The Fear Survey Schedule as a Measure of Anxious Arousal: Evidence from ERPs

Aminda J. **O'Hare**[1], Joseph **Dien**[12]

[1]Department of Psychology, University of Kansas, Lawrence, KS

[2]Department of Psychology, University of Louisville, Louisville, KY

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Abstract

Anxious arousal and anxious apprehension have been proposed to be two aspects of anxiety that are differentially lateralized. Two prior event-related potential (ERP) studies have found right-lateralized ERPs that correlate with scores on the Fear Survey Schedule (FSS) but not with the Spielberger State-Trait Anxiety Inventory (STAI) scores. This study attempts to replicate the findings of right-lateralization of FSS correlates using high-density ERPs (n = 58). A spatial cueing task where emotional faces validly or invalidly cued targets was used. A right-lateralized posterior component (P296) greatest in amplitude for high FSS scores was found. This finding further supports the proposition that the FSS measures anxious arousal and that anxious arousal can be right-lateralized.

Introduction

It has been proposed by a number of researchers that there are actually two types or aspects of anxiety with distinct properties [1,2]. One dual-anxiety model makes the distinction between anxious apprehension (AA) and anxious arousal (AR) [2]. AA is typified by worry and verbal rumination [3] about perceived threats in the immediate or distant future [4]. AR is typified by somatic tension and physiological hyper-arousal due to perceived threats in the immediate future [5].

According to this model, these aspects of anxiety occur to varying degrees in different disorders [2], with AA being more prevalent in general anxiety disorder (GAD) and obsessive-compulsive disorder (OCD), and AR being more prevalent in panic attacks and high-stress situations [5]. An initial study found differential lateralization for AA and AR using resting electroencephalography (EEG) asymmetry [2]. It was found that high AA individuals had more brain activity over the left frontal lobe than the right; however, when a state of AR was induced via emotional narratives, more activity was recorded over the right posterior area than the left.

Whereas frequency-domain EEG is a powerful approach for measuring ongoing neural activity, event-related potentials (ERPs) can provide complementary information about specific stages of information processing and their timing. In one such ERP study [6], trait AA was measured by the trait scale of the Spielberger State-Trait Anxiety Inventory (STAI-T) [7] and trait AR was measured by the Fear Survey Schedule (FSS) [8]. Participants viewed moving numbers and were to report if they were even or odd or going up or down. A left-lateralized N1 component correlated with high STAI-T scores, and a right-lateralized P1r component correlated with high-residualized FSS (rFSS) scores (residualized scores controlled for the part of the FSS accounted for by the STAI-T). Interestingly, another ERP investigation [9] found an increased P1 component over right posterior sites to correspond with high FSS scores during the gender or valence classification of emotional faces and an increased right-lateralized N170 component that corresponded with Social Phobia and Anxiety Inventory (SPAI) scores and viewing angry faces in social phobics, but no effects were found for the STAI-T.

These two ERP studies [6,9] yielded results that were somewhat discrepant with each other. Although both reported right-lateralized effects correlating with the FSS, the components were quite different in nature. The so-called P1r component [10], despite the name reported by the earlier study, actually peaks at about 300 ms whereas the effect found in the latter study peaked at about 104 ms. Furthermore, only the former study found a left-lateralized effect correlating with STAI-T. One possible reason is the difference in the stimuli (numbers in the former and faces in the latter), which are stimuli that tend to be favored by the left and right hemispheres respectively. Additionally, in the latter study, one of the tasks was to directly process the emotional content of the faces, which was done to directly influence the cognitive processes of the participants' phobias. Another possibility is the difference in the nature of the participants (college students in the former and individuals with social phobia in the later). Due to these differences, it is unclear what these differences in ERP effects signify.

The current study is designed to investigate this issue further. This study uses target stimuli (simple shapes) whose processing are not as right-lateralized as emotional faces. Furthermore, the design is intended to be more comparable to experimental paradigms currently being used to study anxious cognition. The spatial cuing task used in this study is adapted from that used in previous investigations of anxiety and attention [11]. Emotional face cues were used as they are more relevant for examining the cognitive effects of anxieties, as it has been shown that high anxiety individuals process threats differently than low anxiety individuals [11,12], and faces are more ecologically valid than emotional words or other stimuli as we encounter them on a daily basis [9,11].

One further aspect of the experimental design relates to a line of research that has suggested that rather than having a “hyper-vigilance” for threat stimuli, high anxiety individuals have difficulty disengaging their attention from threat stimuli [11]. This effect was represented by delayed reaction times to targets invalidly cued by angry face stimuli in high anxiety participants and was interpreted as this group of participants needing to obsess on threat stimuli in an attempt to resolve any ambiguities, a characteristic of AA. To further examine this effect, half of the emotional face cues for this study were presented obscured. If high AA individuals do have trouble disengaging their attention from threat stimuli due to their need to resolve ambiguities of the threat, this group should take even longer to respond to targets invalidly cued by obscured-angry faces.

It is hypothesized that the FSS scores will be associated with AR rather than AA. Individuals who score high on the STAI-T (AA) and those who score high on the FSS (AR) are predicted to show differential patterns of brain laterality. A replication of the Dien (1999) findings [6] is expected: High STAI-T (AA) scores will be associated with a larger N1. It is also predicted that individuals who score high on the FSS (AR) will show the enhanced P1r found in the prior study.

Methods

Participants

Participants were 73 right-handed, native English-speaking students participating for course credit. All participants gave informed consent. Participants had no history of head injury or brain pathology, were not taking any psychoactive medications and had never been diagnosed with any attention-related disorders. Fifteen participants were dropped due to excessive artifact or eye blinks, leaving 58 final participants (30 females; mean age = 19.7).

Stimuli

Face stimuli were from the NimStim stimulus set[1]. Happy and angry versions of 18 Caucasian faces (9 female) were chosen from the set. Of these, both a non-obscured and an obscured (90% opacity) version were made.

Targets were a black square and a triangle that were equally likely to appear. All cue and target stimuli were 6.4 degrees in size and their centers were presented 7 degrees from fixation.

Psychometrics

Participants completed the Spielberger State-Trait Anxiety Inventory (STAI) [7] and the Fear Survey Schedule (FSS) [8].

Apparatus

Electroencephalographic (EEG) data were collected using a 129-channel HydroCel Geodesic Sensor Net (Electrical Geodesics, Inc.). Electrode impedances were measured using a criterion of 50k ohms, per manufacturer guidelines for this high-impedance system. Data were recorded with a bandpass of .1 to 100 Hz and digitized at 250 Hz. The EEG was segmented 200 ms before and 1000 ms after the cue onset, retaining only trials with correct responses. EEG data were low-pass filtered at 30 Hz and

[1] Development of the MacBrain Face Stimulus Set was overseen by Nim Tottenham and supported by the John D. and Catherine T. MacArthur Foundation Research Network on Early Experience and Brain Development (please contact Nim Tottenham at tott0006@tc.umn.edu for more information concerning the stimulus set).

baseline corrected. Data were transformed to average reference using the PARE correction [13,14].

Eye blinks were removed using an automated independent components analysis routine (download at [15]) using EEGLAB [16], supplemented by visual editing. Stimuli were presented using E-prime (Psychology Software Tools, Inc). Computerized versions of the STAI and FSS were presented via a Revolution Dreamcard stack (Runtime Revolution).

Procedure

The participants' task was to discriminate between targets by pressing one button for square and one button for triangle (fingers of response were counterbalanced). Participants were told that the location of the cue would predict where the target would appear "most of the time". Ten practice trials were completed, followed by four blocks of 90 trials each. Each trial (75% valid) occurred as such: 1000 ms fixation + 150 ms face cue + 50 ms inter-stimulus interval (ISI) + 2000 ms target (or upon response, whichever was sooner). Lastly, the STAI and FSS were completed.

Behavioral Analyses

All participants had accuracies better than chance (60% correct). Only reaction times (RTs) for correct trials that were longer than 100 ms were included. Median RTs were used for analyses. Residualized scores on the FSS (rFSS) were used to adjust for the correlation between this measure and the STAI-Trait (STAI-T) measure (for more information please refer to [6]). Only the trait, not state, measures were used from the STAI because the theoretical focus was on trait effects. Split-halves of both STAI-T and rFSS scores were used as between-groups factors for all analyses. RT analyses were 3, 2-

level within factors: cue obscurity (non-obscured/obscured), face type (angry/happy), and trial type (valid/invalid) by 2, 2-level between group factors: high/low AA and high/low AR split-plot ANOVAs.

Principal Components Analyses

In order to isolate the primary ERP components contributing to the perception of the cues and targets, a temporo-spatial principal component analysis (PCA) was conducted using the Matlab ERP PCA Toolbox 1.093 [17]. The relational matrix was the covariance matrix. Promax rotation to a simple structure was used [18,19], with Kaiser correction for the Varimax portion of the procedure. A follow-up spatial Infomax rotation was applied, following an initial PCA to obtain a reduced subspace, to each temporal factor score to separate them [20,21], using the routine from EEGlab [16].

For the inferential tests, Keselman's SAS/IML code for robust statistical tests [22] was ported to Matlab [23]. Settings were: 10% symmetric trim rule, seed for the number generation set at 1000, number of simulations used for the bootstrapping routine set at 50,000 (for more information on inferential issues with ERP data please see [24]). PCA factor analyses were 4, 2-level within factors: cue obscurity (non-obscured/obscured), face type (angry/happy), trial type (valid/invalid), and laterality (left/right hemisphere) by 2, 2-level between group factors: high/low AA and high/low AR, split-plot ANOVAs.

Results

Behavioral Analysis

A main effect for trial type, T_{WJt}/c (1, 44.98) = 38.02, $p < 0.01$, was found, such that participants were quicker to respond to valid than invalid trials (invalid: M=410.15 ms, valid: M=397.14 ms). A main effect for trial obscurity, T_{WJt}/c (1, 36.76) = 3.92, p

= .05, was found, such that participants were quicker to respond following non-obscured than obscured cues (obscured: *M*=405.21 ms, non-obscured: *M*=402.09 ms). Significant interactions between trial type and obscurity, T_{WJt}/c (1, 44.10) = 28.54, $p < 0.01$ (Fig 1a), trial type and face type, T_{WJt}/c (1, 40.51)=3.95, $p < 0.05$ (Fig 1b), and STAI-T (AA) and rFSS (AR) scores, T_{WJt}/c (1, 39.88) = 5.80, $p = 0.02$ (Fig 1c), were found.

Figure 1 placed about here

Principal Components Analysis

Scree plots for the temporal PCA suggested 9 factors be retained, accounting for 77.84% of the variance. Scree plots for the spatial ICA suggested 4 factors be retained, accounting for 80.83% of the variance. Thus, the 9 temporal factors were each divided into 4 spatial factors, resulting in 36 total factors in the temporal-spatial PCA. A Bonferroni multiple comparisons correction was used to adjust for the 36 PCA factors in these ANOVAs, setting an alpha level of 0.00139. Factors were dropped if they were determined to represent noise in the data via visual inspections. Other factors were not further analyzed if their effects were no longer significant following the Bonferroni correction.

Figure 2 placed about here

Using the aforementioned robust statistical tests, only one factor was found to have a significant effect following the Bonferroni correction. Factor 20 is a right-lateralized positivity in the posterior channels, peaking at 296 ms post-target (P296) and is greatest at channel PO8 (Fig 2a). A main effect for rFSS scores on P296 was found, $T_{WJt}/c(1, 36.5401) = 13.6813$, $p = .0007$ (high rFSS: M=1.76 µv, low rFSS: $M = .21$ µv).

To test the reliability of the P296, a windowed analysis on the participants' individual average files was run. Two symmetrical clusters were chosen, centering on channels PO7 and PO8. A window of 300-348 ms post-target onset was selected. A main effect for laterality was found $T_{WJt}/c(1, 33.5415) = 14.0217$, $p = .0009$ (right: $M = .89$ µv, left: $M = .22$ µv). An interaction between rFSS scores and laterality was found, $T_{WJt}/c(1, 33.5415) = 7.0193$, $p = .013$, (largest on right for high AR: $M = 1.31$ µv) (Fig 2b). Data was reanalyzed without the baseline correction to check for a contingent negative variation effect in the high rFSS group and no such effect was found. A dipole-source analysis using two dipole pairs was run for the PCA component, providing a rough estimate for its source at the right superior temporal gyrus (rSTG) [48.1, -33.3, 4.1], variance accounted for = 86.39% and at the right orbitofrontal cortex (rOFC) [37.8, 39.8, -1.0], variance accounted for = 94.75% (Fig 2c and d).

Discussion

The main hypothesis, that the FSS provides a more sensitive measure of a right-lateralized aspect of anxiety than the STAI-T, was supported. The prediction for a right-lateralized posterior ERP in the AR group was fulfilled. The prediction for left-lateralized ERPs in the AA group and delayed RTs to targets invalidly cued by obscured-angry faces were not supported.

A right-lateralized ERP component, the P296, was found via PCA to be sensitive to scores on the FSS. The P296 can be considered an indicator of the differences between the FSS and the STAI-T. It seems that the FSS is a more sensitive measure of the AR aspect of anxiety than the STAI-T, and thus would be a more appropriate measure for assessing trait levels of high-arousal in anxious individuals. Hence, not including the FSS as a measure when studying anxiety may result in overlooking valuable data. Indeed, at least one other study discussed earlier has found ERP effects for the FSS but not the STAI-T in a clinical population [9], providing support for this conjecture.

While the P296 matches the laterality predictions for AR, it does not match previously reported ERP components. The ERP study discussed earlier that also looked at the processing of stimuli in high AA and high AR groups [6] found a right-posterior P1r component to correlate with FSS scores and a left-lateralized N1 component to correlate with STAI-T scores. While the latencies of the P1r and the P296 are similar (both around 300 ms), their scalp topographies do not match, with the P1r being located more fronto-centrally than the P296. It is possible that the P296 and the P1r reflect the same cognitive processes in high AR individuals, but the movement of the stimuli used that elicited the P1r may have modified the scalp topography. The current study did not find any ERPs to correlate with STAI-T scores or the N1 previously reported. The lack of findings for STAI-T scores may be due to the nature of the study (the emotional face stimuli) being enough to arouse high AR individuals but not high AA individuals.

The current study also did not replicate the P1 component previously found to correlate with FSS scores in social phobics [9]. The P1 is thought to reflect early visual attention, and thus the ability of social phobics to quickly detect stimuli in their environment. Again, the difference in participants could account for the difference in findings here.

More recently, AA and AR were examined using functional magnetic resonance imaging (fMRI) and the emotional Stroop task [4]. The left inferior frontal gyrus was found to be more active to negative than neutral words in high AA individuals, likely reflecting their verbal rumination over threats, and the right inferior temporal gyrus, the same area found to be sensitive to AR levels here, was found to be more active to the same words in high AR individuals, likely reflecting their readiness to respond to nonverbal threat cues. These data provide strong evidence for the differential processing of emotional stimuli of these anxieties and their separate lateralities, and contribute to the localization of the source of their differential cognitive effects. The results of this imaging study do raise the question of why the P296 effect was not specific to angry faces. The P296 may reflect differential stimuli processing due to the response to overall arousal from both the positive and negative faces.

The first source indicated by the dipole-source localization, the rSTG, falls within 10 mm of an area indicated in the detection of targets in an fMRI study [25]. This fits the characterization that high AR individuals are primed to detect threats in their environment. The second source indicated was the rOFC. This is an area that is often involved in the processing of emotional stimuli (see [26] for a review). Again, the source-analysis conducted for the P296 provides only a rough source location estimates.

Conclusion

Support was found for the FSS being a more sensitive measure of the high-arousal aspect of anxiety than the STAI-T. The right-lateralized P296 component found to be higher in amplitude in high AR individuals matches the predictions of previous dual-anxiety models [2,6]. The P296 localized to the rSTG, an area of the brain implicated in target detection [25]. It is likely that the P296 indicates high AR individuals being primed to detect target locations in their environment. This result has implications for the importance of considering dual-anxiety models in studies of anxiety, as well as for the idea that the FSS may be a more sensitive psychometric for measuring AR levels than the STAI-T. Future directions include investigating the differential temporal processing of emotional stimuli in AA and AR.

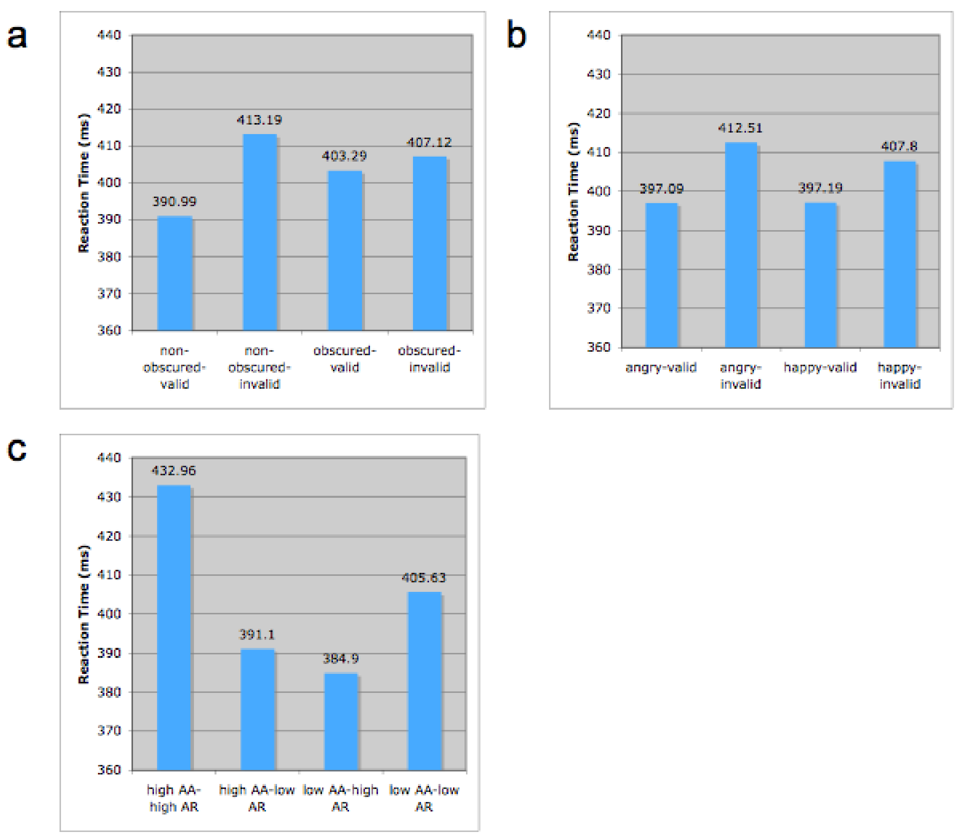

Figure 1. a. Graph of interaction between trial obscurity and trial type. b. Graph of interaction between face type and trial type. c. Graph of interaction between STAI scores (AA) and rFSS scores (AR).

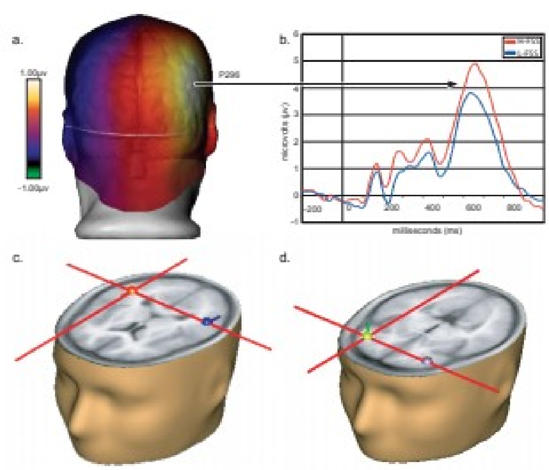

Figure 2. a. Topographical map of the P296. b. Appearance of the P296 in the average waveforms (596 ms post-cue). c. Source localization suggested the rSTG and the d. rOFC as sources for the P296.

References

[1] Gray, J. A. & McNaughton, N. *The Neuropsychology of Anxiety: An Enquiry into the Functions of the Septo-Hippocampal System* (Oxford University Press, Oxford, 2000).

[2] W. Heller, J. B. Nitschke, M. A. Etienne & G. A. Miller, Patterns of regional brain activity differentiate types of anxiety, J Abnorm Psychol. **106** (1997 Aug) 376-385.

[3] D. H. Barlow, Disorders of Emotion, Psychological Inquiry. **2** (1991) 15.

[4] A. S. Engels et al., Specificity of regional brain activity in anxiety types during emotion processing, Psychophysiology. **44** (2007 May) 352-363.

[5] J. B. Nitschke, W. Heller, P. A. Palmieri & G. A. Miller, Contrasting patterns of brain activity in anxious apprehension and anxious arousal, Psychophysiology. **36** (1999 Sep) 628-637.

[6] J. Dien, Differential lateralization of trait anxiety and triat fearfulness: Evoked potential correlates, Personality and Individual Differences. **26** (1999) 24.

[7] Spielberger, C. C. *Manual for the State-Trait Anxiety Inventory* (Consulting Psychologists Press, Palo Alto, CA, 1983).

[8] P. R. Braun & D. J. Reynolds, A factor analysis of a 100-item fear survey inventory, Behavior Research Therapy. **7** (1969) 4.

[9] I. T. Kolassa & W. H. Miltner, Psychophysiological correlates of face processing in social phobia, Brain Res. **1118** (2006 Nov 6) 130-141.

[10] D. M. Tucker, M. Liotti, G. F. Potts, G. S. Russell & M. I. Posner, Spatiotemporal analysis of brain electrical fields, Human Brain Mapping. **1** (1994) 134-152.

[11] E. Fox, R. Russo, R. Bowles & K. Dutton, Do threatening stimuli draw or hold visual attention in subclinical anxiety?, J Exp Psychol Gen. **130** (2001 Dec) 681-700.

[12] C. L. Larson, J. B. Nitschke & R. J. Davidson, Common and distinct patterns of affective response in dimensions of anxiety and depression, Emotion. **7** (2007 Feb) 182-191.

[13] O. Bertrand, F. Perrin & J. Pernier, A theoretical justification of the average reference in topographic evoked potential studies, Electroencephalogr Clin Neurophysiol. **62** (1985 Nov) 462-464.

[14] M. Junghofer, T. Elber, D. M. Tucker & C. Braun, The polar average reference effect: A bias in estimating the head surface integral in EEG recording, Clinical Neurophysiology. **110** (1999) 1149-1155.

[15] J. Dien, http://www.people.ku.edu/~jdien/downloads.html.

[16] A. Delorme & S. Makeig, EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis, J Neurosci Methods. **134** (2004 Mar 15) 9-21.

[17] J. Dien, http://www.people.ku.edu/~jdien/downloads.html.

[18] J. Dien, Issues in the application of the average reference: Review, critiques, and recommendations, Behavioral Research Methods, Instruments and Computers. **30** (1998) 10.

[19] J. Dien, D. J. Beal & P. Berg, Optimizing principal components analysis of event-related potentials: matrix type, factor loading weighting, extraction, and rotations, Clin Neurophysiol. **116** (2005 Aug) 1808-1825.

[20] J. Dien, K. M. Spencer & E. Donchin, Localization of the event-related potential novelty response as defined by principal components analysis, Brain Res Cogn Brain Res. **17** (2003 Oct) 637-650.

[21] K. M. Spencer, J. Dien & E. Donchin, A componential analysis of the ERP elicited by novel events using a dense electrode array, Psychophysiology. **36** (1999 May) 409-414.

[22] H. Keselman, http://www.umanitoba.ca/faculties/arts/psychology/.

[23] J. Dien, http://www.people.ku.edu/~jdien/downloads.

[24] Dien, J. & Santuzzi, A. M. in *Event-related potentials: A methods handbook* (ed T.Handy) (MIT Press, Cambridge, MA, 2004).

[25] M. Corbetta, J. M. Kincade, J. M. Ollinger, M. P. McAvoy & G. L. Shulman, Voluntary orienting is dissociated from target detection in human posterior parietal cortex, Nat Neurosci. **3** (2000 Mar) 292-297.

[26] R. Adolphs, Neural systems for recognizing emotion, Curr Opin Neurobiol. **12** (2002 Apr) 169-177.