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The benefit of heart rate variability biofeedback and relaxation training in reducing trait anxiety†

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Abstract

Previous research studies have indicated that biofeedback treatment and relaxation techniques are effective in reducing psychological and physical symptoms (Hammond, 2005; Manzoni, G. M., Pagnini, F., Castelnuovo, G., & Molinari, E., 2008). However, dearth of studies has compared heart rate variability (HRV) biofeedback treatment and relaxation training to reduce trait anxiety. The objective of this study was to determine the effect of HRV biofeedback treatment and relaxation training in reducing trait anxiety compared to control group without any treatment using students in a science and engineering university of South Korea. For the present study, a total of 15 graduate students with moderate level of trait anxiety were recruited for 4 individual sessions every two weeks. They were randomly assigned into three groups: biofeedback treatment (n = 5), relaxation training (n = 5), and no treatment control group (n = 5). Our results revealed significant difference in change score of trait anxiety between the HRV biofeedback treatment and the no treatment control group. However, no significant difference was found between the relaxation training group and the no treatment control group. In addition, there was no significant difference between the HRV biofeedback treatment and the relaxation training. Results of the present study indicate that there is potential benefit in utilizing HRV biofeedback treatment for stress management programs and/or anxiety reduction treatment

Keywords

HRV biofeedback; relaxation training; anxiety; trait anxiety

It is well known that when people experience stress or anxiety, their autonomic nervous systems become activated. As a result, they will experience psychological or physiological arousal(e.g., rapid heart rate, shortness of breath, anxiety, and irritability). Of these physical symptoms associated with the activation of autonomic nervous system, heart rate is

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particularly sensitive to stress or feeling of fear/anxiety. Gatchal(1977) reported that training to decrease one's heart rate in stressful or fearful situation could lead to changes in emotional states, but also in cognitions associated with stress and fear. Choi & Son(1992) also found that heart rate biofeedback could reduce social anxiety and negative self-evaluation. However, some authors(Rice & Blanchard, 1982) raised concerns that although some individuals could experience an increase in their heart rate in non-stress situations, the opposite could also be true, i.e., some do not exhibit heart rate elevation in stress inducing situations.

Unlike heart rate, heart rate variability (HRV) has recently been recognized as an important and stable marker for the function of autonomic nervous system and indicator to estimate the degree of resistance toward stress (Reiner, 2008). Heart rate variability is the beat-to-beat interval between heartbeats. Lehrer & Woolfolk(2007) indicates that a high level of heart rate variability reflects flexibility in the individual's self-regulatory system. This means that the body will adapt quickly in response to internal changes(i.e., illness, injury) as well as external changes(i.e., environmental changes or stressors). In contrast, decreased HRV is associated with anxiety disorders including generalized anxiety, PTSD, and panic disorder as well as medical conditions such as cardiovascular diseases and cardiac morbidity (Lehrer & Woolfolk, 2007; Reiner, 2008).

Given the importance of HRV in human psychological and physical health, it is not surprising that a growing number of studies in recent years have begun to focus on the effects of HRV biofeedback treatment as a primary or adjunct treatment to reduce psychiatric and physical symptoms. In particular, HRV biofeedback treatment has been shown to be effective in reducing anxiety by increasing heart rate variability. Several studies(Climov, 2008; Reiner, 2008; Ratanasirpong, Sverduk, Hayashino & Prince, 2010) found the effectiveness of combining biofeedback with other therapeutic approaches such as traditional counseling, cognitive behavioral therapy(CBT), and stress management in significantly decreasing anxiety. Other studies found that HRV biofeedback treatment alone significantly reduced level of anxiety compared to: 1) a control group with no treatment(Ratanasiripong, Ratanasiripong., & Kathalae, 2012) and 2) passive biofeedback control where participants observed displayed heart wave on the computer device with no interpretation of displayed waves(Prinsloo, Derman, Lambert, & Laurie Rauch, 2013).

Relaxation techniques including guided imagery, autogenic training, progressive muscle relaxation, and diaphragmatic breathing have each been found to be effective in reducing anxiety(Jorm, Christensen, Griffiths, Parslow, Rodgers., & Blewitt, 20O4; Wachholtz & Pargament, 2005; Manzoni et al., 2008; Reiner, 2008) and therefore, the present study included those four relaxation techniques as part of the study protocol for relaxation training. Relaxation training may be provided in multiple formats, but the most common is a limited number sessions(4–6 sessions) that are scheduled weekly or every two weeks(Lipchik, 2008). Based on these previous studies, the present study 1) included four relaxation techniques mentioned above in relaxation training, 2) provided four separate sessions in order to assist participants to learn each technique individually, 3) and scheduled relaxation training session once in two weeks in order to provide sufficient practice time between sessions.

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Hahn, Lee., & Chon(1996) reported that state anxiety among Korean college students increased significantly before test whereas trait anxiety score did not change significantly when those scores were compared to non-test situation. This result indicates that state anxiety tends to quickly fluctuate depending on daily stressful life events such as test situation for college students. Given that the post test of anxiety for the present study was administered to students during their final exam week, the significant difference in state anxiety scores could have been artifacts of time effect (e.g., final week, defense week) among the students we sampled. In order to avoid potential time effect on anxiety score, the present study utilized trait anxiety as the primary dependent variable. Unlike state anxiety, trait anxiety is stable tendency in respond to a perceived threat. In spite of its tendency to be stable over time, a number of studies revealed that trait anxiety can improve as a result of intervention over time. For instance, previous studies(Borkovec., & Costello, 1993; Eppley, Ambrams., & Shear, 2006; Rice, Blanchard, & Purcell, 1993, Wachholtz., & Pargament, 2005, 2008) found relaxation training including nondirective and applied relaxation training, spiritual meditation and different types of biofeedback treatments(i.e., EMG biofeedback, biofeedback to increase EEG alpha, biofeedback to decrease EEF alpha) effective in reducing trait anxiety. Most recently, Reiner(2008) and Henriques, Keffer, Abrahamson, & Horst(2011) found that computer based heart rate variability (HRV) biofeedback treatment was effective in reducing trait anxiety.

Although previous studies found the effectiveness of HRV biofeedback treatment as well as relaxation training in reducing trait anxiety, there is dearth of studies investigating the effectiveness of HRV biofeedback treatment in comparison to relaxation training in reducing trait anxiety. Therefore, the present study examined the effects of HRV biofeedback treatment and relaxation training in the reduction of trait anxiety by comparing those two groups with no treatment control group among graduate students in a Technology and Science University in South Korea. In order to provide computer based HRV biofeedback treatment, HeartMath's emWave computer program was used. Based on existing literature reviewed in this paper, the present study hypothesized that HRV biofeedback treatment group and relaxation training group will significantly reduce anxiety compared to control group with no treatment.

Method

Participants

Forty Korean graduate students under age 35 were recruited for the present study in a Science and Technology University in Pohang, South Korea. Only students who scored the upper 40% of trait anxiety as measured by State-Trait Anxiety Inventory(STAI) were invited to be included in the final sample. Our final sample of participants scored in the upper 40%, obtained a mean trait anxiety score of 53.67(SD = 4.45), which is significantly higher than the mean trait anxiety score for Korean college students(M = 4453, SD = 9.50; Kim & Shin, 1978). A post hoc power analysis was conducted and revealed that n of approximately 5 people for HRV biofeedback treatment, 9 people for relaxation group, and 9 people of control group would be needed to obtain statistical power at the recommended .80 level(Cohen, 1988). However, twenty five students were disqualified from the present study

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due to their current or recent(i.e., past 3 month) history of psychotherapy or psychopharmacological treatment. Other exclusion criteria included: any experience with biofeedback treatment and relaxation training, anxiety disorder diagnosis, previous heart rate and blood pressure related medical diagnosis, current usage of psychotropic or heart rate altering medications, substance use disorders, and current use of illicit drugs. As a result, fifteen students out of forty volunteers were selected for the present study and among those students, three participants were female(20%) and twelve participants were male(80%).

Measures

State-Trait Anxiety Inventory (STAI)—STAI(Speilberger, 1970) was used to assess anxiety levels. STAI is a 40 item self-report instrument rated on a four-point Likert scale ranging from ‘not at all’ to ‘very much so’ with higher scores indicating greater anxiety. This scale is composed of two subscales: state anxiety and trait anxiety. The present study utilized trait anxiety only as the primary outcome variable.

The STAI has an internal consistency of .86–.92 and seven week test-retest reliability of .85 for trait anxiety among college student population(Speilberger, 1970). This study used STAI Korea which was standardized by Kim and Shin(1978), and they reported internal consistency of .87 with Korean college student population. Current study obtained internal consistency of .88 for trait anxiety.

Procedures

Participants in this study signed informed consent prior to participating, and the present study was approved by the IRB of Pohang University of Science and Technology. Fifteen students were randomly assigned into three groups: HRV biofeedback treatment group, Relaxation training group, and Control group with no treatment. Prior to treatment, participants were interviewed for demographic information and completed STAI. The STAI trait anxiety score was again assessed for treatment groups at the end of the fourth session(about 8 weeks after the initial STAI test). Control group was also assessed for the STAI trait anxiety score 8 weeks after the initial STAI test.

HRV Biofeedback—Four HRV biofeedback sessions were provided for 45 minutes every two weeks. Each individual training session was led by the primary investigator at her office. The participants received psychoeducation regarding links among heart rate variability, physical health, and psychological health. During each session, participants were instructed to find ways(e.g., diaphragmatic breathing technique) to regulate their breathing while receiving feedback from heart rate variability biofeedback device (emWave PC, HeartMath). A sensor was attached to participants’ ear lobe in order to measure their pulse, and this data was calculated into heart rate variability coherence rate, which is shown on a desktop computer for visual and auditory display. Participants were also given a portable biofeedback device for home practice and were advised to practice with this biofeedback device for 5–10 minutes at least 3 times per day. During each session, participants’ progress with home practice was reviewed by viewing the practice data saved in their portable device, and difficulties and barriers to practice as well as ways to overcome those barriers were discussed.

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Relaxation Training—Each of the four relaxation training sessions taught a different relaxation technique. These sessions were provided for 45 minutes every two weeks. The setting to administer this training was identical with HRV biofeedback. Initially, participants were educated about how relaxation techniques can change automatic stress response and decrease anxiety. At each individual session, participants learned and practiced one new relaxation technique(e.g., participants learned diaphragmatic breathing during their first meeting, progressive muscle relaxation during the second meeting, autogenic training during the third meeting, and guided imagery during their last meeting) and were also assisted to practice the technique learned during each session. Each participant was asked to practice the technique for 5–10 minutes at least 3 times daily and complete the daily practice log. During each session, practice log was reviewed, and barriers to practice and ways to overcome those barriers were discussed.

Statistical Analysis

In order to explore differences in the pre-post change scores of trait anxiety after the treatment among HRV biofeedback treatment group, relaxation training group, and control group, a Two-Way Repeated Measures ANOVA was used. Moreover, to address the concern Two-Way Repeated Measures ANOVA often fails to detect the variance of the differences between groups in small samples, the degrees of freedom were corrected using Greenhouse-Geisser correction estimates of sphericity(Field, 2012). Lastly, a Scheffe test was performed in order to further examine between-group differences.

Results

Table 1 displays means and SDs of pre-treatment and post-treatment trait anxiety scores for three groups. In order to determine whether three groups differ in their characteristics on pre-treatment, one-way ANOVA was performed on age of participants and trait anxiety. The result of one-way ANNOVA reveals that there were no significant differences in age, $F(2, 12) = .494$, $p=.622$, and pre-test trait anxiety, $F(2, 12) = .699$, $p=.516$, among three groups.

Differences in change scores of trait anxiety after the treatment among HRV biofeedback treatment group, relaxation training group, and control group were analyzed using Two-Way Repeated Measures ANOVA. As shown in table 2, the analysis reveals that there was significant interaction effect between time (pre-treatment vs. post-treatment) and group $F(2, 8) = 14.83$, $p=.002$. Mauchly's Test of Sphericity indicated that the assumption of sphericity had not been violated, $X^2(2) = 2.793$, $P = .247$. However, there has been criticism of this test as it often fails to detect the variance of the differences between groups in small samples. Thus, the degrees of freedom were corrected using Greenhouse-Geisser correction estimates of sphericity (Field, 2012) and the result shows that the significant effect in interaction between time and group remained after Greenhouse-Geisser correction ($F(1.245, 4.982) = 14.83$, $p=.011$).

In order to further examine group differences, Scheffe test was performed. Test results reveal that HRV biofeedback treatment group experienced significantly more reduction in their trait anxiety compared to control group; however, there was no significant differences in change scores of trait anxiety between relaxation training group and control group as well as change

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scores of anxiety between HRV biofeedback treatment group and relaxation training group(See Figure 1).

According to the practice log, the weekly average time spent in practicing at home were 184.56 minutes (SD = 85.83) for relaxation group and 112.11 minutes (SD = 21.77) for biofeedback group respectively. T-test reveals that participants in relaxation group practiced significantly more compared to biofeedback group participants, F = 10.22, p <. 05.

Discussion

The present study sought to identify the effects of a 4 session HRV biofeedback and relaxation training in anxiety reduction among graduate students in a science and technology university in Korea. Analyses revealed that HRV biofeedback treatment significantly reduced trait anxiety compared to a no treatment control group, which was consistent with previous study (Ratanasiripong et al., 2012). Unlike previous studies that reported the significant effect of relaxation training in anxiety (Jorm et al., 2004; Manzoni, et al., 2008), the present study, however, found no significant difference between relaxation training group and control group.

As the first study comparing HRV biofeedback treatment with relaxation training and no-treatment control group in reduction of trait anxiety, the present study showed a significant change in trait anxiety only for the HRV biofeedback treatment group, but not for relaxation training or the no treatment control group. The present result may be explained by a number of factors unique to HRV biofeedback treatment. First, HRV biofeedback treatment is designed to more directly target the fight or flight response to stress and particularly chronic anxiety by providing immediate feedback for breathing practice (Lehrer, 2007). Previous studies indicated that 1) individuals who develop chronic anxiety tend to report high levels of trait anxiety (Chambers, Power, & Durham, 2004) and 2) chronic anxiety is associated with a reduced level of heart variability in stressful situations (Friedman, 2007). Based on these previous studies, HRV biofeedback treatment is an effective treatment, especially for individuals with chronic anxiety who have high levels of trait anxiety. The notable outcome of the HRV biofeedback treatment to reduce trait anxiety in the present study can be explained by the benefit of biofeedback treatment in decreasing autonomic rigidity, which is often shown among individuals with chronic anxiety. By decreasing autonomic rigidity, individuals will develop more flexible autonomic responses that help individuals to increase their adaptive behavioral and emotional responses to stressful situations (Porges, 1995). While slow breathing techniques such as diaphragmatic breathing have become known as useful relaxation techniques to reduce physiological tension as well as psychological arousal induced by autonomic imbalance (Reiner, 2008), the issue of incorrect practicing of breathing techniques has been recognized as a common problem in relaxation and meditation training. By-providing immediate and tangible feedback in regulating breathing, HRV biofeedback treatment can assist participants to learn how to regulate their breathing in order to decrease their anxiety by reducing the time spent in incorrect practice of breathing exercises. Second, HRV biofeedback treatment, as used in the present study, may address non-compliance issues that are commonly shown in relaxation training. Lehrer and Woolfolk (2007) indicate that low compliance rates and over-report of home exercise for relaxation

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treatment are challenging issues in stress management research. This may have been a factor that explains the current study's non-significant result between relaxation training and no-treatment control group, which was inconsistent with some of previous relaxation studies. Unlike relaxation treatment, HRV biofeedback treatment can provide a portable device for participants to practice. This device records time spent in practice thereby reduces the problem of over-reporting home practice. Reviewing home practice recorded in the portable device also creates the opportunity to generate solutions for the roadblocks to engage in regular practice by eliciting honest discussion about the difficulty in implementing learned techniques (Reiner, 2008). Lastly, HRV biofeedback treatment can be especially effective for technologically savvy young adults as they can easily learn to utilize biofeedback computer program to control over symptoms associated with autonomic nervous system (Ratanasiripong et al., 2010). Furthermore, as Ratanasiripong et al. indicated (2012), the effectiveness of HRV biofeedback treatment may suggest primary or adjunct treatment options for clients who underutilize counseling services due to their cultural belief. Students of Asian descent in Asian countries and other nations are more likely to feel reluctant to utilize the counseling service due to discomfort associated with self-disclosure and difficulty in expressing their emotions and inner thoughts directly. Biofeedback treatment can be viable option for this population as it requires less self-disclosure and provides more opportunities to practice tangible skills such as breathing techniques through a easily accessible and user friendly HRV biofeedback portable devices.

In spite of these benefits related to HRV biofeedback treatment, there are a few general concerns regarding utilizing HRV biofeedback as the treatment of anxiety or stress management According to previous studies (Rice & Blanchard, 1982; Reiner, 2008), HRV biofeedback treatment: 1) usually does not directly alter maladaptive patterns of life and cognitive dysfunction associated with chronic anxiety and 2) can cause rebound anxiety, such as increase in anxiety due to immediate feedback in biofeedback treatment

Despite those concerns, HRV biofeedback treatment of the present study was able to reduce anxiety effectively. HRV biofeedback treatment appears to be effective in reducing some cognitive dysfunction associated with anxiety through cognitive restructuring. Four out of five participants in HRV biofeedback treatment reported successful control over their bodily experience of anxiety due to the HRV biofeedback sessions, as well as home practice with a portable device. They further indicated that HRV sessions and home practice provided a sense of mastery and increased their self-efficacy to manage anxiety or stress (cognitive restructuring). Among participants in relaxation groups, only one out of five participants reported a similar result and most participants reported difficulty in practicing the relaxation techniques at home. Further research is needed to investigate the effects of HRV biofeedback treatment on variables such as self-efficacy or sense of control across different groups of individuals.

Regarding the adverse effect of rebound anxiety in biofeedback treatment, Lehrer and Woolfolk (2007) suggested that teaching relaxation techniques (e.g., diaphragmatic breathing) prior to biofeedback session can be helpful to reduce rebound anxiety associated with biofeedback. In the present study, diaphragmatic breathing technique was taught as a tool to reduce anxiety during the first HRV biofeedback session and it was found to be

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effective for most of participants in reducing anxiety for the initial HRV biofeedback session. In light of this finding, clinicians and researchers may utilize breathing techniques such as diaphragmatic breathing as a way of reducing rebound anxiety during the initial biofeedback session

Although the findings from the present study are noteworthy, there are specific limitations that require attention The sample size is small and the participants who were recruited from a Technology and Science University in Korea were mostly male and highly educated in a scientific field Although the present study may afford insight into the effects of HRV biofeedback treatment on anxiety among the generation of young people who are technologically savvy in Korea and those in other nations, the results of the present study may not be generalized to general population. Furthermore, limited statistical power due to the small sample size in the present study (N=5 for each group) may have played a role in limiting the statistical significance of some of the comparisons conducted. There is a concern whether the interpretation of the present result is skewed due to limited sample size. In order to address this concern, current study examined Mauchly's Test of Sphericity to see whether the assumption of sphericity had been violated and the result indicated no violation. Furthermore, the degrees of freedom were corrected using Greenhouse-Geisser correction estimates of sphericity to address the potential concern that Mauchly's test is less sensitive to detect the differences in variance between groups in small samples (Field, 2012). The result of these additional statistical tests indicates that the significant result remains after Greenhouse-Geisser correction Future studies are needed with larger sample sizes for each treatment group which would allow for more longitudinal analyses such as intra-participant trait anxiety score changes across sessions. Lastly, the current result (i.e., no significant difference between relaxation training and control group) may have been influenced by the fact that participants who attended relaxation training had a limited time to practice compared to participants in HRV biofeedback training. Participants in relaxation training had to learn a new relaxation technique each session so they had one session to practice each relaxation technique compared to HRV biofeedback participants who practiced HRV biofeedback for four sessions. Future study should take into account of this factor and should create relaxation training protocol that is more comparable to HRV biofeedback training.

In spite of the limited sample size in the present study, this study can contribute to the field of stress research as the present study was the first study that compared HRV biofeedback treatment with relaxation training and no-treatment control group for Korean students. There was not only statistical significance but clinical significance as well with the results of the present study among this population Moreover, it should be noted that the present study provided HRV biofeedback portable device ($300 for each device) for home practice of each participant in HRV biofeedback treatment group. Bacchetti, Deeks., & McCune (2011) discussed scientific advantages of studies with small sample sizes despite of its limitation due to statistical power if the study is cost-efficient. They argued that earlier studies have to take cost and feasibility into account when investigators determine sample size. No previous study has been conducted to utilize HRV portable devices for home practice in comparison among HRV biofeedback, relaxation training and no-treatment control group. Therefore, the result of the present study, although the interpretation of the results may be limited due to

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small sample size, can be meaningful as this result provides valuable guidance and information for the future study.

Another consideration is that the individual that did the initial assessment of anxiety was also the therapist in the study provided biofeedback and relaxation treatment Although the anxiety was assessed by the self-report measure, social desirability among participants in the treatment groups may have had influenced participants' responses during the post-test. This issue should be addressed in future studies.

Qualls and Sheehan (1981) found that individuals with high capacity for absorption, which is defined as the imaginative involvement and the tendency to become mentally absorbed across different situations, were most conducive to non-feedback relaxation whereas individuals with limited capacity for absorption responded better to the concrete immediate feedback of biofeedback treatment. Thus, future studies should include the measure of absorption capacity to investigate the differential effect of HRV biofeedback treatment and relaxation training on anxiety based on individuals' absorption capacity and characteristics.

In spite of the limitations, the present study has increased our understanding about the effectiveness of HRV biofeedback treatment to decrease anxiety by comparing HRV biofeedback treatment group with relaxation training group and no treatment control group. Furthermore, the present study presented the opportunities to explore advantages of HRV biofeedback treatment over relaxation training in management of anxiety such as non-compliance issues and the problem of incorrectly practicing breathing exercises to reduce anxiety.

Stress and anxiety share a number of symptoms associated with physiological arousal induced by fight or flight response. It seems that HRV biofeedback not only directly teaches clients to change those physiological reactions to anxiety and stress but also assists clients to enhance self-efficacy and a sense of mastery with direct feedback. Those advantages specific to HRV biofeedback treatment may implicate the potential benefit of utilizing HRV biofeedback treatment in stress management programs and anxiety reduction treatment.

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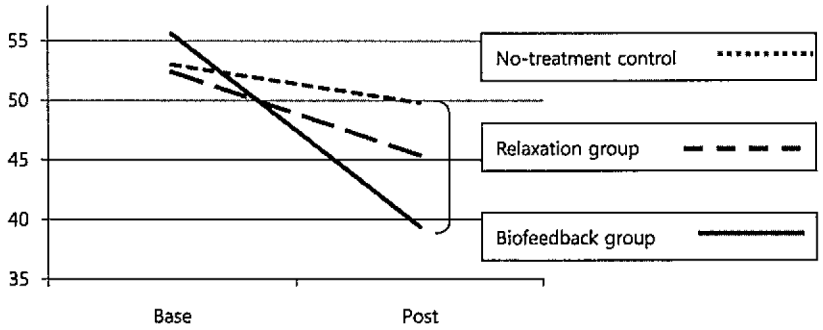

Figure 1.

Trait Anxiety change score across group

Note: Purple line shows the point where the significant difference was found (i.e., the post-treatment scores between no-treatment control group and biofeedback group). Base = baseline anxiety score, Post = post - treatment anxiety score

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Table 1

Means and SDs of age and trait anxiety for three groups

	Biofeedback (*N*=5)	**Relaxation (*N*=5)**	**Control (*N*=5)**
	M(SD)	***M(SD)***	***M(SD)***
Baseline trait anxiety	55.60 (5.73)	52.40(3.13)	53.00 (4.42)
Post-treatment	39.40 (4.39)	45.40(4.28)	49.80 (6.50)
Age	27.60 (3.05)	27.40 (3.36)	26.00 (1.58)

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Table 2

Repeated measures Analysis of Variance

Effect	MS	df	*F*	*P*	Eta^2	Greenhouse-Geisser
Time	580.80	1	17.94	<.05	.818	<.05
Group	39.03	2	1.22	.34	.234	.34
Time* Group	111.70	2	14.83	<.01	.788	<.05