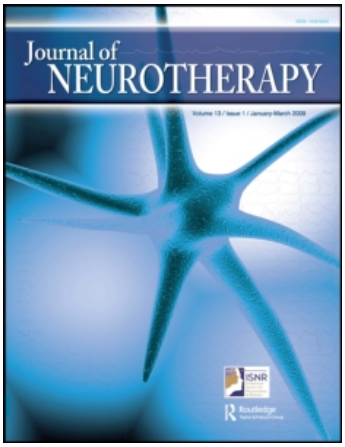

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Alpha Suppression and Symmetry Training for Generalized Anxiety Symptoms

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Alpha Suppression and Symmetry Training for Generalized Anxiety Symptoms

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ABSTRACT. *Introduction*. Twenty-eight anxious adults were assessed for frontal lobe alpha asymmetry, a brain state associated with depression and anxiety. Fifteen of the 28 exhibited significant asymmetry and 12 agreed to participate in a biofeedback program addressed at reducing frontal alpha asymmetry.

Method. The program consisted of earlobe temperature biofeedback (ETB) and two forms of neurofeedback, alpha suppression and alpha symmetry training. Individuals were instructed to warm their right earlobe for six sessions, and half succeeded, though success was not required to advance to the next stage of training. For subsequent EEG training, two anterior sites were selected on the basis of poor alpha coherence. Individuals were trained to reduce alpha magnitude at these sites by 10% for 30 min or more, which took from 6 to 16 sessions to achieve. Once successful with alpha suppression, individuals were trained to improve alpha symmetry between the sites by 15% for 30 min or more.

Results. This feat took 8 to 32 sessions to achieve, and eventually all eight individuals were able to reduce alpha asymmetry. The State–Trait Anxiety Inventory (STAI) was used to measured anxiety levels after each training type and both state and trait scores significantly improved by a 6-month follow-up.

Conclusion. Participants also completed a daily shortened version of the STAI, which indicated that anxiety improved after neurofeedback but not after ETB.

KEYWORDS. Anxiety, EEG biofeedback, generalized anxiety disorder, neurofeedback, STAI

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INTRODUCTION

Generalized anxiety disorder (GAD) is characterized by persistent anxiety or worry about events that occurs more days than not over a 6-month span (American Psychiatric Association [APA], 1994). It afflicts women twice as often as men—more than 4,000,000 (2.8%) Americans a year; runs in families; and typically onsets at adolescence or young adulthood (APA, 1994). People who suffer from GAD commonly experience somatic disturbances including insomnia, muscle tension, headaches, irritability, and even panic, and the disorder is often comorbid with depression, other anxiety disorders, and substance abuse. The disorder is often an obstacle to healthy employment and social functioning.

Increasing alpha magnitude in the parietal and occipital lobes with operant conditioning can produce a calming effect (Hardt & Kamiya, 1978; Hare, Timmons, Roberts, & Burman, 1982; Rosenfeld, 2000), but excessive alpha magnitude in the frontal lobes is associated with negative outcomes such as depression (Baehr, Rosenfeld, & Baehr, 2001; Jenkins & Moore, 1985; Rockstroh, Elbert, Birbaumer, & Lutzenberger, 1990). Excessive frontal alpha activity is often associated with rumination, worrying, repetitive thinking, and other symptoms commonly associated with GAD (Kerson, 2002). Of 62 individuals in Kerson (2002), only 10% with lower (more normal) frontal alpha activity exhibited GAD symptoms, whereas 63% of those with higher alpha magnitude had GAD symptoms (17 of 24). Excessive asymmetry between frontal sites, notably F3 and F4, may be predictive of depression (e.g., Davidson, 1993, 2004) as well as anxiety (Blackhar, Minnix, & Kline, 2006; Thibodeau, Jorgensen, & Kim, 2006). Frontal asymmetry may be a stable trait in many individuals as it presents in those with a history of depression who are not currently depressed (Davidson, 1993). Significant resting frontal asymmetries may also reflect a stable trait in terms of anxiety.

The goal of this study was to reduce generalized anxiety symptoms by remediating alpha EEG abnormalities by means of operant conditioning. A three-step program introduced individuals to biofeedback, focused them on suppressing frontal alpha activity, and finally trained them to improve alpha symmetry at the two most impaired sites as indicated by quantitative EEG assessment.

METHODOLOGY

Participants

Twenty-eight prospective participants were assessed, and 15 had the frontal alpha signature necessary for inclusion in the study. Three candidates could not commit to the study and four people dropped out during earlobe temperature biofeedback (ETB). Of the 8 participants who completed the study, 5 were women and 3 were men between the ages of 32 and 55 (M age = 45 years). Inclusion criteria was presence of multiple generalized anxiety behaviors (n = 10) or a formal GAD diagnosis (n = 2), willingness to perform up to 40 sessions of training at a rate of twice a week, and most important, high alpha activity and asymmetry in frontal sites. Participants were excluded if they had a psychiatric comorbidity, with the possible exception of undiagnosed (mild) depression, sleep deprivation, or some (untreated) inability to attend. This study took place from February 2006 to June 2008.

Materials and Procedures

State trait anxiety inventory. The State–Trait Anxiety Inventory (STAI) measures anxiety in adults and separates a temporary condition (''state anxiety'' or S anxiety) from an enduring habit (''trait anxiety'' or T anxiety). The STAI takes 15 min to administer and has 40 questions with Likert-scale responses that include *almost never, sometimes, often*, and *almost always*. Results are compared to a database of healthy adults. The Daily Anxiety Inventory is an abbreviated version of the STAI developed for this study that allowed an individual to

report his or her daily level of anxiety (see the Appendix).

Study procedure. Each prospective participant completed an intake and consent form, completed a STAI, and was assessed for high frontal alpha activity at six frontal lobe sites: Fp1, Fp2, F3, F4, F7, and F8, referenced to the right ear with the ground on the left ear. Only individuals who scored 40 or higher on the STAI and exhibited frontal alpha magnitude of 4 microvolts or higher on the training software were enrolled in the study. All training sessions regardless of modality were 30 min and occurred twice per week. Daily questionnaires (DAI) were collected at each session.

EEG was recorded from each participant using a 19-site ElectroCap with electrodes positioned according to the International 10–20 system. Data were recorded for approximately 5 min of eyes closed and 5 min of eyes open rest depending upon the quality of the recording. Data were recorded with a Deymed TruScan-32 (Deymed Diagnostic, Payette, ID), which has a maximal input DC offset of 250 mV, an input noise level of 1 μV (peak-to-peak) and a common mode rejection ratio of 102 dB. Data were sampled at 4,096 Hz per channel using 14-bit A/D resolution and digitally down-sampled to 256 Hz. EEG data were recorded prior to all training sessions and 1 week after training was finished.

To evaluate the effect of EEG biofeedback, participants underwent a control (non-EEG) biofeedback for six sessions. The effects of thermal biofeedback have been studied for a variety of clinical conditions including migraine (Gauthier, Bois, Allaie, & Drolet, 1981; Osterhaus et al., 1993; Scharff, Marcus, & Masek, 2002), childhood anxiety, (Wenck, Leu, & D'Amato, 1996), asthma (Meany, McNamera, Burks, Berger, & Sayle, 1988), and schizophrenia (Hawkins, Doell, Lindseth, Jeffers, & Skaggs, 1980). Most studies place a sensor on a finger of either hand, but in our study the sensor was placed on the right earlobe. Earlobe temperature was shown as a moving line on a computer monitor that changes direction in response to temperature changes, moving up-screen when temperature increased and down-screen when it decreased. Auditory feedback was also provided; a tone deepened in pitch whenever temperature increased. Each participant was instructed to move the line up-screen and deepen the tone to the best of his or her ability by encouraging warmth and blood flow to the ear. EEG sensors were placed at sites F3 and F4 to monitor brain activity during these sessions.

Participants underwent two successive forms of EEG biofeedback, suppression training and symmetry training. Two sites were trained in both instances and these sites were selected on the basis of deviant frontal EEG symmetry and coherence using the NeuroRep database (Hudspeth, Los Osos, California). In addition, QMetrx (Burbank, CA) interpreted alpha power and alpha coherence using the NxLink database. Dominant frequency was determined for each individual and the alpha band was tailored to a 3-Hz interval centered on his or her posterior dominant frequency. At the first EEG biofeedback session, a 5-min baseline with eyes open was recorded to determine average frontal alpha activity for each individual.

Individuals were instructed to suppress alpha magnitude 5 min at a time, and sessions continued until each participant reduced frontal alpha magnitude by 10% below the initial baseline recorded at the first session. Alpha magnitude was the average of two frontal EEG channels and was represented visually by a line. Auditory feedback consisted of nine tones that deepened in pitch (lower pitch) when alpha magnitude dropped and gained in pitch (higher) when it increased. The goal was to lower the line and the tone as much as possible below the session baseline.

Once magnitude suppression was achieved, the participant advanced to symmetry training. The same electrode sites were used for both suppression and asymmetry training. For symmetry training the goal was to balance alpha magnitude between sites. A 5-min baseline was taken at the beginning of the first symmetry training session, which became the symmetry criteria to meet or exceed during training. Visual feedback was a balance bar or seesaw. Auditory feedback

consisted of nine tones that lowered in pitch with increasing symmetry but dropped in pitch with asymmetry. The goal was to maintain the horizontal position of the bar ("balancing it") and to lower the tone. The first min of each session provided an eyes-open baseline that was used to set initial thresholds at 80% reward. Thresholds were periodically adjusted by the investigator to maintain an 80% level of reward. Symmetry was measured as (Right − Left)/(Right + Left) × 100 (Baehr et al., 2001) for interhemispheric symmetry and (Posterior − Anterior)/(Posterior + Anterior) × 100 for intrahemispheric symmetry.

Ground and reference ear clips were placed on the right ear and left ear, respectively, or on the contralateral ear when symmetry training was intrahemispheric. Gold electrodes were used for training with the ProComp + encoder (Thought Technology, Montreal, Canada), which has an input impedance of 10 GOhm, a sensitivity of 0.08 μV RMS, with a bandwidth of 0.8–40 Hz, frequency resolution of 0.8 Hz, amplitude range of 0.1 to 200 μV, and common mode rejection at 60 Hz of 180 dB and 130 dB between 3–30 Hz. Training software was BioIntegrator 4.0 (Bio Research Institute, Cotati, CA) with the exact same graphs and tones used between sessions and across participants.

Each participant was made comfortable with pillows and reclined or remained upright in a chair, as per his or her preference. Lights were dimmed and a 30-min training session began. Initial sessions of each protocol often called for some coaching by the investigator; however, over time every participant learned to adjust their psychophysiology accordingly. Progress was monitored by the investigator every 5 min by looking through the glass door into the room and onto the computer screen, being careful not to interrupt the participant. During this check-in, threshold may have been adjusted to continue to administer the 80% reward rate. Participants could request short breaks as well. After each session, the participant was shown the results of his or her session on the computer.

EEG data was acquired 1 week after training was complete. The STAI was also administered at this time. Six months later, participants were reinterviewed with questions directed at the resilience of training impact, compliance to the treatment protocol, current mood and goals, and overall impression of the procedure and the STAI was also administered at this time.

RESULTS

ETB Training Sessions

Average earlobe temperature during each of the six sessions for each participant is shown in Figure 1. Average temperature did not increase systematically across training session for most participants. Four individuals did show an increase in temperature between sessions 1 and 6, but 3 showed a decrease and 1 showed no change.

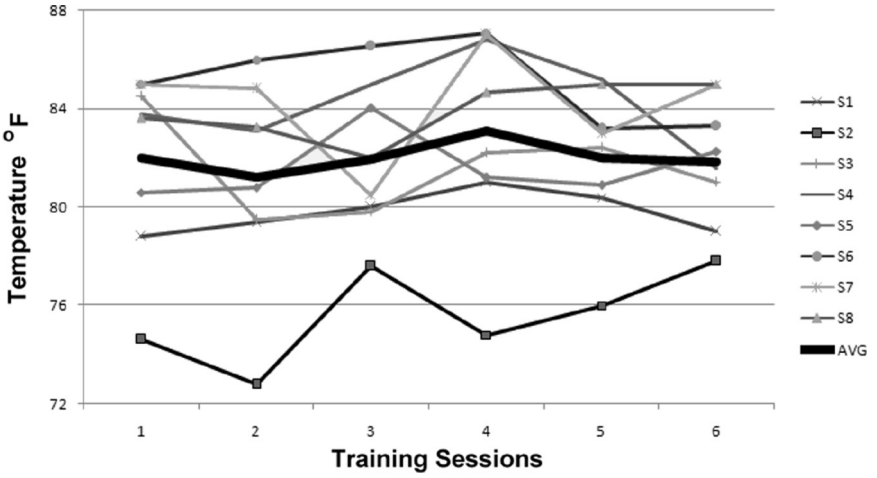
EEG Assessment and Training

Active electrode sites were chosen based on pretraining alpha or alpha asymmetry excesses or deficits and rarely changed throughout the study. Two participants had active site changes: Participant 3 underwent 4 sessions at F7/F8 suppression training amid 8 suppression and 32 symmetry sessions at F3/F4, and Participant 8 underwent 3 sessions of F7/T5 asymmetry training amid 16 suppression and 8 symmetry sessions at F8/T6. These changes were made in response to behavioral or EEG changes during the process.

Mean number of sessions was 12.75 magnitude suppression and 16 symmetry sessions as shown in Table 1. Training produced a mean change of 1.41 z scores as shown in Table 2.

As shown in Figure 2, each participant experienced coherence normalization, with a significant change for the group from −1.87 to −0.65 z scores, $t(7) = 7.72$, $p < .001$, and the medial frontal asymmetry also moderately normalized, $t(7) = 2.86$, $p < .025$, as shown in Table 3.

FIGURE 1. Mean temperature during six earlobe temperature training sessions.



STAI

STAI was administered four times, providing State and Trait percentile scores. Using a one-way analysis of variance (ANOVA), a significant effect of training on the STAI–S was found, $F(3, 21) = 13.9$, $p < .001$. Pairwise comparisons (Tukey Honestly Significant Difference [HSD] [.05] = 23.16; HSD [.01] = 29.34) revealed significant differences between all conditions compared to follow-up only ($p < .05$ and below; see Figure 3). A one-way ANOVA of STAI–T scores revealed a significant effect of training as well, $F(3, 21) = 15.51$, $p < .001$. Pairwise comparisons (Tukey HSD [.01] = 24.63) found significant differences between all conditions compared to follow-up only ($p < .01$). All other pairwise comparisons were not significant.

DAI

The DAI was self-administered each day. The responses to the first question ("Today, I felt nervous and restless") were tabulated with the average of the first 3 days of ETB training compared to the average of 3 days prior to the first neurofeedback (NF) session and the average of last 3 days of participation in the study. Higher scores indicate less anxiety (see Table 4).

A one-way ANOVA revealed a significant effect of training, $F(2, 14) = 4.66$, $p < .05$, due to the improvement from ETB to EndNF

TABLE 1. Number of suppression and asymmetry sessions by participant.

Participant	Suppression Training Sessions	Symmetry Training Sessions	Total No. of Sessions
1	12	12	24
2	16	32	48
3	12	14	26
4	6	18	24
5	15	8	23
6	9	22	31
7	16	11	27
8	16	11	27
Average	12.75	16	28.75

TABLE 2. Statistical deviation of coherence between primary training sites by participant.

Participant	Primary Sites	Pre *z* Score	Post *z* Score	Absolute Value of Difference
1	F7 | T5	−2.98	−1.49	1.49
2	F7 | F8	−1.61	0.2	1.81
3	F3 | F4	2.27	0.88	1.39
4	FP1 | FP2	−1.42	0.27	1.69
5	C3 | C4	1.97	1.48	0.49
6	FP1 | FP2	−1.46	−0.37	1.09
7	F3 | F4	2.23	0.28	1.95
8	F7 | T5	1.09	−0.29	1.38

only (all other comparisons were not significant; Tukey HSD = 0.52).

DISCUSSION

STAI scores did not improve during ETB sessions, improved modestly during NF training, but at the 6-month follow-up they had improved significantly. Symptom improvements in response to operant conditioning took many months to consolidate and were not apparent at immediate post-training testing. Medial frontal asymmetry normalized in response to training, which was desirable, even though only 1 participant trained specifically at F3 and F4. This suggests that training anterior sites to reduce alpha and increase between-site symmetry extended to other sites, notably the site-pair, which, when asymmetric in activity, are associated with mood and anxiety disorders.

Participants had different experiences with ETB ranging from not knowing what to do to change earlobe temperature to experiencing a sense of calm when able to increase its temperature. Some participants felt a positive response from the sessions and comments ranged from "This helped me to discipline myself to stay focused for 30 minutes" to "That was very boring and felt like such a waste of time; I wasn't sure I would have remained in the study without your encouragement."

Participants were cooperative, disciplined, and determined during the NF training period. There was a general sense of relief when they began NF training because they were now doing something that on the face of it appeared to apply to their therapy goals.

FIGURE 2. Change in coherence at training sites in response to earlobe temperature biofeedback and neurofeedback.

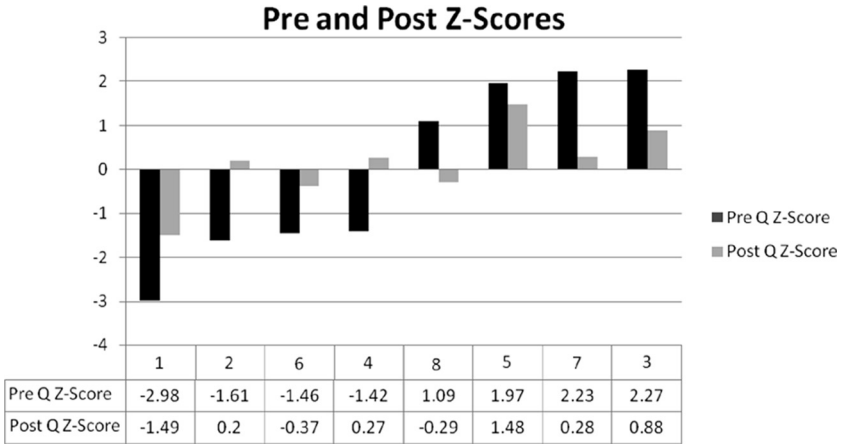


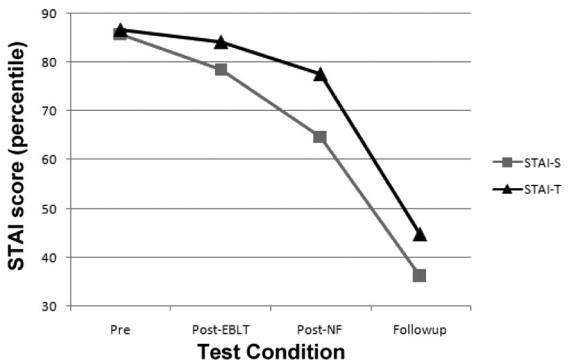
TABLE 3. Change in F3 and F4 power (*z* score) before and after entire biofeedback program.

	Pre			Post			
Participant	F3	F4	F3-F4	F3	F4	F3-F4	Primary Sites Trained
1	0.34	0.06	0.28	−0.06	−0.11	0.05	F7 | T5
2	2.66	2.59	0.07	0.05	−0.07	0.12	F7 | F8
3	0.19	−0.27	0.46	0.90	0.94	−0.04	F3 | Fz
4	−1.77	−1.84	0.07	0.07	−0.01	0.08	FP1 | FP2
5	2.30	2.30	0.00	2.04	2.09	−0.05	C3 | C4
6	0.65	0.49	0.16	0.45	0.48	−0.03	F7 | T5
7	2.47	2.51	−0.04	1.72	2.04	−0.32	F3 | F4
8	−1.69	−1.92	0.23	−1.57	−1.52	−0.05	F7 | T5
Average			0.15			−0.03	

The researcher stayed with each person during the initial sessions, coaching ways in which to access fundamental state shifts in brain activity, how to quiet minds and bodies, and how to stay focused and how to forgive and be less judgmental when they failed to meet criteria. Once the process was understood, the researcher left the treatment room for periods of time so he or she could train independently. In most individuals, anterior homologues were trained. However, 2 participants (1 and 8) trained symmetry between F7 and T5 as indicated by their brain maps.

At the 6-month follow-up, each person were asked about perceived benefits of the study and for the past 6 months. Responses included, ''I didn't notice much while involved in the study, but have since found my reaction to familial problems to be much calmer and with less arousal'' (3), ''I had an A-ha experience about halfway through the neurofeedback training and have maintained that changed state since'' (7), ''The worst part of the study was the goop'' (6), ''I still have trouble sleeping—but it's usually when there are real problems and worries to think about, rather than when things are status quo'' (7), ''My family notices that I'm easier to get along with and I've been getting along better with my step-son than ever before'' (6), and ''I'm less fearful, more optimistic, can let things go more easily, am more focused and am more willing to take things as they come'' (9). Negative responses included, ''I didn't gain as much sense of calmness as I'd hoped, but do feel somewhat better'' (5) and ''I'd hoped to get off all medication, but am still on ½ dose of Wellbutrin'' (3).

FIGURE 3. Change in State-Trait Anxiety Inventory (STAI) State and Trait scores in response to training and at follow-up. *Note.* EBLT = earlobe biofeedback training; NF = neurofeedback.



At follow-up, all participants reported reduction or stabilization in medication dosage, cessation or stabilization of cognitive-behavioral therapy and/or reduction or stabilization of supplement intake. NF may have provided the relief they were missing from other treatments, either on its own or in conjunction, augmenting other therapies by making the brain prepared to learn new ways.

Recent studies have shown that the laterality of the asymmetry may indicate the form of anxiety exhibited as well as predict panic and other comorbid mood

TABLE 4. Mean Daily Questionnaires response for feeling nervous and restless across the study.

Participant	ETB	Pre-NF	End-NF
1	2.66	3.00	3.00
2	3.00	3.00	3.33
3	2.33	2.00	2.66
4	2.66	2.66	3.00
5	4.00	2.66	4.00
6	2.00	1.66	2.66
7	2.33	3.33	4.00
8	2.33	2.66	2.66
Average	2.66	2.62	3.16

Note. ETB = earlobe temperature biofeedback; NF = neurofeedback.

disorders (e.g., Heller, Nitschke, Etienne, & Miller, 1997; Mathersul, Williams, Hopkinson, & Kemp, 2008; Wiedemann et al., 1999). Higher alpha activity in the left frontal lobe during rest may be a marker of an affective style characterized by anger and panic, an overall arousal increase. Higher right frontal resting activation may indicate shyness, apprehension, and avoidance (Beaton et al., 2008). Of the 8 active participants in this study, 6 presented with left resting activation, 1 with little or no asymmetry (with elevated power measures; Participant 5), and 1 with right resting activation (Participant 7). These findings are consistent with the behavioral manifestations found in this group. Participant 7, a computer programmer, proclaimed to be socially phobic and maintained a low-affect in social interactions. The remaining participants reported panic and high arousal and were easily angered when confronted with a perceived stressor.

Frontal alpha asymmetry is a psychophysiological index of frontal lobe function that has been studied for more than 30 years by multiple laboratories (e.g., Davidson et al., 1976). In this study, normalizing this index normalized clinical symptoms not immediately but eventually, which is not typical of epilepsy or ADHD neurotherapy research (e.g., Scott, Kaiser, Othmer, & Sideroff, 2005; Sterman, 2000). Most individuals improved modestly on anxiety scores at training's end, but significantly more improvement was seen at the 6-month follow-up. It may be the case that anxiety reflects a summary of an individual's recent events, a balance sheet of successful and unsuccessful experiences, and such histories take time to accumulate and to have impact on one's emotional traits. Anxiety may not change overnight in response to altered physiology but only through ongoing and slow-going self-reflection (e.g, Conrad, Isaac, & Roth, 2008). Regardless of the model one accepts for the finding, the biofeedback program was successful in getting all individuals to change their psychophysiology toward a desired end and in doing so produced significant clinical symptom remediation.

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APPENDIX

Daily Anxiety Evaluation

Please answer the ten questions below each evening. Consider your experience throughout the day and answer them as honestly as you can.

	No	Part of the day	Most of the day	All of the day
1. Today, I felt nervous and restless	1	2	3	4
2. Today, I made decisions easily	1	2	3	4
3. Today, I felt frightened	1	2	3	4
4. Today, I felt self-confident	1	2	3	4
5. Today, I worried about something that isn't that important	1	2	3	4
6. Today, I was content	1	2	3	4
7. Today, I was indecisive	1	2	3	4
8. Today, I found myself jittery	1	2	3	4
9. Today, I felt pleasant	1	2	3	4
10. Today, I felt rested	1	2	3	4
11. Today, I hoped I could be happier than I was feeling	1	2	3	4
12. Today, I felt secure	1	2	3	4

Code: _____ Date: _____