The treatment of apraxia of speech

Hurkmans, Josephus Johannes Stephanus

Chapter 4

Music

4.1 | Music and language

Music and language are believed to share hierarchical rules (Peretz & Zatorre, 2003). This insight gave rise to the proposal of a formal generative theory of tonal music (i.e., a system of musical organisation) by composer Lerdahl and linguist Jackendoff (1983). They described how a listener recognises music by considering some notes and chords to be more prominent than others. It enables the listener to recognise the construction of a complete piece. This is comparable to how a reader divides a text. A reader distinguishes paragraphs, sentences and constituents. Therefore, language and music have much in common; both disciplines structure and temporally order information the same way (Liberman, 1975; Gilbers, 1992). Also, both music and language show rhythm and intonation and contain syntactically structured sequences. Finally, music is, like language, 'generative' in the sense that it uses rule-governed combinations of hierarchically structured signals (Fitch, 2006).

Patel (2003) assumes similar syntactic structures in language and music and introduced the 'Shared Syntactic Integration Resource Hypothesis' (SSIRH). This hypothesis is based on Gibson's (1998) 'dependency locality' theory and Lerdahl's (2001) 'tonal pitch space' theory. These theories share the notion of structural integration as a key part of syntactic processing, which is connecting each incoming element X to another element Y in the evolving structure.

Patel, Iversen, Wassenaar and Hagoort (2008) tested the SSIRH hypothesis for aphasia. They designed two experiments with Broca's aphasia patients. The first experiment examined linguistic and musical syntactic processing using judgements of the acceptability of sentences (i.e., subject-verb agreement) and chords (i.e., indication of an acceptable sequence). The second study probed musical syntactic processing using harmonic priming. Nine patients with Broca's aphasia listened to a prime and a target chord separated by 50 milliseconds and they were asked to judge whether the second chord was tuned or mistuned. The results of both studies suggested that patients with Broca's aphasia suffer not only from a language disorder but also have difficulty in processing the harmonic syntax of tonal music (Patel et al., 2008).

There is more overlap in the processing of music and language. The musical stream of sounds is hierarchically divided into structural domains. Each domain contains some smaller domains, which in turn contain smaller domains (Schreuder, 2006). The smallest domain in music is the motif consisting of a rhythmic, melodic or harmonic block. Several motifs together form phrases. A phrase is a kind of musical sentence (Randel, 1986). Comparable domains are found in language. The building block in language comparable to the motif in music, is the morpheme. Morphemes are joined together into larger units: words and constituents (i.e., phrases). The melodic division in music is comparable to the rhythmic division in language within a metrical tree structure as described in Chapter 1.

To conclude, music and language show similar structural properties. Both are rule-governed and are recursive.

4.2 | Neural correlates of music and language

In cognitive neuroscience, the functional and neural architecture of music in the brain has been studied intensively over the past 20 years, thanks to the advance of neuroimaging techniques (mainly fMRI, PET and ERP). The primary auditory cortex (i.e., Brodmann's area, BA 41 and 42) is dominant for processing of auditory stimuli. Not only this region of the brain processes language perception, but also critical components of music perception are represented in the primary auditory cortex, including pitch (Bendor & Wang, 2010), harmony (Passynkova, Sander, & Scheich, 2005), timbre (Deike, Gaschler-Markefski, Brechmann, & Scheich, 2004) and musical syntax (Patel, 2003). However, motor regions, including the primary motor cortex, supplementary motor area, Broca's area and anterior insula, have also been defined during music perception (Brown, Martinez, & Parsons, 2006; Chen, Penhune, & Zatorre, 2008). In the context of rhythm, Chen et al. (2008) showed an inherent link between auditory and motor systems of the brain. Furthermore, auditorily presented musical stimuli appeared to activate *bilateral* regions (Brown et al., 2006).

However, not only cortical areas are involved in musical processing. Also, subcortical brain structures, including the basal ganglia and ventral thalamus were shown to play a role in processing various components of music (Brown, Martinez, Hodges, Fox, & Parsons, 2004; Brown et al., 2006; Chen et al., 2008). Finally, brainstem nuclei seem sensitive to rhythm and intensity (Koelsch, 2011; Abrams, Bhatara, Ryali, Balaban, Levitin, & Menon, 2011).

In neuropsychology, patients with amusia, which is a disorder of musical processing, and aphasia have been described to explore the relationship between music and language processing. Basso (1993) confirmed in a review of amusia the classical lateralisation of speech perception in the left temporal areas and, in parallel, music processing in the right hemisphere. In contrast, Patel, Peretz, Tramo and Labreque (1998) showed that the perception of speech intonation and melodic contour share neural resources. They observed two patients with bilateral lesions and, as a result, both suffered from amusia without any signs of aphasia. Prosodic and musical discrimination were assessed using linguistic and musical stimuli in a series of tests. According to the lesion and behavioural data, Patel et al. (1998) suggested that the left primary auditory cortex and the right prefrontal cortex might play an important role in the retention and comparison of pitch and temporal patterns in both musical and linguistic domains. These results were in line with the data of non-brain damaged speakers implicating right frontal circuits in the retention and comparison of pitches in both melodic phrases and syllables (Zattore, Evans, Meyer, & Gjedde, 1992; Zattore, Evans, & Meyer, 1994).

Many brain imaging studies aimed at comparing language and music regarding the functional specificity of cerebral brain regions. Tervaniemi, Medvedev, Alho, Pakhomov, Roudas, van Zuijen, & Näätänen (2000), for example, conducted a PET scan study with 30 healthy subjects to determine whether the neural processing of phonetic and musical information was lateralised in auditory processing. They found that in a word classification task, phoneme change was lateralised in the left auditory cortex whereas sound change in music (i.e., chords) was lateralised in the right auditory cortex.

In songs, language and music are combined. Therefore, songs have frequently been used to determine whether words and melodies in songs are processed interactively or independently. Jeffries, Fritz and Braun (2003), for example, demonstrated different hemispheric lateralisation for sung and spoken language. When healthy subjects spoke words and sang words of a familiar song, Jeffries et al. (2003) found more activity in the left hemisphere for speech and a more active right hemisphere while singing in their PET scan study. Jeffries et al. (2003) suggested that singing involves selective activation of the right hemisphere and concomitant suppression of activity in the left perisylvian areas. Conversely, activity in the right hemisphere may be suppressed when the left hemisphere is more strongly engaged during speech production. Jeffries et al. (2003) emphasised that these lateralisation processes have been observed in homologous brain regions. However, lateralised differences between singing and speaking were larger in non-homologues regions in the brain. For speaking, more activity in the left posterior superior temporal regions was observed, while more right anterior temporal areas were activated for singing. Gordon, Schön, Magne, Astésano and Besson (2010) supported the claim of interaction between words and melody in songs and suggested a network of brain regions typically involved in language and music processing (i.e., left temporal and right anterior areas respectively). They showed in their ERP study of healthy participants that language and music share neural resources through interactive phonological and semantic processing and melodic and harmonic processing.

Rogalsky, Rong, Saberi and Hickok (2011) questioned the view that processing of speech and music rely on the same neural systems. They designed an fMRI experiment with healthy participants. The participants listened to sentences, scrambled sentences (i.e., randomly rearranging the word order) and novel melodies. Rogalsky et al. found some overlap in the activation patterns for speech and music, although this was restricted to relatively early stages of acoustic analysis and not in regions such as the anterior temporal cortex or Broca's area. Even within the region of overlap in the auditory cortex, stimuli yielded distinguishable patterns of activity. Therefore, Rogalsky et al. concluded that different acoustic features are involved in speech and music. They suggested that earlier findings are based on data from higher-order cognitive processes, such as working memory and cognitive control, which can operate both on speech and music domains.

Also, Abrams et al. (2011) disagreed on the claim that speech and music share neural resources. In their fMRI study, non-musicians listened to natural and temporally ordered musical and speech stimuli to examine brain activation in response to manipulations of temporal structure, controlling for arousal and emotional content. The results supported Patel's (2003) SSIRH hypothesis: the same temporal manipulation in music and speech produced fMRI signal changes in prefrontal and temporal cortices of both hemispheres. However, post-hoc analysis revealed different fMRI responses between music and speech. In particular, the inferior frontal cortex, the posterior and anterior temporal cortex and the auditory brainstem bilaterally were found to encode temporal structures in music and speech differently (i.e., high classification rates in various areas but differential sensitivity).

To conclude, there is a great interest in understanding the extent to which the neural resources for the processing of music and speech are distinctive or shared. Neuropsychological research has shown cases of dissociations between music and linguistic processing, for example, patients with amusia and no signs of aphasia (e.g., Peretz, 1993). However, a growing body of evidence from neuroimaging studies suggests that speech and music employ shared computational systems. Recent fMRI studies (Rogalsky et al., 2011; Abrams et al., 2011) confirm that music and speech processing share neural substrates, but that the temporal structure in the two domains is encoded differently.

4.3 | Music therapy

Music Therapy (MT) is a multidisciplinary field that overlaps with several disciplines, including psychology, sociology and neurology (Hillecke, Nickel, & Bolay, 2005). This dissertation focusses on Neurologic MT (NMT; Thaut, 2005). NMT concerns treatment of (1) cognition, such as episodic memory (Sloboda & Juslin, 2001); (2) behaviour, such as movement disorders as in Parkinson's disease (e.g., Thaut, McIntosh, McIntosh, & Hoemberg, 2001) and (3) communication.

Various NMT approaches aim to improve verbal expression and communication, using musical elements, such as melody, rhythm, dynamics, tempo and meter. However, not all therapies using these musical elements automatically qualify as music *therapy*. For example, Melodic Intonation Therapy (MIT; Albert et al., 1973) is not music therapy as indicated by the original developers of the treatment approach and MIT is provided by a speech therapist without the contribution of a music therapist. Within NMT, various modifications have been developed on MIT-principles (e.g., the Modified Melodic Intonation Therapy; MMIT, Baker, 2000). Apart from variations on MIT, within this field various programs aiming at verbal communication have been developed, such as Singen Intonation Prosodie Atmung Rhytmusübungen Improvationen (SIPARI, Jungblut & Aldridge, 2004) and SMTA. The following chapter reviews the existing literature on the effect of music in the treatment of patients with aphasia, AoS and dysarthria.