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The spatiality of sounds. From sound-source localization to musical spaces

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Abstract. The proliferation of and interest in concepts of musical space make the question of why composers, philosophers, and musicologists have used spatial concepts for music – which is typically considered a temporal and ephemeral art form – a relevant issue in the multidisciplinary research on music. In this paper, I suggest distinguishing between a literal and a metaphorical meaning of the term "space" when applied to music and sounds. Thereafter, I investigate the reasons that might have lain behind the metaphorical use of spatial concepts for music, focusing on the concept of movement in music and examining relevant studies in the field of audiovisual correspondences which show that listeners consistently match certain acoustic features to spatial features. Finally, I claim that both the metaphorical and the literal uses of spatial concepts for describing music are rooted in the way people perceive the dynamic change of acoustic features in terms of a (pseudo)spatial phenomenology.

Keywords: Auditory perception, Crossmodal correspondences, Musical space, Phenomenology.

1. INTRODUCTION

The question about the spatial vs temporal nature of sounds has drawn the interest of psychologists, philosophers, and musicologists throughout centuries. In psychology of perception, sounds conceived of as auditory objects have been often discussed in comparison to visual objects. When looking for principles of perceptual organization, therefore, a number of researchers put forward the allegedly natural analogy between the spatial dimension of vision and the temporal dimension of audition (e.g., Kubovy [1988]). In such accounts, auditory perceptual units are assumed to emerge from the parsing of the continuous auditory flow into identifiable fragments thanks to some kinds of temporal *Gestalt*-like principles (e.g., Tenney, Polansky [1980]). By contrast, visual objects are mainly perceived thanks to spatial principles, for instance, the ability to detect change in texture, which is crucial for object segregation in visually-complex environments. Although such view does not necessarily imply that sounds lack spatial dimension, it seems to suggest, at least, that they are primarily defined and perceived as temporal entities.

Beyond psychologists, philosophers have largely agreed on the priority of time over space in the conceptualization of sound. For example, Hegel defined sound as the «cancelling of the spatial situation» (Hegel [1835], vol II: 890), and Schopenhauer wrote that music «is perceived entirely and only in and through time, completely excluding of space» (Schopenhauer [1818], vol I: 294). More recently, Adorno (1995) claimed that «music is a temporal art (*Zeitkunst*)». In these characterizations, the dynamic change of sounds over time seems to override any other perceptual feature, including spatial localization. Such a idea is in line with relevant traditions in the philosophy of perception, in which auditory perception is conceptualized in terms of a temporal process. Starting with Husserl's writings on time consciousness (Husserl [1928]), in which immanent phenomenological time is seen as the special domain of music (Chatterjee [1971]), and extending to more general accounts of auditory perception, time is widely retained as the constitutional factor for the existence of auditory objects, including sounds (e.g., Nudds [2014]; O'Callaghan [2008]; see also Schaeffer [1966]).

In addition to psychologists and philosophers, composers have often stressed the temporal nature of musical sounds. For example, Stravinsky assumed the intimate relationship between music and time as foundational when he wrote: «Music is a *chronologic* art, as painting is a *spatial* art. Music presupposes before all else a certain organization in time, a chrononomy» (Stravinsky [1947]: 28). For Schoenberg as well, music was temporal at different levels: «in a manifold sense, music uses time. It uses my time, it uses your time, it uses its own time» (Schoenberg [1950]: 40).

Notwithstanding such a wide range of consensus on the priority of temporality in music perception, other accounts have stressed the importance of the spatial dimension of sounds (see Harley [1994] and Macedo [2015a], [2015b], for reviews). As pointed out by Juha Ojala in his doctoral dissertation *Space in musical semiosis* (2009), the term «space/spatial» has been associated to music/sound in an impressive number of different occurrences, such as acoustic space (e.g., Tohyama, Suzuki, Ando [1995]), auditory space (Blauert [1997]), composed space (Smalley [2007]), compositional space (Morris [1995]), conceptual musical space (McDermott [1972]), instrumental space (Emmerson [1998]), listening space (Smalley [2007]), melody space (Todd [1992]), multidimensional music space (Juhász [2000]), notational space (Morgan [1980]), pitch space (Lerdahl [1988], [2001]), sound space (Barrass [1996]), sonic space (Wishart [1996]), spectral space (Smalley [1986]), timbre space (Wessel [1979]).

Most philosophical approaches traced the question of spatiality of sounds back to the localization of sounds and the spatial region occupied by the sounding object (see Casati, Dokic [1994]: 44). For example, Nudds (2009) started his investigation over sound with the question: «Where are sounds and where do we experience them to be?» (Nudds [2009]: 69). McDermott (1972) elaborated on the notion of musical space as a conceptual structure that allows us to distinguish between pitches sounded simultaneously that do not blend together indissolubly, i.e., that occupy different places in musical space (McDermott [1972]: 490). The concept of a unitary, «two-or-more dimensional space» has been related to musical ideas by Schoenberg ([1951]: 113). In such space, as Schoenberg noted, «there is no absolute down, no right, or left, forward or backward» (Schoenberg [1951]: 113). More formalized spatial accounts of musical sounds have also been proposed by musicologists, who tried to develop metrics for assessing the distance between sounds within musical space (e.g., Lerdahl [1988]; Reybrouck [1998]). Finally, spatiality has been used as original creative tools in live performances of sonic arts and electroacoustic music since the introduction of multichannel audio, utilized by artists like Schaeffer, Stockhausen, Xenakis or Boulez[1].

In this paper, I try to show that the concept of space has been applied to sounds according to two main different meanings. First, literally, in reference to the external localization of the sound-source(s) (Section 2). Second, metaphorically, the concept of space has been used to describe a perceptual and non-material environment where sounds we listen to are placed and move about (often labelled as «sound space» or «music(al) space») (Section 3). Then, I show that the metaphorical reference to space in music might be rooted in perceptual processes and, ultimately, in the phenomenology of sounds, i.e., in the way we perceive the dynamic change of acoustic features in terms of a (pseudo) spatial phenomenology. To do this, first, I examine how the allegedly natural association between movement and sounds has contributed to shape the conceptualization of sound in spatial terms (Section 4). Then, I consider relevant literature in audiovisual research, which strengthens the idea of the perceptual origins of spatial concepts of sounds (Section 5).

2. LITERAL MEANING: MUSICAL SPACE AS SOUND LOCALIZATION

In our daily life, most of our auditory perceptions are essential as they allow us to gather information about the space in which we move. Environmental sounds are often naively perceived as being essentially located at the place where they originate. Interestingly, we are not only informed that the sound was generated *there* but also that it was generated *by* a specific material object (O'Callaghan [2009]). For example, the sound of a plate which fall to the ground and break will inform us not only about the localization of the event but also on the dimension of the plate. For this reason, Matthen (2010) noted that sounds are not merely located but are *object*-located events. Distinguishing between the when and where subsystems in auditory perception, Kubovy and van Valkenburg (2001) claimed that the where subsystem is mainly devoted to auditory localization and is therefore in the service of visual orientation. Thus, they concluded that space enters the conceptualization of auditory perception mainly due to its relationship with source localization[2].

Most philosophical accounts of sound perception agree on the crucial role of the question about the localization of sounds and the spatial region occupied by the sounding object (e.g., Casati, Dokic [1994]; Nudds [2009]). The (spatial) relationship between the perceiver and perceived sounds has been conceived differently based on their reciprocal distance. Casati, Dokic and Di Bona (2005) classified sound theories into three groups, namely the distal, the medial and the proximal theories. The distal theories hold that sound is located at distance, i.e., where we hear sound source to be localized. To put it with Pasnau, «we do not hear sounds as being in the air; we hear them as being at the place where they are generated» (Pasnau [1999]: 311). In this view, sounds that are generated at a distance are perceived by the subject as though they *are* at a distance. The medial theories include different subsets of theories which holds that sound is properly located in the medium between source and subject. For example, Sorensen suggests to identify sounds with acoustic waves which travel from the source to the perceiver ([2009]: 10). Finally, the proximal theories (e.g., O'Shaughnessy [2000]) claim that sound can be located either in (or very close to) the perceiver[3].

Whereas the distal and the medial accounts

[1] For example, in the mid-fifties, Stockhausen started to use several loudspeaker groups surrounding the audience for some of his performances working with spatial effects like static and moving auditory objects. However, in this paper, I will not delve into spatial-based musical practices and performances.

[2] Such conclusion is apparently confirmed by the «cocktail party» phenomenon (Cherry [1953]), in which a distinct stream of auditory information can be identified also thanks to the spatial localization of the source.

[3] An additional account considered by Casati, Dokic and Di Bona (2005) is the a-spatial theory, which paradoxically claims that sound is an a-spatial item which we hear as occupying no location whatsoever.

seem to align with the commonsensical understanding of sound localization more straightforwardly, i.e., to the fact that we hear sounds that are located at their source (distal) or soundwaves that travel from their origin to our hears (medial), the proximal theories might be less clear and seemingly deny our phenomenological ability to localize sound sources in space, which must be rooted in the sensory information we gather from sound perception. Thus, in what follows, I briefly discuss Nudds' proximal position, which holds that the sounds that we hear are instantiated where we are.

To understand Nudds' claim we must distinguish between the *fact* that we can locate sound (sources) in space and how we actually *experience* sounds. Nudds observed that, although we might be aware of places in virtue of hearing something located there, space in *itself* is no way the object of our auditory experience. Moreover, sounds essentially lack space: «We do not hear sounds as having spatial parts or as having spatial structures» (Nudds [2009]: 81). By contrast with visual experience, Nudds stresses that «our auditory experiences represent space in a way that is often far less determinate» (Nudds [2009]: 88). In fact, whilst visual experience might inform us of space in itself, for instance, about dimension or shape, our auditory experience of space is reduced to the mere awareness of (spatial) relations between sound sources and us, and between sound sources and other sound sources (e.g., distance). In other words, according to Nudds, we experience the *sound sources* as located, but not the *sound* in itself: «When we hear the alarm clock ringing, we can hear where the clock is – that it is on our left-hand side. Do we also hear where the sound of the alarm clock is? In other words, does the sound of the alarm seem to be where the alarm clock seems to be?» (Nudds [2009]: 90). Such phenomenological distinction between sound and sound sources can ultimately ground Nudds' claim to conclude that it barely has no meaning to say that sounds are located at their sources, but more precisely they are experienced where perceivers are.

To summarize, the concept of spatiality of sounds, taken in its literal meaning, is evoked both in philosophy and psychology to discuss issues related to the localization of sound sources, for instance, whether the distal, the medial, or the proximal theory better accounts for the way space is phenomenologically relevant in sound perception (see Di Bona [2019]). However, as Section 3 will make clear, the concept of space has been applied to sound also in an alternative, non-literal, and peculiar manner. In such metaphorical use, space is essentially conceptualized as an autonomous or independent perceptual environment that is intrinsic to musical sounds and in which sounds can be placed and move about.

3. METAPHORICAL MEANING: SPECIFICALLY MUSICAL OR SONIC SPACE(S)

When metaphorically used in reference to sound, the term «space» loses some of the essential features that characterize it in the visual domain, such as being physical and three-dimensional. Moreover, according to Zuckerkandl, what makes musical space different from visual material space is its complete indivisibility: «The ear knows space only as an undivided whole [...] the space we hear is a space without places» (Zuckerkandl [1956]: 276). However, as Lippman noted, sound perception can be still conceived of as a different kind of spatial experience «whose nature is open to question» (Lippman [1952]: 112). In what follows, starting from the pioneering contribution of Hermann von Helmholtz, we try to go deeper into Lippman's question, providing an overview of how the concept of space has been metaphorically applied to sound.

Helmholtz was among the first to clearly emphasize the relationship between space and musical tones, when he observed the analogy between musical scale and space. In his treatise *On the sensations of tones*, we read: «It is an essential character of space that at every position within it like bodies can be placed, and like motions can occur. Everything that is possible to happen in one part of space is equally possible in every other part of space and is perceived by us in precisely the same way. This is the case also with the musical scale. Every melodic phrase, every chord, which can be executed at any pitch, can be also executed at any other pitch in such a way that we immediately perceive the characteristic marks of their similarity» (Helmholtz [1954]: 370). Such structural similarity is seemingly based on the properties that music and space phenomenologically exhibit. As we perceive the motion of physical objects in the empirical space, we (can) perceive sounds changing in pitch as if they were moving from one place to another. Few years later, the German philosopher and psychologist Carl Stumpf stated that we express the sensation of tone «with a certain psychological necessity» in spatial metaphors, most evident in the height of a tone: «The power of spatial imagery of tones is indeed remarkable» (Stumpf [1883]: 189). After Helmholtz and Stumpf, several philosophers and musicologists have elaborated on spatial accounts of musical sounds. Among the issues discussed in the early literature there are the comparison of musical space to the three-dimensional geometrical space, the spatial character and representation of pitch and pitch relationships, and the spatial features of musical time (see Harley [1994]).

Echoing the observations made by Helmholtz, the philosopher and musicologist Ernst Kurth defined musical space as essentially manifested in and through movement. Inner musical geometry is similar to, but not identical with, the geometry of the external space; it is linked to the structure of the intervals, chords, and forms of melodic motion (Kurth [1931]: 121). Kurth noticed in particular the spatial qualities of pitch, melodic line, contrary and oblique motion, as well as the distance of notes in an interval (*Zwischenraum*). Few years later, the distinctions between various types of space in music were refined in the thought of Albert Wellek, who tried to distinguish between hearing space (*Gehörraum*), tonal space (*Tonraum*), and musical space (*Musikraum*) (Wellek [1963]). Hearing space is the aurally mediated spatial orientation, an incomplete "image" of the objective and physical space. Tonal space is an unsteady, indistinct structure or ordering schema in three dimensions. Musical space is a "pure" feeling space idiosyncratic of music, feeding itself from the previous (the tonal space, but also the hearing space), substantially though based on expression of feelings in (absolute) music as such. Of the suggested three dimensions of the tonal space, as described by Wellek, the first, "vertical" one corresponds (primarily) to pitch, while the second, "horizontal", to time and temporal order (see Riedel [2019]).

Kurth's and Wellek's descriptions of musical space remain largely obscure. A certain degree of conceptual obscurity was admitted by Kurth himself, who stated that musical space «is not visible, not touchable, and really hardly conceivable» (Kurth [1931]: 119). Thus, he referred to the idea we have of space in music more as a *space-feeling* than a space-conception. Nevertheless, as Kurth himself recognized, conceptual unclearness is no argument against the existence of musical space, but merely against its identity with external space, which on the contrary rests on the clearest perceptual and intellectual realization (see Kurth [1931]: 127)[4].

A couple of decades later, the fundamental contribution of Edward Lippman explicitly assumed the apparent contradictory nature of the conceptualization of spatiality in music: «The explanation of the spatial aspects of musical experience is obviously not to be found directly in perceptual or empirical space, but there is apparently no meaningful concept of space other than this» (Lippman [1952]: 135). Lippman evidenced that the intrinsic spatiality of music is phenomenologically evident, and grounded on structural similarity, i.e., the many identical formal elements that characterize the experiences of music and of empirical space. For Lippman, the fundamental nature of musical space consists of a spatial con-

[4] A three-dimensional model of musical space (with the axes of pitch, time, dynamics) has been also proposed by the German musicologist and composer Hans-Joachim Moser (1953). This model includes four beats in common time as units on the time axis, and standard dynamic levels (*p*, *mf*, *f*) as units on the dynamic's axis.

tinuum of sensations in a direction which we call by preference "low-high", though there is a feeble connection with the same terms when used to refer to perceptual space (cf. Lippman [1952]: 236). The need to use concepts elaborated for describing empirical space, for Lippman, unavoidably generates the conceptual complexity (if not vagueness) of the notion of musical space itself, which can hardly be explained in analytical terms: «The tendency of musical space to seek embodiment in conceptions of empirical space is so readily understandable as not to require explanation; an identity of structure and of sensational character, and the dominance of utility in establishing meanings are the chief underlying reasons» (Lippman [1952]: 235).

Key reflections on the notion of musical space were provided by Vincent McDermott and Thomas Clifton. McDermott introduced the notion of musical space as a conceptual structure that allows us to individualize objects and distinguish them from one another. According to him, pitches sounding simultaneously that do not blend together indissolubly, maintain separate *positions*, i.e., they occupy different places, in nothing other than a musical space (McDermott [1972]: 490). McDermott grounded his notion of musical space on pitch and depth or masking[5]. The latter dimension is introduced to account for the fact that pitches are perceived as moving not only according to vertical direction, i.e., high-low scale, but also in depth: «Pitches often do not appear on a single plane in our mind's image of the piece, as it grows and as we comprehend it. On the contrary, one sound or group of sounds tends to stand out, to demand more of our attention. Other sounds recede, become obscured by still other sounds» (McDermott [1972]: 492). McDermott referred to this perceptual phenomenon with the psychoacoustical concept of masking. In his view, space is a conceptual tool that we implicitly use when listening to music we are aware of relations of height, interval, depth, or counterpoint. Such relations are, according to McDermott, all conceived of as spatial. However, when it comes to the articulation of such musical space and the positioning of sounds, McDermott explanations become much elusive (as highlighted above for Kurth and Wellek): «Every pitch, timbre, dynamic, every group of tones, every formal intricacy, every durational emphasis, even every rest – in sum, everything about a piece of music – contribute in some manner, substantially or only slightly, to the spatial organization of the work» (McDermott [1972]: 491).

Delving into the phenomenology of sounds, Cliftons' study of «music as heard» touches upon various aspects of the perceptual experience including musical space. For Clifton, musical space is one of the four essential features of musical experience, together with time, play and feeling and understanding. Such notion of musical space is rooted in the peculiar experience of hearing tones as «occupying certain positions of a purely phenomenal, nonphysical nature» (Clifton [1983]: 143). Therefore, the musical space has nothing to share with listener's or sound's localization: «To be in musical space means more than mere existence at a particular place, and therefore has nothing to do with one's physical location» (Clifton [1983]: 141). The notion of space embraces diverse aspects of the perceptual experience of music, for example, line and surface among others. Line is defined as «the narrowest, if not the simplest form of musical space is the single line» (Clifton [1983]: 143). The musical line exhibits some of the properties of geometrical lines, for instance, thickness. Whilst the association of melody with the concept of line seems to be intuitive (e.g., see the common description of melodies as melodic lines), Clifton's characterization of surfaces as elements that vary according to several musical parameters, such as dynamics, intensity, timbral complexity (Clifton, [1983]: 155) seems vague. In this respect, I must agree with Macedo (2015b), who observed that Clifton's notions of line and surface seem to be unclear and unclearly differentiated. In fact, although they seem to be modeled after empirical space, their distinction does not seem to cor-

[5] In line with Helmholtz, McDermott conceives pitch perception as intrinsically spatial: «Pitch change is somehow spatial change» (McDermott [1972]: 489).

respond to a similar distinction in empirical space. Therefore, the impression is that the use of geometrical/visual terms in musical context is exclusively based on metaphorical mapping, that nevertheless remains unclear, and thus fails in clarifying how space can be conceived of as an organization principle for sounds perception.

More formalized accounts of spatiality in sounds perception have been proposed by Fred Lerdahl and Mark Reybrouck. Lerdahl (1988) introduced the notion of pitch space to identify a formal, nongeometrical, layered structure that actually resembles an incomplete matrix of values (Lerdahl [1988]: 8). Such nontopological space accounts for several phenomena, such as pitch and chord proximity, in a highly formalized way, thus assuming the concept of space in a very technical meaning. Grounded in an algebraic approach, Mark Reybrouck (1998) defined the metrics of musical space together with its psychological constraints. Reybrouck conceived musical space-time as a topological space allowing every discretization of the sonorous universe by selecting sets of points, and every possible transformation of sets of points to other sets of points.

Finally, the work of the philosopher and composer Dimitri Tymoczko is worth mentioning here, as he proposed a sophisticated spatial conceptualization of harmony based on geometry (Tymoczko [2011]). Tymoczko talked in terms of «musico-geometrical spaces» as ways of representing musical structural properties (Tymoczko [2011]: 20). Starting from basic elements, such as pitches on a line, he created complex spatial structures (containing twists, mirrors, Möbius strips) that are used to investigate the relations between conjunct melodic motion, harmonic consistency, and acoustic consonance. While gaining in clarity and rigour, such highly formalized models might appear to lose proximity to actual, first-person listening experiences.

The various spatial accounts of sounds summarized here (see, also, Morgan [1980] and Zbikowski [2002]) have a certain number of common features. First, they assume the spatial quality of pitch (from Helmholtz onwards) and make an important distinction between the peculiarly musical and the auditory types of space. The auditory space is the external, physical place where sounds sources are perceived to be located (see Section 2). By contrast, sound space is a phenomenal and non-empirical space to which listeners (might) refer to when describing sounds or music they listen to. It might rely on musical or acoustic features of sounds, such as dynamics and pitch, but it resists to the definition in mere psychoacoustic terms. Second, they highlight the crucial role of the notion of movement in grounding the conceptualization of auditory perception on a spatial basis. Third, they necessarily fail when trying to provide the notion of musical space of a solid and rigorous definition, so that the nature of such musical spaces remains controversial if not unclear (Kania [2015]). Reflecting on the non-literal use of the term 'space' in similar contexts, thus, Lippman (1952) observed that such musical space is rather a *pseudo-space*. To properly understand this notion, we must not restrict *a priori* the notion of space to the commonsensical idea of physical space, i.e., a geometrical structure in which objects exist as material entities[6]. On the contrary, exploiting the rich variety of different conceptualizations of space in different fields, such as physics, mathematics, and geometry (see Jammer [1993]), we can admit the existence of a peculiar sonic, or musical, space as a non-empirical and phenomenologically experienced space whose perceptual features can be, at least to some extent, described. To explore the phenomenology of such space, I will first delve into the association between sound and movement (Section 4) and then, leveraging on literature on audiovisual correspondeces, between acoustic and spatial features (Section 5).

4. MOVEMENT IN MUSIC (SPACE)

If, as Strawson claimed, «a purely auditory concept of space is an impossibility» (Strawson [1959]:

[6] See Mattens (2018) for a phenomenological analysis of the problem of spatiality and the multiplicity of constructs of space.

66), then one might be tempted to ask what has fostered the creation of so many spatial concepts of music/sounds. Several scholars have claimed that movement has allegedly played a role in mediating the metaphorical conceptualization of auditory perception on a spatial basis (e.g., Larson [2012]). For instance, Larson (2012) suggested that the metaphor of musical flow as physical motion is key to our conceptualization of music. Indeed, listeners verbally describe music as something that *moves* over time, saying, for example, that a succession of tones of increasing frequency is an *ascending* melody. Many of the words we use to describe music are also used to describe physical movement, e.g., *ascending* or *descending*, or to refer to situations that imply movement, e.g., *scale*, *steps*. Additionally, a core concept in music theory, namely, rhythm, is often labelled with two different words, i.e., "tempo" and "velocity", both of which relate to movement. Therefore, musical language itself encourages a dynamic of motion. However, puzzlingly, nothing actually moves when we perceive music, and the only movement that allows for music to exist, i.e., the physical movement of acoustic waves, is not the movement we typically refer to when using that language. How to account then for the metaphorical talk of music in terms of movement?

Relying on Lakoff and Johnson's metaphor theory, Cox claimed that «how musical motion and space emerge from the same logic that gives us temporal motion and temporal space» (Cox [1999]: 192). If, as Gärdenfors ([2000]: 176) proposed, «a metaphor expresses an identity in topological or geometrical structure between different domains», then the metaphoric use of terms for describing movement in musical context might be rooted in our perceptual (visual) experience of the motion of physical objects. In this line, Hubbard (2017) suggested that our conceptualization of musical succession in terms of movement is influenced by our perceptual experience of the movement of physical objects through space.

Going deeper into the analogy between musical and physical movement, Larson (2012) holds that musical movement is perceived to be susceptible to forces that are analogous to those that operate the movement of physical objects in space. In particular, he distinguished among three forces that are experienced in tonal music: musical gravity (i.e., the tendency of a note to descend), musical magnetism (i.e., the tendency of an unstable note to move towards the closest stable pitch), and musical inertia (i.e., the tendency of pitches or rhythms to continue in the perceived pattern) (Larson [2012]). Evidence of these perceptual or phenomenological forces might be found in empirical research. For example, musical inertia might be related to findings on sensorimotor synchronization and prediction showing that participants are capable of predicting the next auditory event on the basis of the acquired momentum of previously perceived stimuli (see Repp [2005] for a review). A confirmation of the analogy between musical momentum and physical inertia mediated by movement might come from Friberg and Sundberg (1999), who compared runners' deceleration to the final *ritardandi* from two examples from Bach's works and one sequence of two alternating notes. The results showed that runner deceleration patterns are strikingly similar to the curve representing the final *ritardando* of a musical performance, thus suggesting the existence of motor patterns that govern temporal changes both in music and locomotion.

The metaphorical use of terms that are usually employed to describe physical movements to describe auditory perception thus suggests a structural analogy between the way in which we conceive physical space and auditory space. This analogy appears from the representation of the three-dimensional auditory space, as well as from the reflections on physical forces and momentum put forward by Larson and Hubbard, respectively. The fact that diverse accounts of sound perception converge with the identification of movement as a crucial concept provide a basis for the spatial nature of auditory perception and its objects, herein conceived of not only as the place where sounds originate but also as the nonphysical environment from which perceptual properties emerge. Further insights into the metaphorical/literal use of spatial concepts for describing sounds might derive from literature on crossmodal associations between auditory stimuli and spatial features, such as elevation, distance, and size. In the next section, I thus provide a brief overview of some of the most relevant findings in the field in order to delve into how humans conceive spatiality in music.

5. SUPPORTING EVIDENCE: THE CROSSMODAL ASSOCIATIONS BETWEEN ACOUSTIC AND SPATIAL FEATURES

Auditory-spatial correspondences have drawn special attention in the growing field of crossmodal associations. With the term «crossmodal association», researchers use to refer to those deliberate and consistent matchings between perceptual dimension from different sensory domains that are observed in normal perceivers (i.e., non-synaestheses) (see Spence [2011] for a review). One of the most famous audiovisual associations was discovered almost a century ago by Köhler (1929), who observed that people tend to associate the term «maluma» to curved lines, while the term «takete» to angular lines.

Several studies have demonstrated that non-spatial attributes of perceived sound (e.g., pitch) are consistently associated by listeners with aspects of space and motion (see Eitan [2013] for a review). Importantly, such associations do not seem to be prompted, or influenced by, source localization. In fact, studies showed that listeners consistently associate higher-pitched sounds with higher locations, regardless of the actual source location (Pratt [1930]; Roffler, Butler [1968]; Cabrera, Ferguson, Tilley, Morimoto [2005]). Thus, regarding the suggested distinction between literal and metaphorical use of space concepts in music, these studies can be interpreted as shedding light on the latter use.

Studies on adults demonstrated that perceived pitch direction affects the visual perception of the direction of vertical motion. For instance, Maeda, Kanai, and Shimojo (2004) showed that ambiguous motion generated by two horizontal gratings (parallel bars) moving simultaneously in contrasting directions (up and down), is judged as ascending when accompanied by an ascending pitch, and as descending when accompanied by a descending pitch. Studies showed also that larger physical size is consistently associated with lower pitch (Mondloch, Maurer [2004]). In a dynamic context, people tend to perceive sounds increasing in pitch as becoming thinner, and sounds decreasing in pitch as becoming larger (e.g., Bonetti, Costa [2019]). Pitch-size correspondence is shown to affect also perceptual discrimination tasks. Gallace and Spence (2006) showed that when adult participants were asked to rapidly judge whether a visual stimulus was larger or smaller than a standard stimulus preceding it, responses were faster when the comparison stimulus was accompanied by a sound congruent to it in pitch (i.e., larger size-lower pitch, smaller size-higher pitch) than for incongruent stimuli (larger size-higher pitch, smaller size-lower pitch) (see also Evans, Treisman [2010]). This suggests that the pitch/size correspondence might be based on perceptual processing. Similarly, people tend to judge high-register music as «small» and lower register music as «large» (Eitan, Timmers [2010]).

Loudness has been related to size, as well as to distance. While the association between loudness and distance can be easily explained in terms of environmental auditory experience (i.e., increasing loudness means that the source is getting closer) more interesting is the association between loudness and size in non-dynamical context. Smith and Sera (1992) found that children matched larger objects with louder sounds, and similar results do not apparently depend on culture, language, or musical expertise (Walker [1987]; Lipscomb, Kim [2004]). The loudness-size association may well be based on experiential correlations between the size of objects (including humans and other animals) and the loudness of the sounds they can produce (Carello, Anderson, Kunkler-Peck [1998]).

Evidence thus supports the relationship between music and space by evidencing a perceptual link between the way we perceive spatial and acoustic features. Studies also seemingly confirm that motion plays a crucial role in mediating the association between music and space. In particular, they suggest that the metaphorical use of spatial terminology for describing sounds is rooted in some perceptual process, i.e., it depends on the natural tendency to ascribe movements to sounds that change over time. Noteworthily, studies on infants provided evidence of such crossmodal interaction from as early as 6 months of age, prior to language acquisition (Wagner et al. [1981]; Walker et al. [2010]; Jeschonek et al. [2012]). Similar conclusions are in line with the early intuition by the eminent psychophysicist Stevens (1934), who suggested that sound is phenomenologically experienced as endowed with spatial features. According to Stevens, we perceive sounds as occupying more or less (musical) space, i.e., volume, in such a way that volume increases as sounds intensity increases and as frequency decreases. Thus, for example, to make a sound more voluminous, we can increase its intensity or lower the frequency.

Crossmodal research also demonstrates, however, that the relationship between sounds and motion remains complex, with each of the musical parameters being associated with several spatio-kinetic attributes, and viceversa (see , e.g., Spence, Di Stefano [2022], for a recent review of colour-sound associations). For example, pitch direction was shown to be associated with motion, as well as size, while spatial height and motion along the vertical axis were associated with pitch and loudness. This confirms that, as Lippman suggested, spatiality of music is rather a "pseudo"-spatiality, with some salient features, such as motion, bridging the way we experience music and space, while other features being not univocally perceived (for instance, pitch direction is strongly associated with motion in the vertical axis when pitch descends, but not when it rises).

6. CONCLUSION

In this paper, I have tackled the issue of spatiality of music combining philosophical and musicological sources with psychological literature on crossmodal associations. Based on such literature, I have suggested that the concept of space has been applied to sound in two different ways, namely literally and metaphorically. The literal meaning generally refers to the external localization of the sound source, while the metaphorical meaning refers to an allegedly different context, that is, a perceptual, non-physical space peculiar to musical sounds. Exploiting findings from crossmodal research, I tried to show that the two different meanings have similar origins, as they both rely on perceptual processes. The metaphorical use of terms that are typically used to describe physical movements to describe auditory perception is likely rooted in the phenomenological similarity between the way in which we experience physical space and auditory (pseudo-)space (Larson [2012]; Hubbard [2017]). To conclude, it might be worth going back to the pioneering observation by Helmholtz, who early noted that the dynamic change of pitch over time «has a readily recognised and unmistakable resemblance to motion in space, and is often metaphorically termed the ascending or descending motion» (Helmholtz [1954]: 370).

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