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The importance of integration and top-down salience when listening to complex multi-part musical stimuli

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ABSTRACT

In listening to multi-part music, auditory streams can be attended to either selectively or globally. More specifically, musicians rely on prioritized integrative attention which incorporates both stream segregation and integration to assess the relationship between concurrent parts. In this fMRI study, we used a piano duet to investigate which factors of a leader–follower relationship between parts grab the listener's attention and influence the perception of multi-part music. The factors considered included the structural relationship between melody and accompaniment as well as the temporal relationship (asynchronies) between parts. The structural relationship was manipulated by cueing subjects to the part of the duet that had to be prioritized. The temporal relationship was investigated by synthetically shifting the onset times of melody and accompaniment to either a consistent melody or accompaniment lead. The relative importance of these relationship factors for segregation and integration as attentional mechanisms was of interest. Participants were required to listen to the cued part and then globally assess if the prioritized stream was leading or following compared to the second stream. Results show that the melody is judged as more leading when it is globally temporally ahead whereas the accompaniment is not judged as leading when it is ahead. This bias may be a result of the interaction of salience of both leader–follower relationship factors. Interestingly, the corresponding interaction effect in the fMRI-data yields an inverse bias for melody in a fronto-parietal attention network. Corresponding parameter estimates within the dlPFC and right IPS show higher neural activity for attending to melody when listening to a performance without a temporal leader, pointing to an interaction of salience of both factors in listening to music. Both frontal and parietal activation implicate segregation and integration mechanisms and a top-down influence of salience on attention and the perception of leader–follower relations in music.

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1. Introduction

Our auditory environment consists of complex scenes that have to be analyzed in parts or as a whole. Multi-part music is an example of a complex auditory scene that can either involve focusing on a particular stream or listening holistically to all parts. Mechanisms such as auditory stream segregation allow the brain to separate different sound sources and make it possible to selectively attend to them individually. In order to make sense of a complete auditory scene however, it is necessary also to compare or integrate its composite parts (Nelken, 2011). In the following functional magnetic resonance imaging (fMRI) study, we explore the neural underpinnings of these two attentional mechanisms and how they are differentially employed when listening to and assessing a piano duet with respect to leader–follower relations.

Auditory stream segregation and integration are equally important in the context of musical ensemble performance in which players have to simultaneously attend to different auditory streams including their part (Bigand et al., 2000; Keller, 2001, 2008). Keller (2008) hypothesized that musicians need to employ a specialized form of prioritized integrative attention in order to achieve high synchronization within an ensemble. Attentional resources would be divided between the prioritization of one's own playing and the simultaneous integration of co-performers' sounds in order to match and adjust one's playing for synchronization. In addition, Bigand et al. (2000) were able to show that musicians tend to integrate two parts of multi-part music rather than to divide their attention between them. In an error detection task in which two unknown melodies were concurrently played, musicians' false alarms suggested this kind of listening strategy for multi-part music (Bigand et al., 2000).

The integration of different musical streams thus relies on specific attentional and perceptual processes and is necessary both for synchronized group music making as well as listening to multi-part music. An integration process combines the auditory streams in a

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common representational space for perception of a global sound. A coherent soundscape nevertheless not only includes the combination of streams but also an assessment of their relationship to each other (i.e. temporally, harmonically, etc.) (Bigand et al., 2000; Bregman, 1990; Erickson, 1975).

How complex musical streams are processed during auditory stream analysis will thus depend on the nature of the relationship between the component parts in a musical piece. The structural relationship of the music may be one factor that influences how the streams are individually or globally perceived and assessed. Structurally speaking, in much western music the melody generally dominates over the accompanying harmony (Bregman, 1990; Erickson, 1975). This hierarchal relationship describes the melody as a structurally independent stream while the accompaniment plays a supporting role for the completion or complementation of the melody. These roles characterizing melody and accompaniment have been described as analogous to figure-ground perception (Tagg, 2003a,b), where the melody is the figure and the accompaniment serves as its background. Such hierarchical structuring may of course vary in its degree, but is nevertheless a defining feature of the music's compositional structure and perceptual organization (Erickson, 1975; Tagg, 2003a,b). The prioritization of the melody might additionally be influenced by perceptual salience factors such as pitch height or more complex rhythms (McAdams and Drake, 2002). Within this structural relationship, it is thus generally the case that the melody can be described as 'globally leading' (to the extent that it dominates perception) and the accompaniment as 'following'.

Another factor that can affect the way in which multi-part music is perceived and assessed in terms of leader–follower relations is the temporal relationship between parts i.e. the accuracy with which the notes of different parts are played together. Simply put, one part – for intentional or unintentional reasons – may be played temporally ahead or behind that of others and would, as such, be heard as temporally leading or lagging, respectively (Goebl and Palmer, 2009; Palmer, 1997; Rasch, 2000; Repp, 1996). Which part is intended to lead temporally is a matter of musical style or interpretation (Rasch, 2000; Repp, 1996). Listeners of western classical music might thus be more familiar with a melody lead, whereas jazz fans might be more accustomed to an accompaniment lead. Unintentional timing errors can also result in one player being ahead of the other. Temporal-leader follower relations are beneficial (regardless of whether they are intentional or unintentional), as it has been shown that a certain degree of asynchrony between parts facilitates the perception of separate tones and is required for stream segregation (Handel, 1989; Rasch, 1979; Wright and Bregman, 1987).

Both the structural and the temporal relationship influence the perceived association between parts and can describe a leader–follower relationship in music. Which of these two factors capture our attention when listening to multi-part music has not yet been investigated.

Based on recent studies, we have an understanding of the neural underpinnings involved in selective attention to multi-part music (Janata et al., 2002; Satoh et al., 2001). However little is known about the relative importance of the integration and perception of different types of leader–follower relationships between parts. Importantly, the tasks used in former studies either involved a target detection task or instructions to selectively listen to one part while ignoring the rest. Considering the importance of the integration of parts, not only when playing but also when listening to multi-part music, a task which allows for prioritized integrative attention mechanisms seems to better capture processes involved in music listening (Bigand et al., 2000; Keller and Burnham, 2005; Nelken, 2011). Such a task enables the listener to prioritize one part while still integrating the other part(s) into a coherent soundscape. This more naturalistic way of listening to music facilitates perception of relationships between parts, which is an important component of multi-part music (Bigand et al., 2000; Erickson, 1975). Moreover, although useful for exploring a factor of selective attention, some of the musical stimuli used in earlier studies were synthetically generated and thus had no asynchrony between the different instrumental parts (Janata et al., 2002). In the present study, we therefore more specifically explore the neural correlates of attentional mechanisms used when listening to excerpts from an original performance and from corresponding manipulated stimuli derived from this performance (Janata et al., 2002).

To do so, we implemented a cued attention task allowing us to examine the prioritized integrative attention process involved in listening to multi-part music (Bigand et al., 2000; Keller, 2001, 2008). After listening to a recording of a piano duet with a clear structural relationship (melody vs. accompaniment), subjects were asked to globally assess the relative leader–follower relationship of two parts which made up the stimulus as well as its performance quality and the difficulty of the task. The global relationship assessment necessitated subjects not to attend selectively to the cued part but rather to prioritize it and additionally to integrate the second part. We also included stimuli in which we had shifted onset times of either the melody or the accompaniment part by a fixed amount so that one part was consistently temporally leading. This manipulation thus allowed us to look not only at the influence of a structural but also of the temporal relationship between parts on overall perception of a leader–follower relationship. Specifically, due to the combination of the prioritized integrative attention task and the global assessment of the relationship between parts, we were able to investigate how integration and segregation differ in terms of their neural representation.

As our task required the segregation, organization and integration of diverse aspects of auditory information, we hypothesized the recruitment of the intraparietal sulcus (IPS). Its role in organizing sensory information makes it a prime candidate for the organization of top-down and bottom up information for stream integration (Alexander et al., 2005; Champod and Petrides, 2007; Cusack, 2005; Donner et al., 2002; Foster and Zatorre, 2010; Hill and Miller, 2010; Shafritz et al., 2002; Wei et al., 2011; Zatorre et al., 2010). Stream segregation was expected to mostly involve activation of frontal areas typically seen during working memory tasks as well as in instances of sustained attention (Gaab et al., 2003; Pallesen et al., 2010; Strait and Kraus, 2011). However, as our attention task necessitated subjects to segregate as well as integrate concurrent streams, we expected an interaction of both listening strategies on a neural level. Moreover, a top-down influence for both listening styles via a fronto-parietal attention network was expected (Champod and Petrides, 2007; Corbetta and Shulman, 2002).

Both relationship factors seem important to the production and perception of multi-part music (Bregman, 1990; Goebl and Palmer, 2009; Handel, 1989; Rasch, 1979; Wright and Bregman, 1987). We therefore predicted that both factors would influence attention and thereby the perception and assessment of the relationship between parts. Nevertheless, the individual salience of these factors could still differ. As the stimuli consisted of a western style classical duet, familiarity with melody lead might bias perception and underlying neural correlates. It was also possible that the salience of a part of the duet might interact with the attention task of this study. As both factors may drive attention when listening to music, an interaction of both factors and thus an interaction of their salience was expected to shape the subjective leader–follower rating of the perceived music and maybe even the underlying neural activity (Reddy et al., 2009; Reynolds and Desimone, 2003). Top-down modulatory effects related to increases in salience have been shown to involve a fronto-parietal network, including the dorsolateral prefrontal cortex (dlPFC) and the IPS (Bressler et al., 2008; Corbetta and Shulman, 2002). Such a difference in salience of the two factors might furthermore lead to interference and consequently greater difficulty in the attention task (Lavie and De Fockert, 2005; Lavie et al., 2004). We thus additionally expected a salience difference of the two relationship factors to increase cognitive load and influence BOLD activation (Adler et al., 2001; Pugh et al., 1996). Acquired difficulty ratings were used to disentangle effects of salience and cognitive load.

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