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Research report

Sensory contribution to vocal emotion deficit in Parkinson's disease after subthalamic stimulation

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ABSTRACT

Subthalamic nucleus (STN) deep brain stimulation in Parkinson's disease induces modifications in the recognition of emotion from voices (or emotional prosody). Nevertheless, the underlying mechanisms are still only poorly understood, and the role of acoustic features in these deficits has yet to be elucidated. Our aim was to identify the influence of acoustic features on changes in emotional prosody recognition following STN stimulation in Parkinson's disease. To this end, we analysed the performances of patients on vocal emotion recognition in pre-versus post-operative groups, as well as of matched controls, entering the acoustic features of the stimuli into our statistical models. Analyses revealed that the post-operative biased ratings on the *Fear* scale when patients listened to happy stimuli were correlated with loudness, while the biased ratings on the *Sadness* scale when they listened to happiness were correlated with fundamental frequency (F0). Furthermore, disturbed ratings on the *Happiness* scale when the post-operative patients listened to sadness were found to be correlated with F0. These results suggest that inadequate use of acoustic features following subthalamic stimulation has a significant impact on emotional prosody recognition in patients with Parkinson's disease, affecting the extraction and integration of acoustic cues during emotion perception.

Abbreviations: ^{18}FDG-PET, ^{18}Fludeoxyglucose-Positron emission tomography; BG, basal ganglia; DBS, deep brain stimulation; F0, fundamental frequency; FFA, face fusiform area; fMRI, functional magnetic resonance imaging; HC, healthy controls; IFG, inferior frontal gyrus; MADRS, Montgomery-Asberg Depression Rating Scale; OCD, obsessive-compulsive disorder; OFC, orbitofrontal cortex; STG, superior temporal gyrus; STN, subthalamic nucleus; STS, superior temporal sulcus; UPDRS, Unified Parkinson's Disease Rating Scale.

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1. Introduction

By demonstrating that subthalamic nucleus (STN) deep brain stimulation (DBS) in Parkinson's disease induces modifications in emotion processing, previous research has made it possible to infer the functional involvement of the STN in this domain (see, Péron, Frühholz, Vérin, & Grandjean, 2013 for a review). STN DBS in Parkinson's disease has been reported to induce modifications in all the emotional components studied so far (subjective feeling, motor expression of emotion, arousal, action tendencies, cognitive processes, and emotion recognition), irrespective of stimulus valence (positive or negative) and sensory-input modality. In emotion recognition, for instance, these patients exhibit deficits or impairments both for facial emotion (Biseul et al., 2005; Drapier et al., 2008; Dujardin et al., 2004; Le Jeune et al., 2008; Péron, Biseul, et al., 2010; Schroeder et al., 2004) and for vocal emotion: so-called *emotional prosody* (Bruck, Wildgruber, Kreifelts, Kruger, & Wachter, 2011; Péron, Grandjean, et al., 2010).

Emotional prosody refers to the suprasegmental and segmental changes that take place in the course of a spoken utterance, affecting physical properties such as amplitude, timing, and fundamental frequency (F0), the last of these being perceived as pitch (Grandjean, Banziger, & Scherer, 2006). An additional cue to emotion is voice quality, the percept derived from the energy distribution of a speaker's frequency spectrum, which can be described using adjectives such as *shrill* or *soft*, and can have an impact at both the segmental and the suprasegmental levels (Schirmer & Kotz, 2006). Emotional prosody recognition has been shown to correlate with perceived modulations of these different acoustic features during an emotional episode experienced by the speaker. In the prototypical example illustrated in Fig. 1, taken from Schirmer and Kotz (2006), happiness is characterized by a rapid speech rate, by high intensity, and by mean F0 and F0 variability, making vocalizations sound both melodic and energetic. By contrast, sad vocalizations are characterized by a slow speech rate, by low intensity, and by mean F0 and F0 variability, but have high spectral noise, resulting in the impression of a *broken* voice (Banse & Scherer, 1996). Thus, understanding a vocal emotional message requires the analysis and integration of a variety of acoustic cues.

The perception and decoding of emotional prosody has been studied in functional magnetic resonance imaging (fMRI) and patient studies, allowing researchers to delineate a distributed neural network involved in the identification and recognition of emotional prosody (Ethofer, Anders, Erb, Droll, et al., 2006; Ethofer, Anders, Erb, Herbert, et al., 2006; Ethofer et al., 2012; Frühholz, Ceravolo, & Grandjean, 2012; Grandjean, Sander, Lucas, Scherer, & Vuilleumier, 2008; Grandjean et al., 2005; Sander et al., 2005; Schirmer & Kotz, 2006; Wildgruber, Ethofer, Grandjean, & Kreifelts, 2009). Accordingly, models of emotional prosody processing have long postulated that information is processed in multiple successive stages related to different levels of representations (see Witteman, Van Heuven, & Schiller, 2012 for a review). Following the processing of auditory information in the primary and secondary auditory cortices (Bruck, Kreifelts, & Wildgruber, 2011; Wildgruber et al., 2009), with the activation of predominantly right-hemispheric regions (Banse & Scherer, 1996; Grandjean et al., 2006) (Stage 1), two successive stages of prosody decoding have been identified. The second stage, related to the *representation of meaningful suprasegmental acoustic sequences*, is thought to involve projections from the superior temporal gyrus (STG) to the anterior superior temporal sulcus (STS). These cortical structures have been identified as forming the so-called *temporal voice-sensitive area* (Belin & Zatorre, 2000; Grandjean et al., 2005) made up of voice-sensitive neuronal populations. In the third stage, emotional information is made available by the STS for higher order cognitive processes mediated by the right inferior frontal gyrus (IFG) (Frühholz & Grandjean, 2013b) and orbitofrontal cortex (OFC) (Ethofer, Anders, Erb, Herbert, et al., 2006;

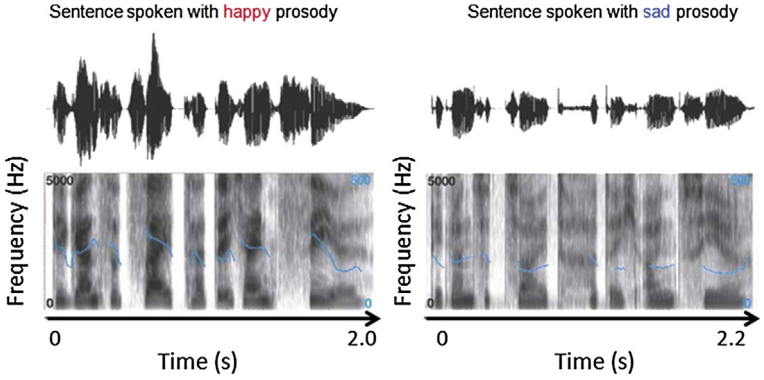

Fig. 1 – Oscillograms (top panels) and spectrograms (bottom panels) of the German sentence "Die ganze Zeit hatte ich ein Ziel" ("During all this time I had one goal"). The sentence is shorter when produced with a happy prosody (2 sec) than with a sad one (2.2 sec). The speech is also louder, as can be seen by comparing the sound envelopes illustrated in the oscillograms. This envelope is larger (i.e., it deviates more from baseline) for happy than for sad prosody. Spectral differences between happy and sad prosody are illustrated in the spectrograms. The dark shading indicates the energy of frequencies up to 5000 Hz. The superimposed blue lines represent the fundamental frequency (F0) contour, which is perceived as speech melody. This contour shows greater variability and a higher mean for happy than for sad prosody. Reproduced with permission (N°3277470398909) from Schirmer and Kotz (2006).