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CONTENTS

<i>List of Figures and Tables</i>	ix
<i>Notes on Contributors</i>	xi
<i>Foreword</i>	xix
<i>Acknowledgments</i>	xxiii

PART I

Music from the Air to the Brain	1
1 Music from the Air to the Brain and Body <i>Edward W. Large</i>	3
2 Music in the Brain: Areas and Networks <i>Psyche Loui and Emily Przysinda</i>	13
3 Music in the Brain: Imagery and Memory <i>Rebecca S. Schaefer</i>	25
4 Music in the Brain: Music and Language Processing <i>Mireille Besson, Mylène Barbaroux, and Eva Dittinger</i>	37
5 Music and the Brain: Music and Cognitive Abilities <i>Reyna L. Gordon and Cyrille L. Magne</i>	49
6 Music, Brain, and Movement: Time, Beat, and Rhythm <i>Molly J. Henry and Jessica A. Grahm</i>	63

7 Music and Health: Physical, Mental, and Emotional <i>Suvi Saarikallio</i>	75
8 Music, Moments, and Healing Processes: Music Therapy <i>Jörg Fachner</i>	89
9 Music, Pleasure, and Social Affiliation: Hormones and Neurotransmitters <i>Roni Granot</i>	101
PART 2 Hearing and Listening to Music	113
10 Musical Structure: Time and Rhythm <i>Peter Martens and Fernando Benadon</i>	115
11 Musical Structure: Sound and Timbre <i>Stephen McAdams and Meghan Goodchild</i>	129
12 Musical Structure: Tonality, Melody, Harmonicity, and Counterpoint <i>Daniel Shanahan</i>	141
13 Musical Structure: Melody, Texture, and Harmony in the Classical Tradition <i>Robert Gjerdingen</i>	153
14 Harmony and Melody in Popular Music <i>David Temperley and Trevor de Clercq</i>	165
15 Musical Structure: Form <i>Richard Ashley</i>	179
16 Music Production: Recording Technologies and Acousmatic Listening <i>Ragnhild Brøvig-Hanssen and Anne Danielsen</i>	191
17 Musical Connections: Absolute Pitch <i>Elizabeth West Marvin</i>	203
18 Musical Connections: Cross-modal Correspondences <i>Zohar Eitan</i>	213
19 Musical Connections: Music Perception and Neurological Deficits <i>Barbara Tillmann, Catherine Hirel, Yohana Lévêque, and Anne Caclin</i>	225
20 Assisted Music Listening in Hearing Loss <i>Tonya R. Bergeson and Rachael Frush Holt</i>	237

PART 3 Making and Using Music	249
21 Creating Music: Composition <i>Roger T. Dean</i>	251
22 Music Improvisation: A Challenge for Empirical Research <i>Peter Viust and Morten L. Kringelbach</i>	265
23 Performing Music: Written Traditions <i>Dorottya Fabian</i>	277
24 Performing Music: Oral and Improvising Traditions <i>Nikki Moran</i>	289
25 Performing Music: Humans, Computers, and Electronics <i>Elaine Chew and Andrew McPherson</i>	301
26 Music with Others: Ensembles, Conductors, and Interpersonal Coordination <i>Clemens Wöllner and Peter E. Keller</i>	313
27 Music Alone and with Others: Listening, Sharing, and Celebrating <i>Alexandra Lamont</i>	325
28 Music and Text: Vocal Musicianship <i>Annabel J. Cohen</i>	337
29 Music and Movement: Musical Instruments and Performers <i>Laura Bishop and Werner Goebel</i>	349
30 Scene and Heard: The Role of Music in Shaping Interpretations of Film <i>Siu-Lan Tan</i>	363
31 Music as Enabling: Enhancing Sport, Work, and Other Pursuits <i>Nicola Dibben</i>	377
PART 4 Developing Musicality	389
32 Music Across the Species <i>Bruno Gingras</i>	391
33 Music Cognition: Developmental and Multimodal Perspectives <i>Sandra E. Trehub and Michael W. Weiss</i>	403

34	Musical Expertise: Genetics, Experience, and Training <i>William Forde Thompson, Miriam A. Mosing, and Fredrik Ullén</i>	415
35	Learning Music: Informal Processes and Their Outcomes <i>Lucy Green and Tim Smart</i>	427
36	Music and Social Cognition in Adolescence <i>Susan A. O'Neill</i>	441
37	Musical Preference: Personality, Style, and Music Use <i>Jonna K. Vuoskoski</i>	453
PART 5		
	Musical Meanings	465
38	Music Cognition: Investigations Through the Centuries <i>Kyung Myun Lee</i>	467
39	Music and Communication <i>Richard Ashley</i>	479
40	Emotion in Music Listening <i>Renee Timmers</i>	489
41	Music, Analogy, and Metaphor <i>Lawrence M. Zbikowski</i>	501
42	Musical Aesthetics and Values <i>Elizabeth Hellmuth Margulis</i>	513
43	Music's Meanings <i>Eric F. Clarke</i>	523
	<i>Glossary</i>	535
	<i>Index</i>	551

FIGURES AND TABLES

Figures

2.1	Anatomical locations of some grey matter regions involved in music perception and cognition. See insert for color figure.	14
4.1	Experimental results of musical training on novel word learning. See insert for color figure.	41
5.1	Differences in brain sensitivity to speech rhythm variations by musical aptitude.	52
5.2	Brain activation during task-switching in (A) musically trained and (B) musically untrained children, and (C) comparison between musically trained and untrained children.	56
6.1	Synchronization of neural oscillations across auditory and motor brain regions.	69
7.1	The music and health framework.	76
10.1	Repeating quarter notes.	116
10.2	Projection and accrual of temporal expectations.	117
10.3	F. J. Haydn, "Austrian Hymn."	118
10.4	Timing contours for two different violinists, from Haydn Op. 76/3, Mvt. 2.	121
10.5	L. van Beethoven, theme from Piano Sonata Op. 13, Mvt. 3.	123
10.6	Rhythm/Meter cycles.	124
11.1	Visualization of Holst, <i>The Planets</i> , "Uranus," mm. 193–236. See insert for color figure.	136
12.1	Excerpt from Francisco Tarrega's "Grand Valse" (1902), commonly known as the Nokia ringtone.	141
13.1	Giovanni di Palestrina, "Sicut cervus," mm. 1–7.	154
13.2	Antonio Vivaldi, Concerto in C Major for Recorder (RV444), Mvt. 1, mm. 6–11.	156
13.3	Rule of the Octave.	158
13.4	Frédéric Chopin, G-Minor Ballade Op. 23, mm. 167–170 with analysis.	161

MUSIC IMPROVISATION

A Challenge for Empirical Research

Peter Vuust and Morten L. Kringelbach

Introduction

At the heart of many musical genres is the highly valued concept of improvisation; usually understood as shorter or longer periods of time where the musicians play what comes into their minds, creating music *in the moment*. Spontaneous improvisation is seen as a hallmark of musical creativity and as such taken to be highly meaningful and pleasurable. In fact, it could be argued that improvisational elements can be found in all kinds of music making (Brattico & Tervaniemi, 2006). While the importance of improvisation varies across genres, there is at least a touch of improvisation when a string quartet plays Joseph Haydn where notes and note values are fixed, but the phrasing is determined by the musicians, or even when DJs mix tracks into each other. Similarly, when composing a piece of music, which is often described as the opposite process of improvisation, improvisation still plays a significant role when composers try out various alternatives, though this process is free of improvisation's usual temporal constraints.

However, there is a big difference between mere interpretation, or ornamentation, of other people's compositions and the creative processes involved in certain musical genres, where musicians in principle have the liberty to play any given note anytime (Cook, 2014), and where the act of improvisation is the central, defining element in which compositions, if present at all, mainly serve as a framework for soloists to improvise on. This is true for many non-Western styles of music, blues or freestyle rap and in particular for jazz music (Berliner, 1994; Monson, 1997). Here, *free jazz*, without compositions or predefined agreements or starting points, but where the music seems to be happening by itself, is often considered the most radical form.

Musical improvisation can be found in solo performances or in group settings where the improvised artwork takes its form in a dynamic interplay between musicians. Collective musical improvisation has often been linked to the concept of musical communication where music acts as a kind of *emotive* language spoken between the musicians, often with an aesthetic purpose.

The present chapter focuses on existing studies of the behavioral and neural correlates of musical improvisation, discussing the prerequisites for being a skilled improviser. Musical

improvisational behavior has been studied through music analyses, mathematical modeling, and using behavioral and neuroscientific experiments; most often using jazz as the prime example. Most of the material covered in this chapter will therefore consider jazz improvisation though many of the aspects and conclusions could perhaps be generalized to improvisation in other styles of music. We will discuss two related questions, central for understanding the cognitive science of music improvisation: To what extent is improvisation in music constrained by context, and can music improvisation be compared to communication or dialogue without words?

Contextual Constraints on Music Improvisation

Let us begin with the key question for improvisation of whether there exists performance deliberated from musical constraints, not conforming to any predefined musical structure or chord scheme. Take, for example, Keith Jarrett's famous *Köln concert*, which is often taken as an example of improvisation without constraints. This performance is in fact not free but constrained by a large number of factors (Ashley, 2011). First, his instrument, the piano, has certain limitations, such as the missing ability to glide between notes as on a guitar, i.e. the music is limited to the well-tempered scale. Second, even though Jarrett is versatile and technically at an extremely high level, there are still limits to what his motor skills enable him to do. Third, what Jarrett can conceive is bounded by his creative skills, his repertoire, what he has listened to during his career, and what his stylistic preferences allow him to play. Fourth, if Jarrett decides to play in tempo, which happens from time to time during the improvisation, he also performs under the constraint of tempo and musical meter.

Modeling Improvisation

Hence, improvisation is invariably subject to stylistic templates and limitations which become even clearer once we consider the more common situation where jazz musicians improvise over a given melody (Large, Palmer, & Pollack, 1995) with an underlying chord scheme. Here, there are rules that the musicians will obey or diverge from dependent on the specific substyle. These rules are especially evident in bebop, which developed in the 1940s and dominated the jazz of the 1950s and has been a starting point for much jazz pedagogy ever since. Take as an example the tones jazz musicians use when improvising on chord progressions. To each chord, there is a scale that expresses the tonality best; a pool of notes improvisers draw their so-called *target notes* from, notes that are heard as belonging to or extending the harmonies. These may be surrounded by *approach notes* that lead to the target notes but are not necessarily within the scales of the given chord. The improviser can choose to play outside of the harmonies to create an effect of surprise or tension but will most often return to target notes within the chord scales. This process has been modeled for bebop (Toivainen, 1995), showing that the pitch organization to a certain extent conforms to pitch organization found in Western music as a whole (Jarvinen, 1995).

Because of its strongly rule-based nature bebop has been the object of many modeling attempts. Researchers have created generative grammars for 12-bar blues chord sequences, common in jazz (Steadman, 1984). Johnson-Laird showed that bebop improvisation is more than stringing licks together or following deterministic rules and theorized that bebop improvisation follows Chomskian generative grammars defining permissible

well-formed structures (Johnson-Laird, 1991, 2002). Keller and Morisson (2007) took a turn away from regular grammars by creating software for generating jazz solos automatically, using probabilistic grammars where production rules are assigned weights or probabilities. Recently, Pachet (2012) presented sophisticated computational systems generating highly ecological, virtuoso bebop solos based on a second-order Markov model (meaning that the probability of the next note is determined by the two notes played just before it), but applying various non-Markovian procedures for incorporating, for instance, chromatic side-slips, chord change negotiation, pitch-range constraints, and intentional target pitches.

Studying improvisation by looking at the melodic material, however, captures only one aspect of improvisation. Phrasing and expressive rhythmic timing of the notes by which the performers add emotions to the melodic content (Ashley, 2002) can be used for various purposes, such as to emphasize phrase boundaries, and the emotional responses in listeners may be captured by skin conductance measures (Dean & Bailes, 2015). Notably, the personal phrasing and timing is often what characterizes the individual style of each musician. It is debatable, though, whether the way expressive timing is used by jazz improvisers is different from the way it is used in non-improvisational musical styles. One key aspect of improvisation is, however, that (when used in a group setting) it involves a unique way of interaction and communication between musicians, which may be performed and learned without verbal instruction (Seddon, 2005). In this respect it resembles spoken language.

Jazz Improvisation as a Form of Communication

The metaphor of music improvisation as a form of language with a generative grammar resonates well with how musicians think about improvising together, namely that they *use* music as a language. This pragmatic aspect of music communication during improvisation was elucidated in a study of the music interactions in Miles Davis's Quintet from the 1960s (Vuust, 2000; Vuust & Roepstorff, 2008) that applied Roman Jakobson's model of verbal communication (Jakobson, 1960). According to this model the *message* (e.g. a musical phrase) is sent from sender to receiver through a channel (live music) in a certain code (jazz) in a certain context (a concert hall in the 1960s). In praxis, since music, in contrast to language, allows for simultaneous playing, the messages constitute more of a patchwork than a sequential conversation.

Hence, music improvisation can be argued to resemble spoken language up to a certain point, not only at a structural level (Besson & Schön, 2001), but also at the pragmatic level in the way it is used in improvising collectives. The communication between jazz musicians is a tool for exchanging musical ideas and fostering creativity, which is not captured well by the recent modeling attempts. However, a number of interaction studies outside the field of music, most relevantly interactive tapping studies, have shown microtiming adjustments as a result of social interaction (Konvalinka, Vuust, Roepstorff, & Frith, 2010). Communication is necessary for making every improvisational performance unique and interesting and dependent on the fact that musical phrases can assume different communicational functions, just like in spoken language. In accordance with the viewpoint held by some ethnomusicologists of music as fundamentally a social activity (McLeod, 1974), to the musicians, the main value of playing jazz may lie in participating in the musical communication process more than in the artwork itself (see also Monson, 1997, chap. 3).

In the following, we shall discuss recent neuroscientific experiments and their consequences for our understanding of music improvisation as a creative and communicational human activity.

Brain Correlates of Improvisation

Is it possible to find neural correlates of musical improvisation? This question has recently been examined in a number of brain scanning studies which informed this chapter's questions about the contextual constraints and communicational aspects of musical improvisation. They point towards a network consisting of prefrontal brain regions, including the pre-supplementary motor area (pre-SMA), medial prefrontal cortex (MPFC), inferior frontal gyrus (IFG), dorsolateral prefrontal cortex (DLPFC), and dorsal premotor cortex (DPMC). These findings seem reasonable since music improvisation involves motor planning and execution, known to be related to activation in the above mentioned motor areas, some sort of self-generated internal cognitive processes, related to activation of MPFC, and communication, which has been linked to IFG.

Improvisation: A Tough Challenge for Cognitive Neuroscience

The results of the neuroscientific endeavors into improvisation, all of which use functional magnetic resonance imaging (fMRI), however, highlight a general problem with this technique and also point to an unsolved philosophical question about improvisation. In studies of improvisation it has been common to contrast improvisation with a control condition, e.g. memory-retrieval, or to contrast different types of improvisation. The inherent problem using this approach is that whereas memory-retrieval supposedly is a confined task with a clearly defined outcome, improvisation is highly individual (Norgaard, 2011). Therefore, the outcome will differ between participants in which motor sequences that are executed leading to differences in motor activity, which notes are being played entailing different auditory activity, and other cognitive and perceptual differences entailing a much more diverse brain activity during improvisation. Since the brain activity recorded during the improvisation conditions, in the worst case, will be comparable to random noise, the contrast images may reveal something about the control condition but not necessarily be very informative as to understanding the neural underpinnings of improvisation *per se*. Note that this problem is not confined to studies of improvisation but a general problem in all neuroimaging studies, including those on e.g. free will (Brass & Haggard, 2007), creativity (Geake & Kringelbach, 2007) or resting state fMRI (van den Heuvel & Hulshoff Pol, 2010).

The Role of the Dorsolateral Prefrontal Cortex (DLPFC) in Improvisation

One of the first and most notable studies on musical improvisation highlights this inherent problem. Limb and Braun (2008) fMRI scanned six professional jazz musicians playing on an fMRI-compatible piano keyboard contrasting over-learned control conditions with free improvising. In one experiment the improvisation was confined to the notes of a C major scale within one octave while playing the scale up and down one octave acted as the control condition. The other experiment contrasted free improvising on a given chord progression

with a memorized novel melody on the same chord progression. The most prominent finding was less activity while improvising in large portions of the frontal lobe, the dorsolateral prefrontal cortex (DLPFC), and the lateral prefrontal regions (LOFC), which in other studies have been related to executive functions, working memory, and cognitive control (Smith & Jonides, 1999). This was paired with an increase of the activity in the medial prefrontal cortex (MPFC), which has been related to introspection (van der Meer, Costafreda, Aleman, & David, 2010).

One interpretation of these results is that improvisers use less neural resources related to cognitive control functions when improvising compared to when playing musical phrases by memory. In other words, the deactivation of the frontal lobe should reflect a suspension of the conscious monitoring and inhibition of the participants' actions. A similar study (Liu et al., 2012) contrasting freestyle rap in twelve freestyle rappers with conventional rehearsed performance similarly found decreases in DLPFC and increases in MPFC in support of Limb & Braun's findings. The authors of this study proposed that this dissociated pattern between MPFC and DLPFC reflects a state in which internally motivated, stimulus-independent behaviors (reflected by the activity in MPFC) are allowed to unfold in the absence of conscious volitional control (reflected as a decrease in DLPFC).

A down-regulation of the prefrontal brain activity in DLPFC resonates well with the way many jazz improvisers describe their mental state while improvising, in that these musicians often point to a deliberate loss of control in order to be able to unfold their creativity freely. Therefore, this has been a credible account of the findings. However, the other possible interpretation, that the musical memory task put stronger demands on networks for memory and cognitive control including the DLPFC is equally likely, and the data at hand do not favor one explanation over the other. Note also that in *real* improvisation overlearned material is widely used, such as when jazz musicians cite previous recordings by other jazz musicians or even themselves (Berliner, 1994), a fact that confounds the contrast between improvisation and memorized material.

Donnay and colleagues (2014), in contrast to Limb and Braun (2008), found activation of DLPFC. They used a particularly ecological approach, scanning subjects while they were *trading fours* playing piano keyboards with the investigators who were situated outside the scanner. Trading fours means that the two musicians alternate playing four bars each, something that happens frequently during jazz improvisation especially between soloists and drummers. Mimicking the earlier study, one experiment contrasted scale improvisation with playing up and down the scale. The other more complex experiment contrasted a memorized jazz composition with improvisation restricted only by having to be monophonic. The main difference between the two studies was that Donnay's study showed interaction between the person in the scanner and the experimenter. This resembles the communication between musicians, which takes place in real jazz performances, but could place greater demands on performance monitoring. Hence, it seems that the relative activation or deactivation of DLPFC is related to the context or difficulty of the tasks involved rather than a specific difference between improvisation and memory retrieval.

Motor and Language Brain Areas Involved in Improvisation

Another approach for studying improvisation has been to contrast different types of improvisation (Berkowitz & Ansari, 2008, 2010). Using fMRI, de Manzano and Ullén (2012)

scanned 18 classical pianists performing melodic and rhythmic improvisation at three different levels of difficulty as well as producing random notes. Comparing the improvisations with random note generation, they found activation of DLPFC, pre-SMA, MPFC, insula, IFG, and the cerebellum. The left IFG is part of Broca's area, which is considered one of the most important language areas implicated in both syntax, semantic processing, and more generally in processing of word order (Burholt Kristensen, 2013). Recently, the IFG has also been implicated in a number of musical studies on melody performance in people suffering from amusia (Mandell, Schulze, & Schlaug, 2007), processing of complex musical rhythms (Vuust, Wallentin, Mouridsen, Ostergaard, & Roepstorff, 2011), and harmony errors (Garza-Villarreal, Brattico, Leino, Ostergaard, & Vuust, 2011). Whereas language predominantly activates the left IFG, music studies often report right or bilateral activation though modulated towards the left hemisphere by musical expertise (Herholz, Lappe, & Pantev, 2009; Vuust, Ostergaard, & Roepstorff, 2006). We may hence speculate that the activation of these language areas in musicians and the left lateralization seen e.g. in de Manzano and Ullén's (2012) study may reflect a more language like use of the musical material, corroborated by the finding of left IFG also in Donnay et al.'s study (2014), which involved actual music interaction. Interestingly, there were only subtle differences between the rhythmic and melodic conditions indicating that these tasks to a large extent draw on similar neuronal resources. Importantly, this study was the first to use a larger sample size of participants, and the statistics were more conservatively corrected for multiple comparisons than previous studies.

The Influence of Expertise on Brain Processing during Improvisation

One thing that tends to vary across investigations of improvisation is the individual expertise of the participants both with regard to motor abilities, ear training, music theory, and familiarity with improvisation. A few studies have tried to determine the influence of improvisational expertise on brain activity during improvisation. Pinho et al. fMRI scanned 39 pianists with a university degree in either classical or jazz music (Pinho, de Manzano, Fransson, Eriksson, & Ullén, 2014). They computed an index of improvisational experience and correlated it to activation during four slightly different improvisation modes. They found the total hours of improvisation experience to be negatively associated with activity in DLPFC bilaterally and the angular gyrus, consistent with the idea that the more expertise, the less attentional resources needed, which is in line with the lower DLPFC activation in Limb and Braun (2008). In contrast, improvisation training was positively associated with functional connectivity of the bilateral dorsolateral prefrontal cortices, dorsal premotor cortices, and pre-supplementary motor areas, which may reflect a more efficient integration of representations of musical structures at different levels of abstraction, as well as strengthened connectivity between cognitive and sensorimotor aspects of improvisation. Importantly, the effects were significant when controlling for hours of classical piano practice and age. So this study points to more efficient processing in and greater connectivity between the networks required for musical improvisation as a result of improvisational training, which is consistent with models of improvisation (Pressing, 1988) that propose that as expertise increases, processing demands should be minimized so that attention can be allocated to higher order goals and cognitive monitoring. The same conclusion was drawn by Berkowitz and Ansari (2010) in a study that compared classical pianists to non-musicians. They found a deactivation of the right temporoparietal

junction during melodic improvisation in musicians only. This brain area is considered part of the so-called attention network, and the data hence suggest that there is an inhibition of stimulus-driven attention, freeing up resources for a more goal-directed performance state that may be beneficial to improvisation.

Improvisation and Random Number Generation

None of the above mentioned studies on musical improvisation deal convincingly with the fundamental challenge of understanding what actually happens in the minds of participants when they are asked to improvise. In a broader perspective this challenge has been addressed extensively in studies of random number generation. Participants are instructed to say the numbers one to nine in a random fashion for a number of trials in synchrony with a pacing stimulus. This is in some ways similar to improvisation in that it involves efficient control of voluntary goal-directed behaviors and requires suppression of competing or habitual responses so that the appropriate responses are selected. When contrasted to a condition in which the participants are merely counting, there is significant activation of a network, consisting to a great extent of brain areas that also have been implicated in the above studies of improvisation: left DLPFC, the anterior cingulate, the superior parietal cortex bilaterally, the right IFG, and the left and right cerebellar hemispheres (Jahanshahi, Dirnberger, Fuller, & Frith, 2000). Interestingly, when the pace is increased, the regional cerebral blood flow decreases in the left and right DLPFC and the right superior parietal cortex. This is paired with an increasingly more habituated behavior: The subjects tend to *count in ones*. Earlier studies using transcranial magnetic stimulation (TMS) had shown that if you knock out the activity in DLPFC, the most habitual response, *counting in ones*, increases at the expense of the controlled response behavior of *counting in twos* (Jahanshahi & Dirnberger, 1999). The authors therefore concluded that the role of the (left) DLPFC is to suppress habitual counting and that at faster rates, where the synchronization demands take priority, this breaks down evidenced by lower activity in the DLPFC paired with more predictable number sequences.

Translated to improvisation this provides a putative explanation to the apparent discrepancy in activation of the DLPFC observed in the different studies. The consistent pattern in these studies is that participants who are proficient improvisers show deactivation of DLPFC while inexperienced improvisers show activation of the same brain area. Proficient improvisers hence seem to exert less cognitive control and rely more on their automatized motor programs whereas less experienced improvisers may need a strong cognitive control partly to avoid repetitions of the same musical material. Importantly, these studies also tell us something crucial about improvisation, namely that improvisation is not only choices of what to do but also choices about what *not* to do.

Do Improvising Musicians Process Auditory Input Differently from Others?

The above studies indicate that musical expertise and experience with improvising heavily influence the brain processing associated with improvising. Does this generalize to the way improvisers listen to music? In general, differences in instrumental and stylistic requirements between musicians lead to differences even at the very basic levels of auditory processing of music and sounds. Musicians who need to intone while playing their instrument, such as violinists, display greater sensitivity to small differences in pitch compared to non-musicians

(Koelsch, Schröger, E., & Tervaniemi, 1999) and to other instrumental groups. Similarly, singers respond with a stronger brain response than instrumentalists to small pitch changes (Nikjeh, Lister, & Frisch, 2008), while conductors process spatial sound information more accurately than professional pianists and non-musicians (Münste et al., 2001), and rhythmically skilled jazz musicians respond to rhythmic deviations with a stronger, more left-lateralized and faster brain response than non-musicians (Vuust et al., 2005). Using a novel musical EEG paradigm and behavioral measures, Vuust and colleagues (Vuust, Brattico, Seppänen, Näätänen, & Tervaniemi, 2012a; Vuust, Brattico, Seppänen, Näätänen, & Tervaniemi, 2012b; Vuust, Brattico et al., 2011) recently showed that the style/genre of music professional musicians are engaged with influences their brain responses to changes in acoustically presented melodic lines. In particular, there were larger overall brain responses in jazz musicians compared to classical musicians, rock musicians, and non-musicians across six different sound features (pitch, timbre, location, rhythm, phrasing, and intensity). This indicates a greater overall sensitivity to sound changes in jazz musicians as compared to other types of musicians. These results were paired with the fact that jazz musicians scored higher in musical aptitude tests than rock musicians and non-musicians, especially with regard to tonal abilities. It is therefore reasonable to think that the need for improvising musicians to be able to decipher and respond to what the other musicians are playing and the derived focus on ear training in their daily practice lead to what we observe as enhanced brain responses to unpredictable events in the music they listen to. Hence, the auditory skills and the related pre-attentive brain processing needed for fast communication with the other musicians during musical improvisation seem to be enhanced in improvising musicians.

Conclusion

The behavioral and neuroscience studies reviewed in this chapter have pointed to two important aspects of improvisation. First, music improvisation in any form is constrained by a number of formalized, unspoken or unconscious contextual factors. Attempts to model music improvisation typically use formalized constraints, such as time signature, key, and chord progression as starting point and can be used for generating solos. These models are most successful in improvisational styles with strong grammars linked to the formalized constraints, such as bebop, whereas it is harder for models to incorporate the unspoken or unconscious contextual factors. These constraints also pose a serious problem to the neuroscience of improvisation. The existing studies use very limited settings where participants, who may not be top-level musicians, improvise on simple chord progressions with one hand on a computer keyboard located at the front end of an MRI scanner. In general, these studies implicate a network consisting of areas related to the motor system, cognitive control, and language processing. However, since contextual factors, skills, and strategy of the improvisers vary so much in different experimental settings, there is substantial variation in brain activation between studies. The most problematic finding is the activation/deactivation of DLPFC since, as the studies on random number generation show, it is heavily dependent on task difficulty. On the other hand, letting go of cognitive control is probably something that many improvisers use as a successful strategy even though this may not be possible to track through brain scanning techniques.

Second, collective improvisation could be thought of as speaking a language that has an esthetic message to deliver, and this is reflected in recruitment of brain areas specialized for language processing. However, the fact that these areas are present does not necessarily mean

that music and language are processed similarly by the brain when musicians communicate, but it indicates that music and language brain modules may be overlapping. Especially, the inferior frontal gyrus is increasingly being thought of as a multi-purpose area, or at least involved in a number of cognitive tasks, and is consistently implicated in the reviewed neuroscientific investigations into improvisation. That music improvisation employs networks specialized for other cognitive tasks gives rise to speculations about a putative transfer to other domains (Husain, Thompson, & Schellenberg, 2002; Thompson, Schellenberg, & Husain, 2001). This is an important task for future research to test whether there is a transfer effect of music improvisational skills to other cognitive abilities. As clearly demonstrated by neurophysiological studies on auditory processing in musicians, there are domain-specific advantages of musical improvisational training. Beaty and colleagues (2013) furthermore showed that semi-professional jazz musicians' scores on general creative thinking ability tests predicted the quality of their improvisations as rated by a team of experts. This points to a potential overlap between the ability to generate creative ideas in general and the ability of jazz musicians to generate novel music sequences. Future studies may show to what extent musical creativity can be trained and whether this training would also enhance creative abilities in general. In relation to this it would also be interesting to understand whether there is a critical period for learning, so that you may need to learn to improvise from an early age.

Core Reading

- Beaty, R. E. (2015). The neuroscience of musical improvisation. *Neuroscience & Biobehavioral Reviews*, 51, 108–117.
- Berliner, P. F. (1994). *Thinking in jazz: The infinite art of improvisation*. Chicago, IL: The University of Chicago Press.
- Norgaard, M. (2014). How jazz musicians improvise: The central role of auditory and motor patterns. *Music Perception*, 31(3), 271–287.

Further References

- Ashley, R. (2002). Do[n't] change a hair for me: The art of jazz rubato. *Music Perception*, 19, 311–332.
- Ashley, R. (2011). Musical improvisation. In S. Hallam, I. Cross, & M. Thaut (Eds.) *The Oxford handbook of music psychology* (pp. 667–679). Oxford: Oxford University Press.
- Beaty, R. E., Smekens, B. A., Silvia, P. J., Hodges, D. A., & Kane, M. J. (2013). A first look at the role of domain-general cognitive and creative abilities in jazz improvisation. *Psychomusicology: Music, Mind, and Brain*, 23, 262–268.
- Bengtsson, S. L., Csikszentmihalyi, M., & Ullén, F. (2007). Cortical regions involved in the generation of musical structures during improvisation in pianists. *Journal of Cognitive Neuroscience*, 19(5), 830–842.
- Berkowitz, A. L., & Ansari, D. (2008). Generation of novel motor sequences: The neural correlates of musical improvisation. *Neuroimage*, 41(2), 535–543.
- Berkowitz, A. L., & Ansari, D. (2010). Expertise-related deactivation of the right temporoparietal junction during musical improvisation. *Neuroimage*, 49(1), 712–719.
- Berliner, P. F. (1994). *Thinking in jazz: The infinite art of improvisation*. Chicago, IL: The University of Chicago Press.
- Besson, M., & Schön, D. (2001). Comparison between language and music. *Annals of the New York Academy of Sciences*, 930, 232–258.
- Brass, M., & Haggard, P. (2007). To do or not to do: The neural signature of self-control. *Journal of Neuroscience*, 27(34), 9141–9145.

- Brattico, E., & Tervaniemi, M. (2006). Musical creativity and the human brain. In I. Deliège & G. Wiggins (Eds.), *Musical creativity: Multidisciplinary research in theory and practice* (pp. 289–321). New York, NY: Psychology Press.
- Cook, N. (2014). *Beyond the score: Music as performance*. Oxford: Oxford University Press.
- De Manzano, O., & Ullén, F. (2012). Goal-independent mechanisms for free response generation: Creative and pseudo-random performance share neural substrates. *Neuroimage*, 59(1), 772–780.
- Dean, R. T., & Bailes, F. (2015). Using time series analysis to evaluate skin conductance during movement in piano improvisation. *Psychology of Music*, 43(1), 3–23.
- Donnay, G. F., Rankin, S. K., Lopez-Gonzalez, M., Jiradejvong, P., & Limb, C. J. (2014). Neural substrates of interactive musical improvisation: An fMRI study of 'trading fours' in jazz. *PLoS ONE*, 9(2), e88665.
- Garza-Villarreal, E. A., Brattico, E., Leino, S., Ostergaard, L., & Vuust, P. (2011). Distinct neural responses to chord violations: A multiple source analysis study. *Brain Research*, 1389, 103–114.
- Geake, J., & Kringelbach, M. L. (2007). Imaging imagination: Brain scanning of the imagined future. *Proceedings of the British Academy*, 147, 307–326.
- Herholz, S. C., Lappe, C., & Pantev, C. (2009). Looking for a pattern: An MEG study on the abstract mismatch negativity in musicians and nonmusicians. *BMC Neuroscience*, 10, 42–52.
- Husain, G., Thompson, W. F., & Schellenberg, E. G. (2002). Effects of musical tempo and mode on arousal, mood, and spatial abilities. *Music Perception*, 20, 151–171.
- Jahanshahi, M., & Dirnberger, G. (1999). The left dorsolateral prefrontal cortex and random generation of responses: Studies with transcranial magnetic stimulation. *Neuropsychologia*, 37(2), 181–190.
- Jahanshahi, M., Dirnberger, G., Fuller, R., & Frith, C. D. (2000). The role of the dorsolateral prefrontal cortex in random number generation: A study with positron emission tomography. *Neuroimage*, 12(6), 713–725.
- Jakobson, R. (1960). Closing statement: Linguistics and poetics. In T. A. Sebeok (Ed.), *Style in language* (pp. 350–377). Cambridge, MA: MIT Press.
- Jarvinen, T. (1995). Tonal hierarchies in jazz improvisation. *Music Perception*, 12, 415–437.
- Johnson-Laird, P. N. (1991). Jazz improvisation: A theory at the computational level. In P. Howell, R. West, & I. Cross (Eds.), *Representing musical structure* (pp. 291–325). London: Academic Press.
- Johnson-Laird, P. N. (2002). How jazz musicians improvise. *Music Perception*, 19, 415–442.
- Keller, R. M., & Morrison, D. R. (2007). A grammatical approach to automatic improvisation. In *Proceedings of the 4th Sound and Music Computing Conference* (pp. 330–337).
- Koelsch, S., Schröger, E., & Tervaniemi, M. (1999). Superior pre-attentive auditory processing in musicians. *Neuroreport*, 10(6), 1309–1313.
- Konvalinka, I., Vuust, P., Roepstorff, A., & Frith, C. D. (2010). Follow you, follow me: Continuous mutual prediction and adaptation in joint tapping. *Quarterly Journal of Experimental Psychology*, 63(11), 2220–2230.
- Kristensen, L. B., Engberg-Pedersen, E., Nielsen, A. H., & Wallentin, M. (2013). The influence of context on word order processing—An fMRI study. *Journal of Neurolinguistics*, 26(1), 73–88.
- Large, E. W., Palmer, C., & Pollack, J. B. (1995). Reduced memory representations for music. *Cognitive Science*, 19(1), 53–93.
- Limb, C. J., & Braun, A. R. (2008). Neural substrates of spontaneous musical performance: An fMRI study of jazz improvisation. *PLoS ONE*, 3(2), e1679.
- Liu, S., Chow, H. M., Xu, Y., Erkinen, M. G., Swett, K. E., Eagle, M. W., Rizik-Baer, D. A., Braun, A. R. (2012). Neural correlates of lyrical improvisation: An fMRI study of freestyle rap. *Scientific Reports*, 2, 834. doi: 10.1038/srep00834
- Mandell, J., Schulze, K., & Schlaug, G. (2007). Congenital amusia: An auditory-motor feedback disorder? *Restorative Neurology and Neuroscience*, 25(3–4), 323–334.
- McLeod, N. (1974). Ethnomusicological research and anthropology. *Annual Review of Anthropology*, 3, 99–115.
- Monson, I. (1997). *Saying something: Jazz improvisation and interaction*. Chicago studies in ethnomusicology. Chicago, IL: The University of Chicago Press.
- Münste, T. F., Kohlmetz, C., Nager, W., & Altenmüller, E. (2001). Neuroperception: Superior auditory spatial tuning in conductors. *Nature*, 409(6820), 580.
- Nikjeh, D. A., Lister, J. J., & Frisch, S. A. (2008). Hearing of note: An electrophysiologic and psycho-acoustic comparison of pitch discrimination between vocal and instrumental musicians. *Psychophysiology*, 45(6), 994–1007.
- Norgaard, M. (2011). Descriptions of improvisational thinking by artist-level jazz musicians. *Journal of Research in Music Education*, 59(2), 109–127.
- Norgaard, M. (2014). How jazz musicians improvise: The central role of auditory and motor patterns. *Music Perception*, 31, 271–287.
- Pachet, F. (2012). Musical virtuosity and creativity. In J. McCormack & M. d'Inverno (Eds.), *Computers and creativity* (pp. 115–146). Berlin: Springer.
- Pinho, A. L., de Manzano, O., Fransson, P., Eriksson, H., & Ullén, F. (2014). Connecting to create: Expertise in musical improvisation is associated with increased functional connectivity between premotor and prefrontal areas. *Journal of Neuroscience*, 34(18), 6156–6163.
- Pressing, J. (1988). Improvisation: Methods and models. In J. A. Sloboda (Ed.), *Generative processes in music* (pp. 129–178). Oxford: Oxford University Press.
- Seddon, F. A. (2005). Modes of communication during jazz improvisation. *British Journal of Music Education*, 22(1), 47–61.
- Smith, E. E., & Jonides, J. (1999). Storage and executive processes in the frontal lobes. *Science*, 283(5408), 1657–1661.
- Steedman, M. J. (1984). A generative grammar for jazz chord sequences. *Music Perception*, 2, 52–77.
- Thompson, W. F., Schellenberg, E. G., & Husain, G. (2001). Arousal, mood, and the Mozart effect. *Psychological Science*, 12(3), 248–51.
- Toiviainen, P. (1995). Modeling the target-note technique of bebop-style jazz improvisation: An artificial neural network approach. *Music Perception*, 12, 399–413.
- Van den Heuvel, M. P., & Hulshoff Pol, H. E. (2010). Exploring the brain network: A review on resting-state fMRI functional connectivity. *European Neuropsychopharmacology*, 20(8), 519–534.
- Van der Meer, L., Costafreda, S., Aleman, A., & David, A. S. (2010). Self-reflection and the brain: A theoretical review and meta-analysis of neuroimaging studies with implications for schizophrenia. *Neuroscience & Biobehavioral Reviews*, 34(6), 935–946.
- Vuust, P. (2000). *Polyrhythm and meter in modern jazz—A study of Miles Davis' Quintet from the 1960s (Danish)*. Aarhus, Denmark: Royal Academy of Music.
- Vuust, P., Brattico, E., Gleason, E., Seppänen, M., Pakarinen, S., Tervaniemi, M., & Näätänen, R. (2011). New fast mismatch negativity paradigm for determining the neural prerequisites for musical ability. *Cortex*, 47(9), 1091–1098.
- Vuust, P., Brattico, E., Seppänen, M., Näätänen, R., & Tervaniemi, M. (2012a). Practiced musical style shapes auditory skills. *Annals of the New York Academy of Sciences*, 1252, 139–46.
- Vuust, P., Brattico, E., Seppänen, M., Näätänen, R., & Tervaniemi, M. (2012b). The sound of music: Differentiating musicians using a fast, musical multi-feature mismatch negativity paradigm. *Neuropsychologia*, 50(7), 1432–43.
- Vuust, P., Ostergaard, L., & Roepstorff, A. (2006). Polyrhythmic communicational devices appear as language in the brains of musicians. *Proceedings from the 9th International Conference on Music Perception and Cognition* (pp. 1159–1167).
- Vuust, P., Pallesen, K. J., Bailey, C., van Zuijen, T. L., Gjedde, A., Roepstorff, A., & Ostergaard, L. (2005). To musicians, the message is in the meter: Pre-attentive neuronal responses to incongruent rhythm are left-lateralized in musicians. *Neuroimage*, 24(2), 560–564.
- Vuust, P., & Roepstorff, A. (2008). Listen up! Polyrhythms in brain and music. *Cognitive Semiotics*, 3, 131–159.
- Vuust, P., Wallentin, M., Mouridsen, K., Ostergaard, L., & Roepstorff, A. (2011). Tapping polyrhythms in music activates language areas. *Neuroscience Letters*, 494(3), 211–216.