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Review

Electrocortical measures of information processing biases in social anxiety disorder: A review

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ABSTRACT

Social anxiety disorder (SAD) is characterized by information processing biases, however, their underlying neural mechanisms remain poorly understood. The goal of this review was to give a comprehensive overview of the most frequently studied EEG spectral and event-related potential (ERP) measures in social anxiety during rest, anticipation, stimulus processing, and recovery. A Web of Science search yielded 35 studies reporting on electrocortical measures in individuals with social anxiety or related constructs. Social anxiety was related to increased delta-beta cross-frequency correlation during anticipation and recovery, and information processing biases during early processing of faces (P1) and errors (error-related negativity). These electrocortical measures are discussed in relation to the persistent cycle of information processing biases maintaining SAD. Future research should further investigate the mechanisms of this persistent cycle and study the utility of electrocortical measures in early detection, prevention, treatment and endophenotype research.

1. Introduction

Social anxiety disorder (SAD) is a highly prevalent and debilitating disorder characterized by fear and avoidance of social or performance situations that might lead to scrutiny and/or negative evaluation by others (Rapee & Spence, 2004; Spence & Rapee, 2016). It is posited that social anxiety is expressed along a severity continuum (Rapee & Spence, 2004). That is, many people experience symptoms of social anxiety without meeting the clinical diagnostic criteria for SAD. When social anxiety symptoms hinder someone's daily-life functioning to such an extent that they avoid social situations, these people often meet the diagnostic criteria for SAD (APA, 2013). SAD is among the most prevalent psychiatric disorders, with a life-time prevalence ranging from 5.0% to 12.1% in the United States (Grant et al., 2005; Kessler et al., 2005). Patients with SAD have an increased risk for developing comorbid disorders, such as other anxiety disorders, depression, and substance abuse (Grant et al., 2005; Rapee & Spence, 2004; Spence & Rapee, 2016). Therefore, the identification of mechanisms underlying and maintaining SAD is of critical importance to improve (preventive) interventions for SAD.

Many cognitive-behavioral studies have demonstrated that information processing biases play an important role in the development and maintenance of SAD (Bögels & Mansell, 2004; Clark & McManus, 2002; Heinrichs & Hofmann, 2001; Hirsch & Clark, 2004; Morrison & Heimberg, 2013; Wong & Rapee, 2016). Information processing biases might be displayed as biases in attention (e.g., hypervigilance, or self-focused attention) (Bögels & Mansell, 2004), interpretation (e.g., evaluating own behavior very critically, or interpreting social situations in a negative way), memory (e.g., selectively retrieving negative information), and imagery (e.g., experiencing images of oneself performing poorly in social situations) (Heinrichs & Hofmann, 2001; Hirsch & Clark, 2004; Morrison & Heimberg, 2013). Cognitive models posit that patients with SAD exhibit a persistent cycle of information processing biases, which perpetuate different stages of processing (i.e., automatic and controlled) and reinforce socially anxious behaviors over time. These information processing biases are triggered when the person is confronted with a socially stressful situation, repeated while in the situation, and carried forward in time when anticipating similar future events (Clark & McManus, 2002; Morrison & Heimberg, 2013). Electrocortical measures that are related to social anxiety could provide more insight in these information processing biases. So, to delineate electrocortical measures underlying the different stages of this persistent cycle of information processing biases, we reviewed EEG measures during rest, anticipation of, and recovery

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from socially stressful situations, as well as event-related potential (ERP) measures during the processing of socially threatening stimuli.

We reviewed electrocortical measures of SAD, because EEG/ERP offers an online, objective and direct measure of brain activity. Of note, the future utility of potential electrocortical measures is highlighted by the relative ease of application and cost-effectiveness (Amodio, Bartholow, & Ito, 2014; Luck, 2005). Most importantly, the high temporal precision of ERPs is very useful for capturing the precise timing of information processing biases during stimulus processing (Amodio et al., 2014; Cohen, 2011; Ibanez et al., 2012; Luck, 2005). The goal of this review was to provide a comprehensive overview of the most frequently studied EEG and ERP measures during rest, anticipation, stimulus processing, and recovery. These electrocortical measures may give insight into the mechanisms underlying and maintaining the persistent cycle of information processing biases in SAD, and might eventually be used in early detection, prevention, treatment and endophenotype research.

1.1. Focus

To delineate electrocortical measures related to the information processing biases in SAD, we reviewed studies that have reported on EEG spectral characteristics during rest, anticipation and recovery from a socially stressful situation, as well as ERPs during stimulus processing. Given that the social anxiety literature on EEG spectral characteristics has largely focused on power of the alpha frequency band and the correlation between the power of delta and beta frequency bands, these two EEG metrics were included in our review (Table 1). These EEG metrics were studied during resting state, in which participants sat still for a certain period of time, or during impromptu speech preparation tasks.

With respect to ERPs, studies on social anxiety have primarily investigated stimulus processing in face processing and in cognitive conflict paradigms. ERPs give precise insight in the timing of biases in processing of faces and errors/feedback. To put the ERPs into context and to show that differences in ERPs are not caused by differences in behavior, we also reported on behavioral findings in the tasks. Studies using face-processing paradigms typically include negative emotional faces as socially threatening stimuli because they communicate social dominance (Öhman, 1986) or disapproval for violated social rules or expectations (Averill, 1982, as cited in Kolassa and Miltner, 2006). In this review, we further distinguished between explicit and implicit face processing paradigms (Table 2) to examine the effects of task-relevant (explicit) versus task-irrelevant (implicit) faces on the modulation of early and late ERP components (Schulz, Mothes-Lasch, & Straube, 2013). In explicit paradigms, participants are required to direct their attention to the emotional valence of stimuli. In implicit paradigms, participants are presented with emotional faces, but are required to direct their attention to different aspects of stimuli (e.g., indicating the gender of stimuli, or responding to a target replacing the faces). Our review focused on the early P1, N170, and P2 components, and the late P3 and late positive potential (LPP) components, since studies on social anxiety have examined these ERP components.[1]

A recent and very relevant line of ERP research in social anxiety has focused on ERP components of feedback processing and performance monitoring in cognitive conflict paradigms. We reviewed ERP studies that have focused on the N2, feedback-related negativity (FRN), error-related negativity (ERN), correct response negativity (CRN), and positive error (Pe) components in these cognitive conflict paradigms (Table 3).[2]

We included studies reporting on patients diagnosed with SAD, as well as high socially anxious individuals, because both are expressions of social anxiety at the more severe end of the continuum (Rapee & Spence, 2004). We also reviewed studies examining constructs related to SAD, such as fear of negative evaluation, social withdrawal, shyness, and behavioral inhibition, since these constructs share common symptoms of SAD (Stein, Ono, Tajima, & Muller, 2004). Fear of negative evaluation is considered as a hallmark cognitive feature of SAD, whereas social anxiety is a more complete measure encompassing behavioral and affective symptoms (Carleton, McCreary, Norton, & Asmundson, 2006). Social withdrawal is a behavioral style commonly observed in childhood that is characterized by a lack of engagement in social situations or solitary behavior, such as playing alone (Rubin & Burgess, 2001). Shyness is a personality dimension defined as self-preoccupation and inhibition in social situations (Cheek & Buss, 1981). Behavioral inhibition is a temperament observed in infancy as negative reactivity to novel social and nonsocial stimuli (Hirshfeld-Becker et al., 2008). While these constructs are different, they are related to each other and to a greater risk of developing SAD (Clauss & Blackford, 2012; Hirshfeld-Becker et al., 2008; Stein et al., 2004).

We focused our review on studies of adults, due to several factors that hinder a comprehensive comparison between adult and child studies. For instance, brain development should be taken into account when comparing spectral EEG measures and ERPs between adults and children. Brain development is associated with a decline in total EEG power, as well as a shift from dominant slow wave (theta) activity to the dominant alpha rhythm as seen in adults (Marcuse et al., 2008; Segalowitz, Santesso, & Jetha, 2010). Such age-related differences in spontaneous EEG activity question the similarity in the functional significance of electrocortical measures when compared between age groups. Also, different methodological approaches might be required in quantifying these spectral measures (e.g., spectral band-width of alpha power should be different between young children and adults), which does not happen often in the literature. With regard to the ERP technique, comparing data between child and adult samples might be complicated by other factors, such as information processing efficiency, strategies used to allocate attention, and even task instructions (Segalowitz et al., 2010). Therefore, we focused mainly on electrocortical studies in adults, but we included a paragraph on developmental studies at the end of the review (Tables 4 and 5).

This review is organized as follows: First, we describe briefly the information processing biases in social anxiety as recognized in the cognitive-behavioral literature. These cognitive-behavioral findings (e.g., attention biases, hyperviliance/avoidance tendencies) can be used as an information processing framework (Clark & McManus, 2002) for interpreting the electrocortical measures of SAD. Second, we give an introduction to EEG spectral characteristics and then review studies on spectral EEG analyses at rest, during anticipation of and recovery from socially stressful situations. Third, we introduce the ERP method, and review studies that report on early and late ERP components in response to facial stimuli and ERP components in cognitive conflict paradigms as potential indices of information processing biases in social anxiety. Lastly, we conclude by relating our findings to the persistent cycle of information processing biases that maintains SAD, and discussing the utility of electrocortical measures of SAD. We also describe current methodological challenges in electrocortical studies, and developmental studies involving these EEG and ERP measures of SAD.

1.2. Search strategy

We searched Web of Science for electrocortical studies in socially anxious individuals, using the key terms *EEG or ERP or oscillation** and *social anxi* or social anxiety disorder or fear of negative evaluation or social withdrawal or shy* or behavioral inhibition*, combined with *resting state, anticipation, recovery, face, stimulus processing, emotion, error, or performance monitoring*. We also searched the reference list of the articles for additional studies, and searched for other publications of the

[1] For studies using face processing paradigms, we did not report on the C1, N1, P150, N250, FN400, correct-response negativity (CRN), vertex positive potential (VPP), early posterior negativity (EPN), contralateral delay activity (CDA), and stimulus-preceding negativity (SPN) components, because very few (only 1–3) studies have investigated these components in relation to social anxiety.

[2] For studies using cognitive conflict paradigms, we excluded results on the N1, P150, P2, P3, LPP, CDA, and SPN components, because very few (only 1–2 studies) have reported on these components in social anxiety.