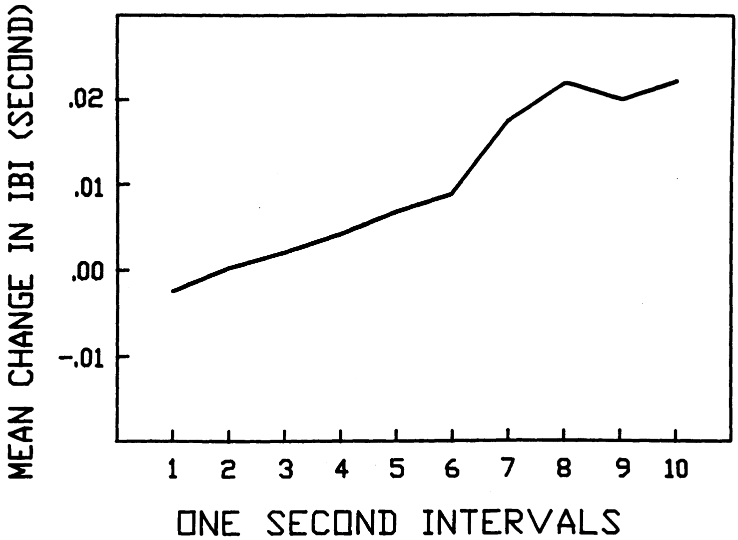

Fig. 2. Mean changes in IBI for all subjects under all experimental conditions in the first 10 successive one-second intervals following the onset of the writing task.

Condition, and Second as the main factors, was performed in order to investigate the change in DPA over a ten-second period. A significant main effect for Second (quad) ($F(1,16) = 6.690, p<0.05$) was revealed, which is illustrated in Fig. 3.

It can be seen in Fig. 3 that, inconsistent with results obtained from average IBI data, the average number of amplitudes during writing (averaging Condition for each of the ten one-second intervals) decreases for the first five seconds whereafter it tends to rise marginally, indicating lower DPA (and hence greater arousal) as the writing commences and higher DPA (thus lower arousal) as writing progresses. No other significant main or interaction effects were found.

2.4. Discussion

The results showed that HR is deceleratory as soon as writing commences and continues to decelerate for the first few seconds whereafter it levels off at a higher level than the pre-writing resting conditions. This finding is in line with other studies investigating the psychophysiological effects of Chinese calligraphic writing, which have found an HR deceleration during the writing of

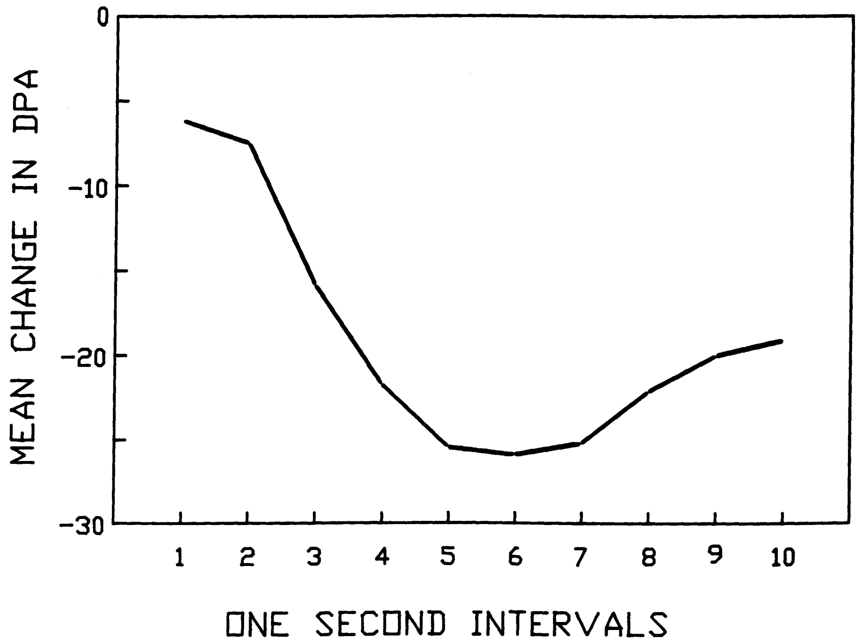

Fig. 3. Mean changes in DPA for all subjects under all experimental conditions in the first 10 successive one-second intervals following the onset of the writing task.

Chinese calligraphy.[2] Thus, the data are consistent with the view that relaxation or calmness develops during Chinese calligraphic writing. The results also indicated lower physiological arousal, as indexed by cardiac measures, during brush writing rather than felt pen writing. According to Lacey and Lacey,[15] heart autorhythmicity is modified by both neural and hormonal factors on the efferent path but in the reverse direction; sensitive inter-receptors feed back to the CNS information about HR. This feedback loop provides an input to the CNS which would lead to a further drop in HR. Thus, it is suggested that due to the pliability of the brush tip, which requires more precise and tight control in hand movements, the loop resulting from brush writing is more efficient as is exhibited in lower cardiac activity during brush writing than felt pen writing.

Contrary to our expectation, the findings from DPA analysis indicated that DPA decreased when writing commenced (thus showing higher arousal) although it marginally increased toward the middle of the first ten seconds as writing progressed. Although these findings appear inconsistent with Kao's[5] finding of a decrease in BP while writing Chinese calligraphy, on closer examination it is actually consistent with his findings. He found a significantly lower pulse rate for experienced calligraphers during writing as compared to resting periods; however, for novices the opposite trend was found, with a higher pulse rate during writing than during the resting periods. According to Kao, calligraphers with long calligraphy experience would have their BP level obviously lower than that of the novices. In a similar line, previous research has shown that BP can be controlled voluntarily to a certain extent. Dicara and Miller[16] for example, found that external feedback and operant reinforcement can elicit systolic BP modifications. Similarly, Shapiro, Tursky and Schwartz[17] found that within a single session of 25 trials the distolic BP for a group reinforced for pressure increases showed a marked positive margin over another group reinforced for pressure decreases. All of this suggests that decreases in BP may not be manifested in short-term writing but rather BP is a physiological state which requires some voluntary control and experience in order to achieve the necessary reduction required for the high level of attentional involvement necessary for successful writing, especially Chinese calligraphic writing. This may explain why DPA is lower for the commencement of writing in the present study. The subjects may be unfamiliar, or not very familiar, with the attentional involvement necessary for writing and have no experience in voluntarily controlling DPA. Perhaps after a few seconds the subjects realise the attentional involvement necessary for writing and subsequently exert more voluntary control over regulation of DPA. However, owing to the limited amount of research that has been done on the relationship between DPA and writing, it is suggested that further research be conducted.

Finally, the findings of reduced HR for both Chinese and non-Chinese subjects writing English words, Chinese characters and geometric figures, extend the effect of handwriting on HR reduction beyond ethnic and linguistic boundaries. Apparently, the difference between Chinese and English languages, and the meaninglessness of stimulus patterns as in the geometric figures, and the languages used are not significantly important to have resulted in any marked effect on the writing tasks.

3. EXPERIMENT 2

3.1. Psychophysiological Changes Associated with Children's Writing of Chinese Calligraphy: The Effects of Character Stroke Forms

Given the general findings on HR deceleration associated with calligraphic writing obtained from adults,[4,5] it was considered of interest to investigate (a) the writing of Chinese calligraphy by primary school children; and (b) the effect of different stimulus patterns on their psychophysiological reactions to this writing performance. Specifically, the psychophysiological measures of HR as measured by IBI, and DPA were recorded while the children traced three designs, namely the detailed, global, and skeletal styles of Chinese character stroke formation. These three writing styles require different perceptual variations. The global style is characterized by closure in which the lines are thin and form a hollow character. The detailed style has characters with solid firm strokes which are square, polyangular and straight. The skeletal style also has characters which are square, polyangular and straight, however the lines are more simplistic being thin and of equal thickness. The stylistic variations of Chinese calligraphy as exemplified in these three styles of calligraphy provide variations of structure, stroke independence, angular displacements, inter-stroke spatial relationships and perceptual complexity.

3.2. Method

3.2.1. Subjects

There was a total of 10 subjects in the present experiment. Five were primary school children between 10 and 12 years old who attended weekly calligraphy lessons at school. Three were females and two were males. The remaining five were university undergraduate students and teaching assistants between 19 and 32 years old. Three were females and two were males. All 10 subjects were right-handed.

3.2.2. Stimulus Words and Material

The set of stimuli consisted of two arbitrarily chosen Chinese characters: 母 (Mother), and 羊 (Goat). Both characters were presented in three styles (detailed, global, and skeletal) representing the three styles of Chinese calligraphic writing taught in schools (see Fig. 4). Each character, presented in each style, appeared 5 times in a vertical column on a single sheet of paper. Hence, the children as well as the adults were asked to reproduce, in total, 30 characters, tracing them from top to bottom using a large writing brush. The size of each character was about 4 cm × 4 cm.

3.2.3. Experimental Design

The study consisted of three within-subject factors and one between-subject factor. The within-subject factors were: writing style (global, detailed and

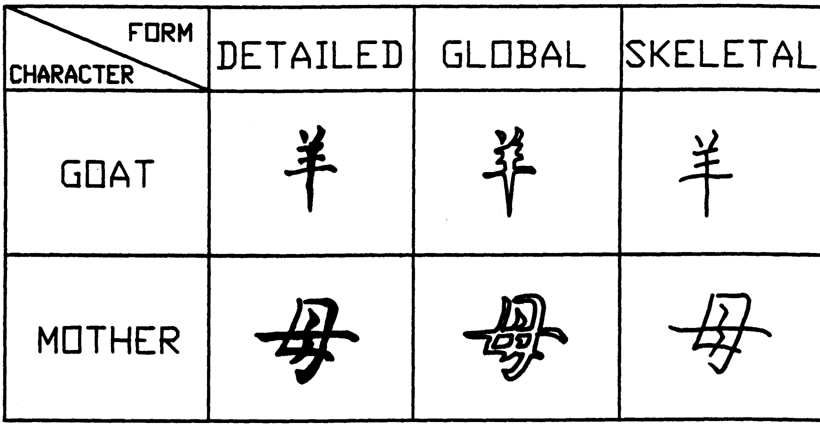

Fig. 4. Two Chinese characters, each with 3 styles of stroke formation used as the writing tasks.

skeletal), character (goat, mother), and second (ten one-second intervals). The between-subject factor was age (child and adult).

The procedure and data methods of analyses were similar to those in Experiment 1, except that cardiac and digital pulse activities were measured by an Oxford Ambulatory Monitoring System, Model Medilog 4-24 Recorder and recorded signals were converted via an Oxford PMD-12 Display System onto the Hewlett Packard 3968A Instrumentation FM Tape Recorder.

3.3. Results

The data were analyzed by ANOVAs using a conservative estimate of degrees of freedom.

The HR data were first analyzed by a three-way ANOVA with Age Group (adult, child), Condition (mother, detailed; mother, global; mother, skeletal; goat, detailed; goat, global; goat, skeletal; pre-writing eye-open; pre-writing eye-closed; post-writing eye-open; post-writing eye-closed), and Second (ten one-second intervals)[14] as the main factors. The results showed a significant main effect for Second (lin) ($F(1,8) = 5.410$, $p<0.05$) which is graphically presented in Fig. 5.

As seen in Fig. 5, the average IBI during writing (averaging Condition for each of the ten one-second intervals) increased for the ten seconds, indicating less cardiac activity. This indicates that as writing begins and progresses there is a reduction in HR suggesting that writing is associated with a relaxation effect (at

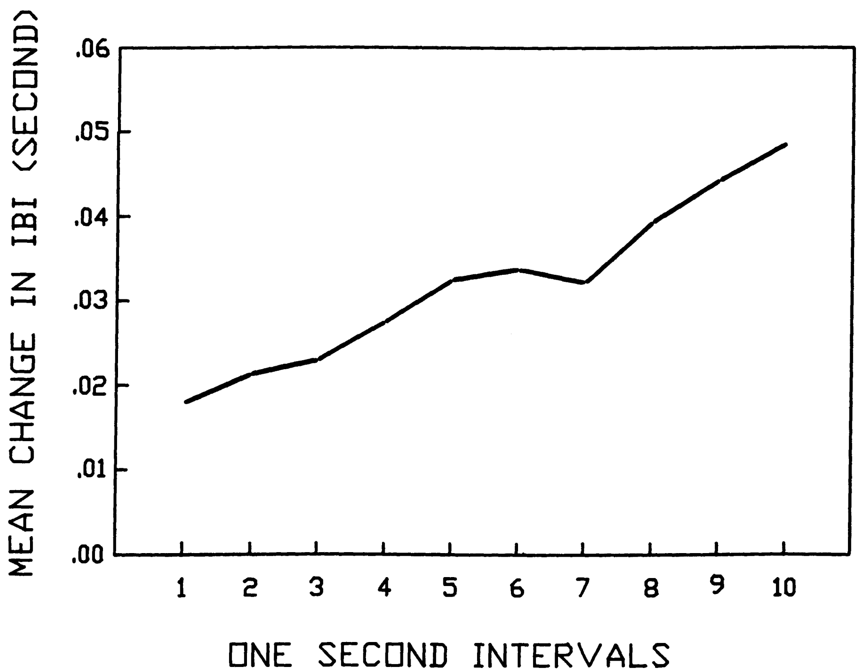

Fig. 5. Mean changes in IBI for all subjects under all experimental conditions in the first 10 successive one-second intervals following the onset of the writing task.

a physiological level). There were no other significant main or interaction effects.

In order to compare the mean IBI in the pre- and post-writing resting periods and eye-open and eye-closed conditions, a four-way ANOVA was done. The main factors were: Age Group, Second, Resting (pre-writing, post-writing), and Eye State (eye-open, eye-closed). There was a marginally significant main effect for Resting ($F(1,8) = 5.146, p = 0.053$) with a mean IBI for pre-writing resting period of 0.0082 second/beat per one second, increasing to 0.03 second/beat per one second for the post-writing resting period. This suggests that after the writing has concluded there is a lower HR than before writing, illustrating the possibility of a more relaxed physiological state after writing. There were no further significant main or interaction effects.

Analysis of the mean IBI for the three writing styles (excluding the pre- and post-writing resting periods) and two characters was done by a four-way ANOVA. The four independent variables were Age Group, Character (goat, mother), Writing Style (detailed, global, skeletal), and Second. There was a marginally significant interaction effect for Writing Style × Age Group ($F(1,8) = 3.277$, $p = 0.064$). The mean IBI for the two groups and the three writing styles is shown in Fig. 6.

Although only marginally significant, examination of Fig. 6 shows interesting results. The detailed and skeletal styles of writing tend to be associated with a much higher average IBI for adults whereas for children, they are associated with a much lower average IBI, indicating that these two styles of writing may be associated with a decreased HR for adults but an increased HR for children. Planned comparisons using Tukey(a) Test showed a significant difference ($p<0.05$) between the adults and children in the skeletal style of writing. No other significant main or interaction effects were found.

Analysis of DPA was first done using a three-way ANOVA with Age Group, Condition, and Second as the main factors. Consistent with the HR data, a significant main effect was found for Second (lin) ($F(1,8) = 7.096$, $p<0.05$). The change in DPA over a ten-second period is shown in Fig. 7.

As seen in Fig. 7, for the first four seconds the change in DPA decreases (indicating greater arousal). However, it then sharply increases and continues to

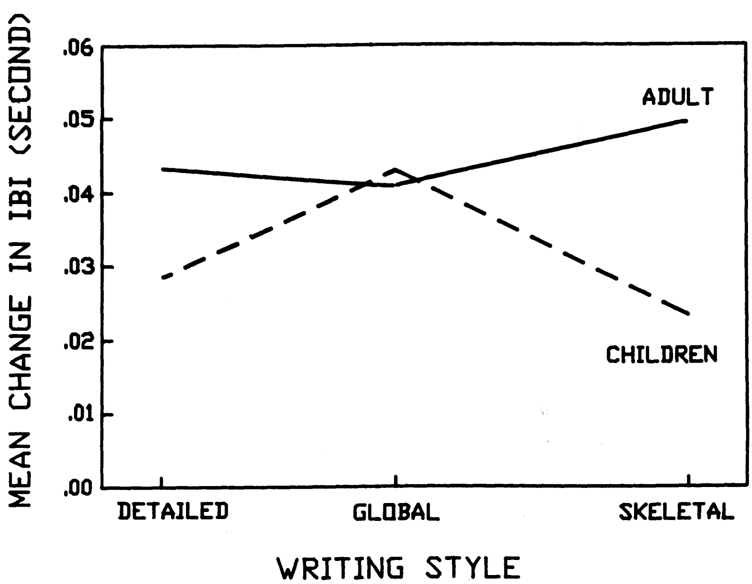

Fig. 6. Interaction of mean changes of IBI for adults and children writing 2 characters in 3 styles of character stroke formation.

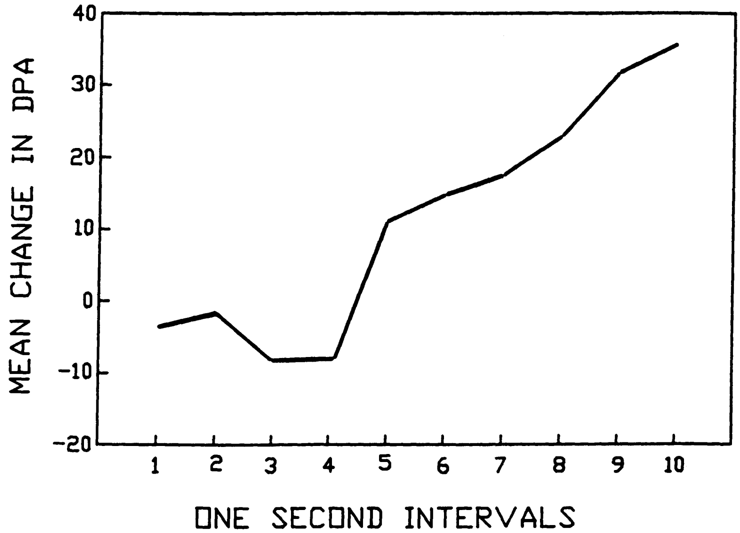

Fig. 7. Mean changes in DPA for all subjects under all experimental conditions in the first 10 successive one-second intervals following the onset of the writing task.

increase to the end of the writing session. As with cardiac activity, there is reduced arousal level, as indexed by heightened DPA, as writing progresses. No other significant main or interaction effects were found.

Separate analyses were then performed on the children's and adult's data alone. Two two-way ANOVAs measuring IBI and DPA were done for both the children's data alone and the adult's data alone with Condition and Second as the main factors. The ANOVAs revealed no significant main or interaction effects for either the children's or the adult's data. To examine the changes in the mean IBI and DPA for the different writing styles and characters, two three-way ANOVAs were done with Character, Writing Style, and Second as the main factors. With respect to mean IBI for the children's data alone, a general trend was found for mean IBI to be differentially associated with Writing Style. The mean IBI changes associated with the three styles of writing are illustrated in Fig. 8.

Figure 8 shows that the global writing style produced a much greater increase in mean IBI than the skeletal and detailed styles of writing, suggesting lower cardiac arousal for this writing style. Planned comparisons of the means using Tukey(a) Test showed only a significant difference ($p<0.05$) between the global and skeletal writing styles. There were no other significant main effects or interactions in either ANOVA.

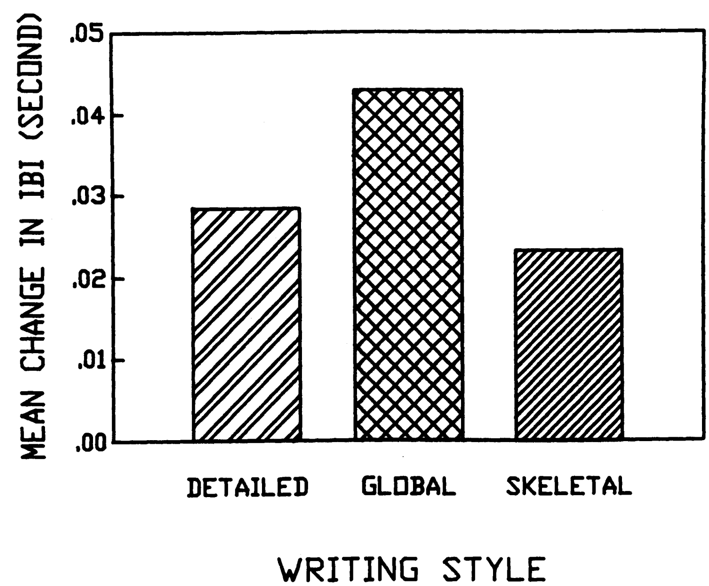

Fig. 8. Mean changes in IBI for children's writing of 2 characters in 3 styles of character stroke formation.

3.4. Discussion

The results for children and adults combined data show that there is a significant reduction in HR and an increase in DPA as the writing of Chinese calligraphy progresses. The data are in line with Kao's[5] finding of a gradual beat-by-beat HR deceleration during the performance of calligraphic writing with the fluctuations in HR during the resting condition tending to become regular as the writing progresses. In addition, Kao found the BP level during writing to be significantly lower than that at the short intervals between the writing of each stimulus, illustrating that the concentration behavior may have an influence on BP.

The finding of no significant reduction in HR or increase in DPA during writing for the children alone or the adults alone is contrary to expectations. This may be due to the small number of subjects used in the two groups and it is suggested that future studies investigating this area should employ a larger sample size.

The finding of a trend for the three styles of stroke formation of the Chinese characters, the detailed, global and skeletal, to be differentially associated with cardiac activity indicated that for adults the detailed and the skeletal writing styles were associated with a greater reduction in HR than the global writing style, whereas for children the global writing style was associated with a greater reduction in HR than the detailed and skeletal writing styles. Furthermore, there was a significant difference between cardiac activity in the skeletal style of writing; for adults there was a reduction in HR whereas for children there was an increase in HR. The findings from the data on the children alone also indicated a significant difference between the global and skeletal writing styles, with a more reduced HR for the global style than the skeletal style of writing. These findings suggest that the perceptual variations in the three visual stimulus patterns for the writing task may have been sufficiently large to have affected the HR changes for the adults and children. This indicates that writing may involve perceptual processes: visual pattern recognition of the characters, as well as cognitive/psycho-motor processes coordinating the sequential movements.

The trend in the present experiment for HR deceleration in the three styles of stroke formation of the Chinese characters studied may be regarded, according to Lacey *et al.'s*[7] baroreceptor theory which states that attention to the environment is accompanied by cardiac deceleration, as the effects of attention. Thus it can be inferred from the HR data that different degrees of attention are involved in these styles of stroke formation of the characters. A similar line of reasoning is found in the 'cardiac-somatic coupling theory'[10,11] which asserts that HR changes are best understood as a peripheral manifestation of some central processes that have already taken place. Cardiac deceleration is thus viewed as representing 'somatic-quieting' or 'motor inhibition' with a drop in metabolic requirements. It is thus suggested that HR deceleration in these writing styles can be regarded as an indication of attention, and these HR changes might indicate the differential allocation of attentional resources to the organism.

The finding that children have a lower HR than adults during the global writing style whereas adults have a lower HR than children during the writing of detailed and skeletal writing styles can be further explained as the results of attention as suggested by Chen.[18,19] He states that a primitive and general function of the visual system may be the perception of global topological invariants such as closure. Similarly, Treisman[20] found that closure is detected prematurely and appears to be the most complex property that pops out pre-attentively. Thus, the children in the present study may devote more attention to the global writing style as the closure properties automatically pop out for them. Hence, the lower reduction in HR may be due to primitive and general preattentive visual pattern recognition (perceptual processes) with simultaneous coordination of sequential movements (cognitive/psycho-motor processes). As adults have more exposure to everyday perceptual experiences they are more likely to further process the visually processed information based on their intuitive experiences, resulting in greater attention to skeletal and detailed writing styles and the corresponding HR deceleration. It should be emphasized, however, that the above results were only marginally significant and due to the small sample size; further confirmatory testing is needed before any substantial conclusions can be drawn.

As the present study was an exploratory investigation of the psychophysiological changes accompanying children's writing of Chinese calligraphy of different stimulus patterns, it is suggested that future research in this area should be carried out.

4. EXPERIMENT 3

4.1. Psychophysiological Changes Associated with the Writing of Chinese Calligraphy: The Case of Schizophrenic Patients

Previous investigation of the psychophysiological changes associated with the writing of Chinese calligraphy has indicated that HR, BP and respiration decelerate during the act of Chinese calligraphy.[5] This experiment attempted to extend these general findings by investigating the possibility of developing Chinese calligraphic writing as a potential therapeutic technique for the purpose of generating a relaxed and tranquil physiological state in the treatment of mental patients. The psychophysiological measures of HR variation (as measured by IBI) and DPA were collected from nine chronic schizophrenic patients and nine normal subjects to reflect the effect of Chinese calligraphic writing on the subjects. In addition, BP was measured using pulse transit time (PTT). Previous research suggests that BP is a physiological state which requires some voluntary control,[16,17] thus, a BP reduction accompanying Chinese calligraphic writing would necessitate a high level of attentional involvement.[5] As schizophrenia is considered a disorder of attention,[21] and as the writing of Chinese calligraphy involves attentional involvement, it was considered of interest to examine if Chinese calligraphic writing would demand enough attention to affect not only HR and DPA, but also BP. This would have implications regarding using Chinese calligraphic writing as a means to improve schizophrenics' attentional defects.

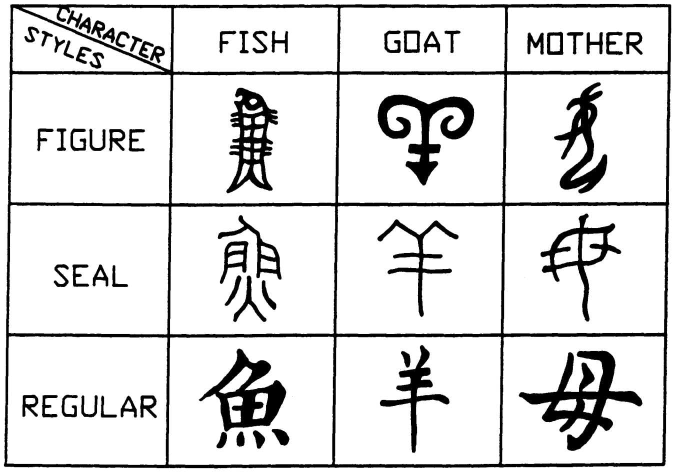

Fig. 9. The stimulus characters each with 3 styles of stroke formation used as the writing tasks.

4.2. Method

4.2.1. Subjects

There was a total of 18 right-handed subjects used in the experiment. Nine were normal males between 19 and 57 years old who were undergraduate students or teaching staff of the National Chengchi University, Taipei. The nine chronic schizophrenic patients were from a large psychiatric hospital in Kaoshiung, Taiwan and were males between 26 and 40 years old with a period of hospitalization from 2 to 8 years.

4.2.2. Stimulus Words and Materials

The set of stimuli consisted of three arbitrarily chosen Chinese characters: 母 (mother), 魚 (fish), and 羊 (goat). Each character was presented in three styles: ancient images (figure), bone characters (seal), and regular style characters (regular) (see Fig. 9). These three styles reflect three stages of development in Chinese writing, from the primitive and graphic figure style to the more detailed and refined regular style presently used today. Each character, presented in each style, appeared five times in a vertical column on a single sheet of paper. Hence, the normals as well as the schizophrenics were asked to reproduce, in total, 45 characters, tracing them from top to bottom using a large brush. Each character was about 4 cm × 4 cm in size.

4.2.3. *Experimental Design*

The study consisted of three within-subject factors and one between-subject factor. The within-subject factors were: writing style (seal, figure, regular), character (goat, mother, fish), and second (ten one-second intervals). The between-subject factor was mental group (schizophrenic, normal).

The procedure and data quantification analyses were similar to those in Experiment 2. In addition, PTT was analyzed by taking the distance in time between the peak of the heartbeat and the peak amplitude of the DPA.[22] It was the basis of computing BP changes during the writing act.

4.3. Results

The data were analyzed by ANOVAs using a conservative estimate of degrees of freedom.

In order to examine the average IBI, DPA and PTT within each of the ten one-second intervals, the data for all 18 subjects were first analyzed by three three-way ANOVAs. The following were the three main factors: Mental Group (schizophrenic, normal); Condition (fish, figure (FF); fish, seal (FS); fish, regular (FR); mother, figure (NF); mother, seal (NS); mother, regular (NR); goat, figure (GF); goat, seal (GS); goat, regular (GR); pre-writing eye-open (EO); pre-writing eye- closed (EC); post-writing eye-open (MO); and post-writing eye-closed (MC)); and Second (ten one-second intervals).[14] With respect to average IBI, the results showed a significant main effect for Second (lin) ($F(1,16) = 10.99, p<0.01$). The average HR over ten successive seconds (with Condition and Mental Group averaged for each of the ten one-second intervals) is presented in Fig. 10.

Inspection of Fig. 10 shows that as writing and resting progress the average IBI increases for the ten seconds (thus indicating less cardiac activity). There was also, for DPA, a significant main effect for Second (lin) ($F(1,16) = 5.619$, $p<0.05$) (averaging Mental Group and Condition for each of the ten one-second intervals). The change in DPA over a ten-second period is illustrated in Fig. 11.

Consistent with the HR data, Fig. 11 reveals that DPA increases (thus indicating lower arousal) as the writing and resting periods progress.

Although no significant main effect was found for Mental Group there was a trend for the schizophrenic subjects' HR to decelerate more than the normal subjects'. Analysis of the PTT data did, however, reveal a significant main effect for Mental Group ($F(1,16) = 7.108$, $p<0.05$). The schizophrenic's BP was significantly lower (as indicated by the increased PTT) than the normals' BP.

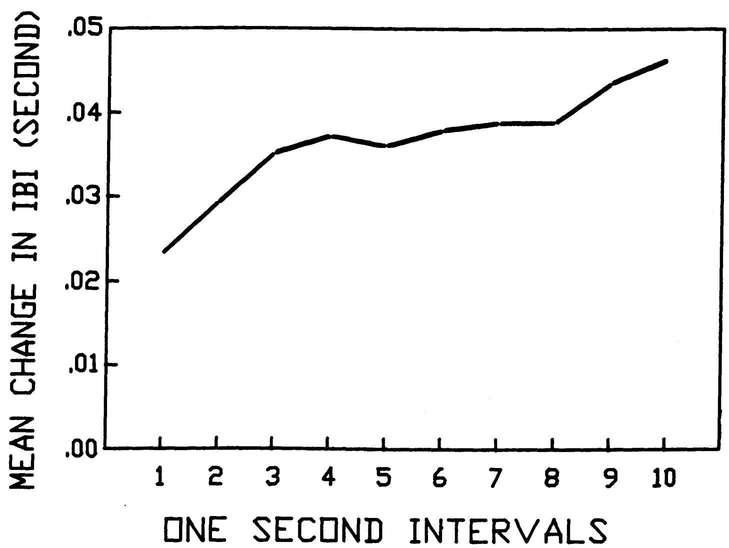

Fig. 10. Mean changes in IBI for all subjects under all experimental conditions in the first 10 successive one-second intervals following the onset of the writing task

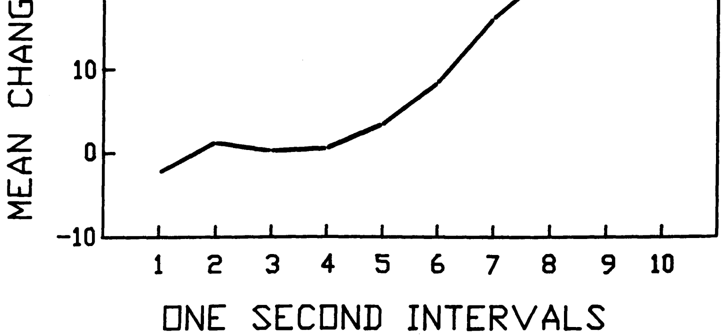

Fig. 11. Mean changes in DPA for all subjects under all experimental conditions in the first 10 successive one-second intervals following the onset of the writing task.

The results from these two ANOVAs on HR and BP indicate lower arousal for the schizophrenic than the normal subjects. There were no other significant main or interaction effects in any of the three ANOVAs.

In analyzing the differences in HR, DPA and BP between the pre-writing and post-writing resting periods, three four-way ANOVAs were done with Resting State (pre-writing resting period, post-writing resting period), Eye State (open, closed), Second, and Mental Group as the main factors. The ANOVA analyzing the HR data revealed a significant main effect for Second (lin) ($F(1,16) = 9.18$, $p<0.01$). The change in mean IBI for the resting periods (with Resting State, Eye State and Mental Group averaged for each of the ten one-second intervals) is illustrated in Fig. 12.

Inspection of Fig. 12 reveals that average IBI increases from the first to the tenth second of the resting period indicating a reduction in HR as the resting period progresses. The analysis of the DPA data indicated a significant main effect for Second (lin) ($F(1,16) = 5.92$, $p<0.05$) (averaging Eye State, Resting State and Mental Group for each of the ten one-second intervals) which is shown in Fig. 13.

Examination of Fig. 13 reveals that the change in DPA over a ten-second period increases, thus indicating that consistent with the HR data, arousal, as measured by DPA, decreases as the resting period progresses. There were no other significant main or interaction effects in any of the three ANOVAs.

Three further three-way ANOVAs were performed with Mental Group, Eye State Condition (EO, EC, MC, MO) and Second as the main factors. With respect to HR, a significant main effect was found for Second (lin ($F(1,16) = 9.184$, $p<0.01$). The mean IBI (averaging Eye State Condition and Mental Group for each of the ten one-second intervals) once again increased indicating a reduction in HR as resting progressed. The ANOVA on the DPA data revealed a significant main effect for Second (lin) ($F(1,16) = 5.92$, $p<0.05$). Consistent with the results of a lower arousal (as measured by DPA averaging Eye State, Resting State and Mental Group) as resting progressed, shown in Fig. 13, the results of the present ANOVA revealed the same decrease in arousal (as indicated by heightened DPA) as resting progressed. No other significant main or interaction effects were found in any of the three ANOVAs.

To analyze the effects of the three writing styles and the three characters on HR, DPA, and PTT, three four-way ANOVAs were performed on the writing conditions alone excluding the pre- and post-writing resting periods. The main factors were: Mental Group, Writing Style (figure, seal, regular), Character (mother, fish, goat), and Second. With respect to PTT, there was a significant

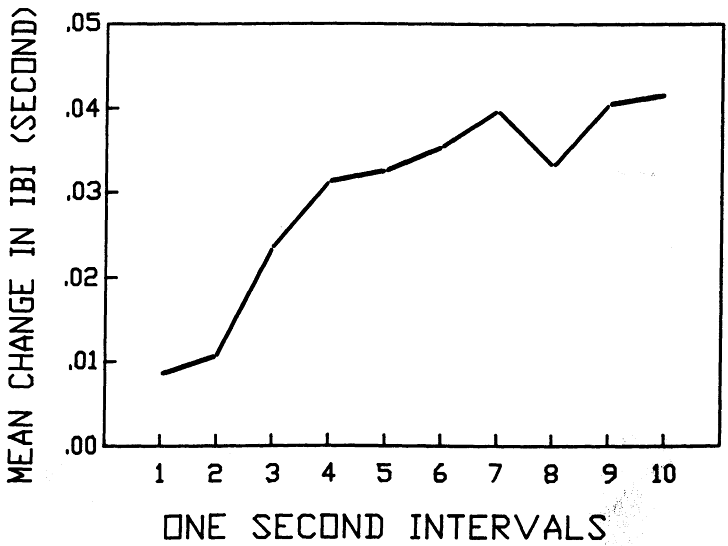

Fig. 12. Mean changes in IBI for all subjects in the first 10 successive one-second intervals of combined resting periods and eye-open, eye-closed states.

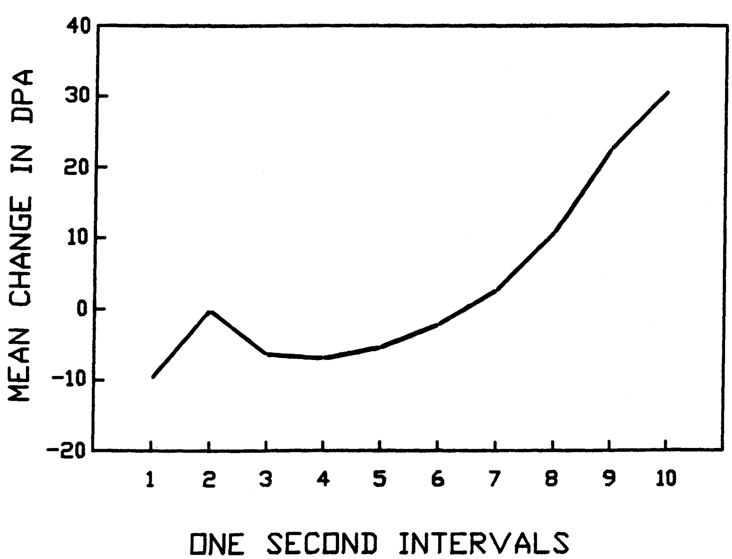

Fig. 13. Mean changes in DPA for all subjects in the first 10 successive one-second intervals of combined resting periods and eye-open, eye-closed states.

main effect for Writing Style ($F(1,16) = 6.636$, $p<0.05$), showing that the Figure style of writing is associated with the lowest BP. Comparisons using Tukey(a) Test indicated significant differences between Figure and Seal ($p<0.05$) and Figure and Regular ($p<0.05$) and insignificant differences between Seal and Regular styles ($p>0.05$). These results suggest that the visual stimulus value of these three patterns of writing and the three different stroke formations of the characters were sufficient to have caused an effect on the subjects' psychophysiological responses.

Although there was no significant main effect for Mental Group, there was a trend for HR to be lower during writing for the schizophrenic subjects than the normal subjects (the mean IBI was 0.05 second/beat per one second for the schizophrenic subjects and 0.028 second/beat per one second for the normal subjects). There was, however, a significant main effect for Mental Group ($F(1,16) = 11.401$, $p<0.01$) with respect to the PTT data. The schizophrenic subjects had a significantly lower BP when writing than the normal subjects. These results suggest that the writing of Chinese calligraphy is associated with lower cardiac activity and BP for the schizophrenic subjects than it is for the normal subjects. No other significant main or interaction effects were found in any of the three ANOVAs.

Further analyses were then done on the data of the schizophrenic subjects alone. In order to examine the effects of the three characters and the three styles of writing on HR a three-way ANOVA was done on the writing conditions alone (excluding the pre- and post-writing resting conditions). The three factors were Second, Writing Style and Character. While no significant main effects were found for these three factors there was a very general trend for mean IBI (averaging Writing Style and Character for each of the one-second intervals) to increase as writing progressed suggesting that attention to the act of writing is associated with a reduction in HR. This is shown in Fig. 14.

In analyzing the differences in average IBI between the pre-writing and the post-writing resting periods, a three-way ANOVA was done with Resting State, Eye State, and Second as the factors. A trend was found for Second, and the change in average IBI for the resting periods (with eye-open, eye-closed, pre-writing resting period, post-writing resting period averaged for each of the one-second intervals) is illustrated in Fig. 15.

As seen in Fig. 15, average IBI increases from the first to the tenth second indicating a reduction in HR as the resting period progresses. In considering this figure with Fig. 14 which shows a general trend for HR to reduce as writing progresses, there is in Fig. 15 a similar reduction in HR as the resting period

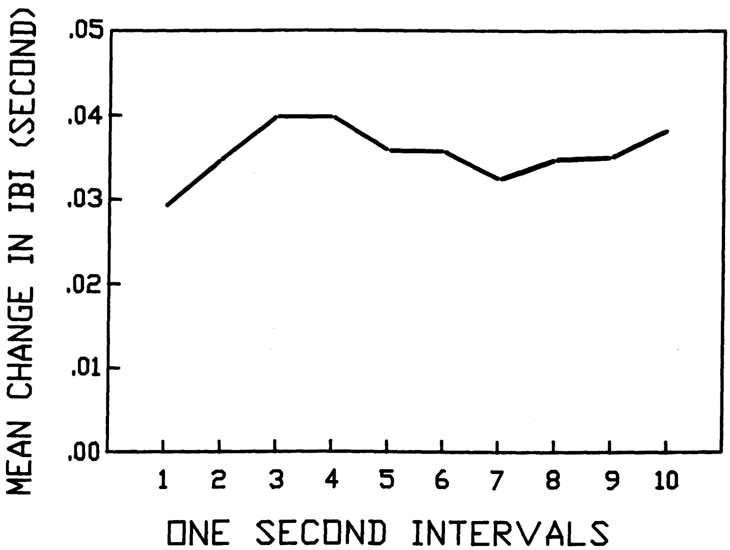

Fig. 14. Mean changes in IBI for schizophrenic subjects' writing of 3 characters in 3 styles of stroke formation in the first 10 successive one-second intervals following the onset of the writing task.

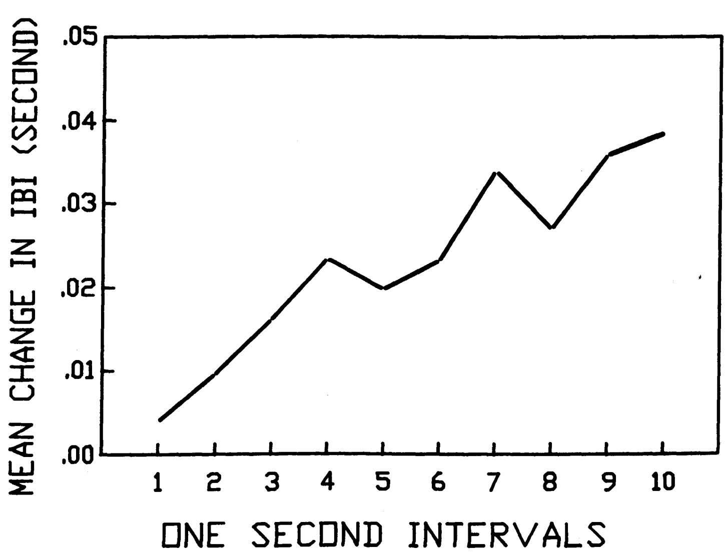

Fig. 15. Mean changes in IBI for schizophrenic subjects in the first 10 successive one-second intervals of the combined resting periods and eye-open, eye closed states.

progresses. This implies that the writing of Chinese calligraphy is associated with the same change in HR as that during the resting periods; in both cases HR is reduced which is consistent with the results of the schizophrenic subjects and normal subjects combined. No significant main effect was found for Resting State, however comparison of the resting conditions before and after the writing sessions showed a trend for a reduced HR during the post-writing resting session combining both the eye-open and eye-closed conditions. Furthermore, there was no significant interaction effects.

4.4. Discussion

The results for schizophrenic and normal subjects combined show that there is a significant reduction in HR and lower arousal as measured by DPA, as the writing of Chinese calligraphy progresses. In addition, the results show a trend for HR deceleration and DPA increment as a component of handwriting. This is consistent with previous investigation of normal subjects which has confirmed that bodily functions slow down and HR steadily decelerates as a function of the writing task progression,[4,5,23] and thus indicates that calmness or relaxation develops during Chinese calligraphic writing.

During the writing of Chinese calligraphy there is a trend for HR to be lower for schizophrenic subjects than normal subjects and a significantly lower BP for schizophrenic than normal subjects. These findings indicate that while for both normals and schizophrenics bodily functions slow down as a function of writing Chinese calligraphy, the reduction is much more in the schizophrenic subjects than the normal ones.

The findings in the present study for reductions in HR and increases in DPA as writing progresses are similar to the significant reductions in HR and increases in DPA, for both schizophrenics and normals combined as well as the trend for HR reduction for schizophrenics alone, found during the resting periods. The implication from this is that the writing of Chinese calligraphy may lead to a calmness or relaxation comparable to that of resting. Furthermore, there was a trend, in the schizophrenic subjects alone data, for HR to be lower and DPA higher during the post-writing resting period than the pre-writing resting period. This trend for lower arousal as measured by DPA after the writing session was especially pronounced in the eye-closed condition. Therefore, the writing of Chinese calligraphy may possibly lead to reduced bodily functions not only during the actual act of handwriting but may also persist into the post-writing resting period. This suggests that this effect may not be confined only to the writing session but may extend beyond that period into the post-writing resting period. If this is the case, the writing of Chinese calligraphy could develop into an effective therapeutic technique for the relaxation treatment of chronic schizophrenic patients. Chinese calligraphy could replace medication in relaxing schizophrenic patients, thereby reducing its often unpleasant side effects as well as allowing the patients to have more control in administering their own form of relaxation treatment. As the present experiment was a preliminary investigation in this direction and only a small sample of schizophrenic subjects was used, future research probing further into this area should prove fruitful.

The finding of a further significant BP reduction and trend for HR reduction for the schizophrenic subjects compared to the normal subjects has widespread implications. According to Venables and Bernstein,[21] it is surprising that, since HR orienting response has been considerably investigated in work on attention, investigations using HR as a variable have been so limited, considering that schizophrenia is seen to be a disorder of attention. Previous investigations of HR orienting response to stimuli have found no HR response to visual stimulation but an acceleration to auditory stimuli which decelerated over the first few post-stimulus beats.[24,25] Venables and Bernstein[21] provide a tentative summary suggesting that schizophrenics may display an early decelerative component to simple stimuli; however, this does not persist into late normal deceleration. The results from the present study, however, suggest that if the stimuli are ones which require attention in the form of concentration, HR and BP may decelerate not only during the initial attention to the stimuli but may continue to decrease linearly for at least ten seconds. Therefore, the writing of Chinese calligraphy may be useful not only as a potential therapeutic technique for the purpose of inducing a relaxed and calm physiological state in the treatment of schizophrenic patients, but also in helping them to improve upon their attentional defects.

Furthermore, in a discussion of hemispheric specialization and schizophrenia, Venables and Bernstein[21] state that a commonly accepted notion of the right hemisphere as a global, parallel processing system and the left hemisphere as a sequential, serial, detailed mechanism may imply that the right hemisphere is involved in pre-attentive processing followed by data handling by the left-hemisphere for focal attentive processing. There is evidence[26] suggesting that the right hemisphere pre-attentive processing is defective in schizophrenia so that the left hemisphere in coping with data in a sequential manner is overloaded.[26] Therefore, because the reading and writing of single Chinese characters is more of a right hemispheric activity,[5,27] it is possible that the writing of Chinese calligraphy would require schizophrenics to more actively use the right hemisphere which may, with continual and regular practice with

Chinese calligraphy and hence usage of the right hemisphere, help them to overcome their present defect in right hemisphere pre-attentive processing.

The increasing evidence suggesting that the exercising of a high level of attentional involvement necessary for the writing of Chinese calligraphy leads to certain activities of an individual's physiological system, namely a reduction in physiological activity,[4,5] together with the findings in the present study for reduced HR, BP and increased DPA comparable to that of resting, during and after the writing session, provides interesting therapeutic possibilities. The findings in the present study were most encouraging and suggested the possibility for the writing of Chinese calligraphy to develop into a therapeutic method for the relaxation treatment of chronic schizophrenic patients. The development of the graphonomic act of handwriting in this direction in general deserves serious future attention and investigation.

5. CONCLUSIONS

This study has investigated the psychophysiological activities accompanying the writing of Chinese calligraphy. The three experiments reported have examined (1) the HR and DPA activities accompanying the writing of different stimulus configurations using two writing instruments of subjects with different language experiences; and (2) the differential effects of stylistic variations of Chinese orthography on (a) adults' and children's HR and DPA activities, and (b) schizophrenic and normal subjects' HR, DPA and PTT activities. The overall results of these experiments have confirmed the hypothesis that there is a reduction in psychophysiological activities for subjects during the writing of Chinese calligraphy, suggesting a calm and relaxed physiological state. The major findings of these experiments are summarized as follows:

(1) There is a reduction in HR during the commencement and progression of handwriting with a greater reduction during brush writing than felt pen writing. However, DPA decreased (hence greater arousal) as writing commenced, although it began to increase marginally as writing progressed.

(2) The reduction in HR during handwriting was found for both the Chinese and non-Chinese subjects writing all three types of stimulus configurations, extending the effects of handwriting on HR reduction beyond ethnic and linguistic boundaries.

(3) There was a reduction in HR and increase in DPA during the writing progression of Chinese calligraphy for the combined results of the adults and children.

(4) There was a trend for the three stylistic variations of Chinese orthography

to be differentially associated with cardiac activity; for adults there was a greater HR reduction associated with the detailed and skeletal writing styles, whereas for children there was a greater HR reduction for the global writing style. It was suggested this may be due to children's reliance on general pre-attentive visual pattern recognition and adults' further reliance on intuitive experience.

(5) There was an HR reduction and lower arousal as measured by DPA for the combined results of schizophrenic and normal subjects during writing, as well as resting, progression suggesting the writing of Chinese calligraphy may lead to relaxation similar to that of resting.

(6) The trend for the schizophrenics' HR to be lower and DPA higher during the post-writing than the pre-writing resting conditions implies that the effect of Chinese calligraphic writing on physiological activity may extend beyond the writing period into the post-writing resting period. Furthermore, there was a trend for a lower HR and a significantly greater BP reduction for schizophrenics than normals. Thus, the writing of Chinese calligraphy as a therapeutic technique for the relaxation treatment of schizophrenic patients seems promising.

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