HHS Public Access
Author manuscript
Int J Sports Med. Author manuscript; available in PMC 2017 July 13.

Published in final edited form as:
Int J Sports Med. 2014 July ; 35(8): 708–713. doi:10.1055/s-0033-1363235.

Anxiety and Attention Shifting in Professional Baseball Players

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Abstract

Based on the work of both Eysenck and Nideffer, we hypothesized that higher ranking players (HRP) would have lower competitive anxiety and more flexible attention-shifting, compared to lower ranking players (LRP). In addition, different patterns of attention (low anxiety and flexible attention) would be represented by a different pattern of brain activity within the temporal lobe and dorsolateral prefrontal cortex. In accordance with the rookie draft ranking, the players were classified into 2 groups: HRP (top 30 % of those selected in the draft) vs. LRP (bottom 30 % of those selected in the draft). For assessment of executive function, a computerized version of the Wisconsin Card-sorting Test (WCST) was used. Brain activity was assessed using 1.5-Tesla functional magnetic resonance imaging. In response to scenes depicting baseball errors, HRP showed increased activation in the left cingulate cortex and decreased activation in right middle temporal gyrus, compared to LRP. In response to the simplified WCST in the scanner, HRP showed increased activation in left superior frontal cortex (DLPFC), compared to LRP. The present results suggest that HRP may demonstrate elevated cingulate activation and lower temporal cortex activation in response to scenes depicting baseball errors.

Keywords

professional baseball players; attention shifting; anxiety; temporal cortex; cingulate; dorsolateral prefrontal cortex; perseverative error

Introduction

Anxiety, performance, achievement and errors

Performance in sports is thought to be associated with anxiety states of athletes under high-pressure conditions [9]. Player concerns about other people’s evaluations of their performance has been reported to provoke competitive sports anxiety in youth skiers [4]. Indeed, several studies have noted that perfect skills and a lower rate of errors in elite players

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in sports might result from lower competitive anxiety during game play [5]. Examining a basketball free throw and a darts task, Englert and Bertrams [9] suggested that self-control reduced anxiety, which improved athletic performance under pressure. Wang et al. [37] reported that the best predictors of performance failure in a high-pressure situation (choking) in sports were self-consciousness and high trait anxiety. Indeed, several studies have noted that perfect skills and a lower rate of errors in elite players in sports might result from lower competitive anxiety during game play [5, 20]. Coelho et al. [5] reported that reduced competitive state anxiety was associated with decreased perceived stress and increased self-confidence in elite tennis players. High self-confidence with low competitive anxiety has been proposed to increase the intensity of feeling total control over performance [20]. In addition, past studies have shown negative correlations between cognitive anxiety and accuracy of sports skill in elite athletes [3]. Several studies have reported that elite athletes have lower competitive anxiety, which was inversely associated with performance during game play, compared to general athletes [16, 19]. In a comparison of rugby, basketball, soccer and field hockey athletes with higher or lower levels of competitive anxiety, athletes with lower anxiety were less discouraged and reported less stress than athletes with higher anxiety [16]. In our previous study, we reported that elite professional soccer and baseball players had lower stress and anxiety during competitive situations, compared to general players [19].

Attentional set-shifting and good performance

Attentional distraction involving set-shifting is one of the primary strategies that individuals use to regulate anxiety [23]. Attentional shifting is thought to be an automatic strategy for the regulation of emotion, since it requires minimal cognitive effort [35]. As a strategy for emotional regulation, attentional set shifts one aspect of a situation to another aspect of the situation or entirely away from the situation altogether [17]. In an analysis of 142 undergraduate students, attentional shifting was negatively correlated with state anxiety [36]. Attentional shifting which was associated with flexible problem-solving has been thought to reduce instrumental disability in older patients with depression [33]. For controlling competitive anxiety, elite players are thought to use attentional shifting which may be associated with excellent performance [19, 39]. The Wisconsin card-sorting test (WCST) is known to assess selected task components including set-shifting, working memory and inhibitory control processes [25]. One of the sub-components of the WCST, perseverative errors, may reflect ‘set-shifting’ which consists of shifting subject focus from a previously relevant dimension to a new dimension [7].

Brain imaging studies in sports

The results of functional brain imaging studies in sports may be important for characterizing practice-dependent areas during sports performance [1, 6]. Badminton expertise is reported to be associated with increased functional connectivity in frontoparietal regions [6]. Body awareness is important for performance-monitoring in expert basketball players, while higher-order decision-making strategies are used for performance-monitoring in novice basketball players [1]. A number of brain imaging studies have reported that the temporal lobe, including the amygdala, hippocampus and insular cortex activate in response to phobic or anxious stimulation [22]. In addition, attentional shifting and perseverative responses have been associated with dorsolateral prefrontal cortex activity [32].

Hypothesis

Attentional control theory developed from Eysenck and Calvo's [14] processing efficiency theory rests on 2 assumptions: (1) state anxiety is associated with performance effectiveness, and (2) the working memory involving attentional shifting is affected by anxiety. The test of attentional and interpersonal style (TAIS) has suggested 2 types of attentional focus, a dimension of width (broad to narrow) and a directional dimension (internal or external) [30, 31]. In response to each focus type, the response is different: (1) broad-external focus – environmentally aware and ready to react automatically and/or instinctively to something occurring around athletes; (2) broad-internal focus of concentration analysis, strategy and planning; (3) narrow-internal focus – assessing and manipulating internal state in some systematic way to mentally check breathing rate; and (4) narrow-external focus – actually performing some physical (e. g., hitting a ball) or interpersonal (asking a question or confronting an issue) task. Increased arousal (anxious and stressful conditions) breaks down attention shifting and narrows the attentional width to be more internally focused [30]. In addition, under stressful situations, there are involuntary biological changes, including heart rate, respiration rate, muscle tension and pupillary constriction which affect athletic performance [13].

Based on the work of both Eysenck and Nideffer, we hypothesized that HRP would have lower competitive anxiety and more flexible attention shifting, compared to LRP. In addition, different patterns of attention (low anxiety and flexible attention) would be represented by a different pattern of brain activity within the temporal lobe and the dorsolateral prefrontal cortex.

Methods

Subjects

All subjects were rookie players in the Korean Baseball Organization (KBO) during 1 of 3 seasons: 2009, 2010, or 2011. 2 probaseball teams annually select about 8–10 amateur baseball players from high school and university teams. Of 57 rookie players on 2 professional baseball teams, 33 players agreed to participate in the current study. In accordance with published rookie draft rankings, the players were classified into 2 groups: 13 higher ranking players (top 30 % of those selected in the draft) vs. 20 lower ranking players (bottom 30 % of those selected in the draft). The Chung Ang University Institutional Review Board approved the research protocol of this study. Written consent was provided by all players. In addition, all authors read and understood IJSM' ethical standards and the current research met the ethical standards of the IJSM [21].

Assessments

Anxiety—The Korean version of Spielberger's State-Trait Anxiety Inventory (STAI form Y) was used for estimating trait anxiety of subjects. State anxiety during game play was assessed using the Korean version Competitive State Anxiety Inventory-2 (CSAI-2) [26].

The internal consistency of K-CSAI-2 has been reported to range from 0.75 to 0.90 [26]. To identify an appropriate stimulation for anxiety provocation in the scanner, we first conducted a survey of the 33 participants. An open ended question, “What makes you anxious during baseball game play?” was asked, and the number of answers was not limited. The answers included: errors during play (23), slumps (15), spectators (15), consecutive defeats (12), opposing team players (9), weather (7), same team coach (5), same team players (3), none (2) and others (11). Based on that information, we selected scenes which depict errors during play in order to provoke anxiety.

Cognitions

For assessing executive function, a computerized version of the Wisconsin Card-sorting Test (CNT4.0, Maxmedica Inc) was used [27]. Baseball players matched each test card to 1 of 4 reference cards. Through trial and error, players would identify the correct sorting rule (color, object numbers or shape). Players performed the test until either the identification of 3 correct sorting rules twice (6 categories) or until all 128 cards had been played. Outcomes were measured by the number of categories completed, the number of perseverative errors and responses, the number of trials taken to complete the first category, and the total number of errors. The reliability of the computerized version-WCST is reported as Cronbach’s α = 0.783. The intelligence Quotient (IQ) was assessed using the Korean-Wechsler Adult Intelligence Scale (K-WAIS). K-WAIS consists of 11 sub-categories (Information, Digit Span, Vocabulary, Arithmetic, Comprehension, Similarity, Picture Completion, Picture Arrangement, Block design, Object Assembly and Digit Symbols). The internal consistency of K-WAIS has been reported to range in Cronbach’s α from 0.78 to 0.94 [24].

Brain activity

Brain activity in baseball players was assessed 2 times using functional magnetic resonance imaging (1.5 Tesla Espree MRI scanner, SIEMENS, Erlangen, Germany) in response to scenes depicting errors and modified WCST performance in scanner. Error stimulation consisted of short videos depicting errors during important moments in the game. For example, a second baseman missed a ball with bases loaded and one out. A first baseman misses an easy foul fly ball with bases loaded and 2 outs. 2 versions of the WCST were administered. Before scanning, baseball players were assessed by the completed WCST-computerized version. Inside the scanner, baseball players watched a black screen consisting of 4 reference cards on the upper section of the screen and one stimulus card in the middle of the lower section of screen. A 2 button keypad was used to match the stimulus card to 1 of the 4 reference cards. Each stimulus card was presented for 4000 ms. After each decision, visual feedback (correct or incorrect) was presented on the screen for 500 ms followed by a blank screen (500 ms). The WCST neutral block consisted of reference cards only in the upper section of the screen without a stimulus card. During the WCST neutral period, baseball players were asked to push the keypad buttons randomly.

Each scenario consisted of a 450-s picture/video with 5 continuous 90-s segments. Each 90-s segment consisted of three 30-s sub-segments. A white cross on a black background (B), a neutral control (N, reference cards + pushing button/mosaic scene) and the task (T, Wisconsin card-sorting test/video depicting errors) were included in these 90-s segments.

The order of 5 segments and the MRI scan protocol were the same as seen in a previous study [18].

fMRI data analysis

The 2 sets of fMRI data were analyzed using the Brain Voyager software package (BVQX 1.9, Brain Innovation, Maastricht, The Netherlands). The fMRI time series data was co-registered to the anatomical 3D data sets using the multi-scale algorithm provided by BVQX. Individual 3D structural images were spatially normalized to standard Talairach space. An identical nonlinear transformation was subsequently applied to the T2*-weighted fMRI time series data. Following preprocessing steps for slice scan time correction and 3D motion correction, the functional data were spatially smoothed using a Gaussian kernel with an FWHM of 6 mm and temporally smoothed using Gaussian kernel of 4 s using algorithms provided by BVQX.

Statistical analysis

The general linear model (GLM) and random effects analysis (RFX) were applied to analyze the fMRI signal time-courses on a voxel-by-voxel basis and to generate individual and group statistical parametric maps of brain activation. For all analyses, we regarded the associations as significant when the uncorrected p-value was less than or equal to false discovery rate (FDR) correction < 0.05 in 40 adjacent voxels. In an F test, interaction within Factor (task scene vs. neutral scene) × between factor (HRP vs. LRP), we found 3 clusters. As a second-level analysis in all players, Spearman correlations were used to evaluate relationships between the mean β value in clusters and draft ranking, cognitive function results and anxiety. To account for multiple comparisons, we set significant p-values as being less than or equal to 0.05/4.

Results

Demographic characteristics

There was no significant difference in terms of age, years of education, years of playing baseball and economic status between HRP and the LRP groups. However, by design, there were significant differences in the earned run average (ERA), batting average and draft ranking between the HRP and LRP groups.

Anxiety and cognitive function

HRP showed lower competitive anxiety on the CSAI-2, compared to LRP ($z = 2.70$, $p < 0.01$). There were no significant differences in IQ between the HRP and LRP groups (Table 1). However, on the full WCST, HRP committed fewer perseverative errors, compared to LRP ($z = 2.08$, $p = 0.03$). There were no significant differences in other sub-categories of the WCST (Table 1).

Brain activity

In response to scenes depicting baseball errors, HRP showed increased activation in the left cingulate cortex, compared to LRP. In response to scenes depicting errors, HRP also showed decreased activation in the right middle temporal gyrus, compared to LRP. In response to the modified WCST performance in the scanner, HRP showed increased activation in the left superior frontal cortex, compared to LRP (Fig. 1) (Table 2).

Correlation of anxiety, cognition and brain activity

The β value of right middle temporal gyrus activation in all baseball players was positively correlated with CSAI-2 scores ($r = 0.52$, $p < 0.01$). The β value of the right middle temporal gyrus activation in all baseball players was positively correlated with draft ranking at a trend level ($r = 0.36$, $p = 0.04$). The β value of left superior frontal cortex activation in all baseball players was negatively correlated with perseverative errors ($r = -0.45$, $p < 0.01$) (Fig. 2). The β value of the left superior frontal cortex activation in all baseball players was negatively correlated with draft ranking ($r = -0.41$, $p = 0.01$). The mean off-line CSAI-2 scores were weakly correlated with perseverative errors in all baseball players. However, this result was not statistically significant ($r = 0.31$, $p = 0.09$).

Discussion

Although the total number of subjects in this study was not large enough to show a direct correlation between anxiety and attention shifting, the current results suggest that HRP have lower competitive anxiety with less activity within the temporal cortex and more flexible attention shifting with greater activation in the dorsolateral prefrontal cortex, compared to LRP. To the best of our knowledge, this is the first report supporting attentional control theory (anxiety and performance, attention shifting and anxiety) [14] with the evidence of brain activation in response to anxiety provocation situations and attention shifting in baseball players.

Anxiety, performance and brain activation in response to anxiety provocation situation

HRP demonstrated lower competitive anxiety compared to LRP. This is not a surprising result, and similar findings have been reported in a number of research studies [19, 38]. Wiggins et al. [38] reported that basketball players who experienced lower anxiety were less discouraged and less stressed during competition, compared to basketball players who reported higher anxiety. Our previous research noted that elite baseball and soccer player groups showed less state anxiety, compared to general player groups [19].

In response to the presentation of errors, HRP showed increased activity in the cingulate gyrus and decreased activity in middle temporal gyrus, compared to LRP. In addition, activity of the temporal lobe in response to errors being committed was positively correlated with measures of competitive anxiety and draft ranking at a trend level of significance across all baseball players. Phobic and anxiety processes are thought to be linked to hypervigilance in the temporal lobe and prefrontal regulatory resources to implement avoidant response strategies [22]. For example, in patients with post-traumatic stress disorder (PTSD), a number of investigators have reported hyperresponsive amygdala activity and hyporesponsive anterior cingulate activity (failing to inhibit an exaggerated amygdala) [34].

The cingulate gyrus in healthy volunteers is thought to regulate emotional conflict including anxiety by dampening the activity of the amygdala [8, 11]. Moreover, the failure of anterior cingulate activation and connectivity with the amygdala in response to an emotional conflict task has been reported in generalized anxiety disorder patients [12]. In particular, the dorsal cingulate is thought to evaluate emotional information and generate appropriate responses [10]. In our results, competitive anxiety was positively correlated with the activity of the middle temporal gyrus. Overall, HRP observed error scenes with less activation of the temporal lobe region and more activation within the cingulate gyrus.

Attention shifting, performance, anxiety and brain activation in response to attention shifting situations

In the WCST, HRP generated fewer perseverative errors, compared to LRP. In an attention shifting test involving reaction time with 12 higher level volleyball players, Fontani et al. [15] found that greater selective attention was accompanied by shorter reaction times. Moreover, Yamashiro et al. [39] reported that baseball-specific training regimens may shorten the response time for motor initiation by alterations in the cortical hand representation areas in baseball players. In our prior research, elite professional players had fewer perseverative errors compared to general professional players [19].

In the WCST stimulation, HRP showed increased activity in the left prefrontal cortex compared to LRP. In addition, the activity of the left prefrontal cortex was negatively correlated with perseverative errors. Barch et al. [2] suggested that response shifting, which includes the evaluative process of determining whether or not to shift a response, was associated with dorsolateral prefrontal cortex activity. Several fMRI studies have already reported that the dorsolateral prefrontal cortex is one of the critical areas mediating perseverative errors [32]. Overall, HRP may use more ‘set-shifting’ with activation of DLPFC, compared to LRP. However, there was only weak correlation between competitive anxiety and perseverative errors in all baseball players. The present study did not show an influence of anxiety on attention shifting in baseball players.

There are several limitations to the current study. First, the number of subjects was not large enough to fully represent the high-ranking players or low-ranking players. However, the subjects are highly qualified baseball players in the professional Korean baseball organization (KBO). Second, the criteria for ‘higher ranking’ and ‘lower ranking’ is somewhat arbitrary because it is based solely on the draft rankings.

This study suggests that high-ranking players may control anxiety with increased cingulate and decreased temporal cortex activation in response to error situations. They also employ flexible set-shifting with increased DLPFC activation during a modified WCST task. From a practical perspective, current results support the potential use of biofeedback and other self-regulation techniques such as imagery for reducing anxiety. Further, mental rehearsal (imagery) of playing for flexible coping method may also be helpful for performance enhancement [28, 29].

Acknowledgments

This work was supported by a grant of the Korean Health Technology R&D Project, Ministry of Health & Welfare, Republic of Korea (A120013).

References

1. Abreu AM, Macaluso E, Azevedo RT, Cesari P, Urgesi C, Aglioti SM. Action anticipation beyond the action observation network: a functional magnetic resonance imaging study in expert basketball players. Eur J Neurosci. 2012; 35:1646–1654. [PubMed: 22541026]
2. Barch DM, Braver TS, Sabb FW, Noll DC. Anterior cingulate and the monitoring of response conflict: evidence from an fMRI study of overt verb generation. J Cogn Neurosci. 2000; 12:298–309. [PubMed: 10771413]
3. Beckmann, J., Kazen, M. Action and state orientation and the performance of top athletes. Seattle, WA: Hogrefe & Huber; 1994.
4. Bray SR, Martin KA, Widmeyer WN. The relationship between evaluative concerns and sport competition state anxiety among youth skiers. J Sports Sci. 2000; 18:353–361. [PubMed: 10855681]
5. Coelho RW, Keller B, Kuczynski KM, Ribeiro E Jr, Lima MC, Greboggy D, Stefanello JM. Use of multimodal imagery with precompetitive anxiety and stress of elite tennis players. Percept Mot Skills. 2012; 114:419–428. [PubMed: 22755446]
6. Di X, Zhu S, Jin H, Wang P, Ye Z, Zhou K, Zhou Y, Rao H. Altered resting brain function and structure in professional badminton players. Brain Connect. 2012; 2:225–233. [PubMed: 22840241]
7. Dias R, Robbins TW, Roberts AC. Dissociable forms of inhibitory control within prefrontal cortex with an analog of the Wisconsin Card Sort Test: restriction to novel situations and independence from "on-line" processing. J Neurosci. 1997; 17:9285–9297. [PubMed: 9364074]
8. Egner T, Etkin A, Gale S, Hirsch J. Dissociable neural systems resolve conflict from emotional versus nonemotional distracters. Cereb Cortex. 2008; 18:1475–1484. [PubMed: 17940084]
9. Englert C, Bertrams A. Anxiety, ego depletion, and sports performance. J Sport Exerc Psychol. 2012; 34:580–599. [PubMed: 23027229]
10. Etkin A, Egner T, Kalisch R. Emotional processing in anterior cingulate and medial prefrontal cortex. Trends Cogn Sci. 2011; 15:85–93. [PubMed: 21167765]
11. Etkin A, Egner T, Peraza DM, Kandel ER, Hirch J. Resolving emotional conflict: a role for the rostral anterior cingulate cortex in modulating activity in the amygdala. Neuron. 2006; 51:871–882. [PubMed: 16982430]
12. Etkin A, Prater KE, Hoeft F, Menon V, Schatzberg AF. Failure of anterior cingulate activation and connectivity with the amygdala during implicit regulation of emotional processing in generalized anxiety disorder. Am J Psychiat. 2010; 167:545–554. [PubMed: 20123913]
13. Eysenck, MW. Anxiety: The cognitive perspective. Hove: Lawrence Erlbaum Associates Ltd; 1992.
14. Eysenck MW, Derakshan N, Santos R, Calvo MG. Anxiety and cognitive performance: attentional control theory. Emotion. 2007; 7:336–353. [PubMed: 17516812]
15. Fontani G, Maffei D, Cameli S, Polidori F. Reactivity and event-related potentials during attentional tests in athletes. Eur J Appl Physiol. 1999; 80:308–317.
16. Graham J, Austin S. Intensity and direction as dimensions of competitive state anxiety and relationships with competitiveness. Percept Mot Skills. 1997:467–472.
17. Grossman JA, Ramos LE, Tidwell M, Price A, Papazian O, Alfonso I. Surgical treatment of children with brachial plexus paralysis. Rev Neurol. 1998; 27:271–273. [PubMed: 9736958]
18. Han DH, Hwang JW, Renshaw PF. Bupropion sustained release treatment decreases craving for video games and cue-induced brain activity in patients with Internet video game addiction. Exp Clin Psychopharmacol. 2010; 18:297–304. [PubMed: 20695685]
19. Han DH, Park HW, Kee BS, Na C, Na DH, Zaichkowsky L. Performance enhancement with low stress and anxiety modulated by cognitive flexibility. Psychiatry Investig. 2011; 8:221–226.
20. Hanton S, Mellalieu SD, Hall R. Self-confidence and anxiety interpretation: a qualitative investigation. Psychol Sport Exer. 2004; 5:477–495.
21. Harriss DJ, Atkinson G. Ethical standards in sport and exercise science research: 2014 Update. Int J Sports Med. 2013; 34:1025–1028. [PubMed: 24293054]

22. Hofmann SG, Ellard KK, Siegle GJ. Neurobiological correlates of cognitions in fear and anxiety: a cognitive-neurobiological information-processing model. Cognition Emotion. 2012; 26:282–299. [PubMed: 21806384]
23. Johnson DR. Emotional attention set-shifting and its relationship to anxiety and emotion regulation. Emotion. 2009; 9:681–690. [PubMed: 19803590]
24. Kim JK, Yum TH, Oh KJ, Park YS, Lee YH. Factor analysis of K-WAIS revised version. Korean J Clin Psychol. 1992; 11:1–10.
25. Konishi S, Jimura K, Asari T, Miyashita Y. Transient activation of superior prefrontal cortex during inhibition of cognitive set. J Neurosci. 2003; 23:7776–7782. [PubMed: 12944506]
26. Lee CS. Analysis on characteristics of Competition State Anxiety among high school athletes. Korean J Sport Psychol. 2003; 14:283–303.
27. Lee JA, Shin DJ, Lee CU, Lee MS. Executive function in psychiatric patients groups through Wisconsin Card-sorting Test Computer Version (WCST). J Korean Neuropsychiatr Assoc. 2002; 41:322–334.
28. Levy AR, Nicholls AR, Polman RC. Pre-competitive confidence, coping, and subjective performance in sport. Scand J Med Sci Sports. 2011; 21:721–729. [PubMed: 20459476]
29. Martin J. Mental preparation for the 2014 Winter Paralympic Games. Clin J Sport Med. 2012; 22:70–73. [PubMed: 22222589]
30. Nideffer RM. Test of attentional and interpersonal style. Social Psychol. 1976; 34:394–404.
31. Nideffer, RM. Theoretical and practical relationships between attention, anxiety, and performance in sport. In: Hackfort, Spielberger, editor. Anxiety in sports: An international perspective. New York: Hemisphere Publishing; 1989. p. 117-136.
32. Pedersen A, Wilmsmeier A, Wiedl KH, Bauer J, Kueppers K, Koelkebeck K, Kohl W, Kugel H, Arolt V, Ohrmann P. Anterior cingulate cortex activation is related to learning potential on the WCST in schizophrenia patients. Brain Cogn. 2012; 79:245–251. [PubMed: 22554566]
33. Potter GG, McQuoid DR, Payne ME, Taylor WD, Steffens DC. Association of attentional shift and reversal learning to functional deficits in geriatric depression. Int J Geriatr Psychiat. 2012; 27:1172–1179.
34. Rauch SL, Shin LM, Phelps EA. Neurocircuitry models of posttraumatic stress disorder and extinction: human neuroimaging research – past, present, and future. Biol Psychiat. 2006; 60:376–382. [PubMed: 16919525]
35. Sheppes G, Catran E, Meiran N. Reappraisal (but not distraction) is going to make you sweat: physiological evidence for self-control effort. Int J Psychophysiol. 2009; 71:91–96. [PubMed: 18625273]
36. Spada MM, Georgiou GA, Wells A. The relationship among metacognitions, attentional control, and state anxiety. Cogn Behav Ther. 2010; 39:64–71. [PubMed: 19735025]
37. Wang J, Marchant D, Morris T, Gibbs P. Self-consciousness and trait anxiety as predictors of choking in sport. J Sci Med Sport. 2004; 7:174–185. [PubMed: 15362313]
38. Wiggins MS, Cremades JG, Lai C, Lee J, Erdmann JB. Multidimensional comparison of anxiety direction and burnout over time. Percept Mot Skills. 2006; 102:788–790. [PubMed: 16916158]
39. Yamashiro K, Sato D, Onishi H, Yoshida T, Horiuchi Y, Nakazawa S, Maruyama A. Skill-specific changes in somatosensory-evoked potentials and reaction times in baseball players. Exp Brain Res. 2013; 225:197–203. [PubMed: 23224701]

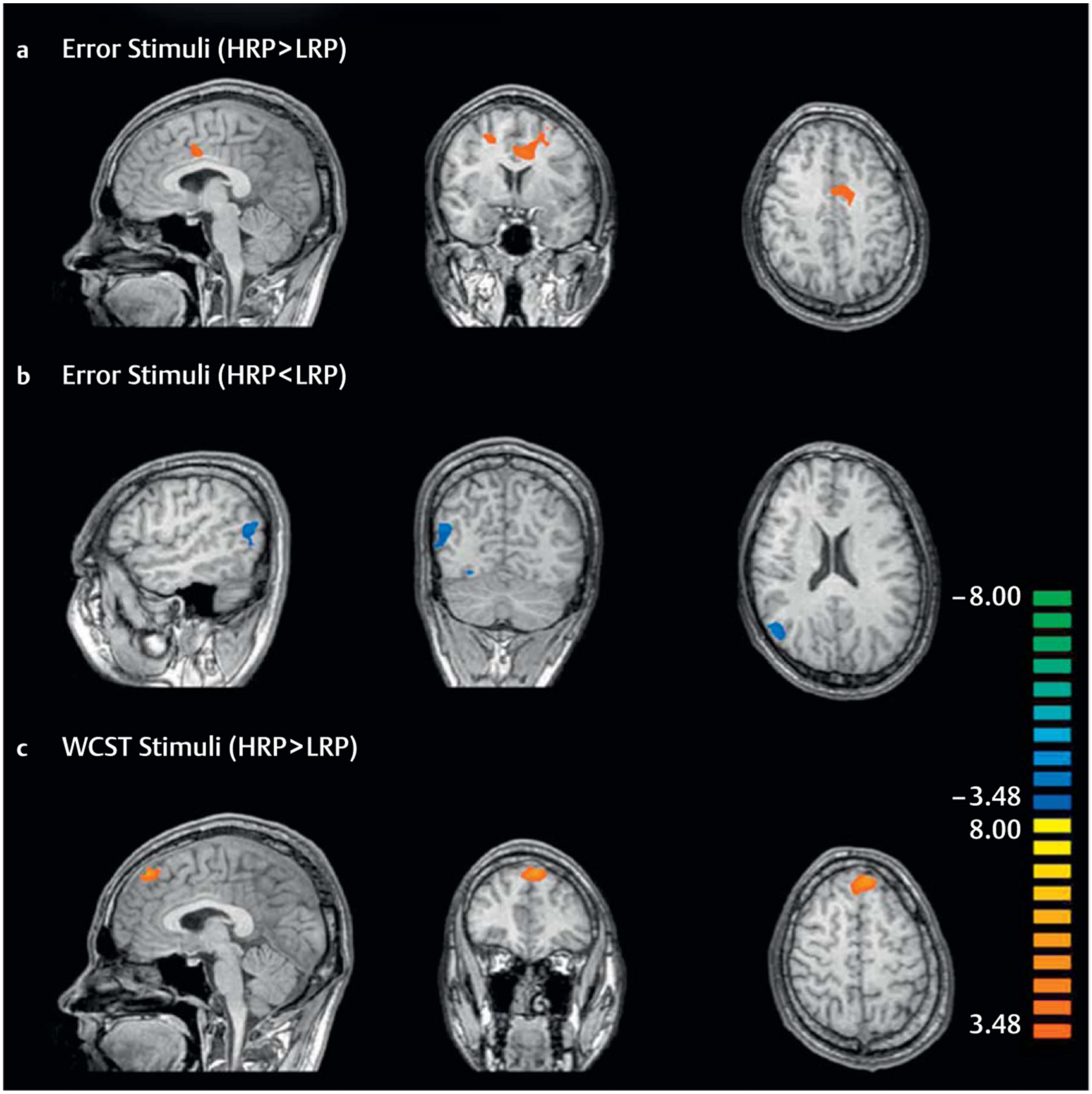

Fig. 1.

Brain activity in response to Wisconsin card-sorting test/error stimuli. HRP: higher ranking players LRP: lower ranking players.

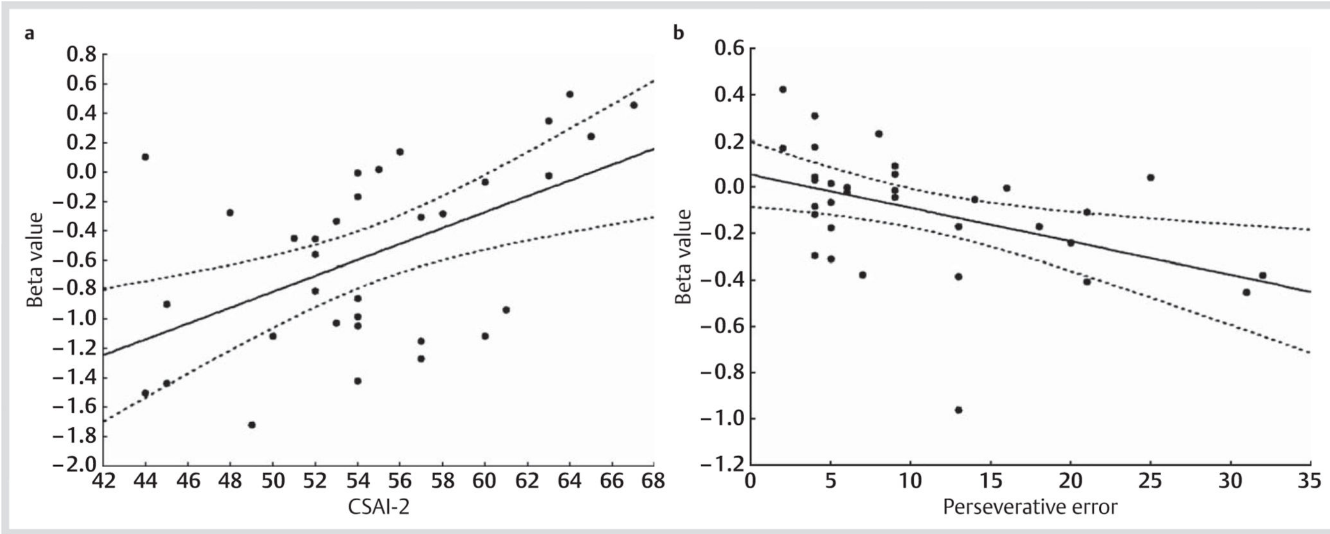

Fig. 2.

The correlation between β value of brain activity and anxiety/perseverative error. **a** The β value of right middle temporal gyrus was positively correlated with competitive anxiety ($r = 0.52$, $p < 0.01$), competitive state anxiety inventory-2 (CSAI-2). **b** The β value of left superior frontal cortex activity in all baseball player was negatively correlated with perseverative errors ($r = -0.45$, $p < 0.01$).

Table 1

Demographic and psychological characteristics.

	Higher ranking players (N = 13)	Lower ranking players (N = 20)	Statistics
Demographic data			
Age	19.7 ± 1.5	20.4 ± 1.8	z = 1.1, p = 0.27
Years of education	12.9 ± 1.75	14.0 ± 2.1	z = 1.3, p = 0.19
Years of playing sport	9.8 ± 1.8	10.6 ± 2.3	z = 1.1, p = 0.25
Position (pitcher/field player)	9/4	8/12	χ^2 = 2.7, p = 0.10
ERA/batting average	2.17/0.488	4.01/0.285	z = 2.8, p < 0.01 */z = 2.9, p < 0.01 *
Draft ranking	16.6 ± 8.4	75.3 ± 18.1	z = 4.8, p < 0.01 *
Psychological data			
Anxiety			
Trait Anxiety	38.8 ± 8.2	41.3 ± 8.4	z = 0.60, p = 0.54
CSAI-2	51.3 ± 6.4	57.2 ± 4.9	z = 2.70, p < 0.01 *
K-WAIS	103.4 ± 13.7	100.5 ± 15.2	z = 0.74, p = 0.38
WCST			
Total Trial	89.1 ± 16.5	98.5 ± 21.0	z = 0.26, p = 0.79
Total error	16.5 ± 8.6	19.3 ± 9.3	z = 0.35, p = 0.72
PR	55.2 ± 14.7	60.7 ± 11.4	z = 1.03, p = 0.08
PE	6.5 ± 3.7	13.4 ± 9.2	z = 2.08, p = 0.03 *
NPE	9.1 ± 5.5	9.4 ± 7.7	z = 0.26, p = 0.79

*Statistically significant,

ERA: earned run average, Korean-Wechsler Adult Intelligence Scale (K-WAIS), PR: perseverative response, PE: perseverative error, NPE: non-perseverative error, CSAI-2: Competitive State Anxiety Inventory-2

Table 2

Brain activity and regions in response to Wisconsin card sorting test/error stimuli.

	x	y	z	Vxl	statistics	regions
Error stimulation (higher ranking player > lower ranking player)						
A	−4	12	32	80	$P_{FDR} < 0.05 = 0.0005$	left cingulate gyrus
Error stimulation (hgher ranking player < lower ranking player)						
B	46	−61	18	60	$P_{FDR} < 0.05 = 0.0024$	right middle temporal gyrus
Wisconsin card-sorting test stimulation (higher ranking player > lower ranking player)						
C	−3	43	47	80	$P_{FDR} < 0.05 = 0.0009$	left superior frontal cortex

Vxl: voxels, Talairachcode (x, y, z), FDR: false discovery rate