# A Randomized Controlled Trial for Solving Job Stress of Financial Employees Based on Neurofeedback Training

**Changju Liu*, Hongwang Cha**

**ABSTRACT**

This paper aims to verify the effect of neurofeedback (NFB) training in stress relief among financial employees. For this purpose, the randomized controlled trial (RCT) was adopted to carry out a 13-week 26-session NFB training of 49 volunteers in the upper-alpha (UA) band (8~13Hz). To assess the electroencephalography (EEG) changes, each session was designed with five training trials (4min/trail), a pre-EEG screening and a post-EEG screening. The experimental results show that all participants significantly enhanced the UA band in task-related EEG within the training sessions. This proves that the NFB training intervention is effective in improving such functions as work ethic, attention, memory, efficiency, and work execution. Suffice it to say this research provides new insights into job stress relief of financial employees.

**Key Words:** Neurofeedback (NFB), Electroencephalography (EEG), Randomized controlled trial (RCT), Upper-alpha (UA), Stress

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## Introduction

In the financial industry, brokers, traders, investment advisers and investment bankers manage assets worth trillions of dollars. The huge assets have become a heavy burden on these professionals. A survey shows that 61% of brokers suffer from serious depression, and financial professional are 40% more likely to commit suicide than the American workforce as a whole (Manjunatha *et al*., 2017). What is worse, long-term exposure to stress, anxiety, and depression is a potential challenge to the physical health of employees. In recent years, scholars in various fields are competing to resolve job stress in the financial industry (Shakya *et al*., 2017; Lenka, 2016; Li *et al*., 2015). Neurofeedback (NFB) training has stood out as a promising solution to the issue (DeRubeis *et al.,* 2008).

The NFB training is a neuro technique that allows the user to modulate his/her brain rhythms. The training consists of the following phases: measuring brain activity, processing the brain rhythms of interest, and providing the user with feedback stimuli depending on the desired results of these rhythms (Başar *et al*., 2008). The most popular way of brain activity measurement is electroencephalography (EEG). The EEG-based NFB has been widely adopted to study various neurological and psychological disorders (Ahmadi *et al*., 2014; Blum, 2015; Fattahi *et al*., 2017). However, there is rarely any report on solving the job stress of financial employees based on NFB training. With the use of NFB training, individuals can reduce their stress by adjusting their EEG frequencies and amplitudes (Ikemi, 1988). Among the different types of NFB.

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training, the upper-alpha (UA) NFB training is known for the experiential state of deep relaxation for stress relief. The UA band, as the dominant rhythm of the human EEG, is represented by a peak in the spectra within the frequency range (7~13Hz) (Cho *et al.,* 2008). The band has an impact on some cognitive factors (Bauer, 1976). The previous studies have shown that increasing the alpha band of EEG amplitude can elicit the relaxation response. Nevertheless, there is neither sufficient clinical evidence nor clear understanding of the rationale for that intervention.

One of the best methods to verify the effect of the UA NFB intervention on job stress is the randomized controlled trial (RCT). The RCT is a type of medical experiment with the aim to reduce the bias in the test of a new treatment (Chalmers *et al.,* 1981). Over the years, the RCT has been frequently employed to test the effects of different intervention methods, especially the adverse effects (Moher *et al*., 2012). The participants in the trial are randomly allocated to the test group (new treatment) and the control group (standard treatment). With the other variables remaining constant, the randomization lowers selection bias and balances both known and unknown prognostic factors. In this way, the researchers can determine any effect of the treatment by comparing the two groups. Figure 1 is the flowchart of the two-group RCT.

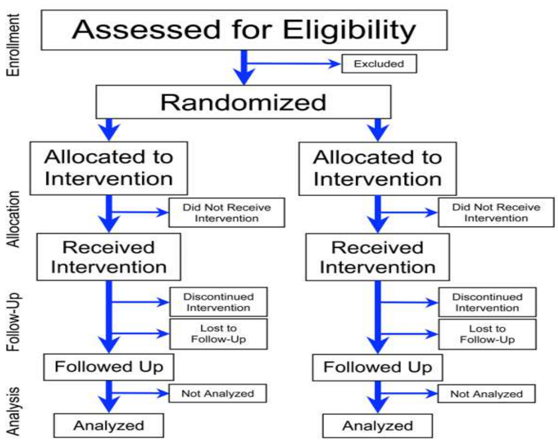


**Figure 1.** The flowchart of a two-group RCT

## Methods

### *Participants*

The participants were 49 volunteers (mean age: 44.28±5.77), including 30 males and 19 females. All of them are employees engaging in finance for over 8 years. All participants had normal vision and hearing. None of them suffered from any neurological disorder, or used to receive EEG-based NFB training.

Before physiological measurements, their job stress had been evaluated using Stress Response Inventory (SRI) and work stress questionnaire. The SRI is a common way to evaluate the stress response of participants to experimental stimuli (Margaret *et al*., 1994).

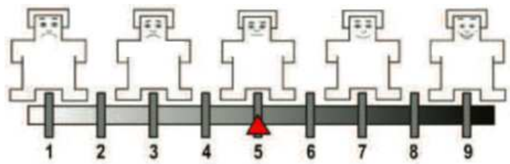


**Figure 2.** The evaluation criterion of the SRI

According to the evaluation criterion of the SRI (Figure 2), the pleasant or unpleasant emotion caused by stress is quantified on a nine-point scale in the SRI.

### *Procedure*

26 NFB sessions were designed for a period of 13 weeks. Each session lasted 32min. Two additional sessions (hereinafter referred to as the first session and the last session) were arranged with no feedback training before and after the 26 NFB sessions. The test procedure is given in Figure 3.



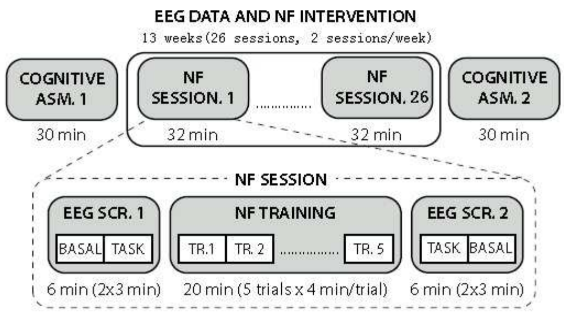


**Figure 3.** The test procedure

Each participant received the 26 sessions on alternate days (2 sessions per week). Each session consists of five training trials (4min/trail), a pre-EEG screening and a post-EEG screening. The screenings were designed to assess EEG changes.

All sessions were arranged in a sound-proof room, and recorded with a standard 4-electrode system. The brain wave recording started whenever the impedance fell below 5kΩ, the brain wave recording will begin. At the beginning of each session, a 6min baseline reading of UA amplitude was recorded. Based on the results, the threshold was computed for each participant in each session. The final threshold was set to 85% of the UA baseline amplitude, and the NFB depends on the presence of the UA (7-13Hz) amplitude.

The sound feedback (stimulating sound) and visual feedback (coloured bar graph) were released to each participant, once the threshold was reached. At the end of each session, all brain waves of the participant were recorded to reflect his/her subjective experience of the session.

### *EEG-based NFB intervention*

The EEG was amplified and digitized by a 16-sensor *gTec* system, and *Bit & Brain* was adopted to capture signals, process them, and present the feedbacks. The EEG signals were screened before and after the NFB training in each session. In each screening, the data were collected from a basic EEG and a task-related EEG. The NFB intervention was achieved by enhancing the UA power. In each 4min NFB trial, the UA power was calculated with the progression of sliding window in fast Fourier transform (FFT) phase (Zrenner *et al*., 2015).

The UA frequency band was defined as the range of frequency [IAF, IAF+2] Hz, where the IAF is the individual alpha frequency, i.e. the maximum power value in the UA range (7~13Hz) (Klimesch *et al*., 1999). The IAF was computed according to the power spectra in the pre-test EEG screening of each sensor. If there was no obvious peak of UA amplitude, the power spectra should be replaced with that of the basic EEG screening. Then, P3, Pz, P4, and the other two feedback sensors were used to compute the UA power for training settings.

The mean UA power of the feedback sensors was calculated, and normalized by the mean values of the UA amplitudes distribution between 95% and 5%. During the NFB intervention, the feedbacks were visually expressed on a screen as a square whose colour changed with the alpha amplitude. The intensity of the colour, revealing the deviation of the UA power from the baseline, was updated automatically every 30msec.

### *EEG recording and analysis*

After 26 sessions of the NFB training, the mean amplitude for UA frequency increased from 18.8$\mu V$ in the initial session to 23.8$\mu V$ in the last session. The brain waves collected after the 26 sessions are listed in Table 1. The information of the collected brain waves is depicted in Figure 4.



**Table 1.** The brain waves collected after 26 sessions

| Session | Brain Waves | | | | | |
|---|---|---|---|---|---|---|
| | Delta (0.5-4 Hz) | Theta (4-8 Hz) | Alpha (8-13 Hz) | H Alpha (10-13 Hz) | SMR (13-15 HZ) | Beta (16-22 Hz) |
| 1 | 19.5 | 10.8 | 18.8 | 15.7 | 8.5 | 6.1 |
| 2 | 16.7 | 10.4 | 17.4 | 14.5 | 7.5 | 5.6 |
| 3 | 15.2 | 10.9 | 19.5 | 16.1 | 7.9 | 5.7 |
| 4 | 16.6 | 10.8 | 18.6 | 15.6 | 7.9 | 5.9 |
| 5 | 17.3 | 10.4 | 18.9 | 16.1 | 8.3 | 5.9 |
| 6 | 17.6 | 11.2 | 20.1 | 17.1 | 9 | 6.4 |
| 7 | 16.8 | 10.4 | 18.6 | 15.7 | 8.1 | 6 |
| 8 | 16.5 | 10.1 | 19.2 | 16.9 | 8.7 | 5.8 |
| 9 | 16.3 | 9.6 | 17.8 | 15.4 | 7.4 | 5.3 |
| 10 | 17 | 10.2 | 19.5 | 16.9 | 8 | 5.7 |
| 11 | 16.4 | 10 | 18.5 | 15.8 | 8.1 | 5.9 |
| 12 | 17.3 | 10.6 | 20.5 | 17.5 | 8.4 | 6.1 |
| 13 | 18.6 | 10.2 | 18.9 | 16.2 | 7.8 | 5.9 |
| 14 | 17 | 9.6 | 18.8 | 15.8 | 7.1 | 5.4 |
| 15 | 19.7 | 10.5 | 19 | 15.9 | 7.5 | 5.5 |
| 16 | 19.2 | 10.3 | 18.6 | 16 | 7.4 | 5.6 |
| 17 | 16.2 | 9.2 | 18.8 | 15.9 | 6.9 | 5.3 |
| 18 | 22.1 | 11.8 | 22 | 18.3 | 7.8 | 5.7 |
| 19 | 18.1 | 10 | 17.8 | 15.3 | 7.3 | 5.7 |
| 20 | 18.3 | 11 | 19.6 | 16.6 | 7.4 | 5.4 |
| 21 | 15.1 | 10.4 | 21.2 | 18 | 7.2 | 5.5 |
| 22 | 18.4 | 11.6 | 24.2 | 20.5 | 8.3 | 6.3 |
| 23 | 17 | 10.4 | 20.7 | 17.4 | 7.1 | 5.2 |
| 24 | 21.9 | 10.9 | 23.8 | 20.3 | 8.1 | 5.7 |
| 25 | 18.5 | 10.9 | 22.6 | 19.4 | 8.3 | 5.9 |
| 26 | 18.6 | 11.7 | 23.8 | 20.2 | 8.4 | 6 |

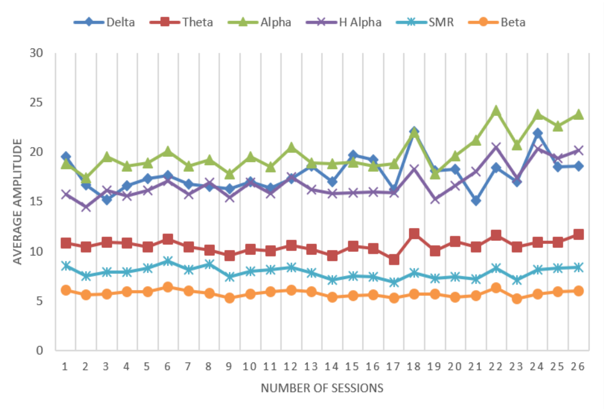


**Figure 4.** The information of the collected brain waves

As shown in Figure 4, the participants could increase UA increase alpha wave amplitude at will under the feedback-absent condition. The trend of brain waves before and after the NFB training agrees well with Thatcher's database (Durousseau, 2013).

Figures 5 and 6 respectively display the UA power for the feedback sensors $p_{UA}^{PO}$ in basic screenings and task-related screenings of all the sessions.

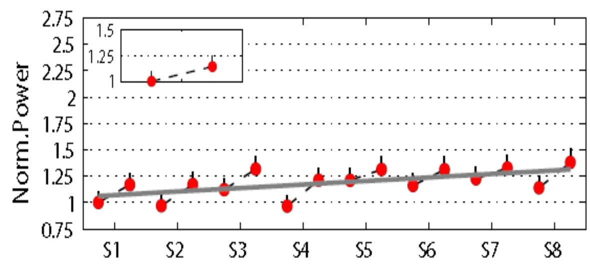


**Figure 5.** $p_{UA}^{PO}$ in basic screenings

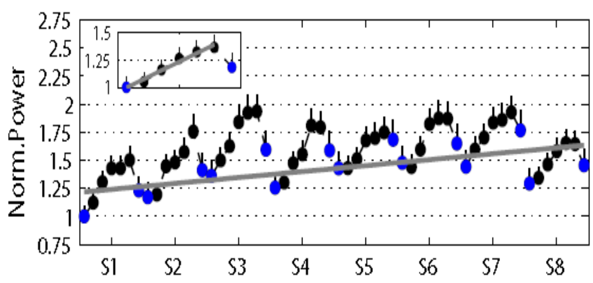


**Figure 6.** $p_{UA}^{PO}$ in task-related screenings

It can be seen that the difference between the pre- $p_{UA}^{PO}$ and post- $p_{UA}^{PO}$ (re-post $p_{UA}^{PO}$ ) increased slightly through all sessions (17.69%, $p$=0.15) and obviously within sessions (13.51%, $p$=0.047) for basic EEG. By contrast, the pre-post $p_{UA}^{PO}$ in task-related EEG grew substantially both through all sessions (44.86%, $p$<0.001) and within sessions (15.77%, $p$<0.001). The tendency of pre-post $p_{UA}^{PO}$ was 0.012 for the basic EEG ($p$<0.001), 0.021 for the task-related EEG ($p$<0.001), and 0.071 within session. Through comparison, it is found that task-related EEG had the higher increasing ratio.

The analysis reveals that the participants learned how to adjust the UA power through the training, and there was a statistically significant increase of pre-post $p_{UA}^{PO}$ in the task-related screenings and NFB training trials across and within sessions.

## Results

The cortisol level was selected to quantify the endocrine response to stress. The exact level was measured from the saliva samples of each participant. A series of t-tests for dependent measures was performed to evaluate the stress changes by cortisol levels before and after the NFB intervention.

**Table 2.** The cortisol levels before and after NFB intervention

| Session | Before session | After session |
|---|---|---|
| 1 | 101.49 | 98.5 |
| 2 | 100.48 | 100.48 |
| 3 | 104.51 | 100.51 |
| 4 | 101.16 | 100.48 |
| 5 | 99.14 | 92.78 |
| 6 | 87.83 | 90.15 |
| 7 | 96.12 | 99.52 |
| 8 | 98.15 | 95.12 |
| 9 | 86.49 | 88.15 |
| 10 | 100.15 | 89.8 |
| 11 | 107.14 | 100.41 |
| 12 | 105.73 | 92.31 |
| 13 | 104.8 | 99.8 |
| 14 | 91.5 | 89.84 |
| 15 | 100.16 | 96.45 |
| 16 | 109.43 | 98.13 |
| 17 | 106.48 | 106.75 |
| 18 | 93.2 | 89.2 |
| 19 | 103.8 | 102.43 |
| 20 | 104.41 | 96.4 |
| 21 | 102.77 | 104.44 |
| 22 | 101.47 | 100.14 |
| 23 | 104.08 | 101.48 |
| 24 | 101.11 | 101.74 |
| 25 | 103.14 | 99.14 |
| 26 | 96.45 | 102.46 |
| 27 | 96.55 | 103.19 |
| 28 | 99.48 | 97.16 |

Table 2 shows the cortisol levels before and after each of the 26 training sessions and the NFB-free first and last sessions. Figure 7 compares the cortisol levels before and after each training session.

The stress relief ability of each individual was measured accurately through a series of



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continuous performance tests called the tests of variables of attention (TOVAs). These tests are well targeted and standardized (Goez *et al.*, 2012). According to the TOVA test results before and after NFB training, the participants managed to enhance the stress relief ability by a big margin.

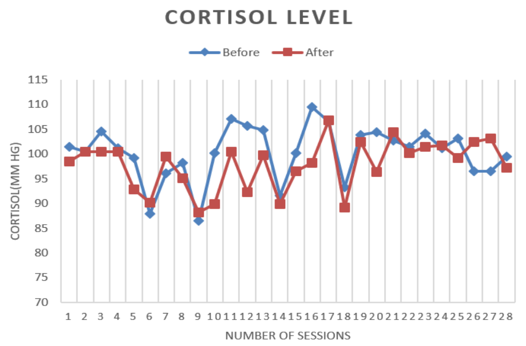


**Figure 7.** The comparison of cortisol levels before and after each session

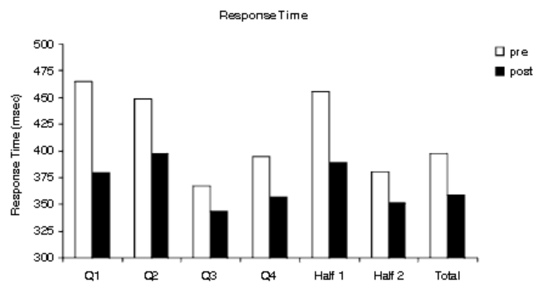


**Figure 8.** Pre- and post-response time data collected from participants

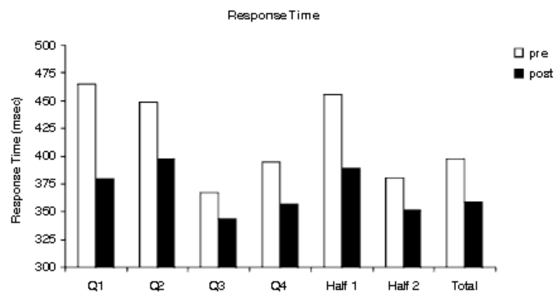


**Figure 9.** Pre- and post-response time variability data collected from participants

Traditionally, it is held that spirituality level is not closely correlated with stress relief. However, recent studies have shown that the two factors are deeply intertwined. For instance, Beddoe and Murphy (2004) found a positive correlation between the time spent in a mindfulness attitude and the ability to face stressful situations. Therefore, the response time and response time variability of mindfulness are measured separately (Figures 8 and 9).

## Discussion

Long-term job stress inevitably leads to the variability of central-autonomic responses and the decrease in physiological adaptability and immunity (Cohen *et al.*, 2000; Hughes *et al.,* 2000). Many scholars have adopted neuron-signals to quantify the job stress associated with mental tasks or work load. Some scholars pointed out that the EEG abnormalities are related to job stress, but failed to explain the scope or reliability of EEG-based stress evaluation. Through EEG recording, the author discovered that UA brain wave activity is correlated to job stress and salivary cortisol. These close relationships prove the effectiveness of NFB training in job stress relief.

The recent research on EEG-based stress evaluation mainly focuses on the relationship between the EEG and the dispositional tendency towards positive or negative effects (Dern *et al.*, 2014). In addition, some scholars highlighted the importance of the UA band in the EEG (Zoefel *et al.*, 2011). For example, Ruths *et al.*, suggested that the participants under stress exhibits reduced UA (11~12Hz) activity, and increased EEG amplitude in UA (19~22Hz) at both Cz and FCz sites (2007); the activity in the 19~22Hz band is related to stress intensity, while the activity in the 23~36Hz band reflects the active brain state of anxiety. Thus, our findings are consistent with the results of the existing research.

In summary, our experimental results show a general improvement in job stress after the NFB training intervention targeting functions such as work ethic, attention, memory, efficiency, and work execution.

## Conclusions

The previous studies have shown that an NFB training intervention in the UA band can enhance the health performance of users. Nonetheless, this strategy has not been applied to the stress relief of financial employees. To make up for the gap, this paper performs a 13-week 26-session NFB training of 49 volunteers in the UA band (8~13Hz). To assess the EEG changes, each session was designed with five training trials (4min/trail), a pre-EEG screening and a post-EEG screening. Besides, the RCT was introduced to reduce the bias in the test. The experimental results show that all participants significantly enhanced the UA band in task-related EEG within the training sessions. This proves that the NFB training intervention is effective in improving such functions as work ethic, attention, memory, efficiency, and work execution. Suffice it to say this research provides new insights into job stress relief of financial employees.

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