Motivic similarity and form in Boulez's *Anthèmes*

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To the memory of the musical genius Pierre Boulez (1925-2016),
whose music and words inspired the very genesis of this research project.

Abstract

This dissertation combines theoretical, analytical, and empirical methods to study aspects of motivic similarity and form in Boulez's *Anthèmes.* The concept of similarity is central to the definition of motives and musical form. Nevertheless, little is known about the perception of motivic relationships and form while listening to post-tonal music. The most traditional theoretical methods used for post-tonal analysis (such as pitch-class set theory) have tended to emphasize abstract similarity relations based on local pitch and interval structures, disregarding features other than pitch as well as larger formal levels. However, experimental research has demonstrated that the perception of these pitch relationships in post-tonal music is secondary and extremely difficult. According to the empirical evidence, the kinds of structures that are particularly salient during music listening (including post-tonal music listening) are defined by both local- and global-level relationships involving surface features such as articulation and rhythm. This marks a gap between theoretical and perceptual research agendas. Boulez seemed to be aware of this disconnect, as he explicitly intended to reconcile perception with compositional practice. He described the form of *Anthèmes* in terms of constantly changing yet clearly recognizable motives, with surface features acting as large-scale formal markers. The two versions of *Anthèmes*—*Anthèmes 1* (1992) for violin and *Anthèmes 2* (1997) for violin and electronics—can be understood as two different formal and timbral settings for the same motivic materials.

This dissertation aims to begin filling the gap that separates theory and perception in the scholarship of post-tonal music. Chapter 1 introduces the topic of motivic similarity and its relationship to form, reviewing previous literature within the context of Boulez's ideas about music. Chapter 2 investigates aspects of motivic categorization and similarity in *Anthèmes* out of the context of the piece. Two theoretical analyses of *Anthèmes 1* combined with the results of three perceptual experiments show that (1) motivic materials can be grouped in families with different degrees of internal consistency, and (2) the perception of similarity relationships is highly dependent on the surface features of the materials and the conditions under which those materials are heard. Chapter 3 integrates formal and feature analyses with findings from two perceptual experiments to study the perception of motivic relationships while listening to *Anthèmes 1* and *Anthèmes 2.* I propose that predictability, formal-unit blend (due to a lack of surface contrast), and elapsed musical time (resulting from the development and organization of materials) shift the listeners' attention to different formal levels. A basic model of form perception is sketched based on these findings. Chapter 4 concludes the dissertation with a discussion about the effects of the musical context on motivic similarity perception, and an overview of the limitations and possibilities for future research on this topic.

Résumé

Cette thèse combine des méthodes théoriques, analytiques et empiriques afin d'étudier les aspects mis en œuvre dans *Anthèmes* de Boulez concernant la similitude motivique et la forme. Le concept de similitude est central dans la définition des motifs et de la forme musicale. Néanmoins, les connaissances sur la perception des relations motiviques et de la forme pendant l'écoute de la musique post-tonale sont encore très limitées. Les méthodes théoriques les plus traditionnellement employées pour l'analyse post-tonale (telle que la théorie des ensembles de classes de hauteurs) ont eu tendance à mettre l'emphase sur les relations de similitudes abstraites fondées sur les structures locales de hauteurs et d'intervalles, ignorant ainsi tous les paramètres autres que ceux liés à la hauteur et aux niveaux de forme à plus grande échelle. Cependant, la recherche expérimentale a mis en évidence que la perception de ces relations entre hauteurs dans la musique post-tonale était secondaire et extrêmement difficile. Les résultats empiriques révèlent que les types de structures les plus saillantes pendant l'écoute (y compris l'écoute de la musique post-tonale) sont définis à la fois par les relations locales et globales qui impliquent des traits de surface tels que l'articulation et le rythme. Ceci souligne l'existence d'un écart entre les programmes de recherche théorique et perceptif. Boulez semblait être conscient de cette coupure et cherchait en effet explicitement à réconcilier la perception avec sa pratique compositionnelle. Il décrivit la forme d'*Anthèmes* en termes de motifs changeant continuellement tout en restant clairement reconnaissables, les traits de surface agissant ainsi comme marqueurs de la forme à grande échelle. Les deux versions d'*Anthèmes*—*Anthèmes 1* (1992) pour violon et *Anthèmes 2* (1997) pour violon et électronique live—peuvent être interprétées comme deux manifestations de forme et de timbre des mêmes matériaux motiviques.

Cette thèse a pour objectif de commencer à combler le vide séparant la théorie et la perception dans l'étude de la musique post-tonale. Le premier chapitre introduit le thème de la similitude motivique et de sa relation avec la forme au regard de la littérature existante et dans le contexte des idées de Boulez sur la musique. Le deuxième chapitre étudie différents aspects concernant la catégorisation et la similitude des motifs en dehors du contexte de l'œuvre. Deux analyses théoriques d'*Anthèmes 1*, combinées avec les résultats de trois expériences perceptives montrent que (1) les matériaux motiviques peuvent être classés en familles ayant des degrés de cohérence interne différents et (2) la perception des relations de similitude dépend fortement des traits de surface des matériaux ainsi que des conditions dans lesquelles ils sont écoutés. Le troisième chapitre intègre l'analyse de la forme et celle des traits avec les résultats de deux expériences perceptives afin d'étudier la perception des relations motiviques pendant l'écoute d'*Anthèmes 1* et *2*. Nous proposons que le caractère prévisible, l'intégration des unités de forme (due à un manque de contraste de la surface) et le temps musical écoulé (conséquence du développement et de l'organisation des matériaux) déplace l'attention de l'auditeur sur des niveaux de forme différents. Le quatrième chapitre conclut la thèse avec une discussion concernant les effets du contexte musical sur la perception de la similitude motivique, ainsi qu'avec un aperçu des limites et perspectives de recherches concernant ce sujet.

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Contributions of Authors

Professors Robert Hasegawa and Stephen McAdams were equally involved as supervisors of this dissertation. Both provided general guidance and revision and contributed to all the stages of the research to a greater or lesser extent, according to their area of expertise. Robert Hasegawa was particularly concerned with the theoretical and analytical portions of the document. Stephen McAdams provided support with issues related to experimental design and data analysis and was especially involved in reviewing the cognitive and perceptual sections of the work. As director of the Music Perception and Cognition Lab, Stephen McAdams provided all the laboratory equipment and funding necessary for the experimental work. REB # 156-0107.

My contribution includes the conception of the project, design of all the experiments, interpretation of the results, and authoring of the complete dissertation. I was also responsible for preparing the experimental stimuli, running all the participants, and analyzing the data.

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Chapter 1
Introduction

This dissertation explores analytical and perceptual aspects of motivic similarity and its relationship to form in post-tonal music in general, and in Boulez's *Anthèmes 1 and 2* in particular. The notion of similarity has been, more or less consciously, an essential component of the history of music theory and analysis. The concept is central to the definition of traditional formal models and the conception of musical motive. Concordantly, empirical evidence suggests that similarity plays an important role in the perception of post-tonal music. Similarity relationships contribute to the way listeners make sense of the unfolding of musical forms (temporal development of music). Based on the importance of the concept of similarity for music theory, musical form, and music perception, this project combines theoretical, analytical, and experimental methods to investigate some of the ways in which the constant and changing characteristics of the musical materials (the similarity/dissimilarity relationships among those materials) influence the experience of listening to a post-tonal piece of music.

The most traditional theoretical methods used for post-tonal analysis such as set theory and transformational models have tended to emphasize similarity relations based on abstract pitch and interval structures. Nevertheless, empirical evidence has demonstrated that the perception of these structures in post-tonal music is, at the very least, extremely difficult and secondary to the perception of surface patterns such as similarities in overall melodic contour and rhythm. This indicates a dissociation between the theoretical and perceptual research agendas of post-tonal music. Based on the relevance of similarity for both music theory and analysis—particularly with respect to musical motives and form—on the one hand, and for the perception of post-tonal music on the other, the methodology implemented in this dissertation combines theoretical analyses with experimental tests with the ultimate purpose of bringing together theoretical and perceptual approaches to post-tonal music. This purpose is addressed through the more specific objective of investigating different facets of similarity that could potentially serve as fundamentals for the development of models that are both perceptually valid and theoretically applicable.

From around 1970, Pierre Boulez becomes remarkably aware of issues of perception, as documented in his writings, interviews, and analyses. The composer explicitly refers to perceptual issues of motivic similarity and form with respect to his work *Anthèmes*, a composition in which the musical materials appear to be conceived in categories—groups of motives— that play an important structural role. As a result, *Anthèmes* is ideal for the purposes of this project.

Similarity perception

Similarity is an essential feature common to form perception across all sensory modalities. As is the case for many topics in perception, the extensive literature in the visual domain serves as the basis for investigating other perceptual fields. Perhaps because comparing unknown with known items is one of the most natural ways to learn about the world around us, similarity decisions are often based on pure intuition. Nevertheless, research has shown that the way in which we determine the similarity of objects is quite complex and not so obviously predictable. Many different factors, ranging from the intrinsic characteristics of the objects being compared to contextual aspects such as the entire set of objects available or the purpose of the comparison, can affect the perception of similarity. Following this, the notion of similarity is much less intuitive and simple than it appears at first glance.

Many different models of similarity (reviewed in Blough, 2001) have been proposed throughout the history of visual research. For instance, Blough—in a relatively comprehensive literature review—distinguishes five theoretical approaches to similarity: (1) common element, (2) template models, (3) geometric models, (4) feature models, and (5) Geon Theory. The first approach exclusively explains similarity perception by recounting the features shared by the two objects being compared (their similarity is comparable to the intersection of two Venn diagrams corresponding to their features). Template models compare point by point two image representations, accounting for the correspondence of their (visual) structures within a space (e.g., relative location of the points of the images). Geometric models represent the similarity between two items as a distance in a coordinate space whose dimensions are defined by the investigator; so that the proximity of any two items often depends on the specific dimensions that are chosen to build the space, but it is unique and fixed once those dimensions are defined. Feature models, best represented by Tversky (1977), account for common and distinctive features among the objects

being compared, and incorporate the notion that similarity perception can be asymmetric and referential (as discussed below). Finally, the Geon Theory (Biederman, 1981) proposes that two objects are more likely to be perceived as similar when they share components and features in a way that allows for a kind of cognitive generalized representation (that works as a kind of abstract reference) based on primitive shapes. These models originated in and are most directly linked to research in visual perception. Geometric models have been the most commonly applied to empirical research in auditory perception.

Most importantly for the purposes of this dissertation, the models of similarity perception that have been proposed differ in the aspects of similarity perception that they emphasize, revealing the relevance of three interrelated, central questions concerning the cognitive formation of the similarity of stimuli: (1) how might considering only common features as opposed to both common and different characteristics alter similarity perception? (2) how might the perceived similarity between two items change depending on the context? and (3) how might interchanging the functions of reference (model to which other items are compared) and variant in a pair of stimuli during their presentation affect the perceived similarity between the stimuli, suggesting an inherent directionality or asymmetry to similarity perception?

The first question simply refers to whether only common elements (as proposed by Blough, 1975) or both common and distinctive features (as emphasized by Tversky, 1977) play a role. The overall similarity between two items that share some features and differ in some other characteristics is different depending on whether only the commonalities, or both common features and distinct or absent (unique-to-one-item) characteristics are taken into consideration. For instance, if two items have a smaller number of commonalities than differences, then they are likely to be judged as quite similar when ignoring the divergences, but as quite dissimilar when accounting for them. In addition, the importance or weight of the specific features being compared is likely to play a role, i.e., certain shared/diverging properties might increase/decrease the perceived similarity of two items more than others. These weights might depend on many factors, including the task, personal differences among observers, and the context (Tversky, 1977). For instance, Gati and Tversky (1984) propose, based on evidence from a series of experiments, that common features are particularly important for classification tasks, whereas distinctive features are relevant for discrimination decisions.

The way in which common and distinctive features contribute to similarity judgements is often affected by contextual factors. Strongly related to the first question, the second question points out the importance of context for similarity perception, a topic that has received considerable attention and experimental support in the literature (e.g., Tversky, 1977; Tversky & Gati, 1978; Rips, 1989; Medin, Goldstone, & Gentner, 1993; Goldstone, R. L., Medin, D. L., & Halberstadt, J., 1997; Ramscar & Hahn, 1998). The idea that context can influence similarity perception is quite intuitive. For instance, Tversky and Gati (1978) showed that the judged similarity of two countries from the same continent increases when countries from a second continent are added to the original set. Similarly, Dahr and Glazer (1998) demonstrated that the incorporation of a third brand in the market changes customers' perception of the similarity of two brands. An important aspect of context that is often determined by the experimental instructions and the purpose of the task is the observer's amount of exposure to the stimuli. In this respect, probabilistic models of similarity (reviewed in Ashby, 2014) propose that similarity perception changes over time, particularly due to the effects of repeated exposure. A more abstract type of context related to the probabilistic notion of similarity perception constitutes how each observer's knowledge affects their judgements, which is an aspect likely to change over time. For instance, our perceived similarity of two twin sisters is likely to change when we come to know a third, older or younger sister.

Furthermore, whether we think of twin sister A as being like twin sister B or the reverse is likely to depend on which sister we met first. This suggests that the perceived similarity of two items can be referential. In other words, it is dependent on whether one of the items is perceived or conceived as a point of reference or model in the comparison process, and, if that is the case, which item acquires that referential function. The idea that similarity perception can be referential is linked to the notion of asymmetry posed by the third question. Asymmetry refers to a change in the perceived similarity of two items according to the direction in which the two items are compared. The symmetric perception of the similarity of two stimuli implies that the similarity of item A to item B is the same as that of B to A. This idea is the basis for geometric models of similarity and multidimensional scaling (Shepard, 1962a, 1962b), where the similarity of two objects is represented as a geometric, fixed, and unique distance. Made popular by Tversky (1977), the notion of asymmetric perception of similarity implies that the similarity of A to B can be larger than or smaller than that of B to A. Tversky (1977) explains that the idea of asymmetry is reflected

in the intrinsic directionality that characterizes similarity statements. He claims that the expressions “B is like A” and “A is like B” have different meanings, because the items involved interchange their function: in the first expression, B is the subject and A is the reference, whereas the reverse is the case in the second expression. In light of this, he explains why expressions such as “the portrait resembles the person” and “the son looks like the father” are more common than the reverse statements. Tversky and Gati (1978) were among the first researchers to provide empirical evidence for the idea of asymmetric perception of similarity, showing that the perceived similarity between two countries changes depending on whether the more prominent or the least known country is presented as the reference. For instance, the results showed that Mexico was perceived as being more similar to the USA than the USA was to Mexico. In sum, asymmetry refers to an alteration of the perceived similarity between two objects caused by the specific direction in which the comparison is made—in the examples above, this direction/order is implied by the grammatical structure of the sentences—or by the function acquired by the stimuli that are being compared according to their mode of presentation—i.e., as reference or as variant. Asymmetry refers to the [possible] directionality or order dependency in the perceived similarity of two items. Asymmetry is a factor that is external to the properties of the items involved, and it is, in that sense, an aspect of the context.

Taking the idea of asymmetry even further, Rosch (1978) links asymmetric similarity with perceptual categorization or classification, i.e., the formation of groups or clusters of items, through the notion of prototype. In her conception, the members of a category that are more prototypical belong more uncontroversially to that category than do other, less prototypical elements. Following this, the most central member of a category is the most prototypical one. In this sense, the member around which an entire category can be formed is the prototype, whereas the remaining members of the group are variants of that prototype. Rosch proposes that it is precisely the notion of asymmetry that distinguishes a prototype (central member of a category) from its variants (other members of the group), claiming that the similarity of a variant with respect to its prototype is larger than the reverse. For instance, returning to the same study reviewed above, more dominant countries, such as USA, are more often chosen as reference points for comparing the similarity of the two members of a pair of countries than less dominant countries, such as Canada or Mexico. Specifically, a study showed that people preferred to use the expression “Canada is similar to USA” over “USA is similar to Canada” (Tversky & Gati, 1978). Rosch’s

concept of prototype is only one of the many links that define the relationship between similarity and categorization, and a small one at that. Intuitively, it seems clear that categorization involves the formation of groups or clusters according to similarity judgements. This idea has received large empirical support (reviewed in Goldstone, 1994; and Ramscar & Hahn, 2001). Nevertheless, it is known that similarity judgements do not always predict categorization (for a review, see Ahn & Dennis, 2001) and, consequently the sufficiency of similarity as an explanation for categorization has been greatly questioned (reviewed in Ramscar & Hahn, 2001). Finally, even when the relationship between similarity and categorization is evident, the specificities and boundaries of that relationship are unclear.

This section has reviewed the literature on similarity perception in general, focusing on visual research. The following sections discusses theoretical and perceptual perspectives on musical similarity.

Similarity in music

The possible effects of context along with the notion of asymmetry or directionality become particularly relevant when the items whose similarity is being judged carry within their very definition specific temporal information, i.e., a defined location both with respect to each other and also with respect to other objects, and, with it, a context. Music listening cannot be conceived outside the temporal dimension. Even imagining listening to a piece of music involves time (for a review on music imaging, see Hubbard, 2010). Similarly, theories of musical form have often highlighted the importance of the temporal development of musical materials. Indeed, the simplest and most traditional models of classical form can be very broadly described as ordered, i.e., temporally organized, sequences of musical passages with certain characteristics.

Studies in the similarity of musical motives can be classified in three groups, according to their field of most immediate application: (1) music information retrieval, (2) music perception, and (3) music theory and analysis. The degree to which these studies take context into consideration varies. Most recent studies of motivic similarity have aimed to design computational algorithms for music information retrieval, i.e., databases for melody search (for reviews see Downie, 2003; and Wust & Celma, 2004; Weigl & Guastavino, 2011). As a result, they do not take into consideration issues of context, but instead focus exclusively on mathematically

quantifiable common and different features between melodies. The studies in music information retrieval offer a computational solution for comparison techniques that can be (and often are) done analytically by music theorists when the number of musical materials being compared is relatively small. Therefore, this dissertation is not directly concerned with the literature in music information retrieval.

THE PERCEPTION OF MOTIVIC SIMILARITY

Perceptual studies have suggested that context is important for motivic similarity perception. Empirical research (reviewed in Deliège, 2001; and Hewlett & Selfridge-Field, 1998) shows that different musical features, ranging from all kinds of surface characteristics (as specified below) to deep structural aspects (Serafine, Glassman & Overbeeke, 1989), can shape the perception of motivic similarity. The surface features that have been found to be relevant are different depending on the task, the stimuli, and the listener's acquaintance with the music, suggesting effects of context. In other words, the divergences in the experimental results can presumably be explained as effects of the various contexts determined by the tasks, the stimuli, and the listener's experience[1]. Nevertheless, most perceptual research does not explicitly account for the influence of context on similarity perception, since it evaluates the resemblance of two items by computing the distance between a fixed set of features that represents those items. In music, the effects of context on similarity perception can be associated with at least four main factors: (1) the specific characteristics of a musical composition or excerpt, (2) the complexity and style of the music, (3) the specific listening situation and purpose of the listening task, and (4) the acquaintance of the listener with the music.

With respect to the first factor, traditional models of musical form suggest that Western pieces of music are largely structured in terms of the degree of similarity or contrast of their component musical materials. Partly due to the balance between repetition and variation that characterizes much Western music, the specific musical context, i.e., the individualities of a given piece of music, has the potential to be extremely important for similarity perception in music. Whether two musical fragments are heard as more or less similar might easily depend on factors

[1] The listener's familiarity with the music is here treated as a contextual factor in the sense that it is an aspect absolutely independent of the musical fragments whose similarity is being judged.

such as the presence or absence of an intervening musical passage along with the characteristics of that passage. In addition, the order in which two motives are played might shape the way listeners perceive the similarity of those motives. As a general rule, in music, it is more common to hear the musical material that is stated first as the reference than as the variant.[2] Nevertheless, characteristics of the motivic materials and the musical context in which those materials are presented might easily affect the perceived similarity of the materials based on the order in which they are played. For instance, when the similarity relation between two motives is based on a common feature that is highly salient in one motive and considerably hidden in the other, intuitively, the similarity relation is more likely to be instantly recognized (e.g., during a first hearing of the piece) if the motive hiding the common feature is stated second. To give another example, the temporal distribution of two motives might be particularly relevant for their perceived similarity when an intervening transitional passage leads the motive introduced first to the one presented second in a way that appears to convert one material into the other.

A few studies have demonstrated that the specific musical context—including temporal order—in which motivic materials are heard affects the similarity perception of those materials. Most obviously, Eerola and Bregman (2007) showed that the salient features affecting similarity formation in European folk songs change with the specific context. Bartlett and Dowling (1988) demonstrated that the perceived similarity of two motives (one conforming to the diatonic scale and a similar one slightly deviating from such a scale) can depend on the order in which the two materials are presented—and it is hence asymmetric. Other studies demonstrating that the musical context affects the way listeners form relationships among musical materials are discussed below in connection with factor 2. Indeed, the perceptual literature suggests that context affects the perceived similarity of motivic materials. Nevertheless, to my knowledge, no empirical studies

[2] In this respect, note that syntax for similarity comparisons is different for music than it is for language. Whereas in language the variant is normally stated first (it is the subject of a comparison sentence in active voice), in music the variant is commonly heard after the reference. Indeed, it is in principle necessary to hear the reference before a musical material can be heard as a variation of that reference. Nevertheless, note that in some situations, the idea of a musical variation can emerge with respect to an implicit musical reference. This is often the case for variations of musical patterns that are extremely familiar. For instance, a musical quotation of a melancholic version of the birthday song within a composition is likely to be heard as a variation of the birthday song even if the birthday song is not stated in its most commonly cheerful character within the composition in question. Similarly, ornamented scales can be easily heard as variations of scales even when the plain versions of the scales are not introduced first in the music.

have directly and comprehensively examined the ways in which the specific characteristics of a musical context provided by entire post-tonal compositions shape motivic similarity perception.

With respect to the complexity/style factor (factor 2 above), Lamont and Dibben (2001) showed that similarity judgements in a piece by Schoenberg depended on different features than in music by Beethoven. Based on this and a review of previous evidence, they propose that the complexity of the stimuli is one of four main contextual factors affecting similarity perception. In reference to the complexity factor, they explain that in experiments involving real music stimuli, listeners pay attention almost exclusively to surface features, whereas in experiments using especially composed examples (presumably simpler and more artificial than real music), listeners show an ability to extract the deep structure. The remaining three contextual factors proposed by Lamont and Dibben (2001) can be seen as specific cases of the third and fourth factors proposed above. In regard to the listening situation or purpose of the listening task (factor 3 above), Lamont and Dibben (2001) refer to the complexity or cognitive demands of the task. More specifically, Ziv and Eitan (2007) showed that categorization concurred with similarity judgements in music by Beethoven but differed in a piece by Schoenberg, providing evidence for both task-related and stylistic factors. Finally, with regards to the familiarity factor (factor 4 above), Lamont and Dibben (2001) refer to experience and familiarity to account for the listener's exposure to the music. For instance, they explain that children prioritize loudness, whereas adults pay more attention to contour, and that non-musicians tend to prioritize surface features such as contour, loudness, and texture more than musicians.

By means of the inherent importance of context for both similarity perception and music listening, cognitive studies of music similarity that encompass aspects of context, such as temporal distribution of the materials (form) and asymmetry, contribute to the understanding of the perceptual significance of the temporal organization of the musical materials in a composition.

THEORETICAL CONCEPTION OF MOTIVIC SIMILARITY

In the field of music theory, similarity relations are, more or less consciously, an important part of motivic analysis (e.g., Schoenberg, 1967; Forte, 1973; Schenker, 1979; Carpenter, 1983; Neff, 1984; Ruwet, 1987; Nattiez, 1990; Buchler, 2001; Pearsall, 2004; Buteau & Mazzola, 2008; Solomon, 2013). When dealing with tonal repertoires, the resemblance of

motives is often determined intuitively and contextually. The similarity relation between two motives can be quantified (more or less strictly) by referring to aspects of the harmonic structure at different levels, intervals, rhythm, etc. Nevertheless, the principles on which such quantification is based depend on interpretative decisions. This is to say, analytical decisions of motivic similarity in tonal music are clearly a matter of interpretation and are, in that sense, subject to change. In addition, scholars are not always inclined to explain the reasons why they choose one interpretation over others. The principles on the basis of which similarity decisions are made (principles whose description is essential for the definition of similarity) change according to the analyst's purpose and the specific musical context. In this sense, the definition of motivic similarity per se is unclear, or, at the very least, largely variable as a function of context. The situation is different for post-tonal analysis, where measures of similarity between pitch-class sets (e.g., Forte's R_n, Morris's ASIM, Rahn's ATMEMB , Lewin's REL, Isaacson's ICvSIM) are often defined according to rather strict mathematical principles. These similarity relations are based on abstract principles and concepts, such as unordered (atemporal) subsets of pitch-class (rather than pitch) intervals, and are thus questionable from a perceptual perspective. As Lewin himself remarks in a Music Theory Online talk from March 30, 1995 (quoted as mto-talk message in Hermann, 1995), the use of the term similarity in music analysis is problematic, since it is based on intuitions that are often unreliable:

> "While the word [similarity] is suggestive, it might be a good idea to stop using it in formal theoretical discourse, because the intuitions it invokes are not all that reliable. (Except we probably can't stop using it at this stage of matters, …" (Lewin as quoted in Hermann, 1995).

While the term similarity seems quite necessary for music scholarship, its meaning and use within the discipline of music theory appear to be quite questionable, or, at the very least, ambiguous. Following Lewin's thought, the similarity of two musical fragments can be truly meaningful only when such similarity is further qualified. In line with Lewin's intuitions, several experimental studies have shown that the kinds of similarity measures proposed by post-tonal theory are perceptually invalid (e.g., Bruner, 1984; Gibson, 1986, 1988, 1993). Finally, in the post-tonal repertoire, the similarity between two musical materials can be approached either theoretically or perceptually, leading to different results. Theoretical approaches to motivic similarity are based on well-defined yet abstract (often purely conceptual), noncontextual principles, being particularly applicable to composition and structural analysis. On the other hand,

perceptual approaches (discussed above), are based on the [necessarily contextual] listening experience, illuminating cognitive principles of motivic similarity that, due to their universality, could be potentially relevant for a wide range of fields, from composition and analysis to music cognition and human hearing.

The apparent neglect of context that characterizes the abstract similarity relations proposed for post-tonal analysis has been a concern for scholars (e.g., Hermann, 1995; Isaacson, 1996), perhaps because traditional music theory has been historically and largely concerned with context inasmuch as it has emphasized the temporal organization (contextual setting) of the musical materials. The distribution of the materials within a piece of music (in time), particularly in light of the notion of similarity, has been one of the fundamental bases for traditional models of musical form. Ockelford (1991, 2005) claims that the common feature among all traditional models of musical structure—such as those by Berry, Schoenberg, Reti, Schenker, Meyer, Ruwet, and Nattiez—is repetition, and proposes a theory (which he calls zygonic) of perceived order of musical materials within a composition that is based on the degree of resemblance of those materials. Similarity might be considered the most comprehensive principle of formal theories. It is essential for the conception of repetition and contrast that constitutes the basis for traditional formal models of music. Furthermore, conceptions that are crucial components of formal models, especially the notion of musical motive, are absolutely dependent on similarity. Indeed, as remarked by Duker (2008), what makes something a motive is its multiple exact and varied instantiations.

Whereas the relevance of similarity and context for analysis and theory of music from the Common Practice period (for which traditional formal models have been developed) is evident, the situation seems to be different for post-tonal repertoires. The most traditional post-tonal theories that are commonly taught as part of undergraduate music curricula emphasize almost exclusively issues of pitch and interval structures (e.g., Forte, 1973; Klumpenhouwer, 1991; Straus, 2003), disregarding almost completely central aspects of context such as the temporal distribution of materials. A few theories consider aspects other than pitch (e.g., Lewin, 1987; Ockelford, 2005). Nevertheless, they discuss the parameter of pitch first, subsequently transferring the principles proposed in the pitch domain to other domains, and thus prioritizing the parameter of pitch over the others. Furthermore, it is extremely uncommon to find analytical applications of

these models to domains other than pitch. It is also important to point out that even when these theories are explicitly applicable to post-tonal music, they are not exclusively designed for such repertoire. Neither general nor composer-specific formal models have been developed for post-tonal music.

Whereas the importance of context for similarity perception in music has been supported (if only insufficiently) with empirical evidence (presented above), the emphasis that post-tonal theories put on pitch and interval structures have been contradicted by experimental studies. This marks an important dichotomy between theoretical and perceptual research agendas of post-tonal music. In addition to the perceptual literature specific to the theoretically defined similarity relations among pitch-class sets introduced above, evidence suggests a lack of correspondence between perceptual categorization and the interval-based groupings (such as pitch-class sets and segments of twelve-tone row forms) that constitute the basis of the theories (Ziv & Eitan, 2007; Gibson, 1993, 1988; Krumhansl, Sandell, & Sergeant, 1987). Following this, not only the motivic similarity relations that the theories specify, but also the very fundamentals of the theories—which in the case of post-tonal theories are the musical motives themselves—appear to be perceptually invalid. Surface features, especially contour, dynamics, texture, articulation, and rhythm (Dowling, 1971; Deliège, 1989; Clarke & Krumhansl, 1990; Lamont & Dibben, 2001; Lalitte et al., 2004; Ziv & Eitan, 2007), rather than pitch or interval structures, have been demonstrated to be particularly relevant for similarity perception in post-tonal music. The salience of surface features has been associated with certain alternation of contrast and resemblance suggested by their layout. Indeed, it seems intuitively obvious that musical situations of extreme contrast or repetition by themselves do not normally or instantly give rise to salient features. This connects the perceptual importance of surface features with the concept of similarity, and, in turn, with the notion of musical form.

Similarity is an aspect that appears to play a central role for both post-tonal music listening and the history of music theory. By means of investigating similarity, this dissertation contributes to the perceptual and structural levels (esthesic and neutral levels in Nattiez's terms) of post-tonal analysis at the same time that it begins to fill the gap between perception and music theory that characterizes post-tonal scholarship. This study differs from previous research in that it encompasses a relatively wide range of aspects of similarity perception, integrating them to the

extent possible, and it attempts to connect them to musical form. In light of analytical and theoretical methods, these aspects of similarity perception could potentially serve as pillars for developing analytical tools and models that are both reliable from a perceptual perspective and fairly clearly defined in theoretical terms. The attempt to combine the perceptual and structural levels of analysis is not intended to critique, but rather to complement, previous theoretical trends focusing almost exclusively on either the compositional/conceptual (poietic, in Nattiez's terms) or structural (neutral) levels. The incorporation of the perceptual level is particularly illuminative for our understanding of the temporal unfolding of music, an aspect that theoretical approaches have often overlooked in favor of complex relationships among musical materials and properties of the global design.

The preceding sections have examined the importance of similarity relationships for music theory and perception. The next section attempts to point out connections between the literature presented above and Boulez's ideas about musical composition.

Boulez's aesthetics and similarity perception

Boulez's writings and compositions from late in his career reflect a remarkable and explicit increased awareness of issues of perceptual similarity and their possible implications for music composition and listening. Evidenced in the composer's texts, lectures, interviews, and analyses, this increased awareness becomes particularly noticeable around 1970, coinciding with Boulez's growing interest in orchestral conducting and composition with electronic means (e.g., Hopkins & Griffiths, 2015; Goldman, 2011). Furthermore, it was around the same time that Boulez founded (under the request of Georges Pompidou) IRCAM, a research center for contemporary music and related technology that Boulez conceived as multidisciplinary (Manning, 2015). While working at IRCAM, Boulez was in direct contact with scientists, psychoacousticians, and psychologists such as Patrick Greussay, Stephen McAdams, and David Wessel (for a more complete list of Boulez's contacts at IRCAM, see Harvey, 1986). In accordance with this, Boulez's explicit increased concern with the listeners' experience is particularly reflected in his use of terms with strong psychoacoustical connotations (Goldman, 2011). Some of the most preponderant terms are envelope, satellite, aura, signal, and memorization, introduced in "Le système et l'idée" (Boulez, 1995). Boulez defines some of these terms from a perceptual yet theoretical, often

morphological perspective, consequently linking the worlds of perception, composition, and theory. In many cases, he bases the explanation of structural materials and morphological units on essentially perceptual or psychoacoustical features. For instance, he uses the term signal or, more specifically, formant, to indicate a figure without direction and a perceptual cue that, due to its salience, serves as formal marker. Similarly, he uses the term envelope to refer to a perceptually clear contour outlined by smaller musical units (Boulez, 1995). Particularly relevant for a study of similarity, the term memorization appears to occupy a central place in Boulez's writings. The composer conceives memorability as an essential aspect of musical materials:

> "There must be a sufficient number of elements of repetition in order for memory and perception to act in consequence and recognize the initial object across its different representations" (Boulez as quoted in Goldman, 2011, 71).

Evidently aware of the limits of human memory, Boulez recognizes the importance of juxtaposing musical figures that can be easily identified and recalled vs. materials that, due to the overabundance of information that defines them, cannot be naturally cognized in ways that would intuitively allow listeners to remember them:

> "I also like to create a contrast between structures that are extremely clear and those that are so overloaded that they cannot possibly be assimilated" (Boulez, 1976, 51).

In this sense, it is the contrast between memorable and non-memorable materials that builds musical form. Following this, memorability, an aspect that is central to the perception of musical similarity, becomes a defining feature of the basic elements of the structure or form of a composition, namely the musical materials. It is perhaps based on a similar reasoning that Goldman proposes that "the cognitive ability to recognize a thematic entity in any of its many instantiations in the work becomes constitutive of form" (Goldman, 2011, 71).

The perceptual importance given to musical materials along with the emphasis on their recognizability points to the notion of perceptual categories or perceptually salient families of musical materials, an idea that is often implied in Boulez's writings. The idea, which clearly alludes to the notion of categorical perception presented in the first section of this chapter, becomes particularly critical in Boulez's explanation of the motivic materials used in his piece *Anthèmes 2*:

> "I am now convinced that music must be based on recognizable musical objects. These are not 'themes' in the classical sense, but rather entities which, even though they constantly change their form, have certain characteristics which are so identifiable that they cannot be confused with any other entity. This piece [*Anthèmes II*] is replete with such entities, which can be identified very easily. What is less easily identifiable is the order in which they occur, or rather the disorder in which they occur. We recognize a specific event, but we do not know when it will occur; we recognize them after the fact. This is what interests me—to create an effect of simultaneous surprise and recognition. There is variation with respect to a global object, and yet, when an event is heard, this object is highly characterized. This is a possible explanation for the title." (Boulez as quoted in Goldman, 2001, 106).

Composed in 1997, *Anthèmes 2*, for violin and electronics, is quite strictly derived from an earlier work of the same composer, *Anthèmes 1* (1992), for solo violin. The two compositions are based on the same motivic materials; consequently, as remarked by Goldman (2011), the composer's explanation (which refers explicitly to *Anthèmes 2*) truly applies to both compositions. Contrasting playing techniques along with other surface features, in particular rhythm and character, are used to strengthen the connections within motivic families or perceptual categories. Goldman's (2001) paradigmatic analysis of *Anthèmes 1* reveals the relevance of motivic categories. Based on the importance that a categorical conception of the musical materials appears to play at the structural level of both versions of *Anthèmes* as well as on Boulez's explicit concern with the perception and recognizability of those materials within the limits of human memory, *Anthèmes* constitutes an ideal medium for an investigation of musical similarity that combines theoretical and perceptual methods. The composer's ideas about perception and memory as related to issues of motivic and formal structure are particularly attractive for a study focused on motives and form.

Goldman's analytical interpretation along with his more comprehensive work on form in Boulez's late music (Goldman, 2001, 2011) serve as the starting point for this dissertation, including the criteria for selecting the stimuli for the experiments, and will be discussed in the introduction to Chapter 2. *Anthèmes 2* (1997) adds electronics to the original solo part. The electronics create important timbral transformations. In addition, the form is enlarged. As a result, the two versions of the composition can be seen as two different timbral and formal settings of the same motivic materials. Beyond alluding to the notion of perceptual categories in his explanation

of *Anthèmes 2* quoted above, Boulez refers to one particular motivic material—long tones—as fundamental formal marker and signal. Here, he refers to one of the morphological terms that he had previously introduced in "Le système et l'idée" (Boulez, 1995), based on the memorability of such material and the contrast that it creates with respect to the other musical elements:

> "Certainly the most obvious thing that must strike you [when you listen to the piece] are the interruptions, in which, shall we say, not much is happening. These passages, in which [the violin] plays long notes in harmonics, contrast with other moments in which there is much activity. […] And when there are no more notes in harmonics, you can be sure that the piece has ended. […] What I am sending you, what you perceive, are signals." (Boulez as quoted in Goldman, 2001, 108-109).

These quotes on *Anthèmes 2* make explicit Boulez's intent to apply his notions about memory, similarity, perception and form to his composition. At the same time, they encourage an investigation of the connections between the composer's theoretical thinking and his compositional practice.

General aims and dissertation outline

Based on the importance of similarity relations for music theory and perception in general and for musical motives and form in particular (discussed in the first part of this chapter) and on Boulez's theoretical and practical consciousness of their importance (discussed in the section above), this dissertation studies motivic similarity in *Anthèmes 1 and 2* with the purpose of revealing fundamental issues from which post-tonal formal theories could potentially be developed. The core methodology combines experimental tests with theoretical analyses. Musicological techniques are used to a lesser extent, with the purpose of exploring the relationship between the experimental findings and Boulez's conception of music perception. Aiming to connect the theoretical and perceptual discourses from the very beginning, the dissertation starts by proposing a theoretical analysis of the motivic structure of *Anthèmes* that becomes the basis for the empirical portion of the research. This analysis, along with its comparison to the most comprehensive analytical work of the piece identified in the literature (Goldman, 2001, 2011), serves to select the stimuli for and contribute to the interpretation of the results of five experiments. Experiments 1 to 4 are devoted to the study of *Anthèmes 1*. Nevertheless, due to the motivic connections between *Anthèmes 1 and 2*, these four experiments explain perceptual aspects of the

motivic materials of both compositions. Experiment 5 is dedicated to *Anthèmes 2*. These five empirical studies are discussed in two chapters. The first three experiments correspond to Chapter 2. Experiments 4 and 5 are discussed in Chapter 3.

Chapter 2 studies motivic similarity outside the specific musical context of the piece. In this chapter, three experiments use motivic materials extracted from *Anthèmes 1* in order to explore general issues of motivic categorization, similarity, and group prototypicality. The materials belong to five motivic groups defined in terms of their contrasting playing techniques, and are supported by previous analyses (Goldman, 2001). In Experiment 1, 17 musicians freely categorize most potential members of each group (54 motives in total). Hierarchical clustering confirms the perceptual validity of the motivic groups and shows various degrees of internal group complexity—number and strength of subdivisions. This hierarchical clustering allows for the reduction of the motivic material of the piece to a set of motives representing different subgroups of each motivic family. The reduced set is then used as stimuli in Experiments 2 and 3. In Experiment 2, the motives are paired in all possible ways—including the two orders. Twenty-three musicians rate the similarity of the second material with respect to the first on a scale ranging from identical to very dissimilar. After rating all pairs in a group, the participants indicate the importance of several features for their similarity judgements. Score analysis is combined with two perceptual measures: average similarity rating and asymmetry index for each material within its category. In Experiment 3, 27 musicians listen to the materials of each group, choosing its best representative and subsequently completing the same feature-rating task as in Experiment 2. The experiments of Chapter 2 investigate aspects of motivic similarity perception out of the context of *Anthèmes*, with particular emphasis on common vs. different features and issues of asymmetry.

Chapter 3 investigates the effects of piece-specific musical contexts on the perception of motivic similarity and their relationship to issues of form perception. The empirical portion of the chapter takes advantage of the fact that the two versions of *Anthèmes* share the same motivic materials but differ considerably in terms of the musical and formal context in which those materials are set. Based on Experiments 2 and 3, one motive is selected as the model of each group. In Experiment 4, participants are familiarized with the model, and then listen to *Anthèmes 1* in its entirety, pressing a key every time they hear something that reminds them of the model. Experiment 5 is equivalent to Experiment 4, except that participants listen to *Anthèmes 2* rather

than listening to *Anthèmes 1*. The timbral and textural changes resulting from the electronic effects that affect the musical materials, as well as the procedures of formal expansion that take place in *Anthèmes 2*, elucidate the effects of context on the listeners' perception of motivic similarity relationships.

By means of these methods, this dissertation explores the relevance of common and different features as well as asymmetry in the perception of musical motives, the effects of task and context on the cognitive formation of motivic similarity, the puzzling link between categorization and perceived similarity, and the relationships between motivic similarity perception and musical form while listening to entire musical works. In addition, by proposing interpretations of aspects of *Anthèmes 1 and 2* that are supported with, and that simultaneously serve as practical examples for Boulez's writings, this research clarifies the relationship between the composer's theoretical thinking and his compositional practice.

Chapter 2
General aspects of motivic similarity in *Anthèmes 1*

Introduction

This chapter explores aspects of motivic categories and similarity in *Anthèmes 1*. The investigation combines theoretical and empirical methods, with the ultimate aim of providing information that can be both relevant for music theory and analysis and valid in terms of music perception and cognition. The point of departure is a newly proposed score-based analysis of the motivic structure of *Anthèmes 1* and its comparison with Goldman's (2001, 2011) analytical work, which constitutes the most comprehensive analysis of the piece identified in the literature. The analysis proposed here identifies five families of musical motives and serves as the basis for the empirical portion of the chapter. Because Goldman's analysis is very complete and thoughtful, it could in principle have served for the experimental purposes of this chapter. Nevertheless, a new motivic study was completed with three main purposes: (1) to have a point of comparison (with respect to Goldman's analysis) that would allow for conclusions about the consistency of the motivic structure of the piece from an analytical perspective, (2) to start from analytical strategies directly and specifically aimed at the experimental tasks and designs, and (3) to cover analytical points that could enrich the discussion of the experimental results.

The empirical portion of the chapter corresponds to Experiments 1 to 3 and addresses different categorical and similarity aspects of the motivic material of *Anthèmes 1* out of the context of the piece itself. Altogether, the experiments have two general purposes: (1) to explicate the motivic structure of *Anthèmes 1* from a perceptual perspective, complementing the music-analytical investigation; and (2) to ultimately provide well-founded criteria for the selection of the stimuli for Experiments 4 and 5, which examine the perception of the motivic materials of *Anthèmes 1* and *Anthèmes 2*, respectively, within the context of the piece. Experiments 4 and 5 are discussed in Chapter 3. Nevertheless, due to the strong relationship between Experiments 1 to 3 and Experiments 4 and 5, it is necessary to start this chapter by briefly introducing Experiments 4 and 5. Following Boulez's ideas about perception in general and *Anthèmes* in particular (discussed

in Chapter 1), Experiments 4 and 5 assume that *Anthèmes* is structurally conceived in terms of musical objects/entities that are transformed within perceptually recognizable limits, giving place to perceptual motivic categories. The experiments thus aim to investigate online (on-the-go) recognition of motivic transformations while listening to both versions of *Anthèmes* from beginning to end. The idea of motivic transformations implies the perceptual validity of motivic categories. In Experiments 4 and 5, one motive from a given family serves as the point of reference for the identification of the transformed versions. This requires a selection of motivic materials from the piece that can represent a number of motivic categories with relative accuracy, so that they can be introduced to the participants as points of reference to keep in mind when searching for the motivic transformations during listening. Ideally, in order to avoid confounds related to the degree of definition of the motivic categories, each motivic family should be represented by one motive only. As such, the experiments in this chapter serve to determine which motives can best function as referential materials for listeners as they search for transformations while listening to *Anthèmes 1* and *Anthèmes 2* in the later experiments.

Due to their common ultimate objective, Experiments 1 to 3 are strongly interconnected in terms of specific purposes and the musical materials they use. Experiment 1 has the practical objective of selecting the motivic materials for Experiments 2 and 3, two experiments that are specifically aimed to investigate fine-grained aspects of similarity of the motivic structure of *Anthèmes 1*. In order to more accurately and comprehensively reflect these aspects, the stimuli used for Experiments 2 and 3 should include a wide variety of motives taken from the piece. Nevertheless, due to the experimental tasks that are optimal to study the issues in question, using a large number of stimuli would lead to extremely time-consuming experimental trials, limiting the total number of participants and, most importantly, compromising their ability to complete the tasks conscientiously. Experiment 1 is designed to select a set of motivic materials that is both experimentally efficient in number (not too many stimuli) and appropriate in quality (representative of the motivic structure of the piece) for the purposes of Experiments 2 and 3. Keeping this in mind, in Experiment 1, participants freely classify a very large selection of motives extracted from *Anthèmes 1*. This selection is entirely based on the theoretical analysis that constitutes the point of departure of this chapter.

Experiment 2 is specifically aimed to understand the internal similarity structure of each motivic family by investigating the perceived similarity among all the motives in each family. Participants hear all possible pairs of motives within a family a maximum of two times. Immediately after hearing each pair, they rate the similarity of the motive played second with respect to the one that is played first, which is conceived as the reference. This experiment provides information about the degree to which each motive resembles all the other members in its group. This information is particularly useful for selecting the referential motives that are necessary for Experiments 4 and 5, since transformed versions of a motive represent relatively defined ranges and/or kinds of variation of that motive. In other words, materials belonging to the same motivic family of a given motive feature limited degrees and/or types of similarity with respect to that motive; thus, the motives that can work well as references for a family should in principle be those that can be converted into all the members of the family through minimum transformation.

Experiment 3 provides more explicit information about the listener's most direct and intuitive reaction concerning the degree to which each motive in a group can represent the entire group. Following this, in Experiment 3, participants are directly asked to indicate the motive that best represents each group of motives. Marking a difference with Experiment 2, participants in Experiment 3 can hear the motives from each group multiple times and in any order. Nevertheless, they are asked to provide intuitive responses.

Experiments 1 to 3 can only be understood in connection to each other since the purposes of the three experiments presented in this chapter follow a causal logic. Comparisons between the experimental results often reveal information about the effects of context on the perception of motivic similarity, including stimuli readily accessible to the listeners during each experimental task. For pedagogical reasons, this chapter is divided into four parts. The first part presents the theoretical analysis that constitutes the basis for the empirical research, and the remaining three sections correspond to the three experiments. With the purpose of combining experimental and theoretical perspectives, analytical and theoretical discussions are incorporated into the description of the experiments. It is also with this objective that the results and discussion of each experiment are integrated into a single section rather than more conventionally presented as two separate, successive sections. In addition, aiming to better understand the implications of the three

experiments as a whole, the discussion sections frequently integrate observations from different experiments.

Following the above, this chapter is divided into five main sections. The first section presents a motivic analysis of *Anthèmes 1* and its comparison to Goldman's work (2001, 2011). Sections 2, 3, and 4 correspond to the three empirical studies, respectively, including the interpretation of the observed findings in light of the motivic analysis discussed in the first section. A concluding summary closes the chapter.

A motivic analysis of *Anthèmes 1*

This section proposes a theoretical, score-based analysis of the motivic structure of *Anthèmes 1*. In order to explicate the consistency of the motivic aspects of the piece from a theoretical perspective, the analysis is paralleled to Goldman's study of the piece (2001, 2011). The analytical interpretation proposed here along with its comparison to Goldman's work serves as the basis for the experimental studies presented in the successive sections.

The large range of bowing techniques and articulation styles gives the piece a peculiar and rich timbral palette. As described by Goldman, *Anthèmes 1* is a "virtuosic compendium of violin techniques" (Goldman, 2011, 160), which includes both traditional playing techniques such as pizzicato, slurring, and multiple stops, and extended techniques such as ricochet, *sul ponticello* and natural bow position, glissando, and harmonics. He remarks that extended techniques "are used to confer a characteristic contour or colour to the musical figures […], in line with Boulez's renewed interest in thematic writing" (Goldman, 2011, 160). Goldman associates this renewed compositional style with the composer's conviction that "music must be based on recognizable musical objects […] [that] are not 'themes' in the classical sense, but rather entities which, even though they constantly change their form, have certain characteristics which are so identifiable that they cannot be confused with any other entity" (Boulez as quoted in Goldman, 2001, 106). In *Anthèmes*, these musical "objects" (materials or motives) are evident from the very beginning: the introduction of the piece successively presents the basic motivic materials. The analytical method used by Goldman reveals the importance of motivic categories in *Anthèmes*. Known as paradigmatic analysis, the method, invented by Ruwet (1972) and further developed by Nattiez (1975), consists of a type of motivic analysis that tracks both the exact repetitions and the

transformations (of diverse degrees) of a motive occurring at different time intervals throughout a composition. In this way, the method allows for the comparison of all the instantiations of a motive that take place at all hierarchical levels of the form.

In accordance with Goldman's analysis and with Boulez's ideas on the perceptual importance and memorability of musical materials, the analysis presented here attempts to reinforce the notion that categorization is an essential aspect of the motivic structure of *Anthèmes 1*. The analysis proposes five motivic categories identified as Long Tone group, Pizzicato group, Scale group, Trill group, and Melodic group in Table 2.1. These categories do not account for the entire motivic material of the composition.[1] Instead, they attempt to represent the motivic structure of the piece overall. This is to say, the categories represent the motivic content of the formal structure of the composition in a relatively comprehensive way, and they provide a framework for encompassing the range of variation within each parameter. The categories are relevant in terms of their clear definition as relatively independent motivic families, the number of appearances of their motivic members, and the distribution of those members within the composition. They are clearly defined as motivic groups in the sense that they contain motives that are, at least from an intuitive and analytical perspective and in the context of the piece, both quite similar to each other and very different from the materials of the rest of the motivic families. At the same time, the five motivic families represent different degrees of clarity of categorization (group integrity or internal consistency). In other words, the strength of the relationships among the members of a group is different for each motivic family. In this way, the five motivic groups proposed by the analysis reflect the diversity of the piece in terms of motivic characterization and categorical definition, further describing the motivic structure of the piece overall.

The analysis considers all musical parameters. Articulation style, bowing technique, character (in many cases transparently reflected by the expression markings in the score), speed (as defined by the tempo indications and rhythmic notation), dynamic/intensity, texture, rhythmic pattern, and melodic profile are prioritized, because surface contrasts and similarities in these features are particularly salient and appear to play an important role in the motivic organization and formal structure of the composition. Note that this list of musical features is relatively

[1] A more comprehensive list of motivic families is roughly presented in Chapter 3.

comprehensive, covering, more or less explicitly, different facets of the main musical parameters. For instance, timbral characteristics are suggested by the analysis of bowing technique and articulation, durational features are related to the speed and rhythmic pattern, and so forth. The relevance of each feature depends on the motivic category. This is to say, some features that are crucial for the definition of a motivic category are not necessarily important for the description of another category. Cells in Table 2.1 corresponding to features that are particularly meaningful for the definition of a motivic category are shaded in grey. These are the features that are most consistently shared across the members of a motivic family. The non-shaded cells of the table correspond to characteristics of the motives of a group that are largely variable. In this way, the number of shaded and non-shaded cells is an indicator of the degree of categorical clarity of each family. Following this, the Pizzicato group is the most clearly defined, followed by the Long Tone group and the Scale group. Next comes the Trill group and the least clearly defined is the Melodic group. When possible, the characteristics of the motives are based on direct observations from the score that are perceptually salient. Nevertheless, in some cases, analytical interpretations had to be made. For instance, timbre descriptions are often derived from the annotated articulations or bow techniques. Similarly, the speeds were determined perceptually (specifically, by listening to the motives extracted from the recording used for the experiments and comparing them back to back).

This analysis proposes a clear set of (five) motivic categories defined in terms of musical features. A representative example of each of these categories is reproduced in Appendix A. The specific instances of all the motives belonging to each category in the piece can be deduced from the definition and description of the categories in Table 2.1. Following this, the motives listed in the table do not constitute a comprehensive account of all the instances of motivic materials associated with one of the five motivic families in the composition. Instead, they consist of examples representing the range of variation of the categories. Considering that this range of motivic variation constitutes a central criterion for the selection of the stimuli of the three experiments presented in this chapter, the motives in the table constitute the set of stimuli of Experiment 1. Experiments 2 and 3 use a reduced selection from that set. In general, the motives excluded from the table (and from the experiments) are extremely similar to the ones included and can thus be recognized intuitively.

Table 2.1: Motivic families in *Anthèmes 1*

Motivic group name	Long tone	Pizzicato	Scale	Trill	Melodic
Number of motives in group	7	7	11	13	14
Motive labels and positions on the score	L1/2, L2/14, L3/45, L4/66, L5/89, L6/97, L7/165.17-end	P1/15-18, P2/25-29, P3/30-31, P4/32-33, P5/114, P6/122, P7/124	S1/1.13-1.14, S2/3.3, S3/7.7, S4/9.5, S5/46.3, S6/57.2, S7/80.1, S8/98.1-98.3, S9/113, S10/129, S11/161	T1/1.2-1.5, T2/4, T3/8.1-8.5, T4/59.1-70.1, T5/67-68, T6/69.71, T7/73.1-73.10, T8/94.3-96.7, T9/104.5-104.10, T10/108.2-108-4, T11/111.3-111.6, T12/164, T13/165.1-165.16	M1/1.1, M2/73.10-76, M3/99.1-99.2, M4/100.1-100.3, M5/104.1-104.5, M6/105.1-105.3, M7/108.1-108.2, M8/109.1-109.3, M9/115, M10/130.1-130.3, M11/133.1-133.3, M12/144, M13/157-158, M14/162
Chapter 2 Group Features					
Articulation / bowing technique	Sustained	Pizzicato	Mostly jeté/ricochet, except for 3 motives that are slurred.	Slurred or détaché	Various slurred patterns
Timbre	Harmonics			Different positions on the strings: sul tasto, sul pont., regular	Regular bow, with occasional harmonics
Character	Libre (free)	Rythmique (rhythmic), rigide (rigid), agité (agitated)	No character indications on score, but character can be described as rapid and determined (directional)	Avec flexibilité (flexible), except for 3 motives marked agité, instable (agitated, unstable)	No character indications on score, but character can be described as melodic, with some motives being clearly more singable and directional than others
Intensity (dynamic)	Very soft: *ppp-pppp*	*mf-f*	*p-pp*, 3 motives with inflections from/to *mf/f/ff*	Variable	Variable
Texture	Monodic	Mostly monodic, some motives with occasional multiple stops	Monodic, except for 3 motives in double-stops in which the voices are hard to distinguish	Polyphonic or a simple trill	Compound melody suggested by pitch organization of one monodic line
Speed	Very slow, practically immobile	Within a range of moderately fast speeds	Within a range of fast speeds, except 1 motive that is quite moderate	Most motives are within a range of moderately slow, except 3 motives that are fast	Variable
Duration / length (in seconds)	M = 12.26 s SD = 5.39 s Shortest: 5.61 s Longest: 21.12 s	M = 2.90 s SD = 0.82 s Shortest: 1.81 s Longest: 4.08 s	M = 1.17 s SD = 0.75 s Shortest: 0.47 s Longest: 2.89 s	M = 5.83 s SD = 2.88 s Shortest: 1.47 Longest: 11.28 s	M = 2.00 s SD = 1.54 s Shortest: 0.77 Longest: 6.40 s
Rhythm	Long tone(s) with fermata	Mostly isochronous	Perfectly isochronous	Variable	Variable
Pitch contour	Most long tones end on gliss, some of which are ascending, whereas others are descending	Irregular contour (unpredictable ups and downs), leapy	Stepwise contour, some up and others down.	Variable	Variable
Register	Variable, but always centered on the middle register	Middle register	In middle register, except for 1 motive in high register	Variable	Wide in many motives
Pitch content	Variable, with some common notes	Variable	Variable, with a few common notes	Variable	Variable*

* In principle, wide register is a consistent feature, in the sense that many of the motives in this group use a similarly wide pitch range. Nevertheless, the expression wide register is variable in its very definition, and, in that sense, highly unspecified and more difficult to identify as a common element.

For instance, five out of the twenty-six motivic members of the Scale group consist of 8-note ascending scales built with similar pitch/interval collections (similar notes in the same register) and identical rhythm, and played with the same articulation and practically at identical speeds. Keeping in mind that these five motives are practically identical in all characteristics except for specific pitch/interval content, two motives are chosen for featuring a pitch/interval content that best represents the five scalar 8-note motives as a whole as well as the range of variation among them. The labels assigned to the motives (third row of Table 2.1) should suffice for the reader to find the motives in any score of *Anthèmes 1*. Only these two motives are listed in Table 2.1 and used in Experiment 1. (An exhaustive list of the instantiations of each motivic type is presented in Chapter 3.)

The labels are meant to reflect three important aspects:

1. The category to which a motive belongs. This characteristic can be deduced from the first character of the label, which corresponds to the first letter of the name of the motivic category.
2. The within-category order of a motive in the composition. This corresponds to the number following the letter (second character in the label). Note that this ordering accounts only for the motives listed in Table 2.1 and used in the experiments.
3. The specific location of the motive in the piece. This feature is indicated by the suffix (pair of numbers) after the slash, which corresponds to the initial and final measure numbers of the statement of the motive. Decimal points in the suffix separate the measure numbers and the beat number in eighth notes within the measure. When no decimals are specified, the numbers refer to complete measures. For instance, the first motive from the Scale group, which starts on the thirteenth eighth note of m. 1 and ends on the next eighth note of the same measure, is labeled S1/1.13-1.14. To give an example of a simpler case, the first motive from the Long group occupies the entire second measure, and it is thus labeled L1/2. The suffix in the labels of the motives from the Scale and Melodic groups needs further clarification. In the Scale group and to a lesser extent in the Melodic group, some motives end on a trill. Due to their treatment throughout the composition, and to their unique presence as musical gestures, trills are here assigned their own motivic group. Nevertheless, due to the strong directionality of certain motivic instances from the Scale and Melodic groups leading into a final trill, it seemed necessary—for the sake of those particular motives as complete gestures—to include the attack (i.e., only the very beginning) of the trill in those motives. In this way, the motives were

complete gestures without having to incorporate the trill (which was a musical element clearly belonging to a different motivic family). This is particularly important considering that the motives were extracted and used as stimuli in the experiments. Following this, the measure-number portion of the label of the motives from the Scale and Melodic groups that end on a trill includes the beat (measured in eighth notes, consistently with all labels) on which the trill falls.

The segmentation of the motives attempted to reflect the smallest (most local) level of the formal structure. The motives are patterns that recur as independent (and always transformed) units, often implying contrast in surface features. In this sense, the motives can be considered small musical gestures or, perhaps more in accordance with Boulez's discourse, musical objects or entities. In addition to the 52 motives explicitly listed in Table 2.1 or easily deductible from the description of the motivic families in the table, a few materials of *Anthèmes 1* can be interpreted as belonging to more than one of the categories proposed by this analysis, in the sense that they obviously combine distinctive features that are typical of more than one motivic family. Because the distinctive features of the categories to which these materials belong are presented in simultaneity (rather than one after the other), it is not possible to subdivide these materials and separately interpret their components as members of different motivic groups (as was the case for the trills ending some of the Scale motives, for instance). The most obvious examples amalgamate distinctive features from the Trill and Melodic groups and appear towards the end of the piece (mm. 145-163). These amalgamated materials can be described as two melodic layers in double stops. An example is shown in Figure 2.1.

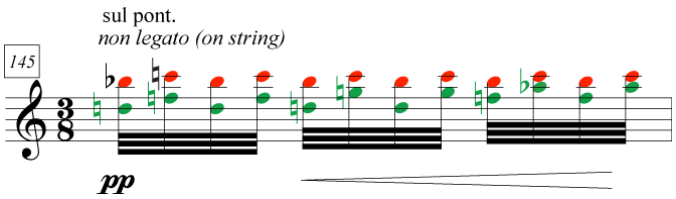

Figure 2.1: TM1[2]

[2] All the musical examples included in this dissertation are reproduced with permission of Universal Edition A.G. (Boulez, 1992).

As illustrated, the upper line is a written-down, slowly moving trill (shown in red in the figure), whereas the lower voice is a more melodic and directional line in which the interval succession implies a compound melody (shown in green in the figure). In this way, the motive overlaps distinctive features from the Trill and Melodic groups. Two materials representing this amalgamated class are employed in Experiment 1. They are referred to as TM1 (shown in Figure 2.1) and TM2, and they are stated in m. 145 and m. 163, respectively. TM1 was selected as a stimulus for Experiments 2 and 3.

THE THEORETICAL CONSISTENCY OF THE MOTIVIC FAMILIES: A COMPARISON WITH GOLDMAN'S (2001, 2011) ANALYSIS

This section discusses the differences between the motivic groups proposed in the analysis above and those suggested by Goldman's paradigmatic analysis. The aim is to further explain the five categories, to demonstrate the importance of motivic categories in *Anthèmes 1*, and to show that some categories are more clearly defined than others in analytical and theoretical terms. Even though Goldman does not give titles to his motivic categories, his motivic labels and descriptions imply a group of long tones, a group of scales, a pizzicato group, and a group of trills. In this sense, the analysis proposed in the previous section resembles Goldman's relatively closely. On the other hand, Goldman's analysis does not suggest a single group with the characteristics of the Melodic group proposed in the previous section. In order to deeply understand the internal similarity structure of the five motivic families selected for this study, the discussion that follows compares each of the five motivic families proposed in the previous section with Goldman's analysis, beginning with the group that differs the most from his classification and moving towards a motivic category that is perfectly congruent with his analysis.

From the five families proposed, the Melodic group is the least clearly defined as a motivic category from a theoretical perspective, at least in the sense that it is the family that differs the most from Goldman's (2001) paradigmatic chart. In light of his analysis, the Melodic group contains motives from four different classes. Three of these four classes are independent in the sense that they are not linked, at a higher level of the analysis, with other motivic categories; i.e., they have their own and unique letter labels in the paradigmatic chart. Goldman considers the internal micro units of what is here (in Table 2.1) motive M2 as a motivic family of its own. He

also includes motive T7 in this family, probably because it is the beginning of the phrase that corresponds to motive M2, even though it is a trill—and in that sense it belongs to the category in which he includes practically every trill. The passage corresponding to T7 and M2 is shown in Figure 2.2. The figure overlaps my analysis (shown in blue) with Goldman's (shown in red). His analysis reflects the complexity of motive M2. The motive is indeed easily divisible into internal units. Nevertheless, motive M2 is clearly a musical entity on its own, which can be characterized as melodic, mostly slurred, and featuring a compound-melody texture in its second half.

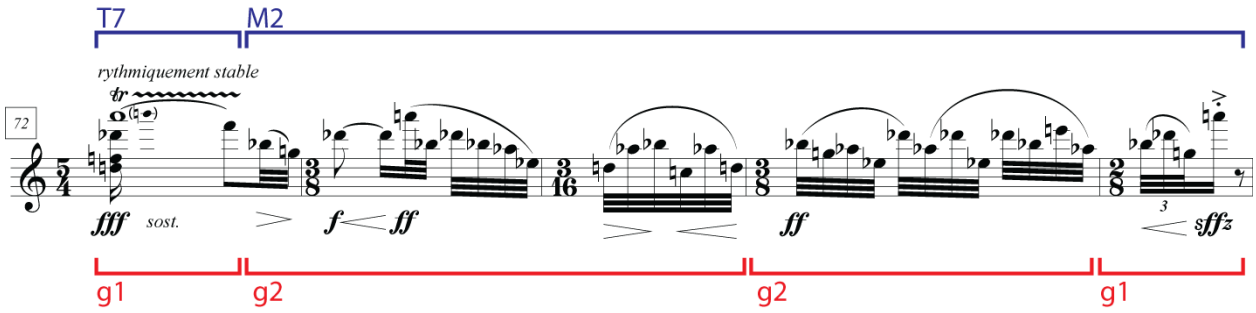

Figure 2.2: mm. 73-76 (T7 and M2)

In this sense, motive M2 fits the description of the Melodic group proposed in Table 2.1. Motives M9, M10, and M11—shown in Figure 2.3—are part of another, separate group according to Goldman. The members of the motivic category to which these three motives belong can be described as short groups of slurred notes starting with a quadruple-stop attack and played with a *brusque* character.

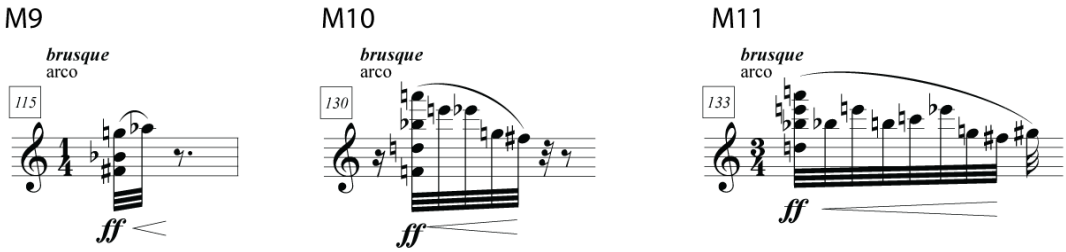

Figure 2.3: M9, M10, and M11

According to Goldman, motives M12, M13, and M14—illustrated in Figure 2.4—constitute yet another, separate class. An analysis of the motives that he includes in this class suggests that it is polyphonic in texture, calm in character, and with timbral changes caused by different positions of the bow on the strings. The polyphonic texture features a two-voice counterpoint either implied through a compound line or explicit in double-stops. Consistently with this description, in Goldman's analysis, this category also contains motives TM1 and TM2 (see Figure 2.1 for an example of this subclass), which are considered members of both the Trill and Melodic groups in the analysis I proposed in the previous section.

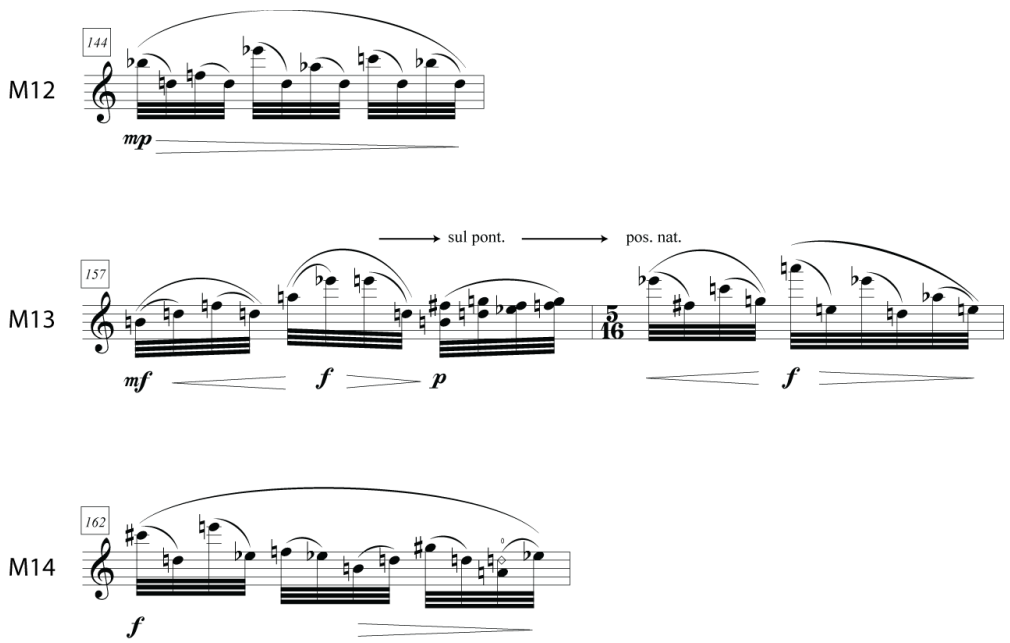

Figure 2.4: M12, M13, M14

Finally, Goldman interprets motives M1, M3, M4, M5, and M6 as variations of a 7-note scale motive that is most commonly played in *jeté* articulation, probably because these five materials work as pick-ups to the trill, exactly as many (although not all) of the 7-note scales do.[3]

[3] Only one of the five motives mentioned here has seven notes. Accordingly, it seems that Goldman has included them in the same group because of their formal function (pickups to trills) rather than the number of component notes. Nevertheless, as Goldman wisely points out, the number seven plays an important role in this piece and Boulez's music in general (Goldman, 2011), and it is indubitable from an analysis of the score that many of the Scale motives

An example of this case is shown in Figure 2.5. The example shows M1 followed by T1. According to Goldman, these five motives belong to the Scale group rather than to the Melodic group. Nevertheless, these variations feature slurs, melodic leaps or skips—the stepwise motion does not necessarily predominate and, in that sense, these motives are not scalar— and often suggest a compound melody. Therefore, in the context of the analysis proposed in the previous section, these five motives belong more to the Melodic group than to the Scale group.

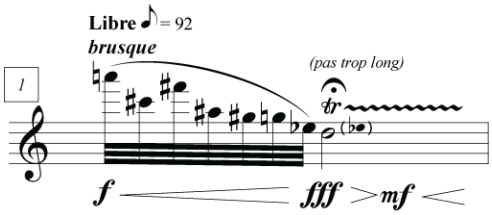

Figure 2.5: M1 and T1

To conclude with this group, many of the motives that are considered here to be members of the Melodic group are, according to Goldman, members of four groups. Goldman's classification accurately reflects aspects of the motives. Nevertheless, the four groups from Goldman's analysis can still be more generally described as melodic (singable and directional), slurred (or with connected notes in terms of articulation), and texturally compound to a certain degree. In this sense, the Melodic group is a family with internal subdivisions—as noted by Goldman—that, even when clearly defined, do not affect the integrity of the motivic class from a music-analytical perspective. In other words, motives M1 to M14 share certain features that serve to justify the existence of the Melodic group as a motivic category. Nevertheless, overall, it is clear that the Melodic group is relatively weakly unified as a motivic category.

along with what I call M1 have seven notes. My analysis disregards the number of notes (even when it comes to the Scale motives) of the motives in favor of features that have been shown to be perceptually more salient, such as articulation and timbre. This is because my analysis attempts to combine score-based analytical methods with perception. To my ears, the exact number of component notes, at the speed that most Scale and Melodic motives occur, is not a defining aspect of the motivic categories.

Since Goldman uses the same label for practically all trills, the Trill group proposed here is quite consistent with his analysis. The difference between my analysis and his is that mine incorporates motives that mix trills with other musical features. Goldman interprets the non-trill portion of these motives featuring trills as derivations of pure trills (i.e., he sees the entire motives as trills superimposed on variations of trills). This is particularly the case for motives T2, T4, and T8, which, as illustrated in Figure 2.6, superimpose a trill or melody of trills on another melody. The only members of the Trill group proposed above that are not related to a trill motive in Goldman's analysis are motives T5, T6, and T7.

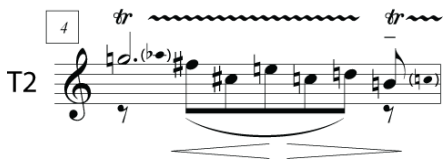

Figure 2.6: T2

As discussed above, Goldman links motive T7 to the more melodic motive M2, probably due to phrase structure. In Goldman's work, motives T5 and T6 belong to a different group that appears to be characterized by trills with occasional multiple stops (see Figure 2.7).[4] Considering this, the motivic family featuring trills is more inclusive in the analysis presented here than in Goldman's. Once again, his analysis highlights internal subdivisions of the Trill group I propose.

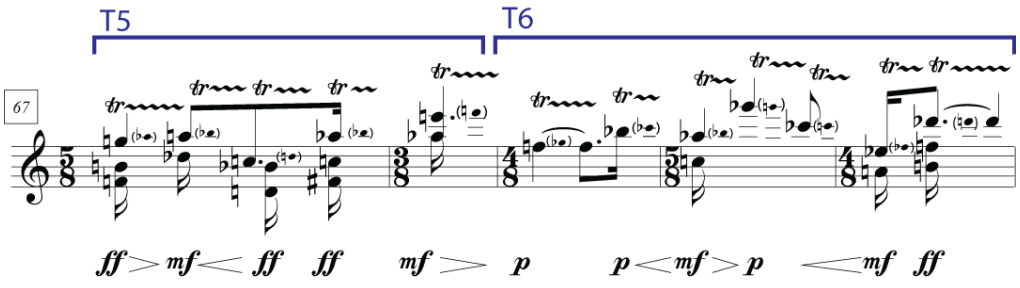

Figure 2.7: T5 and T6

[4] The boundary between T5 and T6 was defined according to the segmentation rules described in Chapter 3 (see Table 3.2 for details).

The three remaining groups are consistent with Goldman's analysis. With respect to the Scale group, Goldman considers scales of different speeds and articulation to be variations of a motive that he defines as a 7-note scale. This marks an obvious parallel between Goldman's analysis and my interpretation. Furthermore, the only divergence between the two analyses is that Goldman interprets scales in double-stops with *ricochet* articulation—specifically S1, S9, and S10 in my analysis—as a motivic group in its own. An example of the double-stops scalar motivic type is shown in Figure 2.8. One reason for Goldman's differentiation could be that the double-stops in those three motives give rise to a two-part texture composed of a stationary (repeated-note) line and a scale.

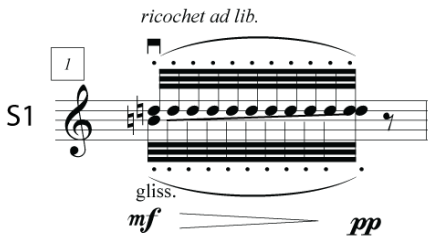

Figure 2.8: S1

The incorporation of scalar motives featuring double-stops into the (more encompassing) Scale group that I propose is based on the following reasoning. The Scale group is defined as containing short scales, and most motives in the Scale group have some type of staccato articulation (the articulations *jeté* and *ricochet* are used interchangeably by many violinists). Accordingly, motives S1, S9, and S10 are played *ricochet*. Even though these three motives feature a two-part texture resulting from the double-stops, the scalar line is considerably more salient than the repeated-note part, probably due to its more interesting melodic motion. It is in this sense that these three motives are clear members of the Scale group.

The Pizzicato group is mostly consistent with Goldman's interpretation, with the important exception that he omits the section containing motives P1, P2, P3, and P4 from the paradigmatic analysis due to its independence from the other sections as well as its "non-directional" and "non-thematic" properties. Nevertheless, he explains the omitted section as a three-voice canon built with very limited rhythmic values that serves "to produce a rhythmically

jagged moto perpetuo" (Goldman, 2011, 169). It is this rhythmic profile that causes the sense of isochronous rhythm characteristic of the Pizzicato group. Furthermore, Goldman refers to the omitted section as "pizzicato section" (Goldman, 2011, 164-5). P1 or the beginning of Goldman's "pizzicato section" is shown in Figure 2.9. Note especially the predominance of sixteenth notes.

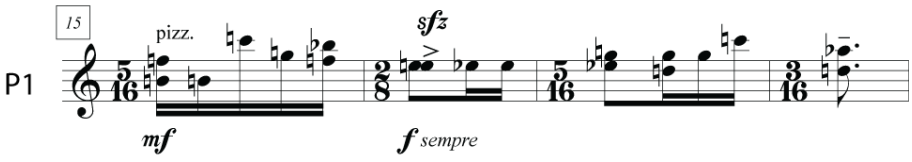

Figure 2.9: P1

Finally, the Long Tone group is perfectly congruous with Goldman's analysis. An example of this group is illustrated in Figure 2.10. It is relevant that this motivic category, which is remarkably differentiated from the rest of the motivic families from an analytical perspective, is precisely the one that contains the materials that, according to Boulez, serve as formal markers of the piece (Goldman, 2001).

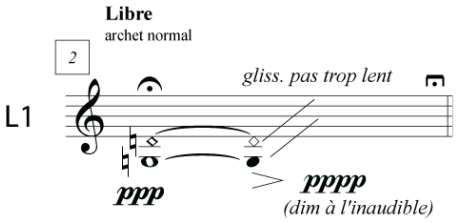

Figure 2.10: L1

For the purposes of this study, the details that constitute the differences with respect to Goldman's analysis are not crucial. Most importantly, the comparison between my analysis and Goldman's reflects three essential aspects of the motivic structure of *Anthèmes 1:* (1) the concept of motivic categories is central to the structure and organization of the piece from a theoretical, analytical perspective—in effect, showing this is an important purpose of Goldman's paradigmatic analysis as well as the main point of the analysis presented in the previous section; (2) the motivic

categories appear to be relatively stable analytically and intuitively, at least in the sense that they do not drastically change from one analyst to another; and (3) some motivic families are more consistently and clearly defined in theoretical terms than others.

The preceding section presented a new music analysis of the motivic categories of *Anthèmes 1* and its comparison with the most comprehensive analysis of the piece found in the literature (Goldman, 2001, 2011). The following sections present three experiments that explore perceptual aspects of the motivic categories and motivic similarity relations discussed in the analysis above.

Experiment 1: Motivic categorization

METHOD

Participants

Seventeen musicians (aged 22-38, *M* = 29, *SD* = 5.5, seven females, all of whom had completed the music theory and musicianship requirements for the Bachelor of Music at McGill University or equivalent) volunteered to participate. Four of the participants were doctoral students in music, had completed at least 4 years of academic training in post-tonal theory or analysis exclusively, identified themselves as composers or researchers of post-tonal music, and indicated contemporary art music as one of the types of music that they heard most frequently. An examination of the data revealed no differences between this group of four people most experienced in post-tonal repertoire and the rest of the participants. Therefore, all data were analyzed together. Before the experiment, participants passed a pure-tone audiometric test using octave-spaced frequencies from 125 Hz to 8 kHz (ISO 389–8, 2004; Martin & Champlin, 2000).

Stimuli

The stimuli were 54 short motives extracted from *Anthèmes 1*. The selection of motives was based on the theoretical analysis presented above. Accordingly, the 54 stimuli correspond to the 52 motives listed in Table 2.1 plus motives TM1 and TM2 explained in conjunction with the table (a representative example of each of the five motivic categories is reproduced in Appendix A). The duration of the sound files ranged from 0.47 to 21.12 seconds (*M* = 4.22 s, *Median* = 2.53 s, *SD* = 4.32 s). The motives are here described as short in the sense that they were practically

indivisible units belonging to a very small level (see motivic analysis above). This was the case even for the longest motives, whose relatively long duration was due to the use of very long, sustained tones. The stimuli were amplified through a Grace Design m904 monitor (Grace Digital Audio, San Diego, CA) and presented over Dynaudio BM6a loudspeakers (Dynaudio International GmbH, Rosengarten, Germany) arranged at ±45°, facing the listener at a distance of 1.5 m. In order to extract the stimuli, the entire CD track (Boulez, 2013) of *Anthèmes 1* was imported to Audacity, where the sound files were cut and exported as .wav files with a 16-bit resolution and a sampling rate of 44.1 kHz. Editing of the sound files was avoided to the extent possible. A minimum amount of fade-out was added when the motives were elided with succeeding musical material. The fade-out time depended on the motive. Sounds were played at a maximum level ranging from 45dB to 70dB SPL, as measured with a Bruel & Kjaer Type 2205 sound-level meter (Bruel & Kjær, Nærum, Denmark) positioned where the center of the listener's head would be. Listeners were seated in a double-walled audiometric booth (IAC Acoustics, Bronx, NY).

The recording used for extracting the stimuli was Jeanne-Marie Conquer's performance at IRCAM in 2002 (Boulez, 2013). This version was chosen due to the high quality of the performance in terms of articulation and phrasing, the experience of the performer in playing Boulez's music, and the clarity of the sound in general. In addition, prior to the completion of this recording, Jeanne-Marie Conquer had recorded the piece in presence of P. Boulez (for further details, see Goldman, 2001, vi).

Procedure

A free classification paradigm was used. The 54 motivic materials were represented by randomly numbered squares and presented to participants on a computer screen. Participants could listen to the materials by clicking on the square as many times as they wished and in any order. Once the participants had heard a motive at least once, they could freely move it around the computer screen by clicking and dragging. Following this procedure, participants freely sorted all 54 materials into as many categories as they wanted. Categories were represented by empty boxes (rectangles) on the computer screen. An empty category was always available. Participants were instructed that each motive was to be included in one and only one category. It was possible to form single-motive groups. Participants were allowed to connect categories that they thought were related and were asked to provide labels for the categories they formed. For the purposes of this

project, connected categories were considered as part of one category larger in size (i.e., only categories of the largest hierarchical level were taken into account), and labels were ignored.[5]

All participants read the same instructions and were then asked to explain them to the experimenter. The experimental trial was preceded by a practice trial monitored and assisted by the experimenter. The practice trial included three motives from the Scale group (S1, S8, and S9) and three from the Trill group (T2, T4, and T8).

Data Analysis

The participants' classifications were converted into a 54×54 co-occurrence matrix in which each cell indicated the number of participants grouping two motivic materials in the same category. This matrix was converted into a dissimilarity matrix in which each cell showed the proportion of participants sorting two motives into separate (rather than the same) groups (this was accomplished by dividing the co-occurrence matrix by the total number of participants and subtracting the result from 1). A hierarchical (clustering) tree structure was built from the dissimilarity matrix using the average linkage method. This method, which calculates distances between two items or clusters based on the mean distance of the objects within them in a hierarchical way, was chosen for giving the highest correlation between the dissimilarity matrix and the cophenetic matrix (distances between motives in the hierarchical tree): $r = 0.98$, $p < .0001$. As explained in detail in the Results section, in this representation, the lower two motives (or groups of motives) are joined in the tree, the larger the proportion of participants classifying them within the same category, and, presumably, the higher the perceived similarity of the motives.

The relatively clear structure of the hierarchical tree served to confirm the motivic analysis presented in the previous section of this chapter and was also interpreted in light of a second motivic analysis presented below.

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[5] The experiment described here was the first part of a two-part experiment. In the second part of the experiment, participants were presented with 6 musical materials that consisted of combinations of motives from different categories. These materials were literally extracted from the piece. In the second part, after hearing all 6 motives at least once, participants had the option to add (including) these materials to the categories that they had formed in the first part of the experiment, or to leave them outside (excluding them from all categories). The second part of the experiment was merely exploratory, and it is thus excluded from the discussion below.

RESULTS AND DISCUSSION

The averaged motivic categorization performed by the 17 musicians is represented in the clustering analysis shown in Figure 2.11. The motivic materials are listed on the x-axis. The y-axis indicates dissimilarity values calculated from the number of participants classifying a pair of motives as members of the same (lower dissimilarity value) or different (higher dissimilarity value) category. The larger the number of listeners who include two motives within the same group, the lower in the y-axis the branches corresponding to those two motives join. Following this, the motives from the Long Tone and Trill groups differ the most with respect to the motives from the Pizzicato, Melodic, and Scale groups because they join only at the top of the tree structure.

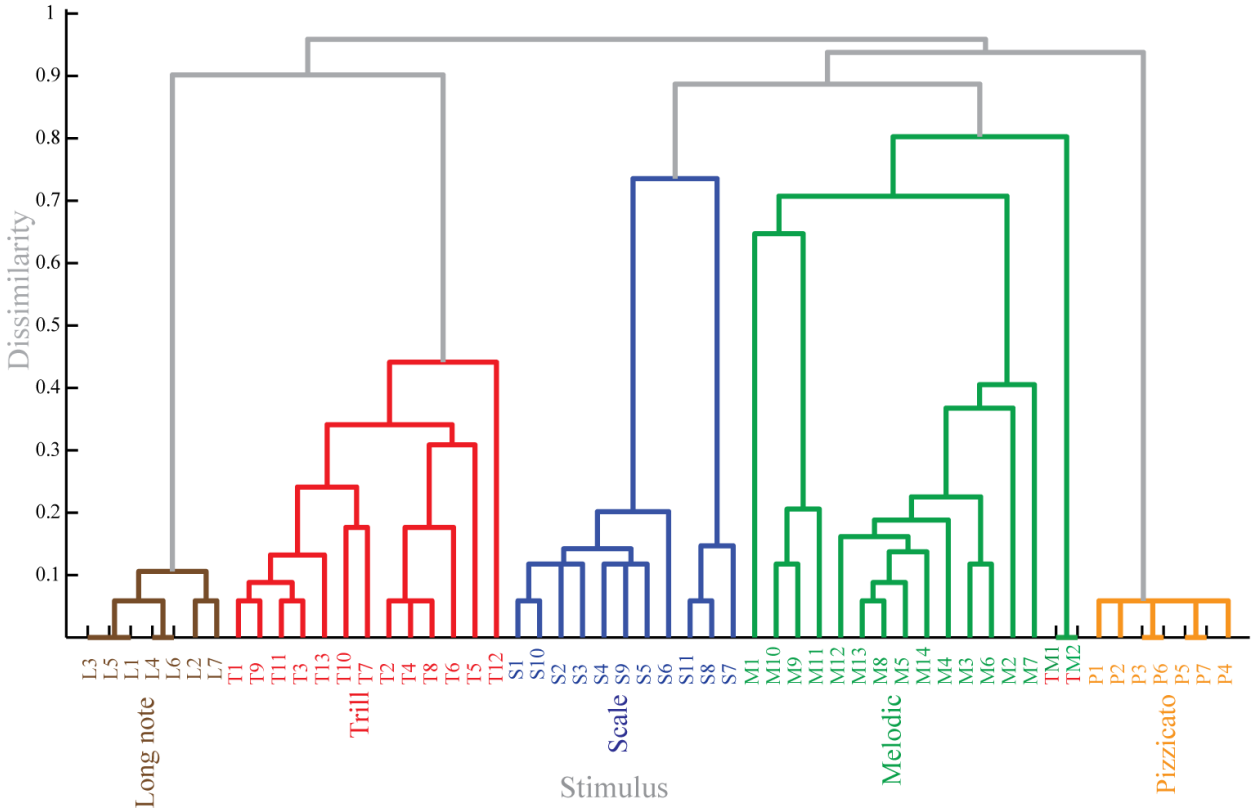

Figure 2.11: Experiment 1: Clustering analysis

The five motivic categories defined by the theoretical analysis in the previous section (Table 2.1 and Appendix A) are displayed in different colors in the clustering tree in Figure 2.11. In general, the clear structure of the clustering tree reflects the perceptual validity of the five

motivic groups analytically defined: the shape and arrangement of the branches of the tree suggest that the motives are of five more or less distinct classes, and the specific motives belonging to each of those classes are in accordance with the analytical predictions. At the same time, in line with the differences between the analysis proposed above and Goldman's, some of the motivic categories appear to be perceptually more robust than others. This can be deduced from the number and position of tree branches corresponding to each motivic group. The following section discusses the clustering analysis in detail with the purpose of elucidating characteristics of the internal structure of the families. Specifically, the examination attempts to quantify the internal robustness of each motivic group, i.e., the perceptual clarity of a motivic family as a separate, relatively independent group.

Internal structure of the motivic families

The clustering tree reveals characteristics of the internal similarity structure of the groups. One measure that reflects aspects of the internal-structure consistency of the motivic families can be derived from the dendrogram in Figure 2.11. This measure of internal-structure consistency consists of the average internal dissimilarity of the family, i.e., the mean of the dissimilarity values for all motivic pairs in the family taken from the dissimilarity matrix from which the dendrogram was built. This is equivalent to the average internal distance value of the family, i.e., the mean of the distance values obtained with the linkage method for all motivic pairs in the family. Motivic groups with a relatively low average internal dissimilarity have a more robust, better defined structure, in the sense that any of their members is perceptually very similar to any other member of the family. Table 2.2 shows the average internal dissimilarity or distance for each motivic family (1=very dissimilar/distant, and 0=very similar/close). In the table, higher degrees of internal-structure consistency (perceptual robustness) are shown in darker shades of grey.[6] For the Trill and Melodic groups, two averages are computed, one including and another one excluding motives TM1 and TM2. The Trill group is marked as more inconsistent than the Scale group because the internal-structure consistency of the former group is .12 higher than that

[6] An equivalent distribution of the groups in terms of their internal structure was found by calculating the average of the inconsistency coefficients for each group individually given by MATLAB's inconsistent(z) function. This MATLAB function compares the height of each link in a cluster tree (as calculated by the linkage function) with the average height of all the other links within two (MATLAB default) hierarchical levels from the target link, computing a value of inconsistency for each link.

of the latter when TM1 and TM2 are included but only .07 lower when TM1 and TM2 are excluded. The motivic analysis outlined in Table 2.1 along with the discussion that compared it to Goldman's work is in line with the perceptual characteristics of the motivic structure of *Anthèmes 1* suggested by the categorization experiment and summarized in Table 2.2. Based on the number and importance of differences in motivic labeling and classification, the comparison of the motivic analysis proposed above and that by Goldman moved from the least clear to the most robust motivic family, starting with the Melodic, Trill, and Scale groups in that order, and ending with the Pizzicato and the Long Tone groups.

The order of the motivic families given by the differences between the two theoretical analyses is basically the same as that reflected by the values of internal-structure consistency (average computations) deduced from the perceptual data and presented in Table 2.2.

Table 2.2: Internal structure of the motivic categories

Motivic group name:	**Long tone**	**Pizzicato**	**Scale**	**Trill**	**Melodic**
Internal-structure consistency (average internal dissimilarity or distance)	0.070	0.053	**0.40**	Without TM1 and TM2: **0.40** With TM1 and TM2: **0.42**	Without TM1 and TM2: **0.47** With TM1 and TM2: **0.54**

The only exception is that the Long Tone group (rather than the Pizzicato group) was identified as the most clearly defined group in the comparison of the two theoretical studies. Nevertheless, both the Long Tone and Pizzicato group were identified as the most clearly defined groups. A parallelism can also be observed by comparing: (1) the proportion of musical features shown as consistent and variable among the motives of each group in Table 2.1; i.e., a recount and verification of the content of the shaded cells in the table, and an examination of features reported as variable; and (2) the perceptual robustness values indicated in Table 2.2.

The similarities between the two theoretical analyses and the results of Experiment 1 suggest that a theoretical, score-based analysis of musical features and a purely perceptual categorization of musical materials taken together can reveal aspects of the motivic structure of *Anthèmes 1*. The following section further explores this idea by employing a different methodology and referring to specific musical examples.

Feature salience as a determining factor for motivic categories: A second motivic analysis

In the previous section, the perceptual motivic categories of *Anthèmes 1* (specifically the clustering tree) complemented and were justified with analytical decisions made a priori. The analytical work guided (perhaps subconsciously) the interpretation of the perceptual results. In order to better understand the interrelations between theory and perception, this section presents a theoretical, mostly score-based analysis of musical features that is directly guided by the experimental data. In this way, this section along with the previous one aims to demonstrate that reverse methodologies—from analysis to perception and vice versa—lead to remarkably similar results concerning the relationship between perceptual and analytical aspects of *Anthèmes 1*, further supporting the strength of that relationship. Accordingly, the clustering tree from Figure 2.11 is here explained in light of analytical descriptions. Specifically, the separate clusters (perceptual categories) at all hierarchical levels shown in Figure 2.11 are here described in terms of the musical features of their component motivic materials. The methodology consisted of searching for common features among motives clustered together in the perception-based tree structure. Those features were mostly noticeable by score analysis, but were additionally corroborated by listening to the performance used for the experiment. An important advantage of the methodology proposed in this section is that the analysis along with the tools that led to it must necessarily be perceptually valid, since it explains characteristics of the motivic structure of *Anthèmes 1* observed from a purely perceptual perspective.

Table 2.3 attempts to reproduce the clustering structure from Figure 2.11 based on analytical observations of different musical features. The dendrogram is here represented in landscape orientation. All motives are listed in the first column, following the order given by the clustering tree (i.e., the first column of the table is equivalent to the x-axis of the figure). Different cells in the table represent diverse clusters (branches joined together) in the figure. The diverse hierarchical levels of the tree are represented by column positions in the table, with the leftmost column corresponding to the lowest level of the clustering tree at which, presumably only very similar motives are classified as being of the same subclass. Together the position and width of the columns in the table correspond roughly to the lengths of the ramifications (branches) in the figure. For instance, the Pizzicato group has the widest rightmost column among all the groups, because it is the class in which the totality of the members was unified by the large majority of

participants. Similarly, the Melodic group has the largest number of columns due to its complex internal clustering structure. In simple terms, the borders of the cells in Table 2.3 correspond to the branches of the tree in Figure 2.11.

One obvious aspect demonstrated by Table 2.3 is that the perceptual categories can be analytically justified.

Table 2.3: Clustering structure of musical features

<table>
<tr><th>Motive</th><th colspan="8">Distinctive feature(s)</th></tr>
<tr><td>L3
L5
L1</td><td>First note ends with gliss up (with pause after gliss.)</td><td colspan="2">More than one pitch (non-stationary melodic contour)</td><td colspan="5" rowspan="4">Sustained long note(s), very soft dynamic, harmonics “libre” (free), very slow</td></tr>
<tr><td>L4
L6</td><td>2 pitches moving up a M7 (in 4, the 2 pitches are connected with a gliss.)</td><td colspan="2" rowspan="2"></td></tr>
<tr><td>L2</td><td colspan="2" rowspan="2">Single note, no gliss</td></tr>
<tr><td>L7</td></tr>
<tr><td>T1</td><td rowspan="2">Louder</td><td rowspan="3">Medium to forte dynamic</td><td rowspan="3">Middle to high register, moderately long</td><td rowspan="4">Trill on single note</td><td rowspan="8">Regular (fast) trill(s)</td><td colspan="2" rowspan="8">Trill(s)</td></tr>
<tr><td>T9</td></tr>
<tr><td>T11</td><td rowspan="2">Medium dynamic</td></tr>
<tr><td>T3</td></tr>
<tr><td>T13</td><td colspan="2">Very soft</td></tr>
<tr><td>T10</td><td colspan="3">Short</td><td rowspan="2">2 highest trills (register)</td></tr>
<tr><td>T7</td><td colspan="3">Attack on multiple-stops</td></tr>
<tr><td>T2</td><td colspan="2" rowspan="3">2 voices = trill(s) + melodic line</td><td rowspan="4">2-voice texture</td><td rowspan="4">Polyphonic texture</td></tr>
<tr><td>T4</td></tr>
<tr><td>T8</td></tr>
<tr><td>T6</td><td colspan="3">Some trills attacked in double-stops suggesting 2-voice texture</td></tr>
<tr><td>T5</td><td colspan="5">All trills attacked in multiple-stops</td></tr>
<tr><td>T12</td><td colspan="6">Written-out (slow), two-voice trill</td></tr>
<tr><td>S1</td><td rowspan="3">2-voice texture created w/ double-stops: one voice stays, one voice glides up or down by an extremely small interval</td><td rowspan="5">Contour up or unclear due to polyphonic texture</td><td rowspan="6">Middle register</td><td colspan="4" rowspan="6">Jeté/ricochet, Soft dynamic</td><td rowspan="13">Scale (stepwise motion), quite short in duration/length, isochronous rhythm</td></tr>
<tr><td>S10</td></tr>
<tr><td>S2</td><td rowspan="2">7-notes moving up by step</td></tr>
<tr><td>S3</td></tr>
<tr><td>S4</td><td rowspan="3">Con-tour down</td></tr>
<tr><td>S9</td></tr>
<tr><td>S5</td></tr>
<tr><td>S6</td><td colspan="3">Highest register</td></tr>
<tr><td>S11</td><td colspan="2" rowspan="2">Slow-to-moderate tempo (S11 = slowest in group)</td><td colspan="5" rowspan="3">Slurred, Noticeable crescendo</td></tr>
<tr><td>S8</td></tr>
<tr><td>S7</td><td colspan="3">Fast</td></tr>
</table>

<table>
<tr><td colspan="8">M1</td><td colspan="4">Monodic line (including initial attack)</td><td rowspan="2">Clear single line, very fast, brusque</td><td rowspan="13">Slurred, melodically directional</td></tr>
<tr><td colspan="2">M10</td><td colspan="2">Shorter</td><td colspan="4" rowspan="2">Initial attack in multiple-stops</td></tr>
<tr><td colspan="2">M9</td><td colspan="6" rowspan="2">Longer</td><td colspan="2">M11</td></tr>
<tr><td colspan="6">M12 Purely compound melody, slower</td><td rowspan="6">Moderate tempo</td><td rowspan="6">Various contours</td><td rowspan="9">Regular, isochronous rhythm</td><td rowspan="9">Medium to long length</td><td colspan="2" rowspan="9">Compound melody to some extent, melodic (singable), slower</td></tr>
<tr><td rowspan="3">M13</td><td rowspan="3">Slower</td><td rowspan="3">Cresc. pre-domi-nates</td><td rowspan="6">Com-pound melody alternated with more monodic line</td><td colspan="2">M8</td></tr>
<tr><td colspan="2">M5 Faster</td></tr>
<tr><td colspan="2">M14 Diminuendo only</td></tr>
<tr><td colspan="6">M4 Purely compound melody, faster</td></tr>
<tr><td colspan="2">M3</td><td colspan="4" rowspan="2">Identical rhythmic pattern and extremely similar contour (same “gesture”)</td></tr>
<tr><td colspan="2">M6</td></tr>
<tr><td colspan="8">M2 Long, complex phrase, rhythmically diverse</td></tr>
<tr><td colspan="8">M7 Very short pick-up preceded by grace note</td></tr>
<tr><td colspan="12">TM1
TM2 2 homorhythmic voices: upper voice is a written-out (slow) trill, lower (more predominant) voice delineates a slightly compound-like melody with clear direction</td><td>(Melodically directional)</td></tr>
<tr><td>P1</td><td>Many double-stops, quite conjunct melodic motion</td><td colspan="12" rowspan="5">Pizzicato, rhythmic character, medium to forte dynamic, moderately fast</td></tr>
<tr><td>P2</td><td>One double-stop only, quite disjunct motion,</td></tr>
<tr><td>P3
P6</td><td>Some double-stops on accented notes, very leapy, irregular contour,</td></tr>
<tr><td>P5
P7</td><td>Shorter (length), constant triplets, occasional double-stops</td></tr>
<tr><td>P4</td><td>Two clear voices (double-stops): repeated notes and desc. scale</td></tr>
</table>

Even when this might not be surprising as an overall observation, the fact that the analytical descriptions serve to justify each and every level of the perceptual categories is encouraging. All divisions of the clustering tree in Figure 2.11 are explained by the feature analysis in Table 2.3.

A detailed examination of the contents of the table reveals information about the musical features that are particularly relevant from the listener's standpoint. Since the different ramification levels in the tree from Figure 2.11 represent the proportion of listeners classifying motives within a single class, the theoretical features in Table 2.3 that explain the longest ramifications along the y-axis (lower-level branches that are isolated from upper-level ramifications) in Figure 2.11, can be considered more salient from a perceptual point of view. Following this, the features listed in the widest rightmost columns in Table 2.3 should be perceptually more relevant for the listener.

As shown in Table 2.3, the musical features that define the Pizzicato and Long Tone groups should be at least partly responsible for the perceptual robustness of those motivic classes. Presumably, those features should also be naturally more salient to the listener than other musical attributes—at least in the context of the features emphasized by the motivic material of *Anthèmes 1*. As listed in the table, the characteristics shared by all the motives belonging to the Pizzicato and Long Tone groups belong to the domains of articulation, character, dynamic level, and speed. Figures 2.12 and 2.13 show L3 and L4, and P1 and P4 respectively, the pair of motives that are perceptually most remotely located within the Long Tone and Pizzicato groups.

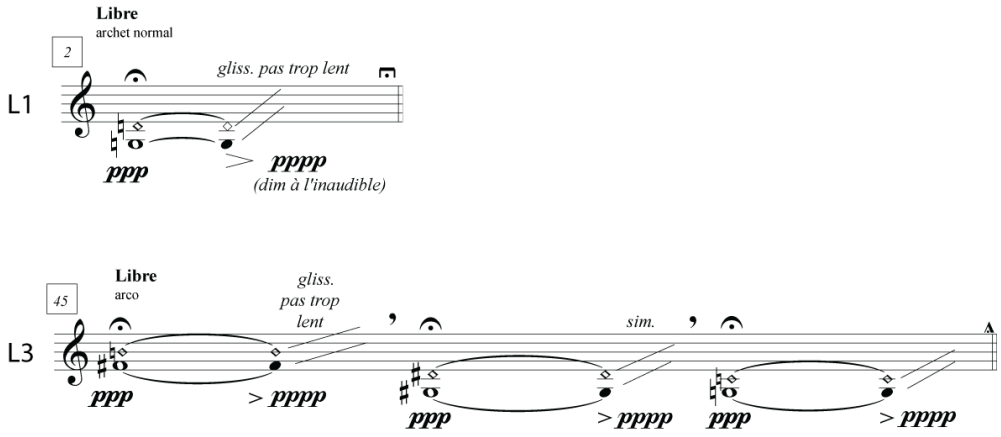

Figure 2.12: Two most perceptually remote motives in the Long Tone group (L1 and L3)

The members of each of these pairs of motives are remarkably similar in terms of articulation, dynamic profile, rhythmic values, and speed, implying the high consistency level of the motivic families to which they belong. In addition, less directly derived from the score-based analysis, timbre plays an important role defining these two groups. The pizzicato playing technique in the violin has an important timbral effect on the sound. Similarly, notes played in harmonics have very different spectral profiles with respect to their counterparts in regular bowing (or pizzicato).

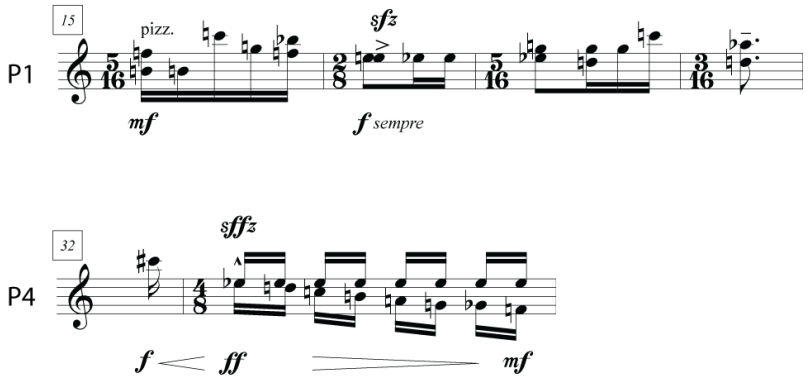

Figure 2.13: Two most perceptually remote motives in the Pizzicato group (P1 and P4)

Two observations are particularly relevant with respect to the musical features (parameters, domains) that perceptually define the Pizzicato and Long Tone as categories: (1) they consists of surface features, in the sense that they do not refer to details on the score but rather to large-scale characteristics that can be used to create greater degrees of contrast; and (2) they reveal remarkably opposite defining elements of one of the motivic groups with respect to the other. With regards to the first point, the features that define the Pizzicato and Long Tone groups are commonly considered secondary parameters in motivic analysis, in the sense that they do not affect the identity of a motive. In music theory and analysis, a motive is most frequently and almost exclusively defined in terms of its (quite specific) intervallic or harmonic characteristics—often referred to as deep-level qualities. Musical materials with different intervallic or harmonic profiles are frequently analyzed as distinct classes, even when the motives are similar in terms of other musical parameters. This is to say, in traditional music theory, the concept of motivic variation is most frequently associated with changes in domains other than the intervallic and harmonic

structure. It is rare that two motives that share elements in terms of register, dynamics, or timbre, but differ in their intervallic or harmonic content, are analytically classified as versions (variations of greater or lesser degree) of the same musical material. The reverse case, however, seems notably common within the analytical literature.

With respect to the second aspect concerning the features that define the Pizzicato and Long Tone groups (point 2 above), it is particularly relevant that the two groups that are best defined (among the five groups) as perceptual categories portray opposite surface characteristics. The Pizzicato and Long Tone groups are contrasting in terms of articulation (pizzicato for the former group and sustained notes for the latter), character (rhythmic for one category and free for the other), dynamic level (medium to *forte* in one case and very soft in the other), speed (moderately fast for the Pizzicato group and very slow for the Long Tone group), and timbre (plucked strings vs. sustained harmonics). This can be verified by comparing Figure 2.12 with Figure 2.13. In line with the importance of surface features discussed above, it seems reasonable to propose that this contrast considerably contributes to the robustness of the Pizzicato and Long Tone groups as perceptual categories. Finally, if the two groups can be portrayed as being perceptually robust due to the large number of perceptually strong surface features shared by their motivic members, it is only due to the contrast between those features that the Pizzicato and Long Tone groups acquire their own identity as separate categories. In effect, the surface features that define the two groups are, in principle, the same. The difference between the groups resides in the particular shape or quality that their motivic members acquire in terms of those features (pizzicato vs. sustained, rhythmic vs. free, fast vs. slow, loud vs. soft). Accordingly, this contrast in surface features at least partly explains the large distance that separates (differentiating) the Pizzicato and Long Tone groups in the clustering analysis of Figure 2.11.

The perceptual importance of surface features suggested by the musical characteristics and perceptual data corresponding to the Pizzicato and Long Tone groups can be further supported by comparing the musical features that define the remaining motivic groups (listed in Table 2.3) to their perceptual categorical structure (Figure 2.11). Two factors related to surface features appear to play a role in the relative lack of perceptual clarity or integrity of the Melodic, Trill, and Scale groups: (1) the surface features that hold all the motives from the group together—listed in

the rightmost column of Table 2.3—are small in number and/or not clearly defined, and (2) surface features play an important role in subdividing these three families internally at all levels.

Following the Pizzicato and Long Tone groups, the next most robust motivic categories according to the tree structure are the Scale and Trill groups. The features listed in the rightmost column of Table 2.3 corresponding to the Scale group are stepwise motion—i.e., smooth melodic contour— length/duration of the motives, and isochronous rhythm. Once again, the characteristics that define the group fall under the umbrella of surface features. Nevertheless, they are fewer in number than the characteristics defining the Pizzicato and Long Tone groups. In addition, articulation and dynamics, once again surface features, lead to a high-order subdivision of the Scale group, greatly increasing the average internal dissimilarity of the motivic family and consequently affecting its integrity. Figure 2.14 shows S1 and S8, two of the most distant motives in the Scale group, illustrating the role of articulation (*ricochet* vs. slurred), dynamics (diminuendo vs. crescendo), and texture (double-stops vs. single line) in the internal structure of the group.

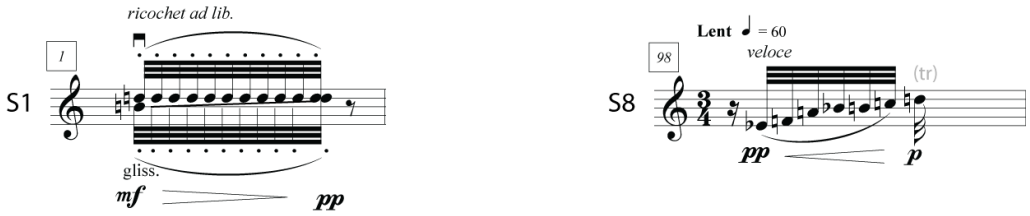

Figure 2.14: Two of the most remote motives in the Scale group (S1 and S8)

The differences between these two motives are particularly prominent when compared to the pairs of perceptually most remote motives from the Long Tone and Pizzicato groups discussed above (compare the two motives reproduced here with those shown in Figure 2.12, on one hand, and those in Figure 2.13, on the other hand).

The analysis of the Trill group presented in Table 2.3 further supports the importance of surface features for motivic categorization. The presence of trills is the characteristic that holds all the members of the group together. Trills are characterized by a very peculiar melodic and rhythmic contour and, in that sense, are defined by surface features. Like the Scale group, the Trill group also contains a prominent high-order subdivision. This subdivision, which separates TM1

(Figure 2.1) and TM2 from the rest of the motives, is likely to be caused by contrasting speeds that result in either an ornament (trill) or a more clearly defined rhythmic pattern (slow, written-out trill characteristic of TM1 and TM2). Once again, the relative lack of internal unity of the group (reflected in high-order subdivisions in the dendrogram) appears to be associated with the presence of clearly different surface features. Another surface feature that plays an important role defining high-order subdivisions within the Trill group is texture (see second-to-highest order subdivision for this group in the table). In this respect, two motives representing monodic and polyphonic textures can be seen in Figure 2.15.

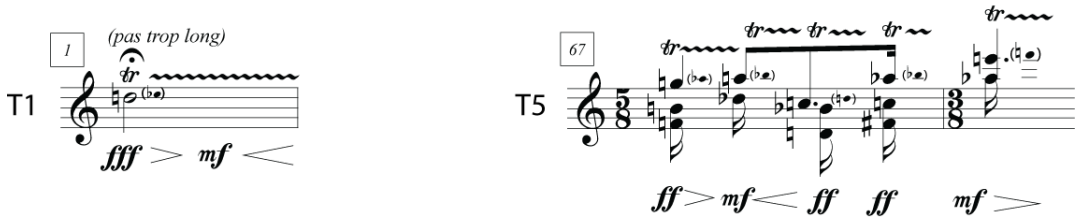

Figure 2.15: Motives representing monodic and polyphonic textures (subgroups) in the Trill group (T1 and T5)

Finally, the Melodic group is the least clearly defined in terms of surface features. The features that define this group (rightmost column) are slurred articulation and melodic directionality. These characteristics are quite contrasting with respect to the main (highest-order) features that define the other motivic groups, and, in that sense, they serve to distinguish the members of the Melodic group from the remaining families. Nevertheless, the characteristics slurred articulation and melodic directionality are too broad and ambiguous to convincingly unify all the motives in the family from a perceptual perspective. Presumably, the lack of definition of the Melodic group in terms of surface features interferes with the perceptual clearness of the group, leading to the relatively high average internal dissimilarity obtained in Experiment 1 (introduced in Table 2.2). In addition, this lack of definition in terms of surface features is likely to be associated with the ambiguity of analytical delimitation of the group suggested by the large number of differences between Goldman's analysis and mine. Furthermore, the fact that Goldman categorizes motives from the Melodic group as belonging to separate groups reflects the internal

inconsistency of the Melodic group as an independent category. As shown in Figure 2.16, Goldman's categories in general do not coincide with the subgroups portrayed by the perceptual dendrogram.

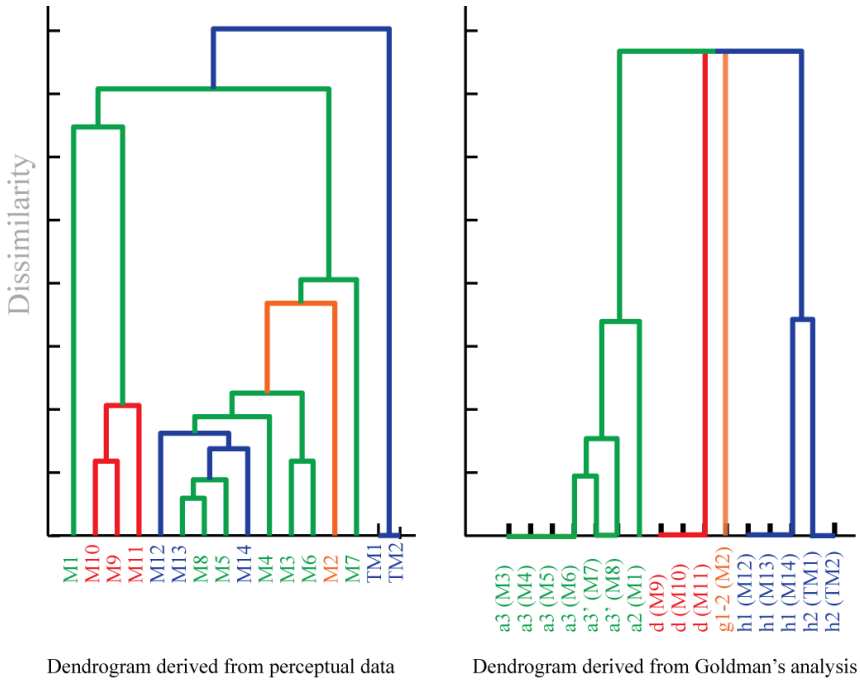

Figure 2.16: A comparison of the perceptual subcategories from the Melodic group (graph of the left) with Goldman's paradigmatic analysis (graph on the right). The colors in both panels correspond to the groups in Goldman's analysis.

The figure shows a clustering tree built from Goldman's analysis (diagram on the right) next to the dendrogram representing the perceptual data from Experiment 1 (diagram on the left). The dendrogram corresponding to Goldman's analysis was deduced from the motivic labels from the theorist's paradigmatic analysis. Specifically, the relative height of the branches (y-axis values) represents the motivic labels—letter names and numbers. For instance, the distance between motives a3 and a3' is smaller than that between motives a3 and a2, which is in turn much smaller than that between motives a3 and d. In addition, similar heights as those seen in the perceptual dendrogram are used to facilitate the comparison between the two visualizations. The four main subgroups (different letter names) from Goldman's analysis are displayed in diverse colors. The differences in the internal structure of the two clustering analyses is evident in the different

distribution of motives along the x-axis (it is necessary to distribute the motives differently in order to properly build the dendrograms) and the inconsistent distribution of the four colors corresponding to Goldman's categorization in the perceptual dendrogram Most obviously, with the only exception of the subgroup {M9,M10,M11}, Goldman's high-order subgroups—{M12,M13,M14,TM1,TM2}, {M2}, and {M1,M3,M4,M5,M6,M7,M8}—do not coincide with the high-order subgroups displayed in the perceptual dendrogram—{M1}, {M2,M3,M4,M5,M6,M7,M8,M12,M13,M14}, and {TM1,TM2}. Note in particular that TM1 and TM2 are clearly isolated from all members in the perceptual dendrogram, but integrated with other motives in Goldman's analysis. In addition, M14 is closer to M5 than to M12 from a perceptual point of view, whereas M14 is closer to M12 than to M5 from Goldman's analytical perspective. One possible very general explanation for the discrepancies is that Goldman is making decisions based on musical features that are (1) relevant in terms of the notation but not necessarily salient perceptually; and (2) important only after considering different thorough analytical possibilities with respect to the diverse musical motives. The following paragraph explores possible specific musical explanations for these differences between the two dendrograms.

As illustrated in Figure 2.17, the set {TM1,TM2} resembles the set {M12,M13,M14} in terms of speed and rhythm, but the two sets differ greatly in terms of relevant surface features such as texture (polyphonic vs. monodic), timbre (*sul ponticello* vs. natural bow position), and, to a lesser extent, register (medium-low vs. medium-high) and articulation (*non legato* vs. slurred). Similarly, as illustrated in Figure 2.18, M14 is closer to M5 than to M12 in terms of overall melodic contour and texture. With respect to contour, M5 and M14 move slightly upward in a relatively short time at the very beginning and then downward—at the global level, at the same time as wandering through the middle register—for the longer remaining part of the motives, whereas the overall contour of M12 delineates an arch. With regards to texture, M5 and M14 start as compound melodies and end as monodic lines, whereas M12 is clearly compound in its entirety—note the alternation of all pitches with D5.

The importance of surface features in the music-analytical and perceptual motivic structures of *Anthèmes 1* explored in the preceding paragraphs had already been anticipated in connection with the table of musical features summarizing the purely theoretical analysis introduced at the beginning of this chapter (first analysis proposed, shown in Table 2.2).

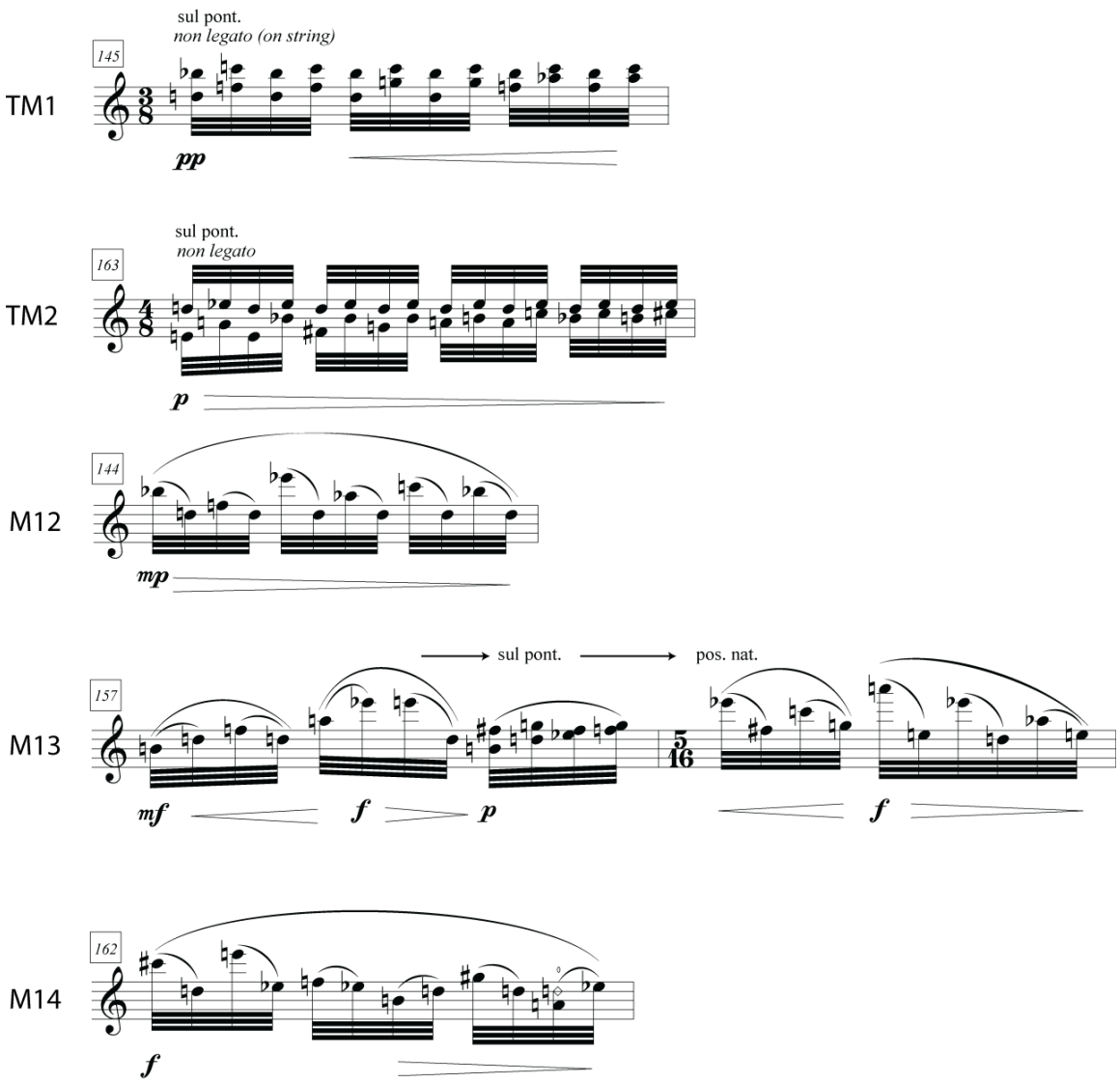

Figure 2.17: Goldman's h group (TM1, TM2, M12, M13, and M14)

This theoretical analysis shows some evident parallelisms with the analysis guided by the perceptual clustering structure discussed above (second analysis proposed, summarized in Table 2.3). Most importantly, the two analyses suggest that the same features acquire a categorically defining role. The features included in the shaded cells in Table 2.2 are basically the same as those listed in the rightmost columns of Table 2.3. Similarly, many features identified as present in some (but not most) motives only in Table 2.2 (features listed in some of the non-shaded cells), such as pitch direction and articulation in the Scale group, are listed in inner columns in Table 2.3.

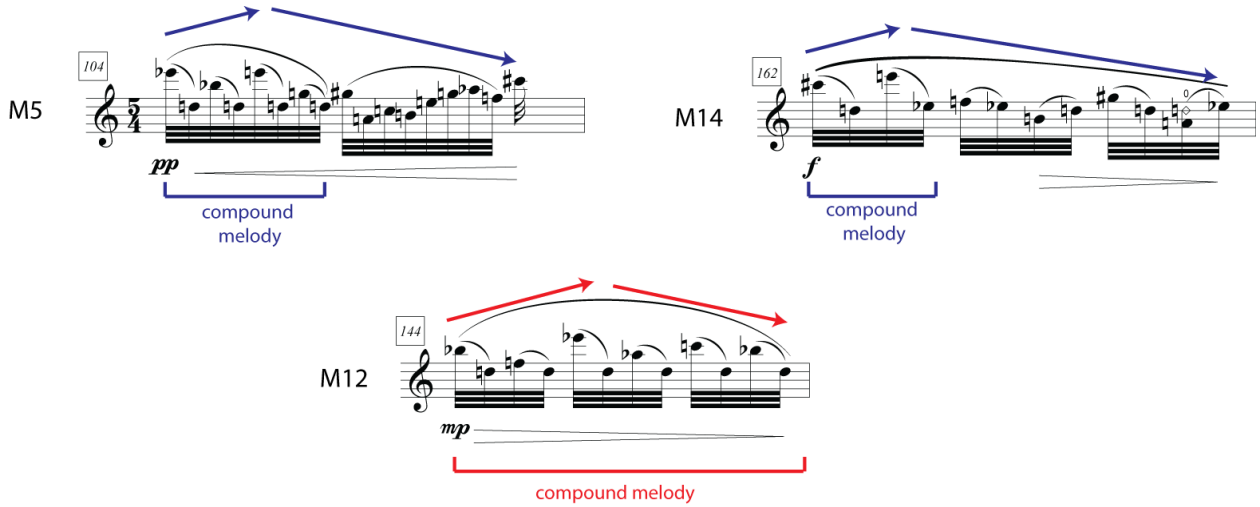

Figure 2.18: M5 vs. M12 and vs. M14

Finally, the two theoretical analyses proposed here and their parallelisms with the perceptual data highlight the importance of surface features for motivic definition in general and confirm previous evidence for the relevance of surface characteristics in music listening. This relevance of surface features for the definition of the motivic structure, which seems intentional in *Anthèmes 1*, demonstrates further connections between Boulez's theoretical conceptions and his compositional practice. In accordance with the composer's notion of musical composition and his specific ideas concerning the perception of motives in *Anthèmes*, Boulez's notation and compositional style at least partly reflect the way listeners categorize the musical materials.

The last two sections have attempted to demonstrate that different analytical methods and perceptual approaches to *Anthèmes 1* lead to similar results, at least in certain important respects concerning the motivic classification of the piece. It is important to recall at this point that the delimitation (segmentation) of the motives used as stimuli for the perceptual experiment was analytically (rather than empirically) determined. For this reason, it is only the categorization of the materials and not the materials themselves that can be said to be analytically and perceptually defined in congruous ways. It is possible (perhaps even probable) that a different selection of materials would have led to a larger number of differences between the theoretical and perceptual perspectives. Nevertheless, it seems at least equally possible that a purely perceptually based segmentation of *Anthèmes 1* (at a low, motivic level) would not have been very different from the

one proposed analytically. This seems particularly probable when considering that the delimitation of the motives in the analysis was based on surface contrasts, which (as discussed in Chapter 1) have been proven to be particularly important for music perception, and the recurrence of the motives throughout the piece. Perhaps even more relevant, the prioritization of surface contrasts and motivic recurrence are both implied, when not directly stated in Boulez's writings about the recognizability and memorability of musical objects presented in Chapter 1. If contrast in the surface and motivic recurrence constituted the basis for the motivic selection used in Experiment 1 for theoretical and analytical reasons, they appear as priorities in Boulez's writings on perceptual grounds.

Whereas Experiment 1 provides important information regarding categorical features of the motivic structure of *Anthèmes 1*, complementing and supporting the analytical study of the composition, Experiment 2 deeply explores the fine-grained aspects of the internal structure of the motivic families observed in Experiment 1 and the theoretical analyses, by discussing an experiment that studies the perceptual similarity of pairs of motives in a more restricted, within-motivic-family context.

Experiment 2: Similarity ratings of motivic pairs

METHOD

Participants

Twenty-three musicians (aged 19-36, M = 23, SD = 4.9, 12 females, all of whom had completed the music theory and musicianship requirements for the Bachelor of Music at McGill University or equivalent) were recruited through email, McGill Classifieds Online, and invitation in high-level music classes held at the Schulich School of Music of McGill University. They were paid for their participation. Before the experiment, participants passed a pure-tone audiometric test using octave-spaced frequencies from 125 Hz to 8 kHz (ISO 389–8, 2004; Martin & Champlin, 2000).[7]

[7] One of the participants showed a threshold higher than 20 db HL for the highest frequency. The participant was still admitted into the experiment based on his notable experience as a musician. Careful examination of the data revealed

Stimuli

The stimuli consisted of 171 pairs of motives built with a selection of stimuli from Experiment 1 (see below), and were amplified through a Grace Design m904 monitor (Grace Digital Audio, San Diego, CA) and presented over Sennheiser HD280 Pro earphones (Sennheiser Electronic GmbH, Wedemark, Germany). Sounds were played at a maximum level ranging from 45dB to 70dB SPL, as measured with a Bruel & Kjaer Type 2205 sound-level meter with a Bruel & Kjær Type 4153 artificial ear (Bruel & Kjær, Nærum, Denmark) to which the headphones were coupled.

From the 54 motives used in Experiment 1, 29 motives were selected for representing a large variety of levels from the clustering analysis (i.e., branches of various heights in Figure 2.11). Fifty to fifty-seven percent of the members of each group were chosen. This includes the pair of motives consisting of a mixture of the Melodic and Trill groups: one motive from the pair was selected. The selected motives are listed in Table 2.4. For each of the main five motivic groups (Table 2.1 and Appendix A), the corresponding selected motivic members were paired in all possible ways accounting for their ordinal position within the pair, i.e., including both possible order successions within each pair (e.g., L3-L4 and L4-L3 were both included as different pairs).

Table 2.4: Motives used as stimuli in Experiment 2.

Long Tone	Pizzicato	Scale	Trill	Melodic	Trill/Melodic
L3, L4, L5, L7	P1, P3, P5, P7	S2, S6, S8, S9, S10, S11	T2, T4, T6, T7, T9, T12, T13	M1, M2, M3, M8, M11, M13, M14	TM1

Note that pairs were built within motivic families only. TM1 was paired with the motives selected from both the Trill and the Melodic groups (i.e., it was treated as a member of both groups). In addition, one pair consisting of two presentations of the same motive was included in each motivic group and was chosen randomly for each participant. Identical pairs were included for quality control of the data.

no important differences between the types of responses given by this musician and the remaining participants. Therefore, his data were included in the final analysis.

Procedure

The experiment was divided into five blocks corresponding to the five motivic families. The order of the blocks was randomized. Each block consisted of three parts: (1) familiarization phase, (2) similarity ratings, and (3) ratings of importance given to a list of musical features during the completion of the second part. During the familiarization phase, participants heard twice all the members of a group played in random order, and were instructed to form an idea of the range of variation among all the motives during this part. In part 2, participants heard one of the pairs of motives from the group, and provided a similarity rating on a continuous scale that ranged from identical to very dissimilar. Specifically, participants were asked to use the slider to indicate how much the motive played second resembled the motive played first. Participants were explicitly told to use the rating scale independently for each motivic group and were told that the aim of the familiarization phase was to help them understand how to use the scale. The motives of a pair were represented by rectangles on the computer screen that lit up while the motives were playing. The rectangle corresponding to the motive played first appeared to the left of the computer screen, and the one corresponding to the motive played second, to the right. The motives were played automatically the first time. Participants then had the option to play each or both of the motives from the pair one more time. Once participants had provided ratings for all the pairs in a group, they rated the importance of the following musical features for their judgments (part 3): (1) length—duration of stimuli, (2) speed/tempo, (3) rhythm, (4) articulation/bowing technique, (5) timbre—tone color, (6) intensity, (7) register, (8) pitch contour—overall shape of melody, (9) pitch content—individual musical notes, (10) transition between Motif 1 and Motif 2—whether Motif 2 sounded as a continuation to Motif 1 or not, (11) character/mood, (12) beginnings of the motifs, (13) endings of the motifs, and (14) texture. In addition, participants had the option to input up to three extra features not mentioned in the questionnaire. The rating scale was a 5-point importance scale with the following labels: not important, slightly important, moderately important, important, and very important.

All participants read the instructions and were then asked to explain them to the experimenter. The experimental trials were preceded by a practice trial monitored and assisted by the experimenter. The stimuli used during the practice trial were absent from the experimental trials (specifically, they were motives T11, T3, and TM2). During the practice trial, participants

had the opportunity to clarify any doubts concerning the procedure as well as the meaning of the musical features presented in the questionnaire of part 3.

Data Analysis and its Musical Meaning

With respect to the first two parts of the experiment, five data analyses of the dissimilarity ratings for pairs of motives lead to the following dissimilarity measures:

1. dissimilarity means for each motive with respect to all the members in its family;
2. dissimilarity means for each motivic family as a whole;
3. asymmetry indices for each pair of motives;
4. mean asymmetry index for each motive with respect to all remaining motives in its motivic family; and
5. mean asymmetry index for each motivic family as a whole.

The next subsection provides a basic explanation of these mathematical measures focusing on their musical significance. The technical details of the data analyses associated with these measures, including significance tests (where applicable), are explained in a subsequent section.

With respect to the third part of the experiment (importance ratings of a list of musical features), special attention was given to the Transition feature. This was done because the transition feature was specific to Experiment 2, and relatively high importance ratings for this feature would indicate that the order of the motives within the pair was perceptually relevant. With respect to the remaining musical features, the purpose of the questionnaire was to compare strategies used for the tasks of Experiments 2 and 3 (similarity ratings vs. choosing the best representative, as described in the introduction of this chapter). Therefore, the data corresponding to those features are discussed only in connection with the data obtained from an equivalent questionnaire given to the participants in Experiment 3 (see Data Analysis and Results in Experiment 3).

The musical meaning of dissimilarity means and asymmetry indices

Measure 1 (dissimilarity means for each motive with respect to all the members in its family) provides information about the degree to which each member of a group perceptually resembles the other members (e.g., which motives are more similar to most motives in the group

and which ones are more dissimilar). The musical meaning of this measure was anticipated in connection with the explanation of the purposes of the experiments in the introductory section of this chapter. In the context of Experiment 2, similarity ratings can range from 0 to 1, with 0 meaning identical and 1 very dissimilar. Following this, the motive with the lowest dissimilarity mean is the member that is most similar to most of the other members in the group, or, in more abstract terms, the member that is most centered in the dissimilarity space of the motivic family. As explained in the introduction of this chapter, this measure plays an essential role in the selection of the stimuli for Experiments 4 and 5.

Measure 2 (dissimilarity means for each motivic family) quantifies aspects related to the internal consistency of the motivic families as it provides a value of how dissimilar the members of a group are to each other on average. A family in which all of the motives are very similar to each other is more consistently defined across all its members. Experiment 2 should provide a more accurate, refined measure of the internal dissimilarity of the groups than Experiment 1 (i.e., measure 2 presented here should be more accurate than row 6 in Table 2.2). In Experiment 2, participants had access to the motives of each group in separate experimental blocks and were explicitly told to consider each group independently in their responses, whereas in Experiment 1 participants had access to all the motives from all the groups at all times and were asked to complete a task that necessarily involved the comparison of the motives across the groups. Following this, in Experiment 2, across-group dissimilarity relationships could have only played a minimum (if any) role, whereas in Experiment 1, the internal dissimilarity of the groups should have been affected by across-group judgments. As has been demonstrated by previous research (discussed in Chapter 1), context plays an important role in similarity decisions. In Experiment 1, the availability of stimuli from all groups at each experimental step and the task are likely to have influenced participants to pay more attention to distinctive features *across* motivic groups rather than *within* them. In addition, the larger stimulus context of Experiment 1 is likely to have increased the perceived similarity among the motives within each group, presumably by making the common features within the group more obvious (as demonstrated by previous research). In Experiment 2, where the context was reduced to the motives belonging to each motivic family and participants were told to make dissimilarity judgments independently for each motivic family, differences across motivic groups should have had a null or minimum effect and distinctive features within motivic groups should have been more readily accessible to the participants. In this

sense, the dissimilarity means for each motivic family derived from Experiment 2 should reflect more accurately the distinctive features among the members of the same group, whereas the internal dissimilarity averages taken from the clustering analysis of Experiment 1 (presented in Table 2.2) should measure more directly distinctive features (or lack thereof) across the motivic families and common characteristics within them.

Measure 3 (asymmetry indices for each motivic pair) compares the perceived similarity values corresponding to the two possible orders of each motivic pair:(x,y) vs. (y,x). Specifically, the measure reflects whether the similarity of a pair of motives is or not affected by the referential or comparison role with which the motives are introduced and, presumably, by the order in which they are played (recall that in this experiment, the motive played first explicitly acquires a referential function). Ultimately, this measure could have important implications for understanding how the order in which motivic materials are stated throughout a musical composition could affect the way listeners and analysts make sense of the motivic and formal structure of the piece. In the context of this study, the concept of asymmetry is directly linked to the referential or comparison role taken by the musical materials. As a result, the concept of asymmetry can be associated with the theoretical and more intuitive notion of musical variation. The relationship of a motive that serves as reference to another one is of similar kind as that of a musical material that is conceived as the model for a musical variation or elaboration. Comparably, variations are often perceived in relationship to the musical models from which they are created rather than the reverse. If the perceived similarity of motivic pairs can be asymmetric, then, the order in which two motives x and y appear within the piece could affect whether motive x is understood—either perceptually or analytically—as: (1) similar to y or completely unrelated to it in the first place—an aspect determined by the degree of similarity of the two motives, (2) a variation of y, or (3) the model for variation y. Furthermore, the perception of the pair of motives x/y could be affected by memories resembling motives x and/or y that could serve as references to listeners and analysts. In this experiment, a motive with a negative asymmetry index with respect to another motive works better as reference in the context in which the stimuli and the task were described to the participants. Note that this is consistent with Rosch's idea (introduced in Chapter 1) that the similarity of the variant to the reference is larger than the reverse.

Measure 4 (mean asymmetry index for each motive with respect to all remaining motives in its motivic family) combines all the asymmetry indices associated with a motive, providing information about the capacity of that motive to alter similarity relations with the remaining motives in its group depending on whether it acquires a referential or comparison function and/or the position in which it is played. The motive with the largest negative mean asymmetry within a group minimizes its own perceived similarity to the remaining motives in the group when it is introduced as the reference and played first. In this sense, the motive with such characteristics works better as a reference or as a musical model than as a comparison element or musical variant. Conversely, the motive with the largest positive mean asymmetry within a group minimizes its own perceived similarity to the remaining motives in the group when it is played second. The position of motives with relatively large mean asymmetries within a musical composition is likely to affect the listeners' formation of similarity relationships and, in turn, their understanding of the motivic structure of the piece.

Finally, *Measure 5* (mean asymmetry index for each motivic family as a whole) computes an overall asymmetry value for each motivic family. This analysis aims to describe the internal structure of the motivic families in terms of the asymmetric similarity relationships between each of their component motives and the remaining members. The measure provides a general idea of the degree to which the order of presentation of all the component motivic members affects the perceived internal dissimilarity of the motivic family (as a whole). In this sense, a motivic category with a relatively high mean asymmetry index indicates that, in general, the order in which its motivic members are presented and/or the referential function that they acquire is likely to affect their perceived similarity. In this way, Measure 5 contributes to the understanding of the effects of order of presentation and referential function on perceived similarity of motivic materials belonging to the same class (i.e., materials that are to some degree variations/transformations of one another).

Data analysis and statistical tests

This section describes the technical details of the data analysis and the statistical tests. The following paragraphs explain the five measures corresponding to the first two parts of the experiment (similarity ratings). A description of the analysis corresponding to the third part (features questionnaire) appears at the end of this section.

Measure 1 consists of the average of the dissimilarity ratings given to all the motivic pairs involving a given motive, and it was calculated for each motive within each motivic family. For instance, the dissimilarity mean for L3 was computed by adding the mean dissimilarity ratings for the pairs L3-L4, L3-L5, L3-L7, L4-L3, L5-L3, and L7-L3 (Table 2.4), and dividing by 6. No statistical tests were applied to these values, because their purpose was simply to quantify the degree of dissimilarity of each motive within its group.

Measure 2 was obtained by averaging the ratings corresponding to all motivic pairs within each motivic family. It combined all the values obtained in the first analysis per motivic family. This second measure was used mainly for descriptive purposes. Nevertheless, t-tests[8] were performed on all possible pairs of motivic groups, applying Bonferroni-Holm[9] corrections for multiple comparisons.

With respect to Measure 3, the asymmetry index for the motivic pair x/y was calculated by subtracting the mean dissimilarity rating of (y,x) from that of (x,y): $Asymmetry_{(xy)} = M_{(x,y)} - M_{(y,x)}$. According to this equation, a motivic pair whose similarity is perceived in a perfectly symmetric way would have an asymmetry value of zero. The statistical significance of the asymmetry indices was tested by comparing the data corresponding to each motivic pair against zero, using Wilcoxon tests and applying [within-motivic-groups] Bonferroni-Holm correction for multiple comparisons.

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[8] T-tests and Wilcoxon tests are hypothesis tests used to examine whether the means (t-test) or mean ranks (Wilcoxon) of two data samples are the same or different in terms of statistical significance. Both tests take into consideration the variance among the data points in each sample. Wilcoxon are non-parametric tests used as an alternative to t-tests when the data samples do not meet the normality assumption (the two data samples are not normally distributed in the case of samples coming from different groups of participants, or the difference scores between paired data points between the two samples are not normally distributed in the case of samples coming from the same group of participants).The distribution of the difference scores (for comparisons of dependent data sets) or scores (for comparisons of independent data sets) was checked for every pairwise comparison test described in this dissertation. T-tests were performed when the data were normally distributed, whereas Wilcoxon tests were applied when the data were not normally distributed. Mann-Whitney Wilcoxon tests or independent-sample t-tests were run when comparing independent samples, and Signed-rank Wilcoxon tests or paired-sample t-tests were performed when comparing dependent samples.

[9] Bonferroni-Holm is a method that controls for possible type-1 errors—incorrect rejections of true null hypotheses—decreasing the probability of making false judgments when multiple hypotheses are being tested. The method sequentially adjusts the p-values obtained for multiple contrast tests based on both the total number of [planned] tests (hypotheses to be tested) and the obtained p-values.

Measure 3 provides important information about the perceived similarity relationships between each motive and each of the other members individually. Nevertheless, it does not directly reflect the degree of asymmetry for each motive within its group as a whole. In order to understand the asymmetric relationship of each motive with respect to all the members in its group (i.e., with respect to the entire group rather than to each member individually), Measure 4 averages the asymmetry indices corresponding to all pairs involving a given motive. For instance, the mean asymmetry index for L3 is equivalent to the average of the asymmetry indices for L3/L4, L3/L5, and L3/L7 (because L3, L4, L5, and L7 are the members of the Long Tone group). This was done with all the motives in each group. The statistical tests performed in relationship to Measure 4 were equivalent to those applied to Measure 3 (with the only exception that t-tests rather than Wilcoxon tests were performed for the Scale group).

Finally, Measure 5 averages the asymmetry indices for all motivic pairs in a group, quantifying, in this way, how asymmetric/symmetric a motivic family is as a whole. The statistical significance of the values obtained from this last analysis was tested by comparing the mean asymmetry values of each motivic group against zero, applying Bonferroni-Holm correction for multiple comparisons. A Wilcoxon test was performed on the data corresponding to the Pizzicato group.

With respect to the third part of the experiment, the data from the questionnaire in which the participants rated the importance of musical features (part 3) were converted from an ordinal to an interval scale, with values 1 to 5 corresponding to the labels “not important,” “slightly important,” “moderately important,” “important,” and “very important,” respectively. Means were calculated for each feature (these data were used later in connection with Experiment 3). Mann-Whitney Wilcoxon tests compared the ratings of the transition feature (feature 11) against different values of the rating scale in order to determine its degree of importance for the participants’ judgments. Multiple comparison tests were run because, even when all the means were greater than “slightly significant”, they were not necessarily significantly different from “slightly significant.”

RESULTS AND DISCUSSION

The dissimilarity means for each motive (Measure 1) are illustrated in Figure 2.19. Dissimilarity means are shown on the y-axis, with zero corresponding to perfectly similar and 1 corresponding to very dissimilar. Individual motives are displayed along the x-axis. Note that there are 30 rather than 29 motives, because TM1 appears as member of both the Trill and Melodic groups. Different groups are represented in different colors. The motives with the lowest dissimilarity means for each group correspond to the striped bars. As shown, L4, S2, T13, M8, and P5 are most similar to all other motives in their group, and are, in that sense, representative of their group. Note that, with the exception of T13, these motives are relatively easy to differentiate from the motive with the second-lowest dissimilarity mean.

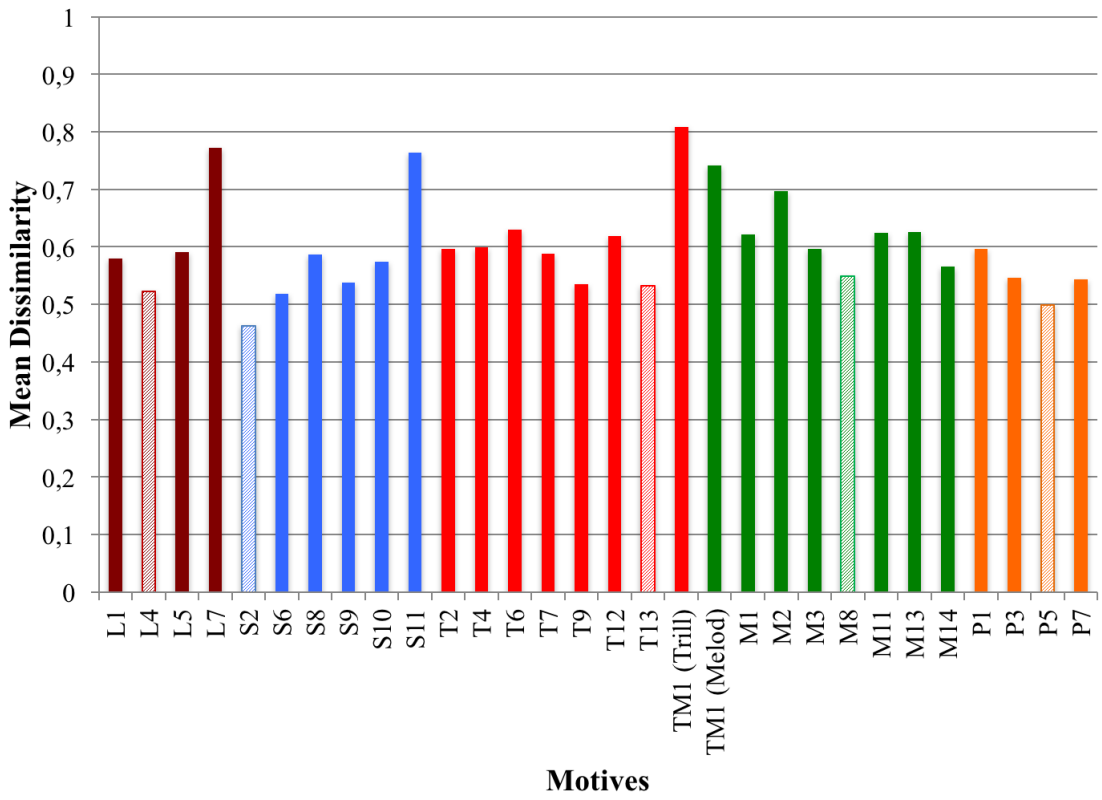

Figure 2.19: Dissimilarity means for each motive (measure 1, Experiment 2)

The dissimilarity mean of T13 is remarkably similar to that of T9, because both T13 and T9 consist of a single trilling note. In this sense, T13 and T9 are two equivalent versions of the same motive.

The motives with lowest dissimilarity means will be reintroduced and further discussed in connection with Experiments 4 and 5.

As suggested by the figure, L7, S11, and TM1 stand out from their group due to their high dissimilarity means. This is consistent with the clustering tree (Figure 2.11) and feature analysis (Table 2.3) presented in Experiment 1. As shown in Table 2.3, L7 is the only motive without glissando from its group, and S11 is the slowest motive in its family. Furthermore, S11 and S8 are the only slurred motives in the Scale group and they are both relatively slower than the rest of the motives (with S11 being the slowest one). It is presumably due to these characteristics that motives S11 and S8 have the two highest dissimilarity means in the Scale group. As expected, TM1 was rated as being very dissimilar with respect to all motives in both the Trill and Melodic group. Nevertheless, the motive better fits the dissimilarity-mean profile of the Melodic group, whereas it is more clearly an outlier in the Trill group. In the Melodic group, many motives have a relatively high dissimilarity mean, ranging from .55 to .70, and the difference between the most dissimilar member of the group (i.e., M2) and TM1 is relatively small (.04). In the trill group, on the other hand, the dissimilarity means range from .53 to .63, and consequently, the dissimilarity mean of .81 from TM1 stands out, differing by .18 from the next most dissimilar motive. Furthermore, TM1 within the Trill group is the motive with the highest dissimilarity mean overall. The better fit of TM1 within the Melodic group is consistent with Goldman's analysis, according to which TM1 is classified within the same category as what is here M13 and M14. Nevertheless, overall, the high dissimilarity mean of TM1 in both the Melodic and Trill groups reflects its uncertain membership status.

A comparison of the dissimilarity means obtained for each motive in Experiments 1 and 2 contributes to the understanding of the effects of task and context. Figure 2.20 illustrates the dissimilarity means for individual motives according to the two experiments. Full colors show means according to the similarity-ratings experiment and transparent colors illustrate averages according to the free-categorization experiment. Three important aspects can be inferred from the figure: (1) dissimilarity perception tends to be generally—although not always—higher when the motives are presented as back-to-back pairs within their families—as in Experiment 2, (2) the perceived dissimilarity of some motives appears to be more robust to task and context than that of other motives, and (3) the distribution of most similarly and dissimilarly perceived motives in each

group seems to depend at least partly on the task and context. Note that points 2 and 3 are related, but point 3 refers to a more global effect.

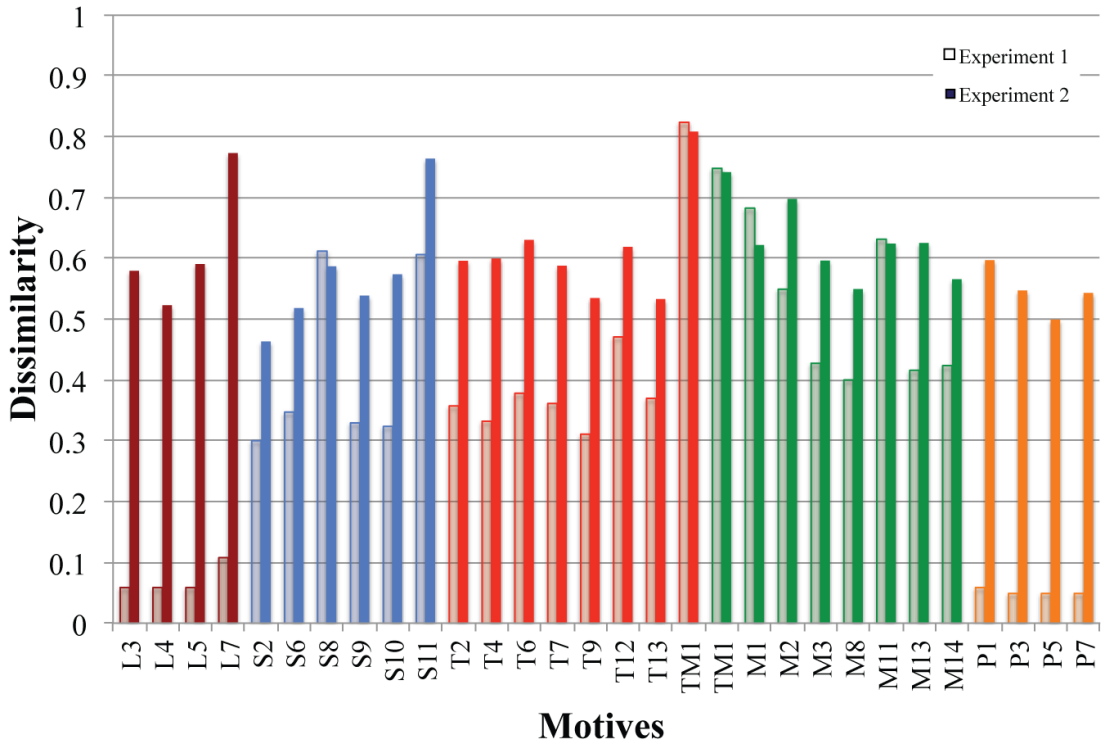

Figure 2.20: Dissimilarity means for individual motives in Experiments 1 (transparent color) and 2 (full color)

The first aspect suggests that the differences between the members of a family become more obvious to the listener in a restricted, within-family context. The higher levels of dissimilarity implied by Experiment 2 are particularly evident for the Long Tone and Pizzicato groups, the two groups that were more robust in the across-family context. This suggests that it is the distinctive characteristics of each of these groups with respect to the other groups, rather than the lack of internal differences among their members, that make these two groups perceptually independent (i.e., the within-group conditions suggest that the members of the groups were quite different to each other). The idea that the descriptive, defining elements of these two groups are clearly differentiated from the essential features of the remaining groups has already been suggested by

the discussion of Experiment 1 in connection with the second motivic analysis presented above. As is evident from Figure 2.20, important differences among the motivic members of the Pizzicato and Long Tone groups become more obvious to the listener when the context is restricted in Experiment 2.

The second aspect is evident when comparing characteristics of the motives that led to similar values of perceived similarity in both experiments with features of the motives that received clearly different similarity judgments in the two experimental settings. S8 and S11 are among the clearest examples of this case. Shown in Figure 2.21, these two motives were the only materials with slurred articulation, crescendo dynamic profile, and relatively slow speed belonging to the Scale group used in Experiment 2. The rest of the motives in the group are characterized by *jeté* articulation, soft and constant dynamic profile, and fast speed. The slurred articulation and relatively slow speed of S8 and S11 mark important contrasts between these two motives and the rest of the motives in terms of surface features. In line with the discussion about surface features presented above, the marked differences (in terms of surface features) between S8 or S11 and the rest of the motives in the group are likely to have affected the belongingness of S8 and S11 to the Scale group during the free categorization task (i.e., the contrasting articulation, dynamic speed, and speed of these two motives might have caused some participants to place them in a separate group). Furthermore, it seems relevant that the relatively slow speed and slurred articulation of S8 and S11 are important characteristics of other motivic groups (mostly the Melodic and Trill groups).

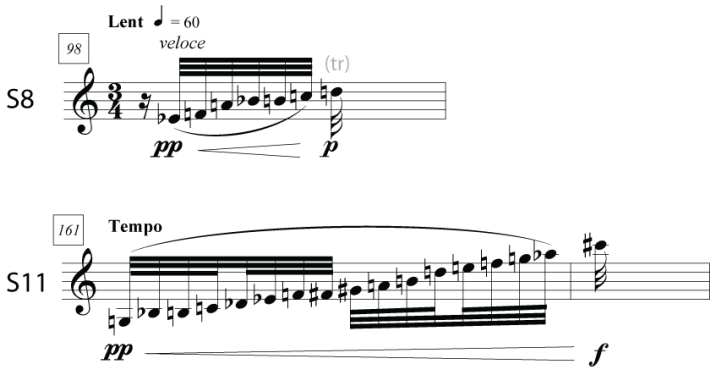

Figure 2.21: S8 and S11

Moving on to the third aspect observed from Figure 2.20, the distribution of dissimilarity means for the individual motives appears to be quite robust across contexts for the Long Tone, Pizzicato, Scale, and Trill groups and less robust for the Melodic group. This can be seen in the figure by comparing the overall contour delineated by the transparent and dark bars for each motivic family. With respect to the difference in perceived similarity manifested for the Melodic group, note especially that M2 was perceived as the most dissimilar motive when presented in the restricted context of its motivic family, whereas it was perceived as relatively similar to most motives when presented in across-family conditions (in which case M1 and M11—apart from TM1—were perceived as the most dissimilar motives in the group). It seems relevant that M2 (shown in Figure 2.2) presents important differences with the other motives in the group. More specifically, the motive is rhythmically quite diverse, not clearly compound in texture, relatively longer, and formally more complex. Most importantly, the characteristics that differentiate M2 from the other motives in its group do not constitute defining features of the remaining motivic families. Specifically, M2 does not feature long tones, trills, pizzicato articulation, or scales. As a result, the within-group distinctive features of M2 did not greatly affect its placement within the Melodic group in across-family conditions.

The effects of task and context discussed above are further supported at a more general (family-based rather than motivic) level by a comparison of the dissimilarity means obtained for each motivic family in the two experiments. The dissimilarity means for each motivic family as a whole (Measure 2) according to Experiment 2 are illustrated in dark gray in Figure 2.22. The error bars show the standard error of the mean.

In order to deeply understand the differences between the internal dissimilarity of the five groups, contrasts tests were performed on all pairs of means. Paired-sample t-tests revealed that, after applying Bonferroni-Holm correction for multiple comparisons, only the Scale and Melodic groups had significantly different dissimilarity means in statistical terms. Nevertheless, the difference between the dissimilarity means of the Pizzicato group with respect to the Long Tone, Trill, and Melodic groups, as well as that of the Scale group with respect to the Trill group were close to statistical significance (and were all smaller than $p = .02$ before the Bonferroni-Holm adjustment). This suggests that the Scale and Pizzicato groups are composed of motivic members that are more similar to each other than are the members of the remaining three groups.

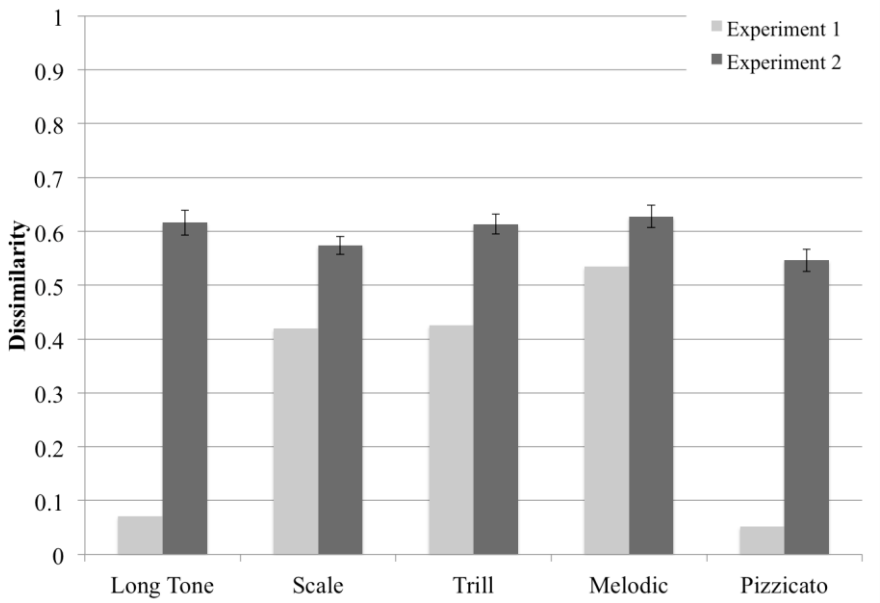

Figure 2.22: Comparison of dissimilarity means obtained in Experiments 1 and 2

As is the case for the dissimilarity means of the individual motives discussed above, the dissimilarity means for the families presented here highlight important differences with Experiment 1. As will be proposed below, these differences, in turn, elucidate aspects of motivic similarity perception.

The results of Experiment 2 suggests the following with respect to the internal dissimilarity of the groups: (1) the Pizzicato group has the lowest internal dissimilarity from all the group: M = .55, (2) the Scale group has the second-lowest internal dissimilarity: M = .57, and (3) the Trill, Long Tone, and Melodic groups have relatively high internal dissimilarity: M = .61, .62, and .63, respectively. On the other hand, the internal dissimilarity averages obtained from Experiment 1 suggest the following: (1) the Long Tone and Pizzicato groups have relatively low internal dissimilarity: M = .04 in both cases, (2) the Scale and Trill groups have relatively medium average internal dissimilarity values: M = .18 in both cases, and (3) the Melodic group has a considerably higher average internal dissimilarity value: M = .26. The differences between the dissimilarity means for each motivic family according to the two experiments are illustrated in Figure 2.22. Darker grey corresponds to Experiment 2. The differences are in line with the effect of context discussed in the musical examples above. They further support the conjecture that the relatively large context of readily available across-group stimulus comparisons in Experiment 1

possibly led participants to pay special attention to distinctive features across the members of the motivic groups and to common features within the members of each group. Conversely, the more restricted within-group stimulus context in Experiment 2 possibly increased the importance that participants gave to the features that differentiated the motives within each group, since those distinctive features were most exposed during the task. Even when it is not possible to rule out a global context effect across the entire duration of Experiment 2, within-group characteristics should have played a more important role, considering the instructions given to the participants and the experimental task. Finally, the average internal dissimilarity values derived from Experiment 2 are more refined than the dissimilarity means obtained from Experiment 1 in the sense that they more exclusively account for within-group (internal) similarity relationships.

Moving on to the asymmetric properties of the motivic groups, the mean asymmetry indices for each motivic family as a whole (Measure 5) are shown in Figure 2.23. In the figure, a value of zero along the y-axis represents perfect symmetry. The higher on the y-axis, the more the perceived similarity of a pair of motives is affected by the referential/comparison role with which the motives are conceived by the listener, and, presumably, by the order in which the motives are played. Single-sample t-tests (against 0) suggest that, in general, the similarity among the motivic members of each group is asymmetrically perceived: $t(1,22)= 10.05$, 17.50, 14.43, 16.29 for the Long Tone, Trill, Scale, and Melodic groups, respectively, and $z = –4.20$ for the Pizzicato group, with $p < .0001$ for all five groups. These results suggest that, overall, the order of presentation and/or referential function assigned to the motives of a group affected the way participants perceived their similarity with respect to other motives in the same category. The idea that the referential role acquired by the motives or the order in which they were played was an important factor in the participants' similarity judgments is supported by their ratings of the transition feature in the questionnaire (part 3 of the experiment). This feature, which explicitly referred to the connection between the first and second motives in the pair, received average ratings ranging between slightly important and moderately important in all the groups. The averages were higher for the Long Tone and Melodic groups ($M = 2.78$), followed by the Pizzicato, Trill, and Scale groups ($M = 2.61$, 2.52, and 2.17, respectively). Mann-Whitney Wilcoxon tests revealed that mean rating for the transition feature in the Long Tone, Melodic, Pizzicato, and Trill groups, was not significantly lower (less important) than "moderately important" ($p > .1$). More specifically, the mean rating for the transition feature was significantly higher (i.e., more important) than "slightly important" for the

Long Tone and Melodic groups (p = .019 and .029, respectively), and significantly higher than "not important" for the Pizzicato, Scale, and Trill groups (p = .001 in all 3 cases). In sum, the order in which the motives were played had a significant influence on the participants' similarity judgments.

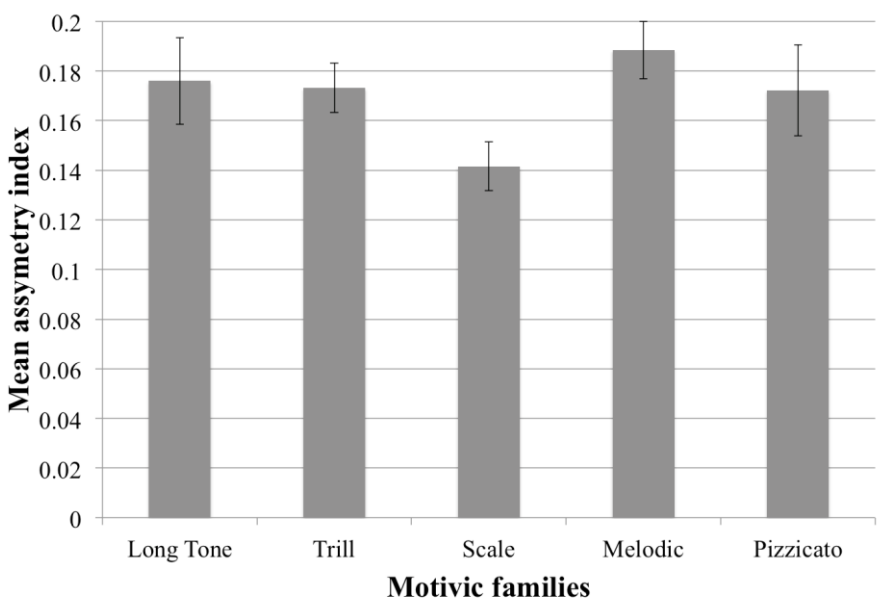

Figure 2.23: Asymmetry means for the motivic families

The asymmetry index for each pair of motives (Measure 3) and the mean asymmetry index for each motive with respect to all remaining motives in its family (Measure 4) revealed that certain motives had a relatively strong tendency to alter perceived similarity relationships depending on the order in which they were presented and/or on whether they were assigned a referential (or comparison) role. A theoretical, score-based analysis of the motives associated with larger asymmetry values revealed certain consistent features among them that could presumably start explaining issues of asymmetry in motivic similarity perception. Only a few motivic pairs and motives proved to be significantly asymmetric in statistical terms after applying Bonferroni-Holm correction for multiple comparisons. These pairs along with the pairs that gave a relatively large (though not statistically significant) asymmetry index are described in detail in the following section. Even when the statistical evidence for the perceptual validity of motivic asymmetries

presented here is weak, the recurrence of features among the motives associated with larger asymmetries tends toward theoretical support for the asymmetric perception of motivic similarity.

To conclude, the idea that the perception of motivic similarity can be asymmetric is supported by four points:

1. the statistically significant asymmetry means of the five motivic groups (Measure 5);
2. the participants' ratings of the transition feature reflecting importance given to the order in which the motives were played;
3. the few motives with statistically significant asymmetries (Measures 3 and 4); and
4. the consistency in the features among the motives associated with relatively large asymmetry values revealed by the theoretical analysis.

The last two points are developed and exemplified in the following section.

A theoretical model for the asymmetric perception of motivic similarity

This section proposes an analysis of the motivic pairs and motives associated with the larger asymmetry values with two purposes. Overall, the analysis provides theoretical support for the asymmetric perception of motivic similarity, by highlighting common features observed among the motives associated with larger asymmetry values. By linking specific musical characteristics with motives whose similarity was perceived relatively asymmetrically, the analysis starts developing a theoretical model for asymmetric similarity of musical motives, a notion that has been absent from the theoretical discourse and is likely to have important implications for the development of analytical tools. As explained above, the asymmetrical perception of the similarity between two motives implies that the reference/comparison or model/variation role acquired—either explicitly or through the listener's judgment—by each motive and/or their order of presentation affects the perceived similarity of the pair. If the perception of motivic similarity is indeed asymmetric, as directly suggested by the evidence presented in the previous section, understanding the specific musical features associated with the phenomenon of asymmetry constitutes the initial step towards the development of a perceptually valid theory of motivic similarity. This could in turn be relevant for models of musical form, because formal structure and motivic similarity have always been strongly interconnected in the theoretical and analytical literature (see Chapter 1). Furthermore, the asymmetric perception of the

similarity of musical materials appears to be linked to concepts that are directly related to form, such as model/variation and temporal distribution.

Based on the above and the interpretation of the experimental findings presented below, I propose that three factors are associated with the phenomenon of asymmetry in similarity perception: (1) abstract knowledge structures, (2) location of common features, and (3) intrinsic formal function of the motives. The discussion is organized according to these factors, with the aim of better conveying the theoretical model that it attempts to propose. The interpretation is supported with analytical explanations for motives that gave relatively large mean asymmetry indices in general (Measure 4 or mean asymmetry index for an individual motive with respect to all motives in its group) and with respect to a specific motive (Measure 3 or mean asymmetry index for specific pairs of motives). Statistics are indicated only for asymmetry indices that were significant.

Abstract knowledge structures: Implicitly learned musical patterns

In music listening, abstract knowledge structures refer to musical patterns learned implicitly, i.e., through exposure and experience (McAdams, 1989). McAdams distinguishes two types of abstract knowledge structures: (1) "systems of relations among musical categories," and (2) a "lexicon of abstract patterns that are often encountered" (McAdams, 1989, 183). The first kind refers to atemporal properties that contribute to the most fundamental organization of parameters within a musical system, such as scale structures and tonal relationships. The second type includes temporal structures that occur frequently in a style, such as familiar rhythmic or melodic patterns and cadential formulae. Abstract knowledge structures directly influence the formation of expectations during music listening. As a result, they play a central role in the way listeners establish the relationships between events more or less separated in time that eventually lead to their experience of the musical form.

In line with this, abstract knowledge structures (of any of the two types mentioned above) tend to work as implicit references during music listening, in the sense that it is only through their activation that musical expectations, and in turn any experiences of musical form, can take place. A few motives from *Anthèmes 1* can be considered abstract knowledge structures of type 2 above. The simplest version of the scale, the single trill, and the simple long tone are abstract knowledge

structures in the sense that they correspond to temporal patterns that are implicitly learned due to their frequent occurrence in Western music. Successions of musical pitches delineating scales are perhaps the most common basic melodic patterns in Western music. In this sense, a simple scale is a clear example of abstract knowledge structures of type 2. The trill and long tone can be interpreted as very simple abstract knowledge structures of type 2, in the sense that they constitute two of the most basic and commonly used musical icons in the history of Western music whose very definition depends on their temporal evolution. Furthermore, they are implicitly learned musical icons that tend to be associated with specific musical situations. For instance, relatively long tones often constitute the end of a phrase and trills most naturally occur with ornamentation purposes. In this sense, simple long tones and single trills evoke abstract signification. Accordingly, the trill and long tone can be seen as examples of the lexicon of frequently encountered abstract patterns.

Considering the function that abstract knowledge structures play in the formation of expectations and formal experiences, it is expected that those motives from *Anthèmes 1* resembling abstract knowledge structures will work better as reference than comparison objects. Because listeners normally, implicitly, and automatically evoke abstract knowledge structures as points of reference for comparison of the ongoing music, the explicit appearance (physical presence) of those structures in the music should facilitate the comparison process (establishment of event relationships) and formation of expectations going on in the mind of the listeners. As a result, abstract knowledge structures that are explicitly stated as musical materials should increase the perceived similarity of relatively similar yet different materials when the former materials work as explicit references. In Experiment 2, the participants were explicitly and clearly told that the motive played first was to be considered the reference. Therefore, at least in the context of this experiment, it is expected that motives consisting of abstract knowledge structures—specifically, the simplest scales, single trills, and simple long tones (based on the justification above)—will be perceived as more similar to all other materials in their group when they initiate the pair of motives heard by the participants. In other words, the perceived similarity of a motive resembling an abstract knowledge structure to the other motives in the group should be larger when the former is played as the reference than when it is played as the variant. In line with the hypothesis proposed here and recalling that the asymmetry index of a pair of motives (x,y) was calculated by subtracting the perceived similarity of y to x from the similarity of x to y, motives resembling abstract

knowledge structures (including musical icons frequently encountered in music) should correspond to motives with relatively high negative asymmetry indices according to the results of Experiment 2.

Accordingly, the motives with the most negative mean asymmetry indices (measure 4) for the Long Tone and Trill groups were L7 ($z = -2.50$, p[10] = .014, the plain long tone (concert pitch D5), and T13, the trill in the middle register (D5-E♭5), respectively. In the Scale group, all motives are scale patterns, and, in that sense, temporal abstract knowledge structures. Nevertheless, some of the materials are more basic scalar patterns than others. A scale can be defined as a collection of relatively similar pitches arranged in ascending and/or descending order in the pitch space. Theoretically and acoustically, all scales can be interpreted as discretization systems derived from the pitch continuum. In terms of patterns encountered in Western music, the closest representation of the pitch continuum is a glissando, i.e., an ordered collection of the maximum number of pitch heights possible according to the instrument capabilities and instrumental techniques used (e.g., a glissando played with a continuous bow in the violin is likely to traverse the entire pitch continuum for the given range, whereas a glissando produced by rapidly sliding the hand on a regular piano is a mere chromatic scale). Following this rationale, the common musical pattern underlying all scales is a glissando, and a technically (in terms of instrument techniques) articulated (discretized) version of a glissando constitutes the most basic scalar pattern possible in music. As shown in Figure 2.24, motive S10 features two voices that are the result of double-stops. The top voice is a repeated D5, whereas the bottom line consists of a descending "glissando" in which the component pitches are discretized with the *portato* articulation. The repeated note in the middle register can be seen as an abstract knowledge structure in the sense that, like the long tone, it is a pattern frequently encountered in music. In addition, probably due to its melodic contour and perhaps also to the intention of the performer, the bottom line is perceptually more salient. Motive S10 can then be analyzed as a rudimentary (basic) descending scale (articulated glissando) glimmered with a repeated note. Presumably due to its close resemblance to the most basic representation of a scale, S10 was the motive with the largest negative mean asymmetry value in the Scale group. Finally, T12, L7, and S10, which can be

[10] All the p-values reported throughout this chapter are corrected for multiple comparisons.

considered musical manifestations of abstract knowledge structures, are the motives that most highly affected perceived similarity depending on their referential role for the listener. Specifically, and as expected according to the role that abstract knowledge structures play in music listening, these motives increase their perceived similarity relationships with the remaining materials in their group when they were introduced as references (and played first).

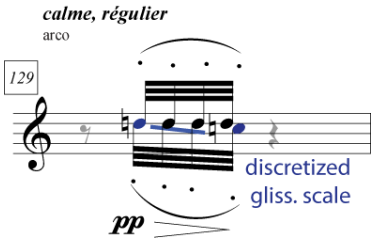

Figure 2.24: Motive S10, most negatively asymmetric motive in the Scale group

The role that abstract knowledge structures appear to play in similarity perception can be further supported with examples of specific pairs of motives. In the Scale group, the motivic pairs with largest asymmetry values involved S10. Particularly obvious in the pairs S10/S6 and S10/S2 (Figure 2.25), the members of the pair were perceived as being more similar to each other when S10 was presented as the reference.

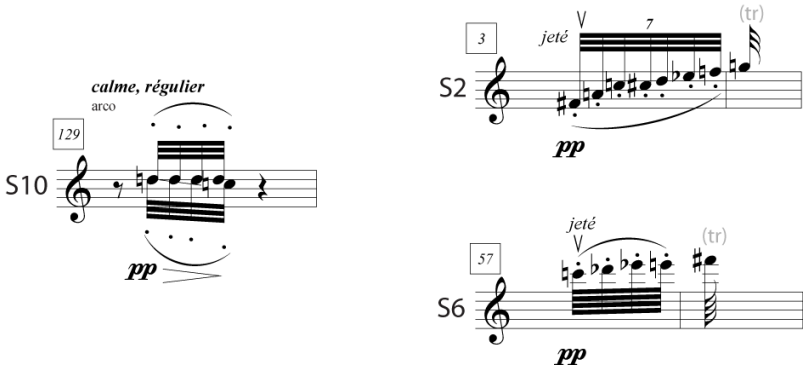

Figure 2.25: Asymmetrically perceived pairs of motives (S10-S2 and S10-S6) from the Scale group

Similarly, the ordered[11] motivic pairs with the two largest asymmetries within the Trill group were T13-T7 and T12-T2. Both motivic pairs consist of a single trill—either regular in the case of T13, or in slow motion in the case of T12—followed by a motive that incorporates the trill in a much more complex texture—a trill attacked on quadruple-stops in the case of T7, and a two-voice texture in the case of T2.

Location of common features within the motivic pair

In addition to abstract knowledge structures, the perceived similarity of a pair of musical motives appears to be affected by the way the specific order of the motives emphasizes or obscures the common features between the motives. Increased similarity perception appears to be associated with the motivic succession that results in the most compact temporal distribution of common features. In simple words, if the end of motive x shares features with the beginning of motive y, then the similarity of the pair is greater when motive x is introduced first and motive y is presented second than when they are played in the reverse order. Note that in this particular case, asymmetric perception is linked to order of presentation of the motives rather than to the referential or comparison role that they acquire.

Figure 2.26 shows all the motives from the Long Tone group presented to the participants in Experiment 2. When played second, L4 was perceived as being significantly more similar to all motives in the group ($z = -3.28$, $p = .004$). Translated to concert (sounding) pitches, L4 starts on a G5 and ends on an F#6. L3 and L5, start on concert pitches F#6 and C#6, respectively, and end on G5 (without considering the glissando tail at the end) and G#5, respectively. In terms of concert pitches, the initial note of L4 is extremely close in pitch (zero and one semitone away, respectively) to the final notes of L3 and L5. In other words, the ends of L3 and L5 are remarkably similar to the beginning of L4 in terms of pitch. Furthermore, the final pitch of L4 is considerably different in pitch from the opening pitches of L3 and L5. As a result, when L4 follows L3 or L5, the common features of the paired motives in terms of pitch—the common tone G5 in the case of L3-L4 and

[11] Ordered motivic pair is here used to refer to a specific order of a pair of motives. When no reference to order is made, the motives of a pair are separated by a slash (e.g., S10/S6). When referring to a specific order of a pair, the members of the pair are separated by a hyphen (e.g., T13-T7).

the extremely close in pitch G#5-G5 in the case of L5-L4—are brought closer together in time, resulting in a smoother melodic (register) contour (see Figure 2.25).

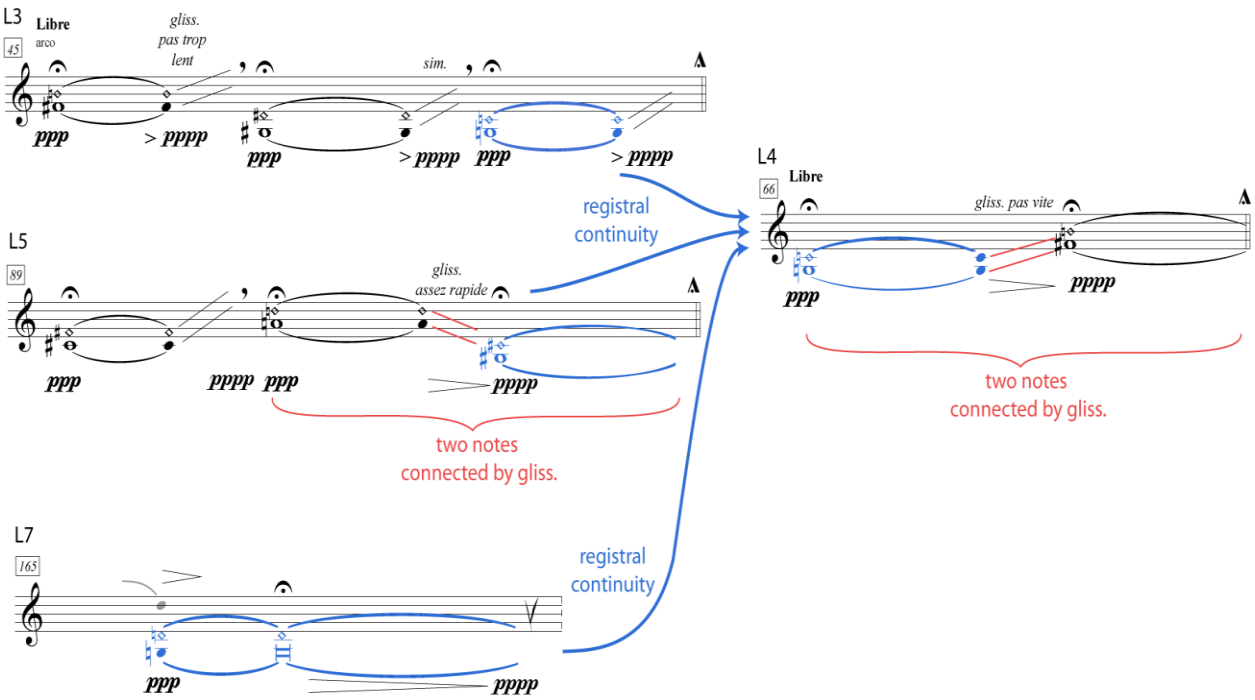

Figure 2.26: Long-Tone group

In addition to bringing the similar pitches of the motives closer together in time, the succession of motives L5-L4 makes it evident that both motives contain two long tones connected with a glissando. As illustrated in Figure 2.25, L5 starts with a long note ending on a glissando and only after a pause (note the breath marking in Figure 2.25) do the two pitches connected with a glissando arrive. This ending pattern is very similar to the entire melodic profile of L4. Because this feature shared by L5 and L4 is portrayed at the end of L5 (and in the entirety of L4), the succession L5-L4 makes the feature more readily accessible to the listener than does the reverse order. In sum, it is possible that L5 is perceived as significantly more similar to L4 when the former motive is played first ($z = -3.44$, $p = .006$) due to the position of this glissando pattern and the similar pitches (G5 and G#5) between the motives. Finally, returning to the pitch similarities of L4 to all the motives in the group, the only motive that has not been yet discussed, L7 consists of a sustained concert pitch D5, a pitch that is closer to the initial tone of L4 (G5) than to its final pitch (F#6).

Furthermore, the succession L7-L4 has a quite smooth ascending register contour. The distribution of common features along with the practically direct relationship of L7 to abstract knowledge structures (pointed out above) possibly led participants to perceive the L7 and L4 as significantly more similar to each other when L7 was played as the reference, and the order of the motives resulted in a smoother melodic contour for the resulting pair ($z = -2.81$, $p = .025$).

The discussion and evidence presented above suggest that the order in which two motives are played can affect their perceived similarity by temporally organizing their common features within the resulting pair in ways that can perceptually enhance or diminish the listener's ability to more readily recognize those features. This idea is further supported by the largest asymmetry indices among the pairs of the Melodic group. The two largest asymmetry indices in this group correspond to the pairs M11/M3 and M2/M8, shown in Figure 2.27. As illustrated, motive M3 is a melodic variation of the final two notes of M11. When these two motives were presented in the order M11-M3, they were perceived as more similar to each other than when they were introduced in the reverse order (marginally significant statistically: $z = -3.04$, $p = .056$). This particular order succession is precisely the one that brings the common features of the motives closer together in time. The idea is that the final two notes of the motive played first are slightly elaborated to become the motive played second. Similarly, motive M2 was perceived as being more similar to M8 when it was introduced first. As illustrated in Figure 2.26, M2 is a very complex motive. It can be interpreted as an entire phrase whose musical features change relatively widely from beginning to end.

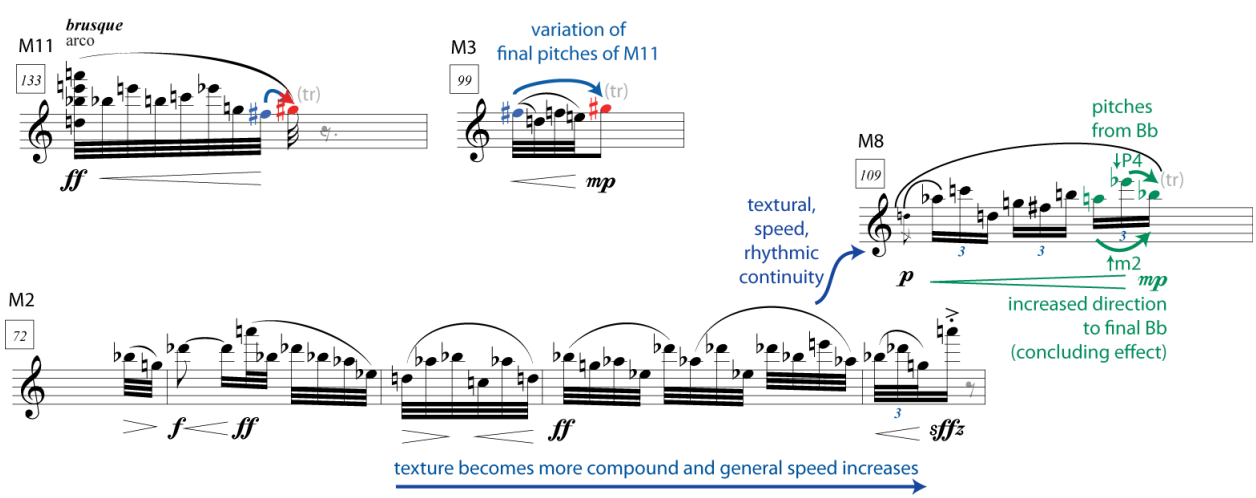

Figure 2.27: Pairs with largest asymmetry indices in the Melodic group

This idea is supported by Goldman's subdivision of the motive into relatively independent subunits (see motivic analysis at the beginning of this chapter). The motive gets faster and texturally more compound-melody-like towards the end, and the rhythm is quite variable, incorporating a triplet on the last beat. Motive M8 is closer in terms of rhythm, tempo, and texture to the end (rather than to the beginning) of M2. The motive M8, which is performed at a speed similar to the final portion of M2, suggests, at times, a compound melody hidden in a rhythm of triplets. Following this, the order M2-M8, once again, highlights the commonalities between the musical materials.

Linking to the next factor proposed by the theoretical model presented here, the asymmetry of the perceived similarity of M2 and M8 can also be related to certain intrinsic characteristics of M8 that could have presumably facilitated the connection between the two motives for the listeners when M8 was positioned at the end of the motivic pair. The final notes of M8 give a relatively strong sense of conclusion to the motive. As illustrated in Figure 2.26, the two voices resulting from a compound melody converge on the B♭ that ends the motive. As shown, the point of convergence is achieved through a descending P4[12] on the top part of the compound melody and an ascending m2 on the bottom part, two intervals of clear melodic directionality. The three final pitches A, E♭ and B♭ are important notes in the tonal hierarchy of B♭ (i.e., they are scale degrees $\hat{7}$, $\hat{4}$, and $\hat{1}$, respectively), suggesting a diatonic context for the m2 and P4. An ascending m2 moving from $\hat{7}$ to $\hat{1}$ is a characteristic closing pattern in tonal melodies that, within the {A, E♭, B♭} context, increases the sense of directionality towards the final B♭. This sense of pitch directionality is reinforced by the crescendo throughout the excerpt and the slight accentuation that the performer appears to add to the final B♭. As a result, the end of M8 is goal-oriented in terms of texture, dynamics, phrase accentuation, and pitch, being thus likely to convey a sense of closure. It is possible that when M8 was the first motive in a pair, its relatively concluding features interfered with the listeners' ability to connect it to the second motive in the pair, obscuring the common features between the motives. Following this, the relatively large asymmetry of the pair M2/M8 could presumably be related not only to the distribution of common

[12] In this dissertation, musical intervals are indicated using the label system in which the letter indicates the quality and the number refers to the quantity (e.g., P4 = perfect fourth). In order to avoid confusion with the labels of the motives, during discussions involving musical intervals, labels of motives that could refer to intervals are always preceded by the word motive.

features within the pair, but also to the conclusive quality of M8. In relationship with this, the following section proposes that when a motive evoking a closing function is the first of two motives played in succession, the perceived similarity of the motives in question tends to decrease.

Intrinsic formal function of motives

Music theorists refer to beginnings, middles, and ends of fragments or sections of musical compositions as formal functions. Empirical studies have shown that listeners are sensitive to the temporal organization of tonal materials, especially at small (Tillmann & Bigand, 2001) and middle (Vallières, Tan, Caplin & McAdams, 2009) levels of the formal structure. Specifically, listeners are in some cases able to identify the formal functions of musical passages even when they are presented out of context. The evidence suggests that endings can be recognized more easily (Vallières et al., 2009). In tonal music, endings are associated with closing patterns that, due to their frequency of occurrence, can be considered abstract knowledge structures. As a result, listeners can naturally identify closing musical passages. In addition, since concluding patterns tend to signal the end of musical units, they play an essential role in music segmentation.

Given the importance of time for music listening and the strong mental schemas associated with concluding passages in tonal music, an alteration in the expected temporal logic suggested by the intrinsic formal functionality of the component fragments of a musical passage should have an effect on the way listeners parse the passage. Specifically, musical fragments that strongly convey a concluding function are likely to demarcate relatively separate, independent cognitive representations for the listeners. Presumably, component fragments of a musical passage that are perceived as strongly independent units should be more difficult to integrate (as a unique musical passage) for listeners, in turn interfering with their ability to hear elements of connection between them. In line with this, in a succession of two motives, the perceptual salience of common features between the motives would be diminished when the end of the first motive has characteristics that are evocative of frequently encountered closing schemas. This is likely to be the case not only for tonal but also post-tonal motivic sequences, like those presented to the participants in Experiment 2. Intuitively, it seems evident that listeners must rely on memory to be able to follow and predict musical compositions independently of their idiom. Presumably, musical patterns that are extremely familiar to listeners should play an important role in this respect. Research has demonstrated the importance of tonality for music listening and memory (for a

review, see Halpern & Bartlett, 2010). Tonal closing patterns are perhaps among the musical materials most frequently encountered by Western listeners in general. It seems reasonable to propose that tonal closing patterns should play a role in listening to post-tonal music on the basis of at least two criteria: (1) the familiarity of Western listeners with tonal musical structures; and (2) previous literature suggesting that listeners often and most intuitively tend to listen to post-tonal music through tonal ears—e.g., Krumhansl et al., 1987; Huron, 2006; Marmell & Tillmann, 2009— presumably due to their cognitive impossibility to naturally ignore musical structures that they have learned implicitly.

Evidently, the motivic materials of *Anthèmes 1* do not follow the rules of tonal syntax, thus their intrinsic formal functionality is difficult to determine. Nevertheless, some of the materials incorporate melodic patterns that are often encountered at the end of tonal melodies, like the "diatonically" contextualized ascending m2 leading to the final B♭ in motive M8 discussed above. According to the proposition in the preceding paragraph, closing patterns are so strongly incorporated in the listeners' mind that, even when set into a broader non-tonal context, are likely to convey a sense of conclusion in some cases, especially when they are supported by other characteristics of the music. In the case of motive M8, in addition to the ascending m2 leading to the final B♭ within a pitch context that suggested the key of B♭, the converging texture and the crescendo reinforce the sense of motion towards the final B♭, providing closure to the motive. M8 was the motive with the largest positive mean asymmetry in its group, implying that the motive was heard as more similar to all motives in its family when it was played in the second position. Note that here asymmetry is once again linked to the order of presentation of the motives. Considering the importance of concluding schemas for music listening, the closing profile of motive M8 might have made the features that M8 shared with each of the motives in the group more accessible to the listeners when M8 was played last, without abruptly interfering with the overall motivic succession of the entire pair.

The example of M8 suggests that motives that evoke relatively familiar [quasi-tonal] closing patterns and are played at the beginning of a motivic pair can interfere with the listener's ability to find the common features between the motives. This idea can be further supported with an analysis of the motives with larger asymmetry values from the Pizzicato group. In Experiment 2, the motive P5 gave the largest positive mean asymmetry in its motivic family. The motive is

shown at the bottom of Figure 2.28. The pitch content of the motive corresponds to the key of A♭, with the following exceptions: (1) scale degree $\hat{3}$ is missing, thus making the mode ambiguous; (2) scale degree $\hat{6}$ is raised—F# instead of F—in its only appearance; and (3) scale degree $\hat{2}$ is raised—B instead of B♭—in one of its 3 statements.

These three exceptions can be interpreted as the result of the superposition of two diatonic keys arising from the complex texture of the motive. Two layers of different hierarchical importance can be distinguished within the texture and associated with the two keys. The most prominent (principal) textural layer (shown in blue in Figure 2.27) can be interpreted in the key of A♭, since the majority of the pitches of the motive (precisely 84% of the notes) correspond to that key. The mode of the key is undetermined due to exception 1 above (absence of scale degree $\hat{3}$).

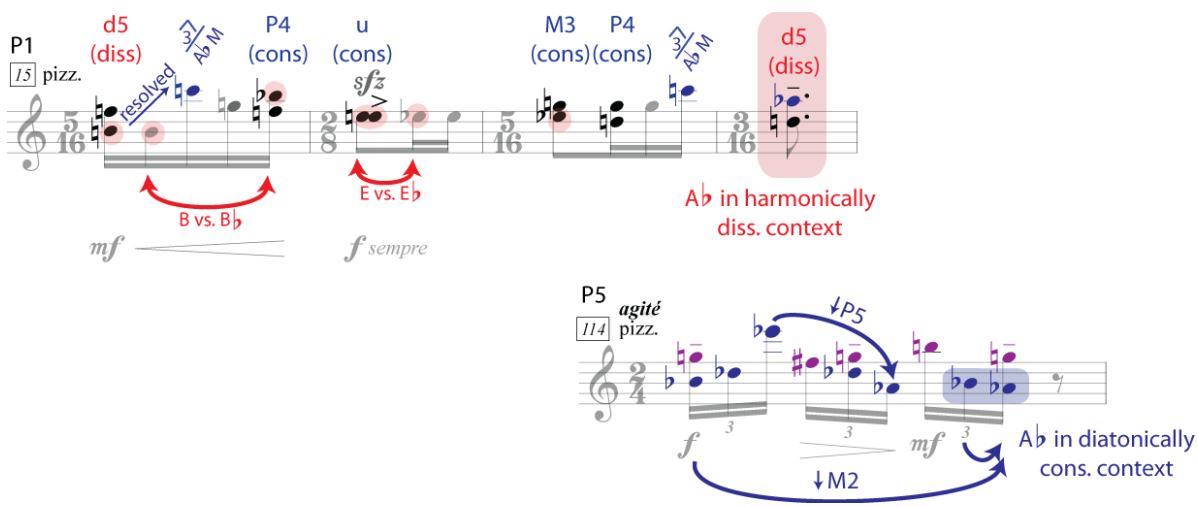

Figure 2.28: P1-P5, the motivic pair with largest asymmetry index in the Pizzicato group

The remaining, least prominent layer (shown in purple in the figure) accounts for exceptions 2 and 3. The deep structural framework of this secondary layer consists of three instances of the pitch G5 highlighted with *tenuto* markings. These three Gs correspond to the initial top note, the middle top note, and the end top note of the motive. The F# (raised scale degree $\hat{6}$, or exception 2 above) directly precedes the second of the three statements of G, leading into it, and reinforcing the importance already given to the note G by its three accented statements. In this sense, F# can be interpreted as a secondary "leading tone" ("applied scale degree" $\hat{7}$) to the second instance of the

structural pitch of the secondary textural layer. The B (raised scale degree $\hat{2}$, or exception 3 above) is associated with this G-centered secondary layer for being scale degree $\hat{3}$ of the key of GM and being melodically (registrally) connected to the third (and final) statement of G. At the same time that the G is highlighted through the accented restatements and the F# and B, the large number of pitches belonging to the A♭ diatonic scale along with the way they appear within the motive strongly suggests the key of A♭, delineating the primary textural layer. First, the highest and lowest pitches of the motive are E♭ and A♭, respectively, the two most important pitch classes in the tonal hierarchy of the key of A♭. The A♭-key context is reinforced by the lower voice of the motive, which moves, at both a large and small scale from B♭ to A♭, emphasizing scale degree $\hat{1}$ of A♭. As shown in Figure 2.27, the initial and final bottom notes of the motive are B♭4 and A♭4, respectively, suggesting a descending M2 from scale degree $\hat{2}$ to $\hat{1}$ at a large level. The scale-degree succession from $\hat{2}$ to $\hat{1}$ is reinforced, at a small scale, at the very end of the motive, where the lower voice descends directly by step to the A♭. Considering the general characteristics of motive P5 and the resulting hierarchical order of its textural components, it seems reasonable to propose that motive P5 as a whole strongly implies the key of A♭ with an emphasis on scale degree $\hat{7}$. In other words, due to its relatively lower prominence with respect to the principal textural layer, the role of the secondary layer appears to be emphasizing scale degree $\hat{7}$ of the key of A♭ (i.e., G). Motive P5 can then be interpreted as mostly centered on the key of A♭, particularly considering its relatively defined tonal tendencies compared to the post-tonal quality of most materials in the piece. Finally, and most importantly for the purposes of this explanation, the descending M2 towards the final scale degree $\hat{1}$, so strongly highlighted by the principal textural layer of motive P5, is a characteristic closing pattern in tonal melodies. In the case of motive P5, given the strong presence of the A♭ diatonic collection, the multilevel M2 descent to the final A♭ increases the motive's ability to convey a sense of conclusion. In the experimental stimuli in which P5 started the motivic pair, the relatively concluding profile of P5 possibly interfered with the overall motivic flow of the pair, presumably obscuring the common features between P5 and the motive that followed it for the listeners. As a result, motive P5 showed the largest positive mean asymmetry index in its group.

The motivic pair P1-P5, illustrated in Figure 2.27, constitutes another example of a large asymmetry index that can be explained in terms of the intrinsic formal functionality of the motives.

The pair gave the largest mean asymmetry index for its group. Perhaps not surprisingly, motive P5 is the motive that ends the pair. If motive P5 suggests an A♭ diatonic context with an emphasis on scale degree $\hat{7}$, motive P1 is built with a pitch collection that is extremely ambiguous in terms of key. In this sense, the two motives have opposing diatonic qualities. Most obviously, motive P1 incorporates both the flat and natural versions of the notes B and E. In addition, the motive ends on the most dissonant harmonic interval in the diatonic scale, a tritone (specifically, a d5). This harmonic interval sounds particularly dissonant in the context in which it is presented. It constitutes the most dissonant of all the harmonic intervals in the motive. The final d5 is the last of six double-stops. Marking a difference with the final double-stop, the second, third, fourth, and fifth double-stops are associated with relatively consonant (although unrelated to each other in terms of key) moments, corresponding to the harmonic intervals of P4, unison, M3, and P4, respectively (see Figure 2.27). The first double-stop consists of a d5, like the final double-stop. Nevertheless, the first d5 is set into a more consonant context than the final d5, since one of its component notes moves by semitone (in pitch-class space) in the expected direction, partially resolving the d5 melodically. Following this, the final d5 is a particularly dissonant moment within the tonally ambiguous motive P1. It seems relevant that the A♭, a pitch class that plays a central role defining the concluding character of motive P5, constitutes the top note of the interval of d5 that ends motive P1. In this sense, motive P1 creates a harmonic tension around A♭ that is diatonically and melodically resolved by motive P5. The tension is not harmonically resolved because the final harmonic interval of motive P5 is the M7 {G,A♭}. Nevertheless, the tension can be interpreted to be diatonically and melodically resolved in the sense that motive P5 presents the note A♭ within a relatively stable and melodically closed diatonic context. Note also that motive P1 emphasizes, by presenting as its highest pitch, the missing scale degree $\hat{3}$ from motive P5. It is possible that when motive P5 is preceded by motive P1, the sense of A♭ key implied by motive P5 increases, making the connection between the motives even stronger. Finally, if motive P5 suggests a sense of closure in the key of A♭, motive P1 can be interpreted to increase that sense of closure by posing conflicts among the closing elements of motive P5. On one hand, the relatively defined key of motive P5 can be interpreted to resolve the absence of sense of key created by motive P1. On the other hand, the tonal directionality of motive P5 towards its final pitch A♭ resolves the dissonant state in which A♭ is left by motive P1.

The motive that gave the largest positive asymmetry value in the Trill group, T4, further supports the idea that musical materials evoking tonal (or quasi-tonal) cadential processes are perceived as more similar to other materials when they are played in the second position. Illustrated in Figure 2.29, motive T4 is composed of two lines or voices converging on a B♭. The upper line delineates at a global level the ascending interval of a P4 from F ($\hat{5}$) to B♭ ($\hat{1}$), and at a local level, the ascending interval of a m2 from A ($\hat{7}$) to B♭ ($\hat{1}$), two typical cadential melodic motions. The E♭ preceding the A in that same line emphasizes the tonic B♭, since it constitutes $\hat{4}$, another crucial scale degree.

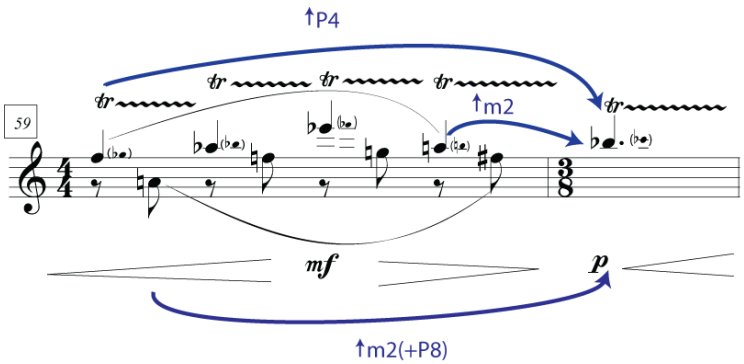

Figure 2.29: T4, the motive with largest positive asymmetry in Trill group

The sense of closing gesture is reinforced by the lower line of motive T4, which delineates at a global level an ascending motion from A ($\hat{7}$) to B♭ ($\hat{1}$).

To conclude, the examples above intend to provide theoretical and analytical support for the idea that the congruency of the intrinsic formal function of two musical materials with the order in which those materials are heard can affect their perceived similarity. Specifically, the discussion above proposes that when a motive with a clear intrinsic concluding function is presented as the beginning of a larger musical fragment, the listener's ability to integrate the motive to the remaining material diminishes.[13] It is important to note that none of the examples illustrating the

[13] Note that the perceived asymmetry associated here with different formal functions of the motives could also be explained by the participants' possible unconscious tendency to confuse perceived similarity with ending satisfaction. In other words, listeners could be inadvertently adding a judgment of ending satisfaction to their similarity ratings. In

possible effects of intrinsic formal function on perceived similarity are supported with statistical data. This marks an important difference with the discussions on the role of abstract knowledge structures and location of common features in perceived similarity, both of which included musical examples that were associated with statistically significant asymmetry values. The hypothesis that the congruency of the intrinsic formal function of musical materials with their order of presentation can affect their perceived similarity is, in principle, only supported with the importance of temporality for music and the relevance of closing patterns for the cognitive formation of musical units (discussed at the beginning of this section). Nevertheless, it is possible that the post-tonal nature of the motivic materials of *Anthèmes 1* prevented them from strongly conveying a concluding formal function, slightly, yet not significantly affecting the similarity judgments of the participants. This would explain why the tendencies to asymmetric similarity perception observed in connection with some of the motives from the Melodic and Pizzicato groups did not reach statistical significance. A similar experiment using tonal materials (outside the topic and scope of this dissertation) should provide further information in this respect, confirming or refuting the hypothesis about the role of intrinsic formal functionality in the perceived similarity of musical motives suggested above.

Finally, the theoretical model proposed above is both theoretically and perceptually valid to a certain extent, in the sense that it is justified with musical examples and their connection with exclusively perceptual data. Experiment 2 explained fine-grained aspects of the internal dissimilarity structure of the motivic families of *Anthèmes 1*, by asking participants to provide dissimilarity ratings of pairs of motives presented in a restrictive within-family context. Experiment 3 further investigates the relationship between these aspects and the listener's conception of the musical motive that "best represents" a group of motives, by directly asking listeners to choose the motive that best represents each of the five motivic families.

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either case, the results reported above suggest that the formal functions of the motives (in particular, closing functions) have the potential to alter the perceived similarity relations among them: either directly, by conveying their most immediate and implicitly learned formal role to the listener, or indirectly, through the sense of ending satisfaction that closing functions can induce particularly in the second motive.

Experiment 3: Best representative of a motivic group

METHOD

Participants

Twenty-seven musicians (aged 20-34, *M* = 26, *SD* = 5.3, 12 females), all of whom had completed the music theory requirements for the Bachelor of Music at McGill University or equivalent) were recruited through McGill Classifieds Online and announcements in high-level music classes held at the Schulich School of Music of McGill University. They were paid for their participation. All participants passed a pure-tone audiometric test at octave-spaced frequencies from 125 Hz to 8 kHz (ISO 389–8, 2004; Martin & Champlin, 2000).[14]

Stimuli

The stimuli consisted of the set of 29 motives extracted from the clustering tree obtained in Experiment 1 (listed in Table 2.4) and used to build the pairs in Experiment 2. In Experiment 3, the 29 motives were organized by motivic family (Table 2.1 and Appendix A), with TM1 included twice, i.e., as a member of both the Trill and the Melodic groups. Sounds were played at a maximum level ranging from 45dB to 70dB SPL, as measured with a Bruel & Kjaer Type 2205 sound-level meter with a Bruel & Kjær Type 4153 artificial ear (Bruel & Kjær, Nærum, Denmark) to which the headphones were coupled. The equipment was the same as in Experiment 1.

Procedure

The experiment was organized in two blocks, each of which was subdivided into five sections. The two blocks were identical except for the order in which they presented the five sections. Each of the five sections corresponded to each of the five motivic families. These five sections were randomly ordered within each of the two blocks. Each of the five sections involved two tasks: (1) choosing the motive that best represents the group of motives, and (2) rating the importance given to a list of musical features during the completion of the first part. During the

[14] One of the participants showed a threshold higher than 20 db HL for middle-range frequencies. The participant was still admitted into the experiment based on his notable experience as a musician and music theorist. Careful examination of the data revealed no important differences between the types of responses given by this musician and the remaining participants. Therefore, his data were included in the final analysis.

first task, all the motives from a group were represented by randomly numbered boxes presented to the participants on a computer screen. Participants could listen to the motives as many times as they wished, by clicking on the boxes in whatever order they wanted. Once they had heard all the motives in the group at least once, they were asked to "choose the motive that best represents the entire group." During the second task, participants completed the same questionnaire about musical features given to participants of Experiment 2, except that the transition feature was removed, given that in Experiment 3 the motives were not paired or combined in anyway to form larger musical fragments. All the participants read the same set of instructions prior to the experiment and completed a practice trial in the presence of the experimenter before starting with the experimental trials. The motives used for the practice trial (S1, S3, S4, S5, and S7) were absent from the experimental trials.

As mentioned in the introduction of this chapter, the main purpose of Experiment 3, along with Experiment 2, was to provide well-founded criteria for the selection of stimuli for Experiments 4 and 5. The specific purpose of Experiment 3 was to better understand the listener's conception of best representative of a motivic family (ability of each motive to represent the entire group). The instructions were worded in favor of this aim. All participants were explicitly told to complete the task as intuitively and naturally as possible. Words like model and prototype were purposely avoided because of their frequent use in connection with ideal, abstract representatives of a category or class. Particularly in the case of music, Deliège (2001a) has proposed that prototypes often correspond to deep-level structures that listeners are able to abstract from the musical surface, and are thus not necessarily explicitly stated as musical materials. More detailed instructions could have easily led to levels of analytical abstraction that would have likely obscured the most natural perceptual immediacy of the characteristics of the motives and their categorical position from the perspective of listeners. This information concerning the natural perceptual immediacy of the motives was essential for both the main and specific purposes of Experiment 3. With respect to the main purpose, an important condition for the motives used for the online (real-time) motivic identification task of Experiments 4 and 5 was their instant recognizability.

Data Analysis

For each of the five motivic families, the total number of times that each motive was chosen as the best representative was converted into a proportion. These proportions reflected the relative frequency with which each motivic material was chosen to best represent its group.

An important part of the data analysis was concerned with the ratings of importance that participants gave to a relatively comprehensive list of musical features after choosing the motive that best represented each group (task 2 above). Recall that importance ratings for the same musical features were equivalently obtained in Experiment 2. Because these ratings were designed to contribute to the understanding of the effects of task and context in similarity perception, the analysis consisted of a comparison of the results from Experiments 3 and 2. The mean importance ratings obtained in Experiment 2 were subtracted from those obtained in Experiment 3, with the purpose of illuminating the perceptual relevance of features within the task and context corresponding to one experiment with respect to the other. Given the two theoretical motivic analyses proposed above showing that the features that theoretically and perceptually defined the motivic families were different for each of the five groups, the differences in the mean ratings between the questionnaires in the two experiments were calculated for each feature and motivic group separately. Because the data obtained in Experiment 2 were subtracted from those obtained in Experiment 3, features with positive values were presumably more important for the task and context of Experiment 3, whereas features with negative values were likely more relevant for the task and context of Experiment 2. For instance, a difference of 1 and a difference of -1 indicate an importance mean rating larger by 1 point (in the 5-point rating scale) in Experiment 3 (with respect to Experiment 2) and Experiment 2 (with respect to Experiment 3), respectively.

RESULTS AND DISCUSSION

Motives are displayed along the x-axis in Figure 2.30 and the five groups (Table 2.1 and Appendix A) are illustrated in different colors. Motive TM1 appears twice, as a member of the Trill and Melodic groups, respectively. The y-axis shows the percentage of times that a motive was chosen as best representative of its group. Striped bars indicate motives that were most frequently chosen as best representatives of their groups.

It is clear from the figure that TM1 cannot represent the Trill group. The motive was never chosen as the best representative of that group. However, TM1 was chosen, although only 6% (.06×100) of the time, as best representative for the Melodic group. In this sense, TM1 appears to belong (at least slightly) more to the Melodic than to the Trill group, as suggested by the results of Experiment 2. Nevertheless, it is impossible to make conclusions in this regard based on this small difference. Overall, it is evident from these results that TM1 cannot represent well either motivic family. As illustrated in Figure 2.29, none of the motivic families contains a single motive that can unequivocally stand for the entire family. Instead, the motivic members represent their group to a greater or lesser degree. Nevertheless, all motivic families contain one motive with relatively higher representativity. Recall that each participant completed the task twice for each motivic family, meaning that it would have been technically possible for two or more motives from the same group to be chosen as best representatives exactly the same number of times.

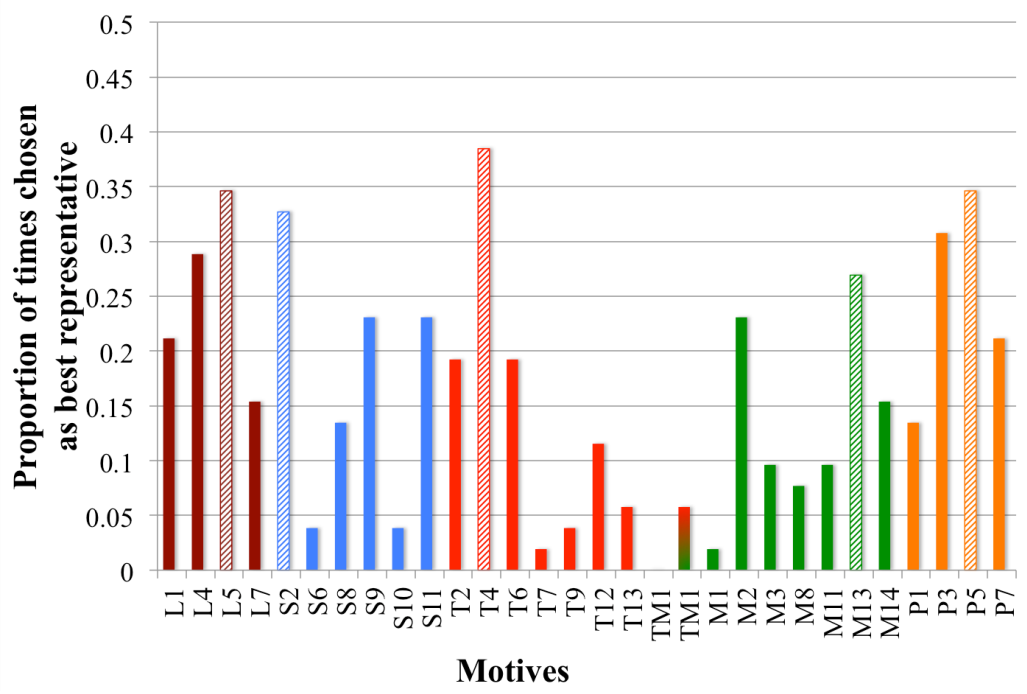


Figure 2.30: Distribution of motives chosen as best representatives (Experiment 3)

Because Experiments 2 and 3 were strongly interconnected in terms of goals, tasks, and stimuli, the results of Experiment 3 are particularly meaningful when compared to those of

Experiment 2. Following this, the discussion below compares the results of the two experiments. In the Pizzicato and Scale groups, the motive that was chosen as the best representative in Experiment 3 coincided with the motive of lowest mean dissimilarity in Experiment 2. This was not the case for the remaining three groups, suggesting that the motive that the listeners conceived as the best representative of a group did not necessarily coincide with the motive that they perceived (perhaps even conceived) as being more similar to most members in the group. Notable differences between the experiments in the results from the questionnaire in which participants rated the importance of musical features suggest that context and task might have affected the participants' evaluation of common and distinctive features among the motives. At the same time, they reveal information about the listeners' conception of the best representative of a motivic family.

Figure 2.31 shows the difference in the importance ratings for each musical feature obtained from the questionnaires in Experiments 3 and 2.

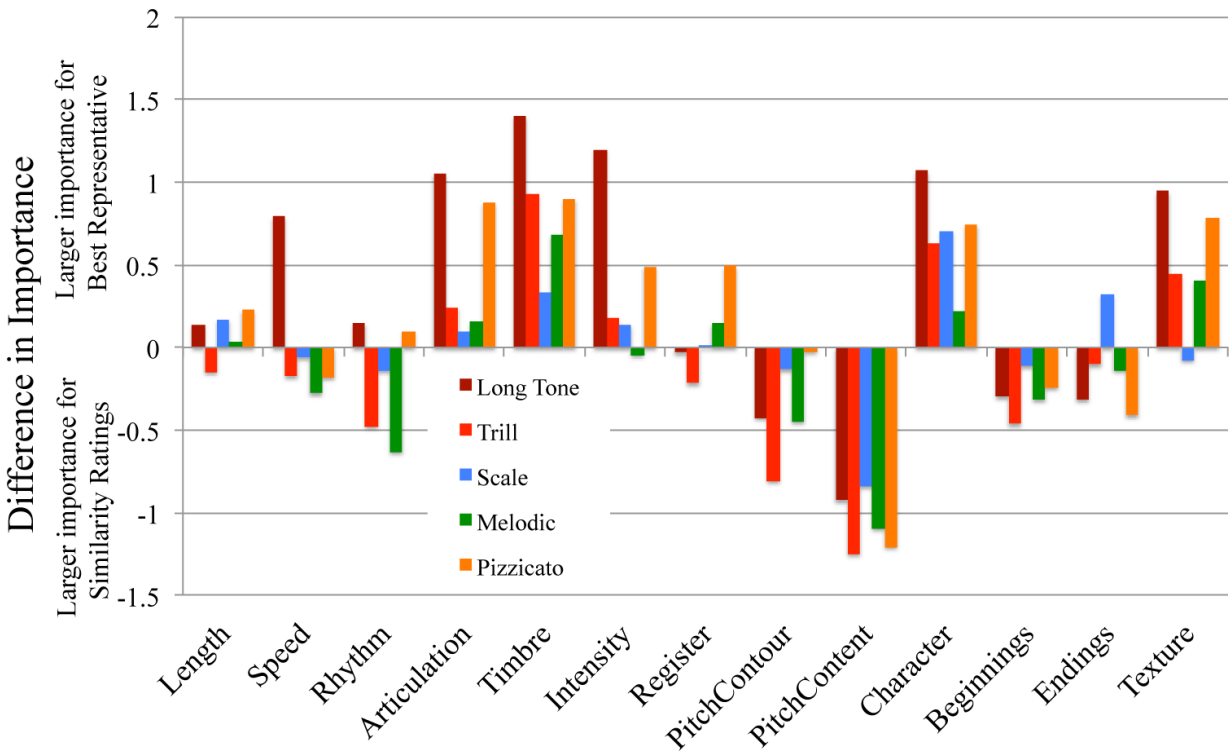


Figure 2.31: Difference in importance of musical features for Experiments 2 (mean similarity) and 3 (best representative)

Different colors show different motivic families. Musical features are listed on the x-axis. The y-axis shows the difference in the importance ratings in Experiment 3 with respect to Experiment 2 (see Data Analysis). Features prioritized during the selection of the best representatives (Experiment 3) are shown above the zero point on the x-axis, and features emphasized during the similarity ratings for pairs of motives (Experiment 2) are shown below zero.

Considering all motivic families together, participants prioritized articulation, timbre, character, and texture when choosing the best representative. Note that these four features were rated at least 0.5 points more important in Experiment 3 with respect to Experiment 2 for two or more of the five motivic groups.[15] These features, which are frequently described as surface features, are precisely the ones that define the five groups as such, separating them from each other.

As already shown by the motivic analyses proposed above (summarized in Tables 2.2 and 2.3), these features correspond to important internal common characteristics of the groups. This is most directly noticeable in the shaded cells of Table 2.1 (first motivic analysis). Figure 2.31 illustrates that articulation was particularly important for choosing the best representatives of the two groups with more consistent articulation. As shown in the motivic analysis summarized in Table 2.1 (and in greater detail in the analysis in Table 2.3), all the motives from the Long Tone and Pizzicato groups featured sustained and pizzicato articulation styles, respectively. Note also the emphasis on intensity during the selection of the best representative for the Long Tone group, a motivic family that was greatly defined by the soft dynamic of its members. Articulation, timbre, and texture appeared to be notably irrelevant for choosing the best representative of the Scale group. As described by the theoretical analyses in Tables 2.1 and 2.3, the motives from this group used a variety of articulation styles, all of which were featured in the selected set of motives played in Experiments 2 and 3. This finding suggests that articulation was important for choosing the best

[15] All the differences in feature-importance ratings discussed in this section are equal to or larger than 0.5 points. Because the rating scale consisted of 5 values equally spaced from 1 to 5, 4 points is the largest possible difference between ratings. Accordingly, a difference of 0.5 in the figure corresponds to a 12.5% difference or, more concretely, half a mark in the rating scale. Given that the purpose of this section is to discuss observed trends, a difference of 12.5% seemed large enough to be worthy of discussion.

representative only when it was a constant feature among the members of a group, as in the Long Tone and Pizzicato groups explained above, but not when it was a variable characteristic, as in the Scale group. A similar case can be observed with respect to timbre, given that changes in playing technique and articulation easily lead to different timbres on the violin. The timbral resemblance of the members of the Long Tone group is further reinforced by the fact that the sustained long notes are played in harmonics. With respect to texture, 33.3% of the motives from the Scale group used in Experiments 2 and 3 had a two-part texture resulting from the use of double-stops, whereas the remaining motives were clearly monodic, making the group divisible into at least two clearly separate subgroups in terms of the textural characteristics of its members. These examples indicate that when choosing the best representative for each motivic family, listeners prioritized common features among the motives of each group and paid less attention to the distinctive characteristics among them.

Conversely, differences in importance ratings shown in Figure 2.30 suggest that distinctive characteristics among the motives in a group are relevant for making similarity decisions concerning two motives that are paired and played back to back. Pitch content was prioritized during the similarity ratings completed in Experiment 2. Note in the figure that the difference in ratings for pitch content is larger than 0.5 points (furthermore, close to 1 point) for all the motivic groups. Pitch content is probably the most variable feature among the motives in every group. Motives from the same group only rarely share many pitches but motives from different groups often do. Accordingly, pitch content is absent from the motivic analysis summarized in Tables 2.1 and 2.3. To a lesser extent than pitch content, pitch contour and rhythm also seemed to be relatively prioritized during the similarity ratings of pair of motives. Like pitch content, pitch contour and rhythm are quite variable among the members of a motivic group. As shown in Tables 2.1 and 2.3, the Long Tone, Trill, and Melodic motives are variable in terms of pitch contour, and the Trill and Melodic motives are variable in terms of rhythm. Consistently, as illustrated in Figure 2.30, pitch contour and rhythm were rated as relatively more important features in Experiment 2 than in Experiment 3 for those motivic groups.

The two paragraphs above support the broader observation that many of the features that the participants rated as important in Experiments 2 and 3 were analyzed as within-group commonalities and differences, respectively, in the theoretical studies summarized in Tables 2.1

and 2.3. If common features among the members of a motivic family appear to be relatively important for choosing the motive that best represents that family, distinctive features among the materials of a group are more essential for judging the similarity of pairs of motives. This difference in the participants' strategies can explain why in only two of the five motivic families the best representative (Experiment 3) and the motive that was most similar to most motives in its family (Experiment 2) were the same musical material. In light of the priority that participants gave to common features in Experiment 3, the degree to which a motive is capable of representing its group depends more on features that the motive shares with the remaining members in the group than on diverging characteristics. This result implies that a motive that shares a relatively large number of features with most members in its group will be chosen as best representative (in Experiment 3), independently of the number of ways in which the motive diverges from the group as a whole. On the other hand, and in light of the priority that participants gave to distinctive features in Experiment 2, the degree of resemblance of a motive with respect to each and all the members in its group after (back-to-back) pairwise comparisons depends more on the absence of distinctive features than on the presence of common characteristics. In this sense, the motive that best resembles all motives in its group according to Experiment 2 is the material with the smallest number of differences with respect to all the members in the group. Finally, whether the best representative and the most similar motive are the same or different materials depends on the internal dissimilarity structure of the motivic category. In groups composed of members that are remarkably similar to one another (such as Pizzicato and Long Tone), commonalities among the members are larger in number and/or weight than divergences among them—overall and independently of the task and context. On the other hand, in groups in which the motives are substantially different from each other (such as Melodic, Scale, and Trill), commonalities among the members tend to be smaller in number and/or weight than divergences among them.

The explanation above elucidates the reason why it was only in the Pizzicato and Scale groups that the motive chosen as best representative in Experiment 3 coincided with the motive of lowest mean dissimilarity in Experiment 2. As shown by the dissimilarity means of the motivic groups in Figure 2.22 (darker grey), the members from the Pizzicato and Scale groups were more

similar to one another than the members of the other three groups.[16] Finally, the comparison of the results from Experiments 2 and 3 revealed important aspects concerning the effects of context and task on the perception of common vs. distinctive features of the motivic materials from *Anthèmes 1*. When interpreted in light of the degree of differentiation among the motives of a group—internal dissimilarity structure of a group— those aspects elucidate the listener's conception of best representative of a motivic family and the relationship of that conception to the degree of perceived similarity of a motive with respect to all motives in its group. The motive that best represents a group is not the musical material that is most similar to most members in the group, but rather the motive that shares the largest number of common features with each and all the members, relatively independently from the diverging features that separate it from them.

Concluding summary

This chapter investigated general aspects of motivic categorization and similarity in *Anthèmes 1*. The methodology combined analytical approaches with perceptual data obtained from three experiments. Two motivic analyses of *Anthèmes 1* were proposed, both of which were mostly based on the score and, in that sense, inspired by music-analytical methodologies traditionally used by music theorists. The first analysis defined five motivic categories for *Anthèmes 1*. This analysis was compared with the most comprehensive analytical study of the piece found in the literature (Goldman, 2001, 2011), with the main purpose of illuminating the degree of consistency of the motivic categories from a theoretical perspective. The categories were perceptually validated with the results from Experiment 1, in which musicians freely categorized a large selection of motivic materials extracted from *Anthèmes 1*. A clustering tree built with the empirical data from this experiment showed diverse degrees of perceptual robustness (clarity/definition as a group) for the motivic categories, suggesting different numbers and strengths of internal subdivisions for each group. These empirical results were paralleled with the first motivic analysis and its comparison to Goldman's in order to better understand the motivic structure of the piece as a whole. The second motivic analysis started from the perceptual results obtained in Experiment 1, justifying all

[16] Recall that the dissimilarity means for the Scale and Pizzicato groups were statistically either significantly or marginally significantly smaller (higher mean similarity among the internal motives of the groups) with respect to the remaining groups. See discussion concerning Figure 2.22 in the Results and Discussion section for details concerning this.

individual branches of the clustering tree with musical features quite directly observed on the score. Whereas the first motivic analysis served as the basis for selecting the experimental stimuli and explicated the interpretation of the perceptual data, the empirical results constituted the starting point for the second motivic analysis. In this sense, the theoretical and empirical approaches were integrated to illuminate the motivic structure of the composition. In addition, the clustering tree built with the perceptual data of Experiment 1 was essential for selecting a more reduced and manageable set of motives that was used as stimuli for Experiments 2 and 3.

In Experiment 2, the selected motives from each motivic category were paired in all possible ways and orders, and musicians provided directional similarity ratings for all pairs (similarity of the second motive with respect to the first). The results suggest that motivic similarity relationships can in some cases be perceived asymmetrically. A model of asymmetry was proposed based on consistent (recurrent) score-based analytical observations of the motives associated with larger asymmetry values. The model was further supported with statistically significant findings concerning the overall asymmetric structure of each of the groups, a number of asymmetry indices for specific motives, and the importance that participants explicitly gave to the order in which the motives were played. The model attributed the asymmetry effects of the perceived similarity of a pair of motives to three factors: (1) resemblance of the motives to abstract knowledge structures: when played as references, motives closely resembling abstract knowledge structures increased the similarity of a pair; (2) the temporal position of common features within the motives in the pair: the similarity of two motives was greater when the order in which they were played brought closer together in time their common features; and (3) intrinsic formal functions: materials with an intrinsic closing nature played as the first motive of a pair tended to decrease the perceived similarity of the pair.

In Experiment 3, musicians chose the motive that best represented each motivic category. The results from Experiment 3 were particularly illuminative when compared to those from Experiment 2. Important diverging points in the results of the two experiments provided evidence for the effects of context on motivic similarity perception. Similarity decisions appeared to be affected by five contextual factors: (1) purpose of the task: similarity ratings of pairs in Experiment 2 vs. choosing the best representative of a group in Experiment 3; (2) stimulus exposure or listening times: hearing the motives a maximum of two times in Experiment 2 vs. hearing them an

undetermined number of times in Experiment 3; (3) stimuli readily accessible to the listeners: two motives in Experiment 2 vs. all the motives in the group in Experiment 3; (4) the internal dissimilarity structure of the motivic families: motivic families composed of members that are relatively different from each other, like the Melodic, Trill, and Long Tone groups, vs. motivic families composed of members that are extremely similar to each other, like the Pizzicato and Scale groups; and (5) the order in which two motives are played: as shown by the asymmetric perception of similarity suggested by the results of Experiment 2.

From a conceptual perspective, these five factors are remarkably close to Pierre Boulez's ideas about memory and music perception introduced in Chapter 1. The results from the three experiments presented in this chapter demonstrated that these factors play a role shaping the perceived similarity of the motivic materials of Boulez's *Anthèmes 1*, establishing direct, concrete links between the composer's ideas and his compositional practice. Furthermore, the connections between the composer's descriptions of the motivic material of *Anthèmes* and the theoretical interpretations and empirical findings presented in this chapter are explicit. Following Boulez's explicit ideas about *Anthèmes*, the theoretical analyses presented in this chapter, and the results from the empirical studies described, the motivic materials of *Anthèmes* can be said to be compositionally conceived, theoretically defined, and perceptually organized in more or less distinct categories. These motivic categories are particularly robust in the sense that they remain relatively stable when they are investigated under the lens of different disciplines of music research.

Finally, as discussed in Chapter 1, similarity is an essential aspect of musical form in traditional music theory and analysis. By affecting similarity perception, the five contextual factors proposed above are relevant for the theoretical study of musical form, another aspect in which Boulez was extremely interested. Based on this, the following chapter explores the effects of the temporal distribution of the motivic materials from *Anthèmes 1* within the formal structure of the piece on the listener's formation of similarity relationships among those materials.

Chapter 3
Motivic similarity in the context of *Anthèmes 1* and *2*: Towards a model of form perception

Introduction

> As structural experience, listening orients itself not only positivistically to the composition of the sounding object, but refines itself by ordering this object in its environment. The perception of the thing sounding grows simultaneously more narrow and more broad through the relations that unfold between the thing and its nearer and farther environment in time and space. In other words, listening simultaneously perceives—consciously and unconsciously—connections pertaining to the thing sounding, connections in which these relations originate, in which they now consist and from which every sounding moment is newly illuminated. (Lachenmann, 2003, 30)

Because music unfolds in time, an important part of its artistic and expressive potential comes from its ability to play with different contextualizations of similar musical objects. Accordingly, discovering the many shapes that a group of musical events acquires throughout different musical settings (hearing the return of the same yet new musical materials throughout a composition) is perhaps among the most engaging aspects of the listening experience of much Western music. Context is as essential to music listening as time itself, and, in this sense, any interpretation of music that disregards the effects of context is incomplete.

Chapter 2 investigated general aspects of the motivic structure of Boulez's *Anthèmes 1* by experimentally and theoretically exploring the musical materials out of the context of the piece. The present chapter complements the previous one by studying the perception of the motivic materials of *Anthèmes 1* within the specific musical context given by the composition and within the extended and electronically enhanced context provided by the second version of the piece, *Anthèmes 2* for violin and electronics. As noted in Chapter 1, *Anthèmes 2* is directly derived from *Anthèmes I*. The motivic materials are preserved in such a way that every musical note in *Anthèmes 1* can be tracked in *Anthèmes 2*, while the form is greatly enlarged at different levels and the electronic effects add a layer of timbral transformation that is more than merely decorative, and

perhaps even structural. The two compositions share the same motivic materials, but they differ in terms of the settings in which those materials are presented. Consequently, *Anthèmes 1 and 2* provide ideal musical environments to investigate the effects of different musical contexts on the perception of the same set of musical motives.

By exploring the perception of motives in the two musical settings provided by *Anthèmes 1 and 2*, Chapter 3 aims to investigate the effects of specific musical contexts on the listeners' understanding of motivic similarity relationships, ultimately explaining the ways in which the organization and transformation of motivic materials throughout a composition could influence the listener's perception of the many levels of the formal structure. The methodology adopted here is similar to that of Chapter 2, in the sense that it combines experimental studies with theoretical interpretation. Like Chapter 2, this chapter starts from a theoretical standpoint. However, with the aim of proposing the foundations for a theoretical model, the main focus is here theoretically abstract rather than analytical. Chapter 3 presents and discusses two experimental studies that are designed to complement and test a theoretical model that is initially proposed on the basis of theoretical intuitions, listening experience, and ideas supported by previous literature. Specifically, these two experiments study the listeners' recognition of motivic relationships—presumably investigating their understanding of motivic transformation or variation—in *Anthemès I* (Experiment 4) and *Anthèmes 2* (Experiment 5) during real-time listening to the pieces. Specifically, the aim of the empirical studies is to discover some of the musical factors that alter the perception of motivic variations throughout the listening experience. Theoretical analyses of the formal characteristics of the compositions elucidate the experimental findings and provide clues about the listeners' perception of musical form. Through these methodologies, Chapter 3 ultimately intends to contribute to the understanding of musical form in ways that are both theoretically applicable and perceptually valid.

The chapter is divided into six sections. The first section presents the view of musical form considered for this project, surveying relevant literature in Music Perception, Music Theory, and Boulez's conception of music. This view of musical form and literature review are used to propose the basic elements of a rudimentary model of form perception in the second section. The third section presents formal analyses of the two versions of *Anthèmes*. The fourth section describes and discusses the two experiments studying the perception of motivic similarity and form

in *Anthèmes*. The fifth section integrates the analytical and empirical approaches with the aim of validating and refining the rudimentary model of form perception proposed in the second section. Finally, the sixth section concludes with a summary.

Musical form

Very generally, musical form can be understood as the temporal development and organization of the musical materials in a composition. This dissertation adopts this broad notion of form, approaching it from two perspectives: theoretical/analytical and perceptual. In this sense, the term form is twofold. On one hand, it describes a *structural analysis* of the musical features (specifically, an interpretation of the organization of the musical materials and the development of the characteristics of those materials over time) that is justified with predefined theoretical principles. On the other hand, it considers the *listeners' perception* of certain (systematic) aspects from those analyses and the theoretical principles that underlie them. Because this project aims to integrate theoretical methods with perceptual findings, the dividing line between the analytical and perceptual approaches to musical form is at times intentionally blurred. It is important to point out that, even when the analyses are presented as fixed structures, their generation was dynamic at least in the sense that they—along with the analytical tools—were defined according to score features that were perceptually salient. The analyses do not intend to convey the impression that the pieces have a unique, fixed form, but rather that it is possible to interpret their temporal structure in relatively methodical (and in that sense objective) ways. It is this predetermined set of systematic principles more than the specific analytical claims derived from them that allows for a hopefully cogent discourse linking the analytical and perceptual formal studies of the compositions.

Based on previous experimental research and traditional theoretical approaches to musical form (discussed under the next two subheadings), this dissertation adopts a *hierarchical* view of form, both from a theoretical/analytical and perceptual perspective. This view implies that music[1] can be analyzed and perceived—to some extent—as a concatenation of relatively short

[1] This view of form is not applicable to all kinds of music. Nevertheless, it has been the most traditional approach to form for Western music. As demonstrated with the analyses proposed below, this view seems appropriate for the pieces discussed in this dissertation.

units (musical passages) that are discrete at the basic, lower level—at which those units cannot be further subdivided naturally or intuitively— yet contiguously connected to one another at more encompassing levels. The basic idea is that formal units of different durations can be interpreted in a nested fashion. In this context, the difference between musical content and form is only of degree: the contents themselves and their organization determine the form. Accordingly, this dissertation is based on the idea that musical form can often be analyzed in a hierarchical way on the basis of theoretically justified methods and that some aspects of that hierarchy can be perceived while listening to a composition. Note that accepting the notion that the form of many musical works can be analyzed hierarchically does not imply that a unique fixed structure underlies those works, but that those compositions can be segmented in relatively short units that can themselves be integrated into longer units at larger, more encompassing levels. For the purposes of this project, the general idea that form can be analyzed (and systematized) and perceived hierarchically is more essential than the specific elements constituting that hierarchy.

Throughout this dissertation, the notion of formal hierarchy is used in a generic way to refer to the two clearly distinct nested levels of a hierarchical formal structure that can be relatively objectively defined from a methodological perspective: (1) the motivic, local indivisible level, where formal units cannot be naturally and instantly segmented; (2) a higher, middle-to-large segmentable level, where formal units enclose lower-level units. The listeners' perception of the local level is here associated with their attention to the musical details and their ability to instantly integrate information that occurs within relatively short and difficult-to-segment formal units. Metaphorically speaking, listeners focusing on aspects of the local level of the formal hierarchy zoom into the musical surface, immediately and most directly integrating events that are relatively close together in terms of the way the musical materials develop over time. Conversely, listeners focusing on aspects of the higher levels zoom out from the musical surface, immediately and most directly integrating events that are relatively far apart in terms of the way that musical materials develop over time. The listeners' perception of the higher (middle-to-large) level is then related to their attention to compound musical processes and ability to instantly integrate information that occurs within relatively long divisible formal units.

The notion of attending to different hierarchical levels of the form during music listening proposed here can perhaps be best explained in connection with diverse types of repertoire. Music

that develops uninterruptedly (without sudden changes in the surface), such as minimal music, Wagner's infinite melodies, or electronic dance music, seems to most naturally emphasize large-scale processes. In this music, gradual developments over long musical passages seem intuitively very salient and easy to follow, whereas changes in the details can be perceived through a more consciously directed focus of attention. Indeed, changes in the details are at times too small to be immediately noticed and the purpose of these minuscule changes seems to be almost exclusively to contribute to the definition of musical developments of larger scope. Conversely, details are essential to classical variation forms, where the most salient elements and obvious differences among large segments of music often occur at the level of the details. The examples presented here attempt to broadly illustrate how the characteristics of the music can affect the listeners' perception of the levels of the formal hierarchy. It is evident that listeners can (and often do) more or less consciously manipulate their attention in different ways during music listening. In addition, it is obvious that the great majority of music (including pieces from the repertoires discussed above) plays with changes at different levels of the structure (highlighting musical details and processes of diverse span) in ways that are likely to influence the listeners' attention to musical elements and processes of various lengths.

Taking into consideration the concept of form presented above, the following three sections discuss musical form in the contexts of previous empirical research in Music Perception, theoretical models, and Boulez's ideas about music and composition, respectively.

PERCEPTUAL VIEWS OF MUSICAL FORM

Particularly within the context of the definition of form provided above, time is an essential factor of musical form. In the domain of listening, the consideration of the temporal quality of musical structures implies the recognition of the limits of human memory. As Boulez himself has claimed, "the only possibility of being able to recognize [musical] form requires the work of the memory" (Boulez as quoted and translated in Walters, 2003). Studies in music perception have led many researchers (e.g., Levinson, 1997; Bigand, 1993; Clarke, 1987; Michon, 1977; Fraisse, 1957) to propose that the music listening experience is almost exclusively shaped in a moment-to-moment way. According to this view, listeners hear music in relatively short lapses belonging to the present and extremely near (seconds-away) past. The duration proposed for these lapses ranges relatively widely, from 2 seconds (Fraisse) to 30 seconds (Levinson). In terms of

musical form, 2 seconds often coincides with a short gesture or motive, whereas 30 seconds can correspond to a variety of levels ranging from a single musical phrase to an entire section (and even to an entire composition in extreme cases such as some of Webern's post-tonal miniatures). Nevertheless, in most musical works, short-term memory spans of 30 seconds would be insufficient for the listener to be able to instantly form connections across middle- and large-scale sections of the formal structure of most musical compositions (because those levels would not even be available). These views of listening limited to a short "perceptual present" (Fraisse, 1957) illuminate the understanding of the perception of musical form at a local level. However, they also imply that (1) listeners, by their natural tendency to focus on small lapses of time during music listening, cannot grasp many—if not all—of the middle- and global-level aspects of the musical form—of the majority of the compositions; or that (2) listeners' ability to perceive connections among musical events that are far apart in time should rely on the instant formation of memory links across those local, "perceptual-present" memory spans, and, in that sense, that it is only through memory that listeners can process—attending and re-attending to—aspects of the middle and global levels of the musical form.

A number of studies have further supported the first of these two ideas, providing evidence that listeners cannot perceive middle- to large-scale aspects of the form such as key modulations (Bigand & Parncutt, 1999), the order of formal sections in tonal compositions (Gotlieb, 1985), and a sense of unity or coherence of complete works from the Common-Practice period (Tan, 2005; Tillmann & Bigand, 1996). Even so, it is clear at the same time that amateurs have no problems accurately learning every single note of a song lasting several minutes by heart and advanced music students can naturally memorize entire compositions that are commonly half an hour long, suggesting that musical memory is somewhat extraordinary.[2] Even when moment-to-moment connections are likely to play an important role in the memorization of long musical works, the formation of a (more or less conscious) understanding of the overall formal plan seems necessary for the memorization of certain types of musical structures in their entirety. For instance, it seems improbable that musicians would rely on moment-to-moment memory connections for

[2] Kinesthetic memory plays an essential role in learning to perform a musical piece. This might mark an important difference between the cognitive processes involved in music reproduction and music listening. I do not intend to imply that memory for music listening is equivalent to memory for music reproduction, but merely to suggest that memory for music in general seems special when compared to other, non-musical domains.

the memorization of traditional rondo forms, where a refrain that is often stated without variation and in the same key is alternated with different and contrasting sections. In cases like this, connections of larger scope apparently allowing musicians to instantly recall the exact succession of large-scale sections (which section comes after which refrain) seem necessary. This provides support for the second idea proposed above, according to which listeners establish connections among musical events that are relatively distant in time by attending and re-attending to those events through the aid of memory. In this sense, memory would allow listeners to zoom out from the musical details and focus on musical developments of larger span.

Remarkably, the literature supporting an exclusive moment-to-moment type of listening experience is linked to the tonal repertoire. On the contrary, a number of studies on the perception of post-tonal compositions have suggested that not only musicians but, perhaps more surprisingly, also nonmusicians can perceive aspects of large-scale form such as the location of fragments within the global structure (Lalitte, Bigand, Poulin-Charronnat, McAdams, Delbé, & D'Adamo, 2004; Clarke, 1990; Deliège, 1989) and a sense of coherence in the order of large-scale formal sections (Tillmann & Bigand, 1996). Furthermore, this line of research has shown that surface features play a vital role in the perception of global coherence and organization of post-tonal compositions (see especially Lalitte et al., 2004; and Deliège, 1989). This idea is consistent with the function that surface-related contrasts play in formal delimitation of post-tonal compositions at the structural level and in music listening in general, an aspect described in Chapter 1 and discussed in Chapter 2.

Finally, a view of musical form that takes into consideration multiple hierarchical levels (as explained above) seems perceptually valid, especially when it comes to post-tonal music. Intuitively, it seems natural that the nuances that are possible within the many characteristics of music have the potential to play with the listener's attention in diverse ways, shifting it among different levels of the formal hierarchy. In effect, research has suggested that specific musical features can shift the listener's attention to larger levels of the formal structure. Specifically, Margulis (2012) found that as listeners hear a musical passage repeated several times (four or more, according to her findings)—either because the passage is restated within a musical piece or because the listeners hear the same piece several times—they can more easily detect repeated statements of that passage when it is long, but only with more difficultly when it is short. Based

on these empirical findings, Margulis proposes that musical repetition can lead listeners to shift their attention from shorter to longer musical segments, and, in that sense, from local to global levels of the formal hierarchy. It is relevant that the research providing evidence for a listening experience that involves multiple levels of the musical structure is so closely tied to repetition, the simplest facet of music predictability. It seems reasonable that higher degrees of predictability would be needed for listeners to efficiently process (from a cognitive perspective) multiple aspects (levels, in this case) of the musical structure. As discussed in the following section, the hierarchical aspect of music has played a central role in the development of theoretical models of musical form. Finally, hierarchy appears to be a potentially important aspect of form perception. It is not possible to infer from the available literature and empirical methods whether perception is itself hierarchical in some ways or able to grasp structural hierarchical aspects reflected in theoretically founded analyses of the music. Nevertheless, unless analysts explicitly avoid taking their perception of the music into consideration, hierarchy perception should in principle interact with hierarchical methods of organization.

THEORETICAL VIEWS OF MUSICAL FORM

The history of theory of musical form commonly distinguishes two trends or types of formal models: (1) architectural or static, and (2) processive or dynamic. The first type (best exemplified by most modern textbook approaches to musical form) sees form as a fixed hierarchical structure, a stereotypical architectonic plan that exists beyond the individuality of musical works and their unfolding in time. The second trend (exemplified by theorists such as Marx and Schmalfeldt) sees form as the result of a dynamic process and normally admits the idea of changing formal interpretations during the listening act. (For reviews on this topic, see Zbikowski, 2002, and Bonds, 1991.)

These theories are designed for the repertoire of the Common-Practice period, and are thus not necessarily (and certainly not directly) applicable to the vast majority of post-tonal music. As discussed in Chapter 1, no formal models have been proposed for the post-tonal repertoire. Instead, theories of post-tonal music have been more interested in developing models of pitch structures that commonly disregard issues related to the definition of the middle- and large-scale form and have been proven to be perceptually invalid (see Chapter 1 for details). The two traditional theoretical views of musical form presented here directly highlight the importance of

two aspects that—according to the perceptual research presented above—have shown potential to be also relevant for the perception of musical forms, in particular for post-tonal music: (1) the hierarchical structure, and (2) the temporal quality of musical forms. As discussed in the previous section, listeners are sensitive to different levels of the structure of post-tonal music. Similarly, time is necessary for music listening and the understanding of the organization of the musical materials. Following this, a model of form perception for post-tonal music should incorporate aspects representing the different hierarchical levels of the form as well as considering possible effects of the temporal organization of the formal components.

BOULEZ'S CONCEPTION OF MUSICAL FORM

Many of Boulez's ideas about musical form corresponding to the time of the composition of *Anthèmes 1* and *2* have been introduced in Chapter 1 and further discussed in Chapter 2. The purpose of this section is to complement information presented elsewhere in this dissertation and to provide an overview of the components of Boulez's conception of musical form that are particularly relevant to this chapter.

The recurrence of the following form-related aspects in Boulez's writings and lectures suggests that they are essential components of the composer's conception of musical form: (1) "formants" or "signals," (2) motivic transformations, (3) memory, (4) global vs. local perception, (5) predictability, and (6) elapsed time. Boulez often uses the terms "formants" or "signals" (point 1) to refer to formal markers for the listeners. In the composer's view, formants or signals help listeners to understand the form:

> The formants—or the sum total of the criteria of selection—in a large structure are the only originators of the perceptible 'points' or 'areas' that make it possible for a form to become articulate, as well as determining the physiognomy of the points and areas thus articulated. (Boulez, 1986, 93)

Boulez directly connects the idea of formants to the global level of the formal structure (Boulez, 1986). As discussed in Chapter 1, perceptual salience is an essential characteristic of Boulez's notion of formant. In this sense, and in line with the perceptual literature introduced above, musical materials acting as formal markers are intrinsically associated with noticeable changes in the surface (e.g., contrasts in surface features). Recall that the composer specifically refers to the long

tones in harmonics as the formal markers (in this case he uses the term "signals") of *Anthèmes*. The idea of motivic transformations (point 2 above) makes reference to the potential for constant variation of musical materials throughout a musical work. Boulez emphasizes the importance of the recognizability of materials that are stated in multiple (varied) forms. The notion of motivic transformations has been largely discussed in Chapters 1 and 2, since it constitutes a central point of departure for the hypotheses proposed in this dissertation and has been explicitly connected to *Anthèmes* by Boulez himself. As is the case for the six aspects of Boulez's conception of form presented here, the notion of motivic transformation is not specific to *Anthèmes*, but is rather more broadly representative of Boulez's later-career thought, as the composer declares, for instance, in his conversations with Deliège (1976). The relevance of memory (point 3) is directly linked to the idea of motivic transformations. The listener's ability to identify those transformations is greatly dependent on memory capacity and the many different ways in which the latter can be affected by the musical context. According to Boulez, an important part of the artistic potential of music resides in its ability to interact with the listener's memory and recognition:

> The play of recognition, the prospects of listening, this is what makes a work successful, what creates in us the feeling of immediate truth of a text and the truth hidden so deep that we are not sure of having grasped it in its totality. (Boulez as translated in Goldman, 2011, 71)

The notion of different levels of perception (point 4) is central to Boulez's late compositional style. He recognizes the significance of creating "a contrast between structures that are extremely clear and those that are so overloaded that they cannot possibly be assimilated," and directly parallels these polar structures with an opposition between a "really total perception," according to which the listener assimilates the details of the music, and an "overall perception," according to which all details get lost in favor of the apprehension of larger-scale structures and processes (Boulez, 1976, 51-52). With respect to predictability, Boulez appears to conceive of form as a relatively predetermined plan that must be flexible enough to admit the exploration of unpredictable paths or spaces. He claims that "form must be allowed to deviate from its expected trajectory in order to discover territories that were not 'programmed' [in advance]" (Boulez as translated in Goldman, 2011, 77). In line with this, he talks about the unpredictable order of the motivic materials in *Anthèmes 2*, an aspect introduced in Chapter 1 that will be further explored in Experiments 4 and 5. Finally, essential to the five aspects discussed above, elapsed time (point 6) constitutes a central

topic among Boulez's writings and lectures. Specifically relevant to the present project, the composer recognizes the necessary role of the passing of time in the listener's understanding of the total form of modern works:

> Since formal schemas today are no longer preconceived but are created, as it were, ambulando, in a sort of time-weave, it is impossible to be aware of the form until it has been actually described… [The listener's] 'angle of hearing' will be established only a posteriori, when the form has been completed. (Boulez, 1986, 94)

More broadly, Boulez's awareness of the temporal quality of music is most well known in relationship to his famous distinction between striated time and smooth time, which refer to a clear and discrete sense of pulse and rhythm and to an undifferentiated and continuously variable sense of time, respectively. Boulez believes that these two opposite tendencies of musical time are "capable of reciprocal interaction, since time cannot be only smooth or only striated" (Boulez, 1986, 87), further emphasizing the dynamic aspect of the perception of the temporal organization of music.

The parallelisms between Boulez's ideas presented above and the perceptual and theoretical literature discussed in the previous sections are remarkable. This is consistent with Boulez's unique view of form as an integration of conceptual thought with listening experience, as he describes it himself in a chapter dedicated to musical form:

> I have … attempted to define form as a group of concepts rather than as a gesture. (If I come to need a gesture, it will find a place within this group of concepts.) Finally it seems to me that I have resolved the antinomy between form as something thought and form as something experienced; since the concrete deductions on which it is founded, within a coherent system of formal logic, demonstrate that it can be experienced only by being thought. (Boulez, 1986, 96)

Based on the information presented here, the previously introduced quotes demonstrating Boulez's awareness of perceptual issues, and the findings reported in Chapter 2, if Boulez's creative work around 1950 is commonly seen to represent a paradigm of structural, mathematical, and carefully calculated musical practice, it seems reasonable to interpret the composer's later compositional style as a successful attempt to maximally unite theoretical (structural, mathematical) thought with listening experience.

Based on the above discussion on the perceptual and theoretical approaches to musical form and their relationship to Boulez's conception of composition, the following section proposes the basic elements for a rudimentary model of form perception.

Basic elements for a model of aspects of form perception

The previous section on musical form suggests remarkable connections among the perceptual, theoretical, and compositional (specifically "Boulezian") worlds, highlighting aspects of form that seem relevant across domains. In this sense and in line with the discussion above, these areas of coincidence are encouraging points of departure for the development of a theoretical model of form perception.

Most evidently, keeping in mind the discussion above, a model of form perception must take the temporal quality of music and listening into consideration, specifically the temporal development of musical events and how that development is perceived. Furthermore, ideally, the model itself should be dynamic in its very nature. In other words, at least some of the components of the model should allow for constant changes, i.e., they should be factors easily manipulated in different ways rather than fixed descriptions of elements. More specifically, they should be flexible factors in terms of the musical features that define them and the ways they can alter the listening experience. One aspect of form discussed in connection with the review of perceptual research and Boulez's compositional thought that is intrinsically dynamic is degree of predictability. Depending on their specific musical characteristics and their distribution, musical materials and sections can lead to different degrees of predictability, presumably revealing or obscuring diverse aspects and levels of the formal structure to the listener. Intuitively, listeners should more naturally relate a transformed musical material to its original (firstly introduced) model when both the original and varied forms follow equivalent musical passages (i.e., the model and variation come after the same or similar musical material). To illustrate this with an everyday example, we are most likely to clearly distinguish an alarm ringtone (of any kind) from a phone ringtone when we are expecting the alarm to go off rather than waiting for a phone call (unless we are dreaming!). We tend to more naturally and accurately identify expected events. In addition to repeated musical sequences, constant associations of certain musical materials with specific and salient features should also

facilitate the prediction and recognition of those materials for the listener. In effect, the ability of the listener to predict is greatly linked to repeated exposure.

Another aspect of form highlighted during the previous section is contrast in surface features. This aspect is not inherently dynamic; nevertheless it acquires a dynamic quality when thought of as an aspect of the blending of formal units or the degree of musical transition between musical materials and between sections. A contrast in surface features implies a sudden change in musical characteristics that are highly salient. It is dynamic in the sense that it requires a change. The degree of change and its immediacy are directly linked to the perceptual efficacy of the contrast as separator of the formal structure—in terms of its salience and its ability to capture the listener's attention. In line with this, it seems reasonable to propose degree of change in surface features or, more simply (and put in the reverse way), degree of formal-unit blend, as one of the dynamic factors for a model of form perception. Formal-unit blend then refers to the degree of temporal transition between musical materials or sections. This degree of musical transition refers to the extent to which the musical features of one formal unit can be thought of as generated through transformation from the features of the immediately previous unit, and to the rate at which that conversion occurs. Two formal units that are highly blended are likely to be perceived as a single unit, not naturally and intuitively segmentable during a first hearing. A sudden drop in formal-unit blend is likely to lead the listener's attention to the musical elements that cause such a drop. An extreme case of a sudden decrease in formal-unit blend would be, precisely, a contrast in surface features, which has been shown to almost immediately capture the attention of the listener. Following this, listeners should be more consciously aware of the return of a musical material or motive (in its exact or varied form) when it is reintroduced after a silence following material that is contrasting with the material in question.

Musical time, degree of predictability, and degree of formal-unit blend (or lack of change in surface features) could then constitute three essential dynamic factors of a model of form perception. The three aspects have been proven to be relevant in the fields of perception, theory, and composition—specifically in connection with Boulez's late style— and have a clear potential to shape the listening experience in dynamic ways. Another aspect recurrently discussed in all the subsections on musical form presented above is hierarchical structure. Boulez and composers in general often spend considerable time discussing and/or conceiving musical materials. The notion

of hierarchy provides an essential connection (and distinction) between musical materials and form. In *Anthèmes*, as is the case for the majority of the repertoire from all times, motivic materials can be seen as the fabric of musical form in the sense that they constitute minimum, indivisible musical units that, when combined and transformed in different ways, give place to larger levels of the formal hierarchy (or, put the other way around: form can be segmented into smaller units, giving place to indivisible musical motives). Following this, it is possible to think of motivic structure and middle- to large-scale formal structure as the most essential elements of the formal hierarchy. Intuitively, and according to previous findings, the listeners' exploration of different levels of the formal hierarchy would result from complex fluctuations of attention points during the listening act. It is particularly in this sense that the formal hierarchy can be seen as dynamic.

Figure 3.1 illustrates the main elements of the theoretical model of form perception proposed here.

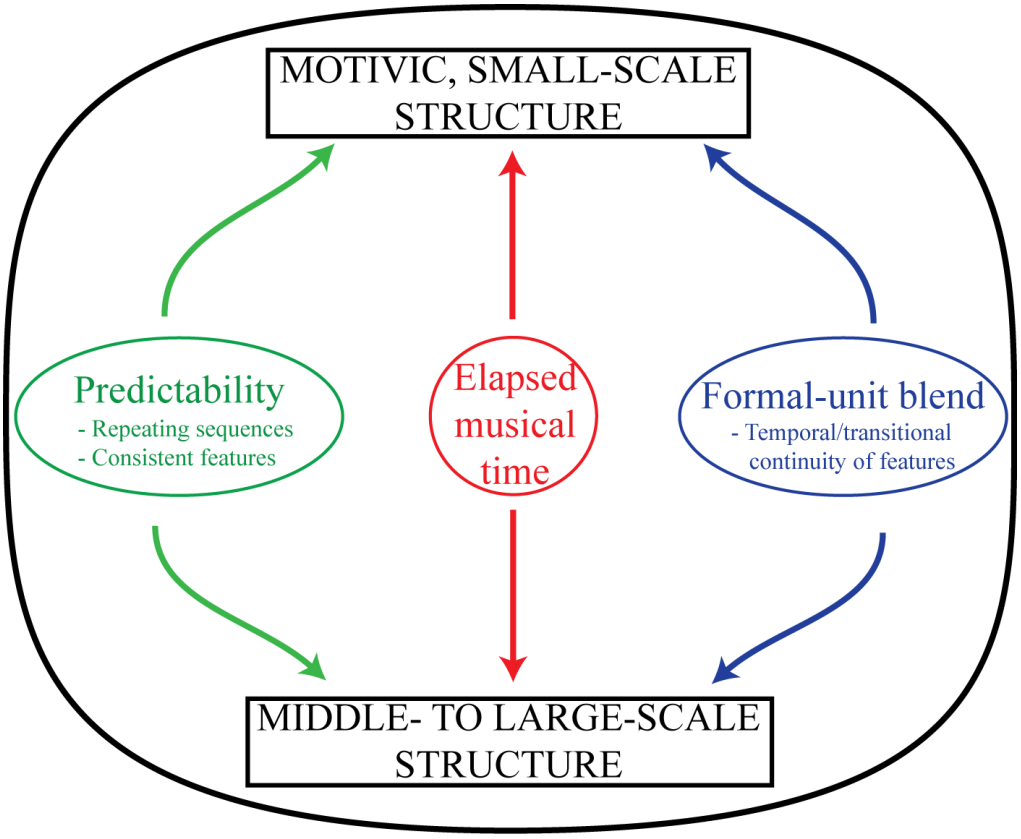


Figure 3.1: A rudimentary theoretical model of form perception

Elapsed musical time, predictability, and formal-unit blend are the central dynamic elements of the model, because they are expected to constantly shape the listeners' experience and apprehension of the musical form by (presumably) more or less consciously guiding their attention during listening to different aspects and levels of the musical structure. Motivic structure and middle- to large-scale formal structure surround the three main dynamic elements, because they represent relatively fixed (systematically determined) theoretical and analytical principles of the musical form whose understanding (perceptual comprehension) depends not only on their interactions, but also, perhaps more importantly, on the way they are affected by the three dynamic elements represented in the center of the figure. The arrows represent acting forces, i.e., interactions, influences, or effects. The specific way in which these forces work during music listening and their role in the listener's comprehension of the formal structure will be discussed in connection with the results of two empirical studies, described below.

In Experiments 4 and 5, listeners press the space bar of a computer keyboard every time they identify variations of a given—previously heard—musical motive while listening to *Anthèmes 1* (Experiment 4) and *Anthèmes 2* (Experiment 5). The participants are musicians who conceptualize musical variations based on their own criteria and perform the task with the five motivic families that were explored in Chapter 2. Accordingly, the results should elucidate musicians' perception and implicit conceptualization of motivic variation or transformation (motivic relationships) during listening. The degree of certainty with which musicians identify motivic instances as variations (the perceptual associations among the different transformations of the motives) within and across the formal sections of the large-scale formal plan, and the musical context in which those instances occur support the formal model proposed above and shed light on how the different factors of the model operate and interact.

The clear formal plan of the two versions of the composition, along with the characteristics of the motivic structure of *Anthèmes* (discussed in Chapter 2), provides an ideal natural musical environment to elucidate the theoretical model of form perception introduced here. Formal analyses of *Anthèmes 1 and 2* are proposed in the following section.

Form in *Anthèmes 1 and 2*

In a discussion with the French musicologist Peter Szendy on the occasion of the premiere of *Anthèmes 2* in 1997, Boulez described the title *Anthèmes* as a "play" on the words anthem or national hymn and theme. He states that the piece is an anthem in the sense that "there is a succession of verses and paragraphs which are constructed as hymns, that is as a kind of refrain," and that it is thematic in the sense that it is full of musical entities that are in constant transformation throughout the piece but are still always immediately identifiable (Boulez as translated in Goldman, 2001, 105-106). He then explains the role that the long tones in harmonics play in defining the hymnic structure of the piece, paralleling their perceptual salience to the formal function that Hebrew letters play separating Latin verses in the Book of Lamentations by the prophet Jeremiah:

> I will discuss, however, what must strike you when you listen to the piece. Certainly the most obvious thing that must strike you are the interruptions, in which, shall we say, not much is happening. These passages, in which [the violin] plays long notes in harmonics, contrast with other moments in which there is much activity. I would compare these—since I have already spoken of verses and paragraphs—to letters. I remember when as a child we used to chant the *Lamentations* of Jeremiah during Easter holy week. What struck me then was that although the text was of course in Latin, the verses were separated by letters, that were themselves chanted, but in Hebrew; that is, *aleph*, *beit*, etc. This is close to the system I have used here. After a short introduction, the first letter announces the first paragraph. This is followed by the paragraph, in which there is a certain amount of activity. (Boulez as translated in Goldman, 2001, 108)

Inasmuch as the title *Anthèmes* is linked to the global formal plan characteristic of hymns and to the idea of thematic—specifically motivic—development, the composition, in its two versions, can be seen to explicitly allude to the two essential aspects of the formal hierarchy incorporated in the theoretical model proposed above (top and bottom elements in Figure 3.1).

ANTHÈMES 1

Formal structure

Table 3.1 illustrates the formal structure of *Anthèmes 1*.

Table 3.1: Form of *Anthèmes 1*

Large-scale form (duration in s)	Formal Procedures	Middle-scale form	Motivic structure	Timings for motives (in s)*
Introduction mm. 1-2 (18 s)	Presentation of one motivic instance of some of the most important motivic families, separated by musical silence.	N/A	M1 T1 Batt S1 Batt L1	0.51 1.12 13.30 18.92
Section I mm. 3-14 (55 s)	Repetition of exactly the same motivic succession: S (*jeté*), T (single trill and two-line-texture trill), GrNotes (The repeated pattern is considered to start with S—rather than with GrNotes—because of the continuity in terms of contour, articulation, and character between T and GrNotes—and the relative contrast in those respects between GrNotes and S—and because in the final statement, GrNotes is clearly the end of the pattern.)	I.1	GrNotes S2 T2 T/5 T/6 GrNotes	 30.16 30.72 35.94 41.46
		I.2	S3 T3 GrNotes	49.67 50.28
		I.3	S4 T/10 GrNotes	58.39 59.04
		I.4	S/10 T/11 GrNotes	63.80 64.34
		I.5	S/12 T/13 GrNotes L2	69.95 70.47 77.93
Section II mm. 15-45 (57 s)	Successive statements of motives from the Pizzicato family.	N/A	P1 P/19 P2 P3 P4 P/34 P/37 L3	85.29 88.40 93.20 96.95 99.79 101.50 104.51 117.14
Section III mm. 46-66 (49 s)	Repetition of exactly the same motivic succession: Trem, S (*jeté*), T (single trill motives the first time, two-line-texture trill motives the second time), Stacc.	III.1	Trem S5 T/47 Stacc	 142.22 142.54
		III.2	Trem S6 T/58 T4 Stacc L4	 156.13 156.48 161.34 175.98
Section IV mm. 67-89 (77 s)	Highly transformed motivic materials. Exclusive use of specific and relatively clear subcategories within each motivic family: trills in multiple-stops, slurred and longer scales, and complex and diverse melodic materials.	N/A	T5 T6 S/72 T7 M2 Accent M/77 S7 T/80 T/81 L5	190.74 196.66 203.58 205.09 210.63 218.19 221.64 222.57 227.07 250.93
Section V mm. 90-97 (36 s)	Symmetrical (palindromic) distribution of motivic categories.	N/A	S/90 T/90 GrNotes Stacc GrNotes T8/94 T8/96 S/96 L6	267.97 268.53 278.27 284.09 289.59 292.78

Section VIa mm. 98-112 (50 s)	Alternation of motives from the Melodic and Trill groups. The alternation pattern is (unpredictably) segmented by the occasional appearance of BrArp followed by musical silence.	VIa.1	S8 T/98 M3 T/99 M4 T/100 M/101 T/101 M/102 T/102 BrArp	303.70 304.44 306.37 306.94 308.51 309.53 311.55 312.37 313.74 314.42
		VIa.2	M5 T9 M6 T/105 BrArp	321.01 322.95 325.88 326.43
		VIa.3	M/107 T/107 M7 T10 M8 T/109 BrArp	332.09 333.02 334.91 335.57 337.20 338.36
		VIa.4	M/111 T11 M/112 T/112	344.13 345.18 348.02 349.72
Section VIb mm. 113-143 (84 s)	Random sequence of motives from subgroups/groups M with *brusque* character, P, S in double-stops with descending direction, and PlTri.	N/A	S9 P5 M9 P/116 S/117 P/118 PlTri M/120 PlTri P6 PlTri P7 S/125a S/125b M/126 PlTri P/128 S10 M10 PlTri P/131 M11 S/133 M/134 S/135 PlTri P/136 S/137 M/137 P/138 S/139 Chord PlTri S/141 Chord PlTri P/142 S/143	353.90 356.50 358.81 360.47 363.27 364.99 369.46 373.80 380.52 383.07 384.09 385.29 389.24 392.81 394.48 397.96 402.25 403.82 405.60 406.69 410.07 414.29 415.99 417.24 420.57 426.04 431.36 435.29

VIc mm. 144-165 (81 s)	Formal-unit blend: boundaries in terms of both musical features and formal segmentation between motives from S, M, T, and TM are blurred.	VIc.1	M12 TM1 BrArp	437.53
		VIc.2	M/148 TM/149 M/150 TM /150 M/152 TM /152 M/153 TM/153 M/154 TM/154 S/154 M/155 TM/155 S/156 M13 TM/159 BrArp	448.16 464.57 465.53 468.03 469.01
		VIc.3	S11 M14 TM2 T12 T13 LongNoH L7 Batt	478.17 480.66 485.32 495.03 507.32

NOTES:
Batt: Clearly separated notes with *spiccato* articulation produced beating the strings with the bow (*battimento*)
GrNotes: Slurred pattern in triplets ornamented with emphatic grace notes.
Trem: *Tremolando* pattern *sul ponticello* ornamented with quick grace notes.
Stacc: Pointillistic texture in *staccatissimo* with sudden and rapid dynamic contrasts.
Accent: A gesture of 2 accented notes that sounds like an emphasized quasi-repetition of the end of M2. Because of the surrounding silences and the contrasting character with respect to M2 and M/77, these 2 notes are here interpreted as a separated, contrasting material.
BrArp: Broken arpeggios with a regular rhythm and diminuendo dynamic profile, in staccato.
PlTri: Rapidly arpeggiated plucked (guitar-style) trichords.
Chord: A trichord in multiple stops and loud dynamic level with *brusque* indication. This material can be seen as related to the Melodic subgroup with *brusque* character. Nevertheless, since it is only one musical event, it does not have any of the characteristics of the Melodic group as defined in Table 2.1.
LongNoH: Long tone on open string and not in harmonics.
* Timings are based on the recording by J. M. Conquer at IRCAM in 2002 (Boulez, 2013).

The large-scale form is shown in the leftmost column. Measure numbers and durations for each section (taken from the recording used for the experimental portions of this dissertation, i.e., J. M. Conquer, 2002—Boulez, 2013) are shown in parentheses. Motivic materials are displayed in the fourth column, illustrating the local level of the formal hierarchy. The labeling system for motivic instances is consistent with that employed for the analyses presented in Chapter 2. Accordingly, the labels for all motives start with the first letter of the name of the motivic category to which they belong, and motives that were used in Experiments 1 to 3 have their independent numbering system, whereas the rest of the motives are labeled according to measure numbers following a slash. Letters representing motivic categories excluded in Experiments 1 to 3 are referenced in the notes below the table (it was necessary to include all motivic categories here, in order to have a

better understanding of the form). Representative examples of the motivic categories can be consulted in Appendix A (motivic categories used for the experiments in this dissertation) and Appendix B (motivic categories excluded from the experiments). For simplification purposes, due to the magnitude of the table, in cases in which the measure number is indicated, only the measure number corresponding to the onset of the motive is indicated and beat numbers are omitted. Motivic family (first letter in the label) and measure numbers (following the slash) should suffice to easily identify on the score all the motivic instances listed here. (Motives used in Experiments 1 to 3 can be localized in the score by consulting Table 2.1 (p. 25), or by approximation with respect to the measure numbers corresponding to the surrounding motives in Table 3.1.) The specific temporal location in seconds for motivic instances as they occur in the recordings used for the experiments is displayed in column 5. Only the timings for the motivic instances studied in Experiments 4 and 5 are included (see the section titled Formal Segmentation and Motivic Analysis below for details). An interpretation of the middle-scale level of the form can be seen in the third column of the table, for cases in which subdivisions at this level were relatively clear. The motivic and middle-scale formal analyses (columns 4 and 3 in the table) are my own interpretation, based on the description of the motivic families proposed in Chapter 2 and on traditional criteria for motivic analysis and formal segmentation. Supported by the perceptual and theoretical literature, my analysis emphasizes contrasts in surface features, musical silence between passages, and repetition of patterns or formal processes. The delineation of the large-scale form follows Boulez's explicit reference to the role of the long tones in harmonics in the definition of the formal structure of the piece.[3]

The interpretation of the final (sixth) part ending with a long tone in harmonics as three large-scale formal units is supported by clear differences in formal processes among those units. Section VIa is mostly based on the alternation of motives from the Melodic group with those from the Trill group. The alternation is interrupted three times with the incorporation of materials consisting of broken arpeggios in staccato ending on a musical rest. These interruptions provide

[3] The long tones in harmonics are, according to Boulez, formal separators. In that sense, they are formally independent musical materials that do not belong to any formal section. Nevertheless, given that the piece ends on such a long tone and with the purpose of including them within the formal plan, they are here analyzed (represented in the table) as the materials ending each formal unit.

clear internal subdivisions to this section. The first of these interruptions within this section is shown in Figure 3.2.

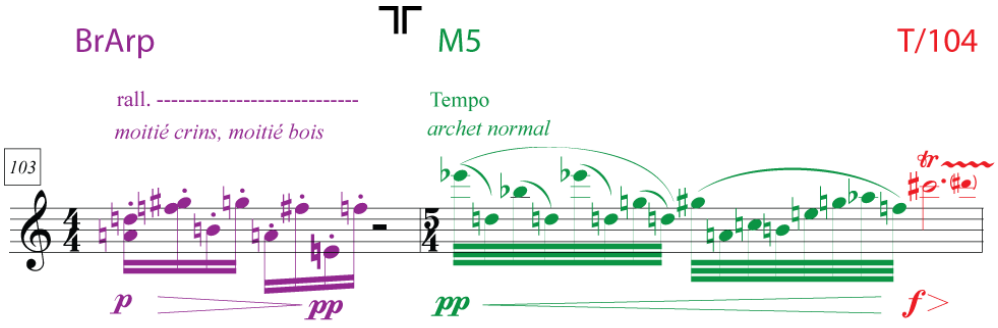


Figure 3.2: Broken Arpeggio motive causing the first internal segmentation in section VIa[4]

Section VIb alternates motives from the Scale, Pizzicato, and Melodic groups as well as materials consisting of plucked arpeggiated trichords in an apparently random fashion, resulting in what I interpret as the most unpredictable section of the piece. Examples of these four families alternated in section VIb are shown in Figure 3.3.

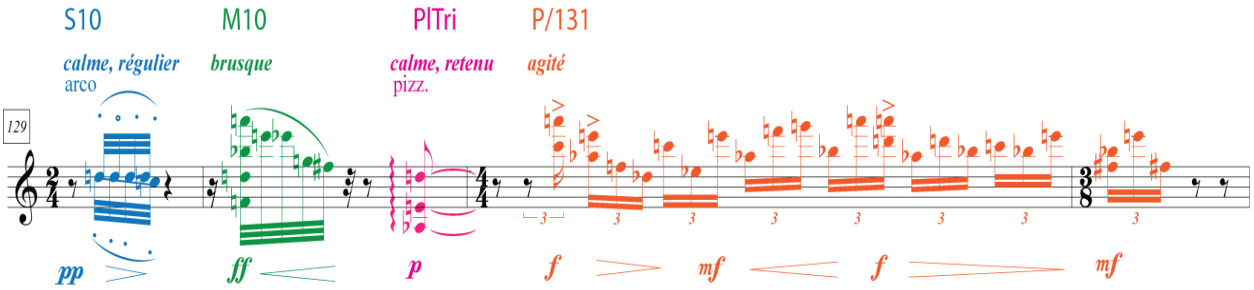


Figure 3.3: Motivic materials in section VIb

The figure corresponds to the passage in mm. 129-132. Finally, the formal process that characterizes section VIc can be described as an uninterrupted transformation of musical materials that results from the lack of clear formal segmentation and the interchange of features across

[4] All the musical examples included in this dissertation are reproduced with permission of Universal Edition A.G. (Boulez, 1992).
Anthèmes 1|für Violine. © Copyright 1992 by Universal Edition A.G., Wien/UE 19992

motivic families. Motives from the Melodic, Scale, and Trill groups are stated almost without surface breaks of any kind at the same time that hybrids from the Melodic and Trill groups of the type of TM1 and TM2 (see description of the TM group in connection with Figure 2.1, p. 27) are incorporated. The lack of surface contrast is the result of the use of an isochronous rhythm, constantly slurred or long articulation style, and dynamic (intensity) and pitch (register) transitions (gradual changes) between the instances from different motivic categories. The process of motivic blurring that characterizes this section is perhaps most clearly illustrated in the final measures (mm. 161-165 or middle-scale section VIc.3, reproduced in Figure 3.4).

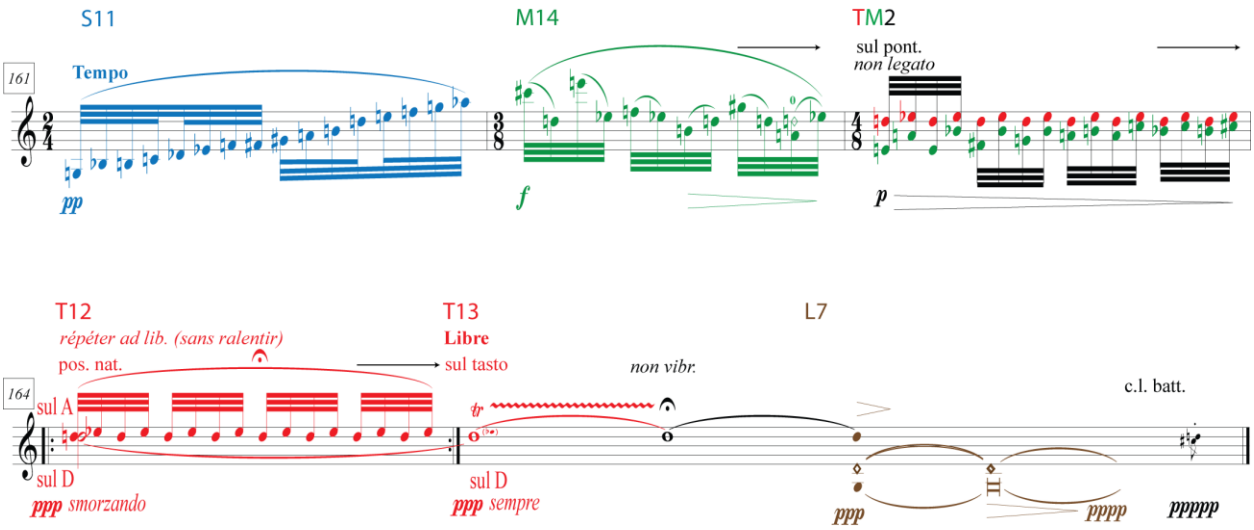


Figure 3.4: Motivic blurring at the end of *Anthèmes 1*

In this final passage, a motive from the Scale group serves as pickup to material from the Melodic group (m. 161-162). This Melodic material is soon hybridized into TM2 (m. 163) to then become a slow trill (m. 164). The slow trill soon becomes a regular trill (m. 165). Finally, the regular trill stops on an open-string long tone that in turn becomes the harmonic of the final statement from the Long Tone group. Section VIc represents the highest degree of formal-unit blend (lowest degree of surface contrast) in the entire composition. In addition to their correspondence to different formal processes, the large-scale tripartite interpretation of section VI is concordant with formal delimitations indicated with Arabic numerals in the published score of *Anthèmes 2* (Boulez,

1997). Furthermore, the subdivision in nine sections of the global hierarchy proposed here is also consistent with Goldman's (2011, 2001) analysis.

The observations indicated in column 2 of the table relate to factors of the theoretical model proposed above, in particular to issues of predictability and formal-unit blend. Sections I and III are the most predictable ones as they are based on a repeating sequence of motives that belong to unique and clearly differentiated motivic families. Section VIc is associated with the highest degree of formal-unit blend. According to the theoretical model proposed above, motivic transformations belonging to a given motivic family should be relatively easily identified as varied instantiations from that family in sections I and III, whereas their perceptual relationship to the family is likely to be obscured by the lack of formal segmentation and clear onsets of the motives that characterize section VIc.

This section has presented a formal analysis of *Anthèmes 1*, with a special focus on the motivic categories and formal procedures. The segmentation of the formal structure was justified at the largest levels of the formal hierarchy on the basis of Boulez's ideas, previous analyses of the piece, distribution of the motivic materials, and formal procedures. The following section explains analytical decisions concerning the segmentation of the formal structure at the lowest hierarchical levels.

Formal segmentation at the motivic level

The identification of all the instances of motives belonging to each family was conducted according to the definition of the motivic categories presented in Table 2.1 (p. 25) and consistently considers a very low level of the formal (grouping) structure. Because the motivic families were largely defined in terms of the contrasting musical features (particularly surface features) among them, the segmentation of the grouping structure was straightforward in cases in which motives from different families were juxtaposed. Partly due to the post-tonal idiom of the piece, motivic segmentation was quite obscure in sections lacking motivic contrast, i.e., in those passages in which motives from the same category appeared in succession. In order to consistently analyze the piece at a local level of the formal structure and due to the relatively fragmentary quality of these passages built with motives from a single category, it was necessary to define a set of segmentation rules to apply to these passages.

The criteria for segmenting successive statements of motives belonging to the same family were based on fundamental Gestalt principles of proximity and similarity. These principles were directly derived from Lerdahl and Jackendoff's *Generative Theory of Tonal Music* (1983). Lerdahl and Jackendoff's theory was chosen on the basis of the following criteria: (1) it is the most popular theory of musical segmentation, (2) the theory was both theoretically and perceptually inspired, and (3) the rules of the theory have been validated empirically—Deliège, 1987. The following rules were defined based on Lerdahl and Jackendoff's grouping preference rules of proximity of attack, change, and intensification[5]:

1. Attack proximity: a relatively long duration (for a given musical context) between the attack of the last event of a musical fragment and the onset of the first event of the following (adjacent) fragment. Considering that relatively long durations between attacks do not indicate phrase limits in post-tonal music as consistently as in tonal music, this rule was further restricted by also including a rhythmic contrast. Specifically, this rule was applied only when the duration between the last attack of a fragment and the first attack of the next (second) fragment was at least twice as long as that between the first and second event onsets of the second fragment.
2. Rhythm change: a clear change in the rhythmic pattern (including sense of speed) of the music in one fragment with respect to the previous one.
3. Register change: specifically, a pitch interval equal to or larger than a seventh between the last note of a musical fragment and the first note of the next fragment. The interval of a seventh was chosen for being considerably larger than the intervals used by the motives within each family, and for suggesting a change in register in the context of a piece in which octaves and intervals larger than an octave are noticeably uncommon.

[5] The GTTM rule of parallelism is excluded here due to the characteristics of the musical style. In *Anthèmes*, there are no instances of exact and immediate (successive) repetition of musical gestures at the motivic, local level (the only case of exact repetition of a motivic material in the entire piece occurs in m. 36 with respect to m. 33, but there is a musical passage in between that is not part of the repeated material). Similarly, transposed or near-exact immediate repetition of small musical gestures is extremely rare and occurs only at an extremely small level—even smaller than what is here considered the motivic level—of the formal hierarchy. Due to the tendency of this style to avoid immediate repetition and to the diminutive level at which such repetition occurs, parallelism plays an integrating rather than segmenting function in the definition of the formal units (even at the motivic level as it is considered throughout the analyses presented here).

4. Contour change: a noticeable change in the overall melodic shape of successive musical segments.
5. Texture change: a clear switch from one texture to another, such as from a monodic melody of trills to a contrapuntal texture of two melodies.
6. Dynamic change: a contrast in the dynamic level of the end of a fragment compared to the beginning of the next fragment.
7. Timbre change: a change in timbre caused by a shift in bow position such as from natural position to *sul tasto*. Note that other kinds of timbre changes were accounted for in the definition of the motivic families and therefore do not occur at the level of analysis being discussed here.

Figure 3.5 illustrates the application of the rules to the delimitation of the Trill motive in mm. 5 and 6, defining the boundary between T2 and T/5. The four rules that apply (change of texture, rhythm, contour, and register) are shown below the musical notation.

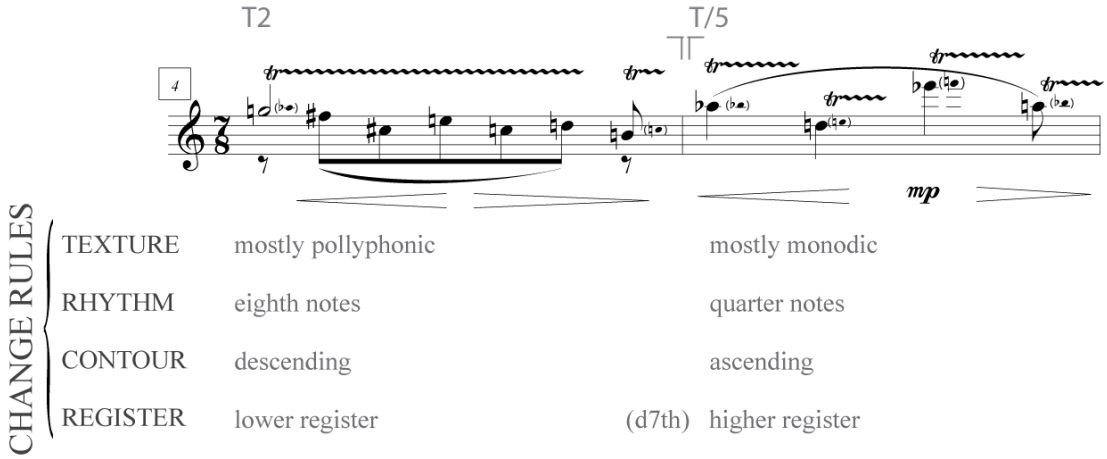


Figure 3.5: Segmentation rules applied to the boundary defining T2 and T/5

The first rule (attack proximity) was given special priority (weight) based on previous findings from perceptual experiments (Deliège, 1987). In passages in which motives belonging to the same family were stated in succession, the musical structure was segmented at points where either (1) at least three of the rules above applied or (2) the first rule applied and could be supported by the application of a second rule. Table 3.2 shows the justification for the segmentation of

motives in passages where the delimitation of the music could not be determined based on the contrasting features that defined the motivic families (i.e., in sections in which motives from the same family were presented in succession). Each pair of consecutive motives from the same family is shown in a different row of the table. As described above, in the final section of the piece (VIc), motives from the Melodic category alternate, on the one hand, with motives that blend the Melodic and Trill categories (TM type), and, on the other hand and more occasionally, with motives from the Scale category or with broken arpeggios in staccato.

Table 3.2: Segmentation of successive statements of motives from the same family

Motives	**Segmentation Rules**							**Observations**
	Attack	**Rhythm**	**Register**	**Contour**	**Texture**	**Dynamic**	**Timbre**	
T2 — T/5								
T/5 — T/6								
P1 — P/19								
P/19 — P2								P2 contains an internal and almost-exact pitch/rhythm adjacent repetition at a very small level (<E-B ♭ -A-D ♭ > followed by <F- B ♭ -A-D ♭ >) that justifies the indivisibility of the motive as a whole (i.e., not segmenting P2 internally).
P2 — P3								
P3 — P4								
P4 — P/34								
P/34 — P/37								P/37 is considered a single unit in spite of its relative internal musical diversity because it contains almost-exact pitch/rhythm adjacent repetitions at a very small level (<G-D-B>, exactly repeated and subsequently followed by <G-E-B>) that stand out together as a unit in the overall motivic complexity of the passage.
T/58 — T4								
T5 — T6		(stable vs. in-stable)						
T/80 — T/81								The rules above might suggest an internal segmentation of T81 on the last eight note of m. 87. Nevertheless, an exact pitch-interval repetition with a proportional rhythmic augmentation coincides with that moment (<A-E ♭ followed by <D-G♯>), suggesting that mm. 81-88 are an indivisible unit.
T8/94.3 — T8/96.1								T8 was originally treated as a single motive in Experiment 1 (and in the analysis presented in Chapter 2). According to the rules applied for the delimitation of motives in relationship to Experiment 4, the motive is split into two smaller segments.
S/125.1 — S/125.4								
T12 — T13				( ) (if heard as succession of 2 alternating notes vs. a single trilling note)				

Taking into consideration the strong resemblance of the motives from the Melodic category with those from the TM type, the delimitation of the Melodic motives in this final section was based on

clearly salient contrasts only. These contrasts were defined as involving the juxtaposition of musical material clearly (and only) featuring aspects of the Melodic family with material from a different motivic category. Following this, Melodic motives were considered to begin only when there were clear contrasts in surface features; specifically, when these motives were preceded by a Scale motive or the broken arpeggios in staccato (contrast in melodic contour and/or articulation). Accordingly, measures 144, 148, 155, 157, and 162 were considered onsets of motives from the Melodic family, and these instances were taken into consideration for the exploration of the perceptual data collected in Experiments 4 and 5. This is why only these instances of the Melodic group have the corresponding onset timings in Table 3.3. The musical materials belonging to the TM hybrid motivic type were ignored in all the statistical analyses corresponding to the Melodic and Trill groups.

ANTHÈMES 2

Formal enlargement

Boulez refers to *Anthèmes 2* as an "expansion" of *Anthèmes 1*, where "the voice of the violin is prolonged and amplified through an electronic device" (my translation from Nattiez, Boulez, Bonnefoy, Bernier, Conquer, & Goldman, 2014, 21). The second version of *Anthèmes* is more than twice as long as the original. Figure 3.6 shows the proportion of duration increase by section in *Anthèmes 2* with respect to the original piece.

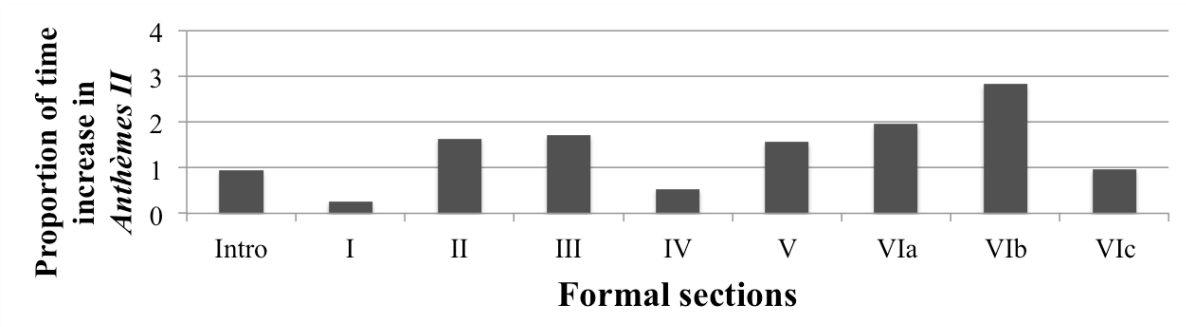


Figure 3.6: Duration (proportion of time) increase per section in *Anthèmes 2* with respect to *Anthèmes 1*

The increase in duration is translated to a proportion on the y-axis, with 1 corresponding to a 100% increase in duration (a doubling of the duration of a section). Proportions are calculated based on the timing of the recordings used for the experiments (Boulez, 2014, 2013). As illustrated, most sections are at least twice as long as the corresponding original section. Section VIb is affected by the largest enlargement.

As mentioned, every musical note in *Anthèmes 1* can be relatively easily found in *Anthèmes 2*. The two versions of the piece share the motivic materials. With respect to the global form, the electronic version expands each of the original sections while keeping both their definition (characteristics that hold those sections together) and their internal organization quite intact. The enlargement is the result of several factors. Most obviously, the resonance of the electronic effects demands longer times than that of acoustic sounds, which in turn affects the performance tempo adopted for the musical passages. In this respect, it is important to note that the electronic resonance has an overall effect in the definition of the formal structure of *Anthèmes 2*, blurring its local segmentation with respect to the form of *Anthèmes 1*. More relevant to a study of form, it is possible to interpret the enlargement of the composition as the result of three types of *formal-enlargement processes*, categorized according to their effect on the hierarchical structure: (1) intra-motivic-level enlargement, IME: motivic extension, interpolation, or expansion within the small-scale, motivic, indivisible level, (2) inter-level enlargement, ILE: motivic extension or interpolation that converts motives into middle-scale, divisible sections, and (3) enlargement through formal-unit addition, UAE—for unit-addition enlargement: large-scale formal enlargement resulting from the interpolation of entire sections built with motivic instances not appearing in *Anthèmes 1*. As explained in the description of these enlargement procedures below, type-2 (ILE) expansions and type-3 (UAE) extensions are theoretically possible, whereas type-3 (UAE) expansions are not (all three enlargement subtypes—extensions, interpolations, and expansions—are theoretically possible within types 1 and 2, whereas only extensions and interpolations are theoretically possible within type 3). Because type-2 (ILE) expansions and type-3 (UAE) extensions do not apply to *Anthèmes 2*, they are not included in the list above.

The first two types of formal processes (IME and ILE) enlarge motivic instances explicitly stated in *Anthèmes 1*, whereas the third type (UAE) adds motivic materials that do not explicitly appear in the original work, but still belong to a motivic category clearly featured in

Anthèmes 1. The difference between intra-motivic-level and inter-level enlargement is given by the level of the form that they affect. In type 1 (IME), the enlargement procedure does not interfere with the internal indivisibility of the musical materials (i.e., the materials remain the small-scale blocks of the formal structure). In type 2 (ILE), the enlargement procedure converts the original motivic gesture into a middle-scale formal unit that is clearly divisible into multiple smaller units. The internal divisions associated with type 2 (ILE) are often the result of musical rests, re-triggerings of the electronic effects, or sequential treatment of the original motive. In terms of motivic materials, musical passages enlarged through type 2 (ILE) remain motivically homogeneous. In reference to type-1 (IME) and type-2 (ILE) enlargement sub-types, extension corresponds to the addition of material after the end or before the beginning of a motive, whereas interpolation corresponds to the incorporation of additional musical events (notes and/or rests) in between the original component events of a motive. Expansion corresponds to a temporal stretching of the motivic material that leaves its pitch structure (and organization) intact, affecting—through augmentation—only the rhythmic (durational) values. In the context of *Anthèmes 2*, expansions (which are all of type 1—IME) do not exactly preserve the rhythmic proportions (relationships among durational values) of the original. However, they convey a sense of temporal stretching that does not disrupt the original rhythmic relationships in any obvious way. (Furthermore, in certain cases the proportions are preserved). Because the difference between type 2 (ILE) and type 1 (IME) is exclusively linked to the internal segmentability (or lack thereof) of the musical materials, extensions, interpolations and expansions are theoretically possible within both types of enlargement.

The third type of formal enlargement (UAE) refers to the addition of entire middle-scale sections into formal units of large scale. These middle-scale sections are made up of motivic materials whose dimensions are comparable to the majority of the motivic material of *Anthèmes 1* (short indivisible motives). In this sense, type 3 (UAE) is the kind of formal enlargement that best preserves the original dimensions of the motivic material—and with it the local level of the original form—although it does so by incorporating new material. The formal processes taking place in the added middle-scale sections are clearly compatible with the formal process defining the original section being enlarged. Theoretically, type-3 enlargement procedures (UAE) can be of interpolating or extending nature. This is to say, it is possible to add small sections within (interpolation) or before/after (extension) a previously conceived formal unit, making it larger.

The effect of the interpolation or extension of middle-scale sections on the overall form of a section is of enlarging rather than interpolating or extending nature, in the sense that it stretches the large-scale formal plan of that section as a unit, elongating the formal process that defines it. Type-3 (UAE) expansions are not theoretically possible, because an expansion refers to the rhythmic alteration of the original musical events and type-3 enlargements necessarily add new events.

Examples of the subtypes of formal enlargement used in *Anthèmes 2* with a focus on the five motivic categories studied in the empirical portion of this dissertation are presented in the following paragraphs. A more rigorous analysis of how the three types of formal enlargement affect all the motivic materials of the piece in each section can be found in Table 3.3.

Type-1 (IME) extensions are featured in the introduction and section III. In the introduction, M1 is extended. In section III, the motives corresponding to the Scale and Tremolo groups are extended. Figure 3.7 shows S5 in its extended (*Anthèmes 2*) form. The notes of the original version that appears in *Anthèmes 1* are shown in black, whereas the added notes are shown in blue. In this case, the extension occurs at the beginning of the original motive.

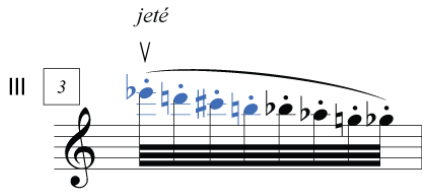


Figure 3.7: Type-1 (IME) extension of S5[6]

Type-2 (ILE) extensions become particularly relevant transformations of motives from the Pizzicato, Melodic, and Plucked Trichord groups in section VIb. In this section, additional motivic fragments are often separated by short pauses, transforming the original indivisible formal unit into a divisible one. Figure 3.8 illustrates the type-2 (ILE) extension of M10. The original version of M10 (as it appears in *Anthèmes 1*) is shown in black, and the added fragments are shown in

[6] All the musical examples included in this dissertation are reproduced with permission of Universal Edition A.G. Anthèmes 2|für Violine und Live-Elektronik. © Copyright 1997 by Universal Edition A.G., Wien/UE 31160

blue. As is often the case with type-2 (ILE) extensions, the extension occurs before the beginning of the motive.

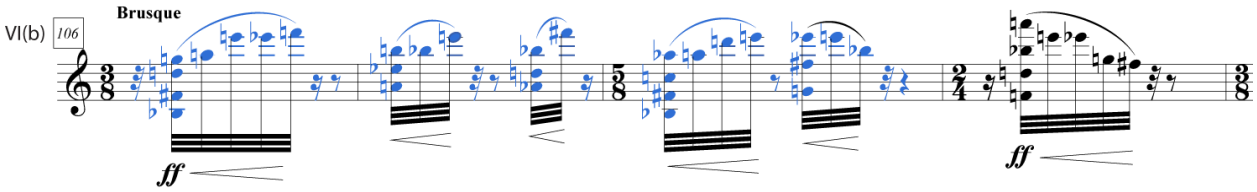


Figure 3.8: Type-2 (ILE) extension of M10

Type-1 (IME) interpolations mostly affect motives from the Scale group in section VIb and motives from the Scale and Melodic groups in section VIc. In all type-1 (IME) interpolations that affect scalar patterns, the boundary notes of the original scale remain the same, but extra notes are added in the middle. The original and interpolated version of S9 are illustrated in Figure 3.9 (top and bottom, respectively).

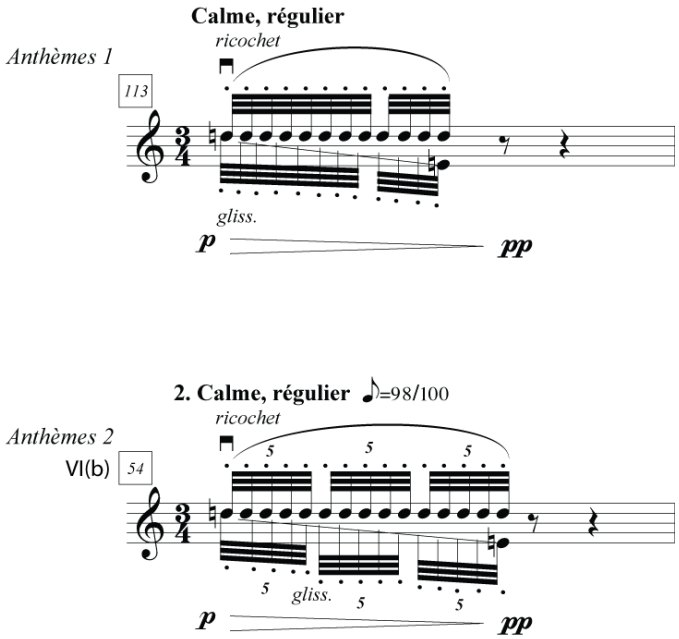


Figure 3.9: Type-1 (IME) interpolation of S9

Three extra notes are interpolated in between the extremes of the original motive (it is not possible to determine which exact notes are the ones being interpolated, due to notation). Type-2 (ILE) interpolations apply exclusively to the broken arpeggios in staccato in section VIc. This motivic material is particularly apt for interpolations that lead to internal segmentations of the original indivisible material, i.e., type-2 (ILE) rather than type-1 (IME) interpolations, because of its tendency to rapidly diminuendo to silence and its directional descending contour. In section VIc, the type-2 (ILE) interpolations of the Broken Arpeggio motive are the result of the sequential treatment of portions of the original motive.

Type-1 (IME) expansions occur in sections I, III, and V, exclusively in connection with motives from the Trill group featuring a two-voice texture. The expanding transformation that affects T2 is shown in Figure 3.10. The figure illustrates the original motive (*Anthèmes 1*) on top and its expansion in *Anthèmes 2* on the bottom. In this case, the rhythm is often augmented either 2 or 3 times (compare the rhythmic pattern of the bottom line in the two versions of the motive).

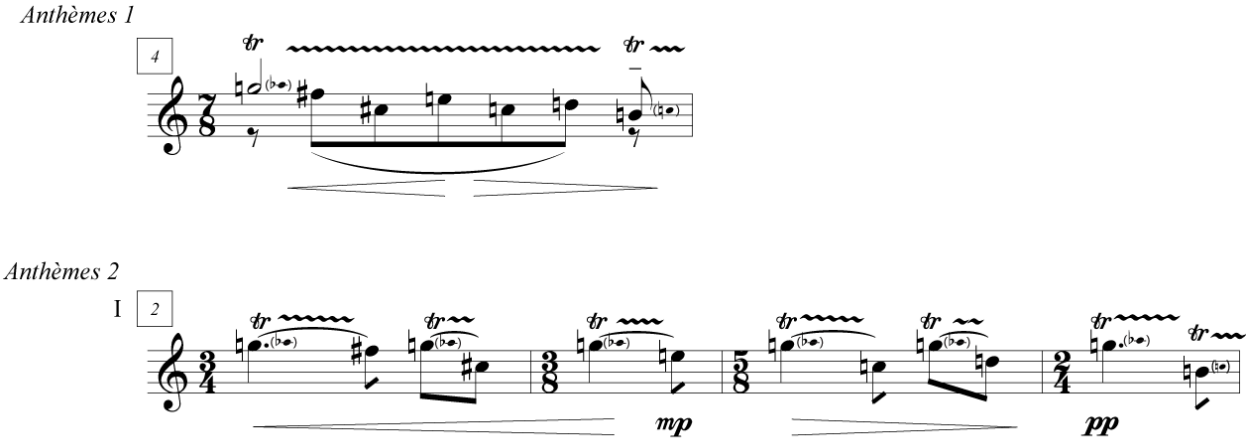


Figure 3.10: Type-1 (IME) expansion of T2

Finally, type-3 (UAE) formal enlargements are exclusive to section VIa, where entire formal units based on the original materials are added (interpolated). The added units feature the alternation of motives from the Melodic and Trill groups ending on broken arpeggios that characterize the original section VIa. As a result, section VIa as a whole is stretched. This is evident

when looking at the sequences of motivic materials in section VIa and the middle-scale form in Table 3.3 (explained below).

To summarize, Table 3.3 illustrates the form of *Anthèmes 2*. The table is equivalent to Table 3.1 (but for the electronic rather than the acoustic composition). The only difference between the two tables in terms of factors being considered is that in Table 3.3 the second column shows types of formal enlargement rather than describing formal procedures. This was done because the formal procedures defining each section of *Anthèmes 2* are equivalent to those explained in connection with *Anthèmes 1* (and can thus be consulted in Table 3.1), whereas the procedures of formal enlargement are unique to the electronic version of the piece.

Table 3.3: Form of *Anthèmes 2*

Large-scale form (duration in s)	**Formal enlargement**	**Middle-scale form**	**Motivic structure**	**Timings for motives (in s)***
Introduction (36 s)	Type-1 (IME) extension (M1)	N/A	M1(intro1) T1(intro1) Batt S1(intro3) Batt L1(/I)	0.32 1.99 16.13 23.24
Section I (69 s)	Type-1(IME) expansion (T2 and T/6)	I.1	GrNotes S2(I1) T2(I2) GrNotes	 36.01 36.64
		I.2	S3(I10) T3(I11) GrNotes	65.52 66.18
		I.3	S4(I12) T/10(I13) GrNotes	75.34 76.03
		I.4	S/10(I13) T/11(I14) GrNotes	80.74 81.37
		I.5	S/12(I15) T/13(I16) GrNotes L2(I/II)	86.76 87.38 95
Section II (150 s)	Type-1 (IME) interpolation (P3, P/34, P/37, L3) Type-2 (ILE) extension (P2, P/37)	N/A	P1(II1) L3(I/II)	105.10 214.97
Section III (131 s)	Type-1 (IME) extension (Trem, S5) Type-1 (IME) interpolation (Stacc) Type-2 (ILE) extension (Stacc)	III.1	Trem S5(III3) T/47(III4) Stacc	 255.35 256.09
	Type-1 (IME) extension (Trem, S6) Type-1 (IME) expansion (T/58 and T4) Type-1 (IME) interpolation (Stacc) Type-2 (ILE) extension (Stacc)	III.2	Trem S6(III35) T/58(III36) Stacc L4(III/IV)	 319.57 320.30 371.78
Section IV (118 s)	Type-1 (IME) interpolation (M/77) Type-2 (ILE) extension (T5, T/80, Accent)	N/A	T5(IV1) S/72(IV12) T7(IV12) M2(IV12) Accent M/77(IV19) S7(IV23) T/80(IV24) L5(IV/V)	386.67 411.99 413.70 419.25 431.01 435.72 437.08 484.12
Section V (92 s)	Type-1 (IME) extension (GrNotes) Type-1 (IME) expansion (T8) Type-2 (ILE) extension and interpolation (Stacc) Type-2 (ILE) extension (L6)	N/A	S/90(V1) T/90(V1) GrNotes Stacc GrNotes T8(V23) S/96(V29) L6(V/VI)	504.68 505.34 546.80 565.27 569.78

Section VIa (149 s)	Type-3 (UAE) interpolation (sections alternating M and T, with S occasionally substituting for M and ending with BrArp are added).	VIa.1	S8(VI1) T/98(VI1) M3(VI2) T/99(VI2) M4(VI3) T/100(VI3) M/101(VI4) T/101(VI4) M/102(VI5) T/102(VI5) BrArp	596.25 596.97 599.14 599.77 601.63 602.82 604.85 605.81 607.01 607.82
		VIa.2	MVI7 TVI7 MVI8 TVI8 MVI9 TVI9 MVI10 TVI10 SVI11 TVI11 BrArp	612.71 613.76 615.45 616.43 618.10 619.06 620.84 621.46 623.49 624.59
		VIa.3	MVI13 TVI13 MVI14 TVI14 MVI15 TVI15 TVI16 BrArp	627.26 627.91 629.34 630.34 632.93 634.54 636.55
		VIa.4	MVI18 TVI18 MVI19 TVI19 SVI20 TVI20 MVI22 TVI22 TVI23 BrArp	642.24 643.47 645.99 647.17 648.73 649.25 654.16 655.41 658.40
		VIa.5	SVI25 TVI25 BrArp	661.62 662.72
		VIa.6	MVI28 TVI28 BrArp	671.86 673.60
		VIa.7	MVI30 TVI30 MVI31 TVI31 MVI32 TVI32 BrArp	677.10 678.08 679.27 681.63 682.62 683.73
		VIa.8	M5(VI34) T9(VI34) M6(VI35) T/105(VI35) BrArp	687.93 689.93 692.06 692.66
		VIa.9	MVI37 TVI37 BrArp	695.63 696.87
		VIa.10	MVI39 TVI39 BrArp	701.12 701.66
		VIa.11	MVI41 TVI41 MVI42 TVI42 BrArp	704.49 705.62 706.51 707.91
		VIa.12	M/107(VI44) T/107(VI44) M7(VI45) T10(VI45) M8(VI46) T/109(VI46) BrArp	712.04 713.08 714.78 715.46 716.82 718.11
		VIa.13	MVI48 TVI48 BrArp	722.42 724.24
		VIa.14	MVI50 TVI50 BrArp	728.28 729.34
		VIa.15	M/111(VI52) T11(VI52) M/112(VI53) T/112(VI53)	733.94 735.12 737.71 739.53

Section VIb (320 s)	Type-1 (IME) interpolation (S9, S10, S/133, S/137, S/139, S/141) Type-2 (ILE) extension (all P, M, PlTri)	N/A	S9(VI54) P5(VI55) M9(VI59) P/116(VI61) S/117(VI66) P/118(VI67) PlTri M/120(VI74) PlTri P6(VI81) PlTri P7(VI88) S/125(VI53) M/126(VI94) PlTri P/128(VI100) S10(VI105) M10>(VI106) PlTri P/131(VI113) M11>(VI119) S/133(VI124) M/134>(VI125) S/135(VI129) PlTri P/136(VI135) S/137(VI140) M/137(VI141) P/138(VI144) S/139(VI149) Chord PlTri MVI150 S/141(VI154) Chord PlTri MVI155 P/142(VI159)	745.13 748.27 760.10 764.21 774.34 776.71 795.93 816.41 840.21 858.02 860.78 878.59 893.97 896.40 917.16 938.79 947.78 949.61 956.96 972.42 989.45 992.05 999.09 1015.16 1017.66 1027.50 1029.69 1046.64
Section VIc (159 s)	Type-1 (IME) interpolation (M12/TM) Type-2 (ILE) interpolation (BrArp)	VIc.1	M12(VI164) BrArp	1065.46
	Type-1 (IME) interpolation (M/148, S/154, M/155, S/156, M13, BrArp)	VIc.2	M/148(VI173) S/154(VI191) M/155(VI192) S/156(VI194) M13(VI195) BrArp	1088.42 1133.01 1134.16 1139.33 1140.45
	Type-1 (IME) interpolation (S11, M14)	VIc.3	S11(VI201) M14(VI202) T12(VI208) L7(VI209) Batt	1160.24 1162.96 1176.09 1199.67

* Timings are based on the recording by J. M. Conquer at IRCAM in 2008 (Boulez, 2014).

The motivic instances affected by the three enlargement procedures described above are shown in parentheses in column 2. Due to the large dimension of the composition and overall blurring of formal delimitation due to the resonance of the electronics, all successive statements of motives from the same motivic family—including those taken into consideration for the analysis of *Anthèmes 1*—are excluded from both this analysis (column 4) and the data analysis corresponding to the empirical study of *Anthèmes 2*. Nevertheless, it is important to recall that all motivic instances appearing in *Anthèmes 1* are stated in *Anthèmes 2*. Successive statements of motives from the same motivic family (omitted in column 4 of Table 3.3) that are subject to enlargement are still referenced in between parentheses in column 2, since they affect the formal structure. To facilitate the comparison between the two versions of the composition, the electronic counterparts of the motivic instances of *Anthèmes 1* are shown in Table 3.3 with exactly the same labels as

those displayed in Table 3.1. In addition, the measure number corresponding to the location of these motivic instances in *Anthèmes 2* appears in between parentheses following the original label. This measure number is preceded by a Roman numeral that indicates the formal section. This labeling system follows the score of *Anthèmes 2*, where separate measure-number regions are used for each of the six sections, which are themselves labeled with Roman numerals. In Table 3.3, those motivic instances that are not stated in *Anthèmes 1* are labeled by motivic category (letter), section (Roman numeral), and measure number (Arabic numeral).

The section above presented a formal analysis of *Anthèmes 2*. The discussion focused on the enlargement procedures taking place in *Anthèmes 2*. The formal role of the electronic effects is explained below.

Formal role of the electronic effects

According to Boulez, "the purpose of electronics is to change the sound." He makes reference to the ornamental role of the electronics as he states that "like in a flower, we have the core and the petals around it" (my translation from Nattiez et al., 2014, 23). Table 3.4 summarizes the electronic effects employed in *Anthèmes 2*. In general, different motivic families are associated with contrasting electronic effects, highlighting and increasing the contrast among them. Nevertheless, it is important to highlight the point that the electronic part often provides further differentiation among the subcategories that constitute each family, and that in some cases the same electronic effect is applied to subfamilies from different families.

Table 3.5 illustrates the relationship between the electronic effects, the form, and the motivic categories and/or subcategories. It is relevant that the subcategories distinguished with the electronics were already implied in the analyses presented in Chapter 2 (Table 2.3, p. 42). Table 3.5 is first organized by motivic family (column 1) and then by formal section (column 2). Effects related to spatial location are omitted because they could not be considered in the experimental studies, due to the impossibility of obtaining a recording with all the necessary tracks to reproduce the spatial effects in a specially equipped audio lab. As illustrated, different electronic effects are applied to various subgroups from the Trill group, and, to a lesser extent, to subsets from the Melodic group (the electronic effects applied to the Melodic subgroups are more similar to each

other than those applied to the Trill subgroups). The motives from the Melodic group are the ones presented in their acoustic version most often (entire section VIa).

Table 3.4: Electronic effects

Electronic effect	Definition
Frequency shifting	Linear and constant displacement of the frequency of the partials of the sound, i.e., change in the frequencies of the partials by a constant number of Hz. The resulting sound disturbs the original pitch relationships between the partials, making the sound more inharmonic.
Frequency modification with harmonizer	Logarithmic change in the frequency of the partials of a sound, i.e., change of the pitch of the partials by a constant musical interval. The result is similar to a musical transposition.
Sampler sequences	A sampler is used to play sequences of pre-recorded violin sounds that include different articulation styles, dynamic levels, and/or emphasis on different spectral components.
Ring modulation + comb filtering	The ring modulator multiplies the input frequencies. The result is the sum and difference of those frequencies. In *Anthèmes 2*, the ring modulator is always combined with a comb filter, which adds a delayed version of a signal to itself, creating a sound wave with moments of greater and lower amplitude.
Reverberation	Prolongation of the resonance of a sound in time.
Delay	Playback of violin part, delayed in time (processed through harmonizer and/or frequency shifting plus change in spatial position—see other electronic effects).
Change in spatial position	Motion of the output sound in a circular space delimited by 8 loudspeakers.
Random pitch-selection processes (specifically, chaotic, cloud, and cluster processes as described in the technical manual)	Aleatoric selection of pitches coming out of the sampler (pre-recorded sounds).

The Scale group is almost always associated with frequency shifting. The only Scale motives that are not processed through frequency shifting are those featuring slurred (rather than *jeté/ricochet*) articulation. These slurred Scale motives are not electronically transformed. In this sense, differences in articulation (within the Scale group) are further emphasized in the electronic piece. However, the electronics do not differentiate the motives from the Scale group in terms of direction or texture (i.e., scales going up or down, in single or double-stops receive the same electronic effect). Finally, the Long Tone and Pizzicato group are the most consistent motivic families in terms of electronics, since they are associated with a single and unique electronic effect throughout the composition.

Table 3.5: Electronic effects applied to the motivic subcategories within each section

Motivic family/subfamily	Formal section	Electronic effect
Long Tone	Introduction, I, II, III, IV, V, VIc	Ring modulator + comb filter + reverberation
Melodic	Introduction	Sampler + reverberation
Melodic	IV, VIc	Sampler + reverberation + randomization of pitches (cloud/cluster process)
Melodic	VIa	None (acoustic version of the motive)
Melodic with *brusque* character	VIb	Sampler
Single trill	Introduction, VIa	Sampler scalar pattern
	VIc	Sampler + reverberation + randomization of pitches (cloud/cluster process)
Single trill and two-line-texture trill	I	Sampler plucked chords + harmonizer + reverberation
	III, V	Sampler plucked chords + harmonizer
Trills in multiple-stops	IV	Sampler + reverberation
		Sampler + reverberation + randomization of pitches (cloud process)
Jeté/ricochet scales of any direction (up/down) and texture (single/double-stops)	Introduction, I, III, V, VIb	Frequency shift
Slurred scales	IV, VIa, VIc	Acoustic over electronic resonance of other materials
Pizzicato	II, VIb	Delay + harmonizer/frequency shift + sampler + reverberation

The preceding sections presented formal analyses of the two versions of *Anthèmes*. In the following section, these analyses are used to interpret the results from two experiments in which listeners search for motivic variations while listening to *Anthèmes 1* and *Anthèmes 2* without pause. The discussion of the results of these experiments has the broad purpose of elucidating the perceptual processes involved during listening of complete post-tonal works, and the more specific aim of contributing to the understanding of the role of the elements of the rudimentary model of form perception proposed above in the perception of the form of *Anthèmes*.

Experiments 4 and 5: Identification of motivic variations in *Anthèmes 1 and 2*

Experiments 4 and 5 take advantage of the resemblances and differences between the formal structure and timbral aspects of the two versions of *Anthèmes* in order to explain the effects of musical context on the perception of motivic materials and form. The results of these empirical

studies provide information that can help us to understand the ways in which the elements of the theoretical model proposed above affect the perception of the formal hierarchy of music. Experiment 4 studies the identification of motivic variations while listening to *Anthèmes I*. Experiment 5 explores the same issue in *Anthèmes 2*. More specifically, these two experiments aim to explore the following research questions:

1. Regarding the *compositions as wholes*, is the perception of the motivic relationships within the five motivic groups studied in Chapter 2 (overall internal similarity perception of the groups) affected by:
   a. the *timbral* differences *between* the two versions of *Anthèmes*?
   b. the *general musical context* in which the motives are presented throughout *each* version of *Anthèmes*?
2. Regarding the *formal structure* of the compositions, is the identification of motivic variations (specifically, as members of the five groups studied in Chapter 2) influenced by:
   a. the *timbral* and *proportional* differences (associated with the addition of electronic effects and formal enlargement procedures, respectively) *between* the two versions of each of the nine large-scale formal sections of *Anthèmes*?
   b. the musical context, specifically in terms of motivic successions and transformations (*predictability*) and surface features (*formal-unit blend*), associated with each of the nine large-scale formal sections of *each* version of *Anthèmes*?
   c. the *overall development* (e.g., changes, similarities) of the musical features from one formal section to the next one in each version of *Anthèmes*?
3. Is the strength of association of certain *specific motivic variations* belonging to the same motivic group affected by:
   a. the *formal function* (beginning, middle, or end) that those variations play in the musical context?
   b. the characteristics of the musical materials *surrounding* those variations in the musical context? (note that this question contributes to questions 1b and 2b)
   c. the general *musical context added* by each version of *Anthèmes* with respect to the strength of association of those variations when perceived *out* of their musical context in Experiment 2?

4. Do the timbral and contextual differences between the two versions of *Anthèmes* influence the perception of the motivic *subfamilies* of the five groups studied in Experiment 2 (motivic associations internal to each of the five motivic groups)?
5. Does *repeated listening* to *Anthèmes 1* (in its entirety) affect the recognition of the motivic variations?

In terms of the model of aspects of form perception proposed above, research question 2b is more directly related to the predictability and formal-unit-blend factors, whereas questions 2c and 5 are more directly associated with the temporal factor (elapsed musical time). Nevertheless, all the questions listed above contribute to the understanding of the model as a whole. In effect, the three factors of the model are contextual, and the aim of all the research questions is to investigate contextual effects with slightly different focus and/or degree of detail. The Results and Discussion sections attempt to answer the research questions above, with the exception of research question 4, which is addressed in Chapter 4.

METHOD

Participants

Forty musicians (all of whom had completed the music theory and musicianship requirements for the Bachelor of Music at McGill University or equivalent) were recruited through email, McGill Classifieds Online, and invitation in high-level music classes held at the Schulich School of Music of McGill University. Twenty musicians (aged 19-31, M = 23, SD = 2.9, 15 females, for Experiment 4; and aged 20-44, M = 26, SD = 6.3, 9 females, for Experiment 5) participated in each experiment. Before the experiment, participants passed a pure-tone audiometric test using octave-spaced frequencies from 125 Hz to 8 kHz (ISO 389–8, 2004; Martin & Champlin, 2000). Experiment 4 was completed in two 90-minute individual sessions held on consecutive days. Experiment 5 was completed in one 120-minute individual session. All participants were compensated for their time.

Stimuli

The experimental stimuli consisted of one motive taken from *Anthèmes 1* acting as model of each of the five motivic families studied in Chapter 2, and the entire recording of *Anthèmes 1*

by Jeanne-Marie Conquer at IRCAM in 2002 (Boulez, 2013) for Experiment 4 or *Anthèmes 2* by Jeanne-Marie Conquer at IRCAM in 2008 (Boulez, 2014) for Experiment 5. The motivic model was selected according to the criteria described below. For the practice trial of both experiments, an artificial musical composition was created. This composition consisted of a musically arranged succession of the 29 motives used in Experiments 2 and 3. All the stimuli were amplified through a Grace Design m904 monitor (Grace Digital Audio, San Diego, CA) and presented over Sennheiser HD280 Pro earphones (Sennheiser Electronic GmbH, Wedemark, Germany). Sounds were played at a level ranging from 65 db to 75 db SPL, as measured with a Bruel & Kjaer Type 2205 sound-level meter and a Bruel & Kjaer Type 4153 artificial ear to which the headphones were coupled (Bruel & Kjær, Nærum, Denmark). The models were presented in stereo, whereas the entire compositions were presented in mono (mixed channels). Listeners were seated in an IAC model 120act-3 double-walled audiometric booth (IAC Acoustics, Bronx, NY).

Selection of the motives acting as models

The model corresponded to the motive with the lowest mean dissimilarity (described as measure 1 in the Data Analysis section of Chapter 2) from each of the five motivic groups according to the results of Experiment 2 (striped bars in Figure 2.19, p. 62).[7] The models are reproduced in Appendix A. The decision to select the motives with the lowest dissimilarity means (Experiment 2) rather than those chosen as best representatives in Experiment 3 was based on four criteria. First, even when neither the best representative (Figure 2.30, p. 89, Experiment 3) nor the motive with the lowest dissimilarity mean (Figure 2.19, p. 62, Experiment 2) were outliers within a given motivic family, the results from Experiment 3 were more unstable than those from Experiment 2. The motive chosen as best representative frequently changed as the number of participants in the experiment increased. This was not the case for Experiment 2, in which the motive with the lowest dissimilarity mean remained relatively constant from the pilot stages to the end of the experiment.

Second, the context in which the motives were presented in Experiments 4 and 5 resembles more closely that of Experiment 2 than that of Experiment 3. In Experiment 3,

[7] The model for the Long Tone group was shortened for practical purposes. The model faded out on the second note, after the glissando.

participants had the choice to listen to the motives multiple times, whereas in Experiment 2, they could listen to each motivic pair a maximum of two times. Even when participants of Experiment 3 were encouraged to make intuitive decisions, the context in which the motives were presented necessarily led to less spontaneous responses compared to Experiment 2. Experiments 4 and 5 consisted of an online (real-time) listening task (see Procedure). Because the participants were asked to identify motivic variations as they heard the compositions without having play/pause control over the music they heard, the experiments measured spontaneous responses. In other words, these experiments are concerned with intuitive (corresponding to the participants' first reaction) rather than carefully thought-out (corresponding to a more conscious analytical process) responses.

Third, the procedure of Experiments 4 and 5 is more similar to that of Experiment 2 than that of Experiment 3. In Experiment 2, participants were asked how much the second motive resembled the first one. In Experiments 4 and 5, listeners memorized one musical motive and then listened to *Anthèmes 1* (Experiment 4) or *Anthèmes 2* (Experiment 5) in its entirety while pressing the space bar every time they heard something that reminded them of the motive they had memorized previously. The word "remind" was a keyword in the instructions of Experiments 4 and 5. In Experiments 2 and 3, the most important keywords in the instructions were "resemble" and "represent," respectively. The expression "remind" is more similar in meaning to "resemble" than to "represent". The first two terms refer explicitly to memory, whereas the third one refers to direct comparison.

Lastly, with respect to the fourth criterion, a score-based analysis compared the motive chosen as best representative (Experiment 3) and the motive with the lowest dissimilarity mean (Experiment 2) for the three motivic families in which these two motives did not coincide (see Chapter 2). This analysis was aimed to better understand, from a theoretical perspective, which of the two motives in each family would work best as model for the purposes of Experiments 4 and 5. The analysis showed that the motives with lowest dissimilarity means were simpler (in terms of the number and variety of their internal elements) as well as shorter (in terms of their total duration) than the best representatives. For instance, for the Trill group, the motive with the lowest dissimilarity mean was an ordinary, single trill, whereas the best representative featured a two-voice texture composed of a moving trill-less melody and a slower line in trills. Given that in

Experiments 4 and 5 the memorization of the motivic models was essential for the completion of the task, it seemed reasonable to choose shorter and simpler motives.

Procedure

Both experiments were divided into five blocks, each corresponding to a different motivic family. These five blocks were presented in random order to the participants. In Experiment 4, each block was performed three times—sub-blocks A, B, and C. Each of these three sub-blocks used exactly the same stimuli, so that participants completed the same tasks with the stimuli belonging to one motivic family three times in direct succession. This was done in order to investigate the effects of exposure (listening times to the complete piece) on the recognition of the motives from each family. This could not be done in Experiment 5 with *Anthèmes 2*, due to the greater duration of the composition.

In terms of tasks, one of the five blocks of Experiment 5 was equivalent to one of the three sub-blocks A, B, C of Experiment 4. Each block of Experiment 5 and sub-block of Experiment 4 consisted of two phases: (1) familiarization with the model, and (2) online, real-time identification of musical materials related to the model while listening to the pieces. Participants were encouraged to take notes on the motives during the familiarization phase and keep them as reference during the online identification task. During the familiarization phase, participants heard the model of a category eight times.[8] In Experiment 4, the number of playing times of the model was reduced to five during the second and third run-throughs corresponding to that model (i.e., the model was played eight times for sub-block A, and five times each for sub-blocks B and C). After that, participants listened to *Anthèmes 1* (Experiment 4) or *Anthèmes 2* (Experiment 5), pressing the space bar of a computer keyboard every time they heard "something" in the music that "reminded them" of the model. The term model was not used in the instructions. Specifically, the participants read the instructions organized in two steps as shown in Table 3.6. Participants completed this task as they heard the complete version of the piece being tested. A practice trial preceded the experimental blocks. The procedure of the practice trial was identical to one block of Experiment 5 or sub-block of Experiment 4. Nevertheless, the motive used for the familiarization

[8] The number of times was determined based on feedback obtained from the participants in a pilot study.

phase of the practice trial was not used in the experiments and was the motive with the second-lowest dissimilarity mean according to the results of Experiment 2.

Table 3.6: Instructions given to participants of Experiments 4 and 5

Steps		What to do?
11	LISTEN to a musical MOTIVE SEVERAL TIMES.	MEMORIZE this motive the best you can. You will need to remember it in order to perform step 2. You can take notes that will help you remember the motive on the paper provided.
22	LISTEN to a musical PIECE in which the MOTIVE that you heard in step 1 might appear in MANY DIFFERENT VARIATIONS (including small portions of it).	AS YOU LISTEN to the piece, PRESS THE SPACE BAR every time you HEAR SOMETHING that REMINDS you of the MOTIVE you memorized in step 1.

This was done to avoid increasing the participants' overall acquaintance with one of the motives used as models during the actual experiment. For the online identification task, the artificial version of the piece described in the Stimuli section was used. All the participants read the same set of instructions before beginning the practice trial, and the experimenter remained in the experimental room during the practice trial in case the participants had questions about the procedure.

Data Analysis

The data output consisted of the time (expressed in ms) at which the participants pressed the space bar. With the exception of the data collected from the trials associated with the Long Tone group, data points within 2000 ms of the onset of motives belonging to the motivic group of the model that were not consecutive to motives from the same group were considered "correct" identifications of a motivic transformation/variation of the model. This 2000-ms window was determined based on previous studies using similar methods (Margulis, 2012), as well as on observation of the distribution of all responses (histogram) with respect to the onset of motives according to the theoretical analysis. In addition, it was necessary to choose a time window that was smaller than the temporal distance between the two closest statements of motives belonging to the same family (and separated by contrasting motivic material).

As mentioned, in Experiment 5 (*Anthèmes 2*), consecutive versions of motives belonging to the same family were disregarded due to the ambiguous formal segmentation of passages

involving such motives caused by the electronic effects. Accordingly, the temporal window for the data analysis of all motivic instances corresponding to *Anthèmes 2* was 2000 ms. For Experiment 4 (*Anthèmes I*), a smaller time window had to be employed for statements of motives that were consecutive to motives of the same group due to the extremely close proximity of some of those motivic instances. This time window corresponded to the distance between the onsets of the two closest consecutive motives in each group: 1010 ms for the Scale group and 1700 ms for the Pizzicato group (for the Trill group, the minimum distance was 2050 ms, and there were no consecutive motives for the Melodic group).

The window chosen for the Long Tone motives was customized for each motivic instance. Specifically, data points falling between the onset of a Long Tone motive and either the end of the first glissando (in motives that include glissandi) or the end of the first note (in motives that did not include a glissando) were counted as "correct" identifications of a Long Tone motive.[9] The customization of the window for the data analysis of the Long tone motives was based on four criteria: (1) the features defining the motives of the Long Tone group change remarkably slower than those that define the rest of the motivic families; (2) the glissando is a characteristic of the motivic model presented to the participants at the beginning of the trial, and it is also a feature of many—4 of 7—of the Long Tone motives throughout the piece; (3) either the glissando or the end of the first long tone constitutes the first clear change in the Long Tone motives. The windows used for the Long Tone group in the two compositions are shown in Table 3.7.

Table 3.7: Temporal window used for the data analysis of the Long Tone motives

	L1	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**
Anthèmes I	6.9 s	5.1 s	5.7 s	5.3 s	3.8 s	3.9 s	3.7 s
Anthèmes 2	6.4 s	8.5 s	4.8 s	5 s	4.9 s	6.1 s	8.5 s

The exact temporal position of the motivic instances was determined using Audacity. All motivic statements were tagged while listening to the imported CD tracks and following the scores

[9] The final Long Tone motive of *Anthèmes 2* was about 25 seconds long. Using a 25s window seemed extreme. Accordingly, the window used for the final Long Tone motive was that corresponding to the motive with the next longest window.

with annotations corresponding to the theoretical analyses. All instantiations of the motives whose temporal locations are listed in Tables 3.1 and 3.3 were in principle considered for the data analyses of Experiments 4 and 5, respectively. Nevertheless, because most conclusions drawn in this chapter are based on a comparison of the results from the two experiments, the majority of the analyses reported below considered equivalent data points in the two versions of the piece. Accordingly, only versions of motives that were not consecutive to motives of the same family were included in the data analyses corresponding to Experiment 4, and only the motivic instances appearing in both versions of the piece were included in the data analysis corresponding to Experiment 5 (extra motives appearing in the electronic piece were excluded).

Alternative ways of analyzing the data were also explored. Data analyses including all consecutive versions of motives from the same family in *Anthèmes 1* did on some occasions lead to different results (especially in connection with the Pizzicato group). When relevant, the results from the analyses including all consecutive instances are reported for Experiment 4 (in these cases, it is clear from the description in the text that all consecutive versions are being considered). Data analyses considering all the extra statements of motives in *Anthèmes 2* (with respect to the statements in the original composition) normally led to very similar results when compared to the data analyses considering only the motivic statements literally taken from *Anthèmes I.* Consequently, only analyses of *Anthèmes 2* that are equivalent to those of *Anthèmes 1* are reported below.

There were two types of “incorrect” responses (i.e., motivic variations not identified by listeners): (1) data points falling outside the time windows mentioned above, and (2) absence of responses—participants not pressing the space bar—for a given motivic instance—variation according to the theoretical analysis. Each “correct” response (identification of motivic instance within the time window and according to the theoretical analysis as described above) was coded as 1. Each “incorrect” response was coded as 0. Therefore, the total number of 1s and 0s for each instance of a motive was equivalent to the number of participants. The sum of all 0s and 1s for a given motivic instance gave the total number of “correct” identifications of that instance. This number divided by the total number of participants gave the proportion recognition/identification for that instance.

For the majority of the data analyses associated with *Anthèmes I*, only the data corresponding to the first listening to the piece for each motivic model were considered. This was done in order to obtain information about the most spontaneous responses (first reaction) of the listeners and to compare the results with those corresponding to *Anthèmes 2*. Four types of *data analyses* were conducted to better understand the identification/conception of motivic variations throughout the piece at different levels of the formal structure, and to investigate the relationship between the identification and perceived dissimilarity of the motives: (1) motivic families: identification of motives for each of the five motivic families, (2) formal sections: motivic-variation identification—abbreviated as motivic identification throughout this dissertation—for each of the nine formal units, (3) preselected motivic pairs: identification of pairs within each family that were preselected before the experiments, according to the hypotheses—see details below; and (4) motivic subfamilies: identification of motivic variations belonging to different subfamilies—based on the musical features of those variations—within each motivic group. These four types were performed on both Experiments 4 and 5 and are described below. In some cases, more than one statistical analysis is associated with the same data-analysis description.

The first analysis (motivic families) consisted of proportion of motivic identification within each motivic family, in each composition. Participants' identification of all variations of each motivic model was calculated for the entire piece. The correct responses for all of these instances were summed per participant individually and divided by the number of motivic instances in that family. This led to a proportion of correct responses representing each participant's recognizability of the motives of each family for the entire piece. Pairwise comparisons tested for differences in motivic recognition for each of the motivic families between the two compositions, on the one hand, and among the five motivic families within each composition (for each composition separately), on the other hand.[10]

The second data analysis (formal sections) was similar to the first, but it focused on formal section rather than on motivic family. This analysis studied participants' identification of

[10] T-tests were performed when the data were normally distributed, whereas Wilcoxon tests were applied when the data were not normally distributed. Mann-Whitney Wilcoxon tests or independent-sample t-tests were run when comparing independent samples, and Wilcoxon signed-rank tests or paired-sample t-tests were performed when comparing dependent samples. In all cases, the results for multiple comparisons were adjusted according to the Bonferroni-Holm method.

motivic variations of the model from each family for each of the nine formal sections of *Anthèmes 1* and *Anthèmes 2* (as reported in the theoretical analyses). In this case, a proportion of motivic identification was calculated for each of the nine sections of the two versions of the piece. All motivic instances were weighted equally, independently of their motivic family and the proportion of appearance of that family within the formal section. Specifically, the proportions of correct responses of each participant were averaged across the motivic instances corresponding to each section of the composition regardless of family. For instance, section I contains five Scale motives, five Trill motives (when disregarding consecutive statements of motives from the same family), and one Long Tone motive. The recognition averaged across participants was 0.75, 0.95, 0.45, 0.85, and 0.85 for the Scale motives, 0.5, 0.8, 0.65, 0.8, and 0.8 for the Trill motives, and 0.6 for the Long Tone motive. The proportion of motivic recognition for section I was the mean of all these averages, i.e., 0.73. The statistical tests associated with analysis 2 were similar to those associated with analysis 1. Pairwise comparisons tested for differences in motivic recognition for each of the sections between the two compositions, on the one hand, and among all pairs of sections within each composition, on the other hand.

In addition, based on the previous literature indicating that musical repetition (and presumably varied repetition) affects repetition recognition in a linear way (Margulis, 2012), a logistic regression of recognition performance (dependent variable: proportion of motives recognized, or count of motives identified over total count of motives) over the nine formal sections was performed for each piece. Additionally, given the very different dimensions of the two versions of *Anthèmes*, a multiple logistic regression analysis tested for differences between the two regressions corresponding to the two experiments (interaction factor Formal Section × Piece).

Data analysis 3 (preselected motivic pairs) was aimed to more deeply study the role of formal organization and motivic distribution in the recognizability of the motivic families and investigate the effects of the musical context on the recognition of the motivic materials. A series of exact McNemar tests[11] tested for differences between the identification of pairs of motivic

[11] The McNemar test is equivalent to the paired-sample t-test, but it is especially designed to be applied to dichotomous dependent variables (as is the case for the recognition of single motivic instances considered here).

instances within each motivic category. These pairwise comparisons were planned before the experiment. They were specifically aimed to explore research questions 3a to 3c (see above) and broadly intended to contribute to the understanding of more general issues related to the influence of context on motivic identification. Eight motivic-pair types of pairs were selected per motivic family. Following research questions 3a to 3c, the motives for these pairs were chosen to represent a variety of formal functions (types 1 and 2 below) and musical contexts (types 3 to 6), as well as special intrinsic (out-of-context) similarity statuses within their motivic family (in order to compare the contextual perceptual motivic relationships explored in Experiments 4 and 5 with the non-contextual perceptual motivic relationships studied in Experiment 2) (types 7 and 8). The Results section discusses only the pairs that yield statistically significant results, with special emphasis on types 7 and 8. The eight types of *preselected motivic pairs* were defined as follows:

1. Beginning-end: a motive located at the beginning of a section (as defined by the long tones) was paired with one located near the end;
2. Beginning-middle: a motive located at (or very near) the beginning of a section was paired with one located in the middle;
3. Frequent-isolated: a motive surrounded by a relatively large number of motives from the same category was paired with a motive relatively isolated from other instances of its category in the music;
4. Contrasting-consecutive: two motives from the same family played in succession were paired (examples were chosen so that the first motive in the pair followed contrasting musical material);
5. Interpolated-1: two motives separated by one short fragment of interleaving consistent (musically unified) motivic material were paired (these were chosen so that in one situation—namely the Melodic group— the first motive of the pair followed a passage in which its motivic family was not represented, and in three situations—namely the Trill, Scale, and Pizzicato groups— from a passage that included motives from the family);
6. Interpolated-2: two motives separated by two or more (different) interleaving materials were paired (in the Long-Tone, Trill, and Scale groups, the first motive of the pair appeared after a passage that did not contain motives from its family, whereas in the remaining two groups, the first motive of the pair was stated relatively shortly after another motivic instance from its family);

7. Most-similar: the two motives with the lowest dissimilarity ratings (per motivic family) obtained in Experiment 2 were paired; and
8. Similar-dissimilar: the motives with the highest and lowest dissimilarity ratings in each motivic family obtained in Experiment 2 were paired.

These eight types of preselected motivic pairs were available in some but not all the motivic families. When possible, one example of each type was selected from each motivic family. The selected motivic pairs were equivalent for the two compositions, except for the pairs including consecutive versions of motives from the same family. In cases in which consecutive versions of motives were chosen for the pairwise comparisons of *Anthèmes I*,[12] those consecutive versions had to be replaced by other motivic instances in the data analyses of *Anthèmes 2*. Accordingly, preselected motivic pairs of type 4 (contrasting-consecutive) had to be completely replaced. In the analysis of *Anthèmes 2*, rather than comparing consecutive and nonconsecutive versions of motives, type 4' compared one of the most acoustic instantiations of a motivic family with one of the most electronically modified motives from that family (acoustic-electronic). In addition, T13 and T6 within type 8 (similar-dissimilar) were replaced with T12 and T5, respectively. T12 and T5 immediately precede T13 and T6, respectively: T12 and T5 constitute the onsets of the motives in question when consecutive versions of the same motivic family are disregarded. Table 3.8 shows the specific pairs chosen for the McNemar tests. The one pair that is different for *Anthèmes 2* is indicated in the table.

Bonferroni-Holm correction for multiple comparisons was applied within each of the five motivic families for each composition. The motives played as models at the beginning of each experimental trial were purposely excluded from the pairwise comparisons, except for types 7 (most-similar) and 8 (similar-dissimilar), which compared those specific motivic instances. Only pairs of motives whose recognition was statistically significant are reported in the discussion section. It is important to note that a lack of statistically significant differences between the recognition of these paired motives does not imply an absence of effects of context related to the

[12] It made sense to include a few consecutive instances in the analysis of *Anthèmes 1* for various reasons, such as the study of recognition of consecutive vs. non-consecutive motives (from the same family, described as preselected motivic pair of type 4 or contrasting-consecutive above). Given that in the original version of the composition the consecutive versions of motives from the same family could be relatively clearly determined according to GTTM rules, it did not seem problematic to include consecutive motives in a few pairwise comparisons.

factors that the eight types of preselected motivic pairs were meant to investigate. Unavoidably, many of the members of the pairs studied here differ from each other in multiple ways that are unrelated to the factors that the motivic pairs are intended to study. Many confounding factors could be affecting the results of these tests on real musical examples.

Table 3.8: Motivic pairs from *Anthèmes 1* selected for statistical analysis

Motivic Family	**Type 1** Beginning-end	**Type 2** Beginning-middle	**Type 3** Frequent-isolated	**Type 4 (*Anth.1*)** Contrasting-consecutive	**Type 4' (*Anth.2*)** Acoustic-electronic	**Type 5** Interpolated -1	**Type 6** Interpolated -2	**Type 7** Most-similar	**Type 8** Similar-dissimilar
Long Tone							L5 vs. L6	L4 vs. L1	L4 vs. L7
Pizzi-cato	P1 vs. P/37-44	P1 vs. P3	P/118 vs. P1	P1 vs. P/19-24	P1 vs. P/116	P/116 vs. P/118	P7 vs. P/128	P5 vs. P7	P5 vs. P1
Scale	S/90.2-90.3 vs. S/96.8	S2 vs. S/10.9-10.10	S/10.9-10.10 vs. S6	S/125.1-125.3 vs. S/125.4-125.5	S7 vs. S3	S/133.4-133.6 vs. S/135.1-135.3	S9 vs. S/117	S2 vs. S6	S2 vs. S11
Trill	T5 vs. T/80	T5 vs. T7	T/100.3-100.6 vs. T/47	T2 vs. T/5	T/98 vs. T2	T10 vs. T/109.4-109.6	T/47 vs. T58	T13 vs. T9	T13 vs. T6 (T12 vs. T5 for *Anth.2*)
Melo-dic		M3 vs. M6	M4 vs. M2		M/101 vs. M2	M3 vs. M4	M/126 vs. M10	M8 vs. M14	M8 vs. M2

Data analysis 4 (subfamilies) had the broader purpose to ultimately compare the results of Experiments 4 and 5 with those of Experiments 1, 2, and 3. Dummy variables[13] were created by averaging the proportion identification for the subfamilies within each motivic group for each of the compositions. Subfamilies were determined based on the analysis and experimental results reported in Chapter 2. Specifically, subfamilies were defined according to higher-level subdivisions of the internal hierarchical similarity structure of each family as reported in Table 2.3 (p. 42). In addition, lower-level subdivisions involving a relatively large proportion of motives

[13] Dummy variables are artificial variables representing subgroups of the predetermined experimental groups/factors. Subgroups of data points are created based on specific (concrete) characteristics and the original data points are mathematically combined (averaged, in the cases considered here) within those subgroups. The specific dummy variables created in connection with this study will become clear in Chapter 4. Nevertheless, by way of example, a dummy variable representing the feature pitch direction for the Scale group divides the Scale group into two subgroups according to whether the motives are ascending or descending scales. These two subgroups correspond to the two levels of the dummy variable pitch direction for the Scale motives. Dummy variables represent musical features, and the levels of the dummy variables correspond to subgroups of motives (motivic subfamilies) defined according to those features. The proportion of motivic recognition is averaged across all the motives within each subgroup (level of the dummy variable), with the purpose of statistically comparing the recognition of the motives in one subgroup with respect to that in the other subgroup.

from the family were tested. The tests were chosen to include the larger possible number of motives within each of the compared subgroups. Subgroups of fewer than two motivic instances were avoided. The dummy variables averaging the identification of the subfamilies were compared in order to determine if the motives belonging to the diverse subfamilies were perceived differently. Bonferroni-Holm correction for multiple comparisons was applied within each motivic family for each composition separately and only significant results are reported. These results were mainly meant to investigate the robustness of the five motivic families to the musical context. Therefore, they are discussed in connection with the results of Experiments 1 to 3 in the general conclusion to this dissertation in Chapter 4.

In addition to these four analyses associated with both versions of *Anthèmes*, two statistical analyses investigated the effects of exposure (listening times) on motivic recognition during listening to *Anthèmes I*. First, because it was expected (according to previous findings reported above) that repeated listening to the same music would lead to a decrease in motivic identification, a logistic regression of identification on Listening Time (1-3) was performed. Second, a within-subjects two-way (Motivic Family, Listening Time) ANOVA[14] tested for differences in motivic identification based on motivic family across the three exposures to *Anthèmes 1* (interaction factor Motivic Family × Listening Time).

RESULTS AND DISCUSSION

General effects of musical context on the perception of motivic relationships

This section aims to very broadly demonstrate that the perception of similarity relationships among musical materials is affected by the context in which those materials are heard. The first subsection (Changing Context) explores general effects of the different settings provided by the two versions of *Anthèmes* on the recognition of the motivic materials of the piece (research questions 1a and 1b). The second subsection (Added Context) investigates the effects of the

[14] The residuals for 60% of the (total of) factorial levels were normally distributed according to both Kolmogorov-Smirnov and Shapiro-Wilk normality tests. Given that the normality plots suggested that the normality assumption was not being violated and that detailed observations of the descriptives did not appear to indicate an interaction between Motivic Family and Listening Time, no further analyses (e.g., statistical tests for non-normal data sets, data transformation) were performed.

addition of a musical context, by comparing the perception of motives in contextual versus non-contextual situations (research question 3c). More specific issues concerning the influence of musical context on the perception of motivic relationships in the two versions of the piece, including all remaining research questions, are addressed under the heading Contextual Effects on the Perception of Form.

Changing context

Anthèmes 2 can be seen as a formally extended and electronically enhanced setting of the motivic structure of *Anthèmes I*. As a result, a general comparison of the participants' cognitive relationships among the many transformations of the musical materials throughout the two versions of the composition sheds light on the effects of musical context on the perception of motivic variation. In general, the results show that context does affect the listeners' identification of motivic variations while listening to *Anthèmes*. Contextual effects were observed with respect to all research questions presented above, with the exception of the final question (effects of listening to *Anthèmes 1* three times on motivic identification). As will be demonstrated, the contextual effects found can be explained by the three principal elements of the model proposed above. The degree to which the formal units are blended or contrasted (*formal-unit blend*), the predictability given by motivic successions or returning (expected) musical features (*predictability*), and the development of the musical materials and form (*elapsed musical time*) constitute three essential contextual factors affecting the way listeners perceive motivic relations during music listening. In line with this, the narrative throughout the Results section is organized by factor to emphasize the elements of the model proposed above. Because most of the research questions that this project intends to address deal with more than one factor of the model, they are often addressed throughout the text. When the reported findings relate most directly to specific research questions, those questions are indicated in the text.

The participants' perception of the motivic relationships within the five motivic families (i.e., musicians' tendency to recognize certain motivic instances as members of the same motivic family) was different for each version of *Anthèmes* (research question 1a). This was reflected in the results of pairwise comparisons of motivic identification among the five motivic families within each piece. Pairwise tests revealed a different distribution of motivic identification for the five families in each of the compositions. In *Anthèmes I*, listeners identified a significantly smaller

proportion of motivic variations for the Melodic group than for all remaining groups: $t(1,19) = 7.95$, $p = .0001$; $t(1,19) = 5.38$, $p = .0002$; $t(1,19) = 3.64$, $p = .0012$, $t(1,19) = 3.33$, $p = .02$, for the Trill, Pizzicato, Long Tone, and Scale groups, respectively.[15] In the same piece, listeners recognized a significantly larger proportion of motivic transformations for the Trill group than for the Scale group: $t(1,19) = 4.15$, $p = .004$. On the other hand, in *Anthèmes 2*, the proportion of variations recognized as members of the Melodic group was significantly smaller than that of the Trill group only, $z = 3.34$, $p = .01$, whereas the proportion of variations identified for all other pairs of motivic families was not significantly different. The different distributions in the identification for the five families between the two versions of the piece imply that the musical context affects the listeners' conception of the five motivic groups (i.e., their formation of motivic relationships).

The identification of motivic variations for the motivic families in each version of *Anthèmes* is illustrated in Figure 3.11.

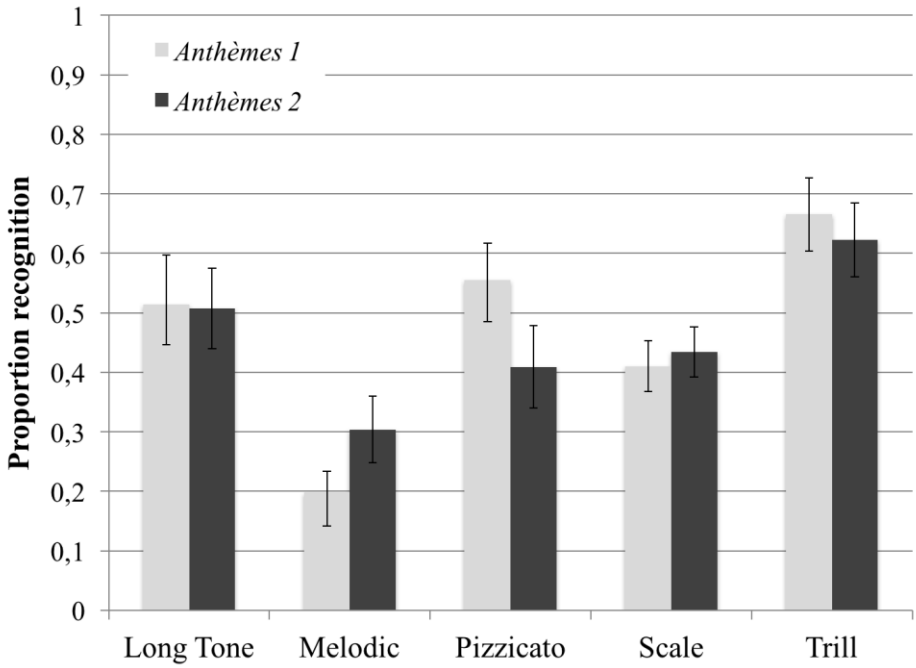


Figure 3.11: Identification of motivic variations for the motivic groups

[15] All the p-values reported throughout this chapter are corrected for multiple comparisons.

The five motivic families are shown along the x-axis, and the proportion of motivic recognition is displayed along the y-axis. A value of 1 on the y-axis means that all the motivic instances of a given motivic family in the entire piece were identified by all participants. The motivic recognition for *Anthèmes 2* is shown in darker grey. The error bars shown in the figure correspond to the standard error of the mean. The difference in the distribution of the motivic identification for the five families between the two compositions appears to be at least partly due to a higher recognition of motivic variants in the Melodic group in *Anthèmes 2* compared to *Anthèmes 1* and the inverse relation for the Trill and Pizzicato groups in the electronic version compared to the acoustic composition. In effect, the motives from the Long Tone and Scale groups were recognized similarly in the two versions of the composition. Although the differences illustrated in Figure 3.11 did not reach statistical significance, the statistically significant differences associated with the distribution of motivic recognition across the five motivic families between the two versions of *Anthèmes* (reported above) encourages a closer examination of the patterns of recognition of each motivic family in one composition with respect to the other.

The differences in recognition of the motivic families between the two compositions appear to be at least partly caused by the electronic effects applied to each motivic family (as defined in and analyzed in Table 3.5). The electronic effects affecting the two motivic groups associated with slightly lower motivic identification in the electronic with respect to the acoustic piece, i.e., the Pizzicato and Trill groups, affect not only the timbral quality but also the textural and rhythmic properties of the motivic members. It is possible that the transformation of surface features associated with the Pizzicato and Trill motives of *Anthèmes 2* led participants to disconnect these motives from the motivic model presented at the beginning of the experimental trial. Conversely, the motivic instances from the Melodic group are very frequently presented in their acoustic version in *Anthèmes 2*. Indeed, a total recount of motivic instances for all groups showed that the largest number of motivic instances presented without electronic transformation belongs to the Melodic group. As a result, the majority of Melodic motives heard during the composition preserve most of the timbral, textural, and rhythmic profile of the motivic model presented before the composition. As already discussed in connection with Experiments 1 to 3 (Chapter 2), the results reported here appear to confirm that the alteration of surface features, particularly timbre, texture and rhythm, affect the listeners' perception of motivic similarity. The findings of Experiments 4 and 5 might imply that listeners' formation of motivic relationships

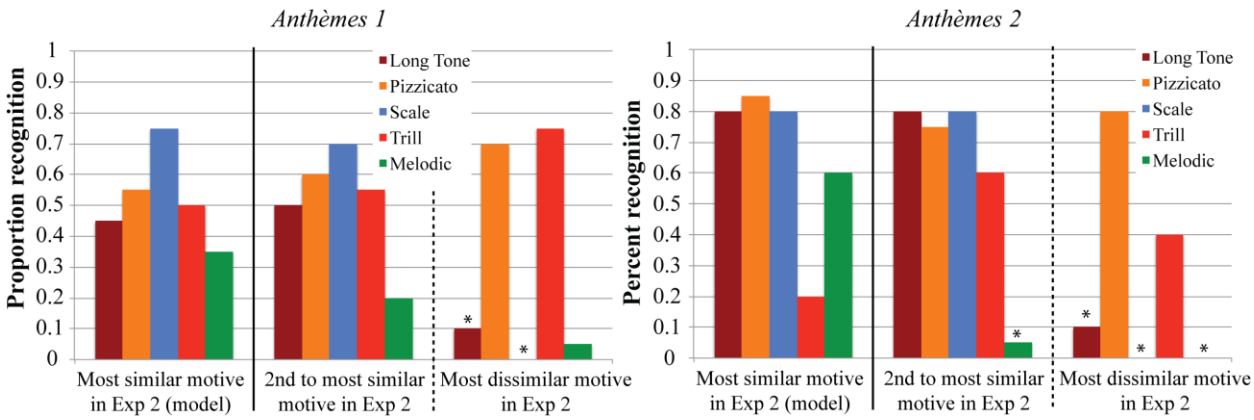
during music listening (their understanding of motivic variation) might depend on the degree with which the timbral, textural, and rhythmic features of the musical materials are kept constant throughout a composition.

Added context

The influence of the musical context on the listeners' perception of motivic relationships can be further supported with a comparison of the results of specific motives in Experiment 2—motives presented out of the musical context of the pieces—with those in Experiments 4 and 5—motives presented within two different musical contexts. Most obviously, an examination of the perception, while listening to the full compositions, of the motives that were perceived as most similar and most dissimilar within their family when presented out of context in Experiment 2, could provide some insights in this respect (research question 3c).

Figure 3.12 illustrates the effects of context in Experiments 4 and 5 on the motives that were perceived as most similar, second-most similar, and most dissimilar when they were presented out of the musical context of the pieces (family-restricted context of Experiment 2). Recall that, in the context of Experiment 2, the motive perceived as most similar is the one that is rated as most similar on average to all the motives in the family, when the motives are heard in pairs. Accordingly, the second-most similar motive and the most dissimilar motive are the motives with the second-highest averaged similarity rating and lowest averaged similarity rating, respectively. The results shown in Figure 3.12 correspond to the motivic pairwise comparisons of types 7 (most-similar) and 8 (similar-dissimilar) as described in the Data Analysis section (analysis 3: preselected motivic pairs) and provide insights to research question 3c (effects of the context provided by each version of *Anthèmes* with respect to the out-of-context situation of Experiment 2 on the perception of motivic similarity relationships). The effects of the context provided by *Anthèmes 1* are illustrated on the left, and the effects of the context provided by *Anthèmes 2*, on the right. The proportion of listeners identifying the motives that were judged as most similar to the other motivic variations out of context in Experiment 2 as members of their respective motivic families during listening to the compositions is shown first (left side) on the x-axis of each figure. In both figures, the proportions shown in the y-axis correspond to the results of Experiments 4 and 5, whereas the labels in the x-axis refer to the results of Experiment 2. McNemar tests compared recognition performance of these most-similar items with that of the second-most similar (on one

hand) and most-dissimilar (on the other hand) motives according to Experiment 2. These comparisons were conducted for each motivic family separately. The proportions corresponding to the second-most similar and most dissimilar motives are shown in the middle and right side of the x-axis, respectively. Statistically significant differences (always with respect to the most similar motives on the left of the x-axis) are marked with an asterisk.



* Indicates statistically significant difference with respect to the first column of x-axis.
The y-axis shows the proportion of motivic recognition during Experiment 4 (left panel) and Experiment 5 (right panel). The labels in the x-axis refer to the results of Experiment 2. For instance, the label "most-similar motive in Exp2" refers to the motive that was rated as most similar (in average) to most motives within its group based on the similarity ratings of pairs of motives in Experiment 2—further details are explained in the text.

Figure 3.12: Contextual perception (results from Experiments 4 and 5) of pairs of out-of-context (Experiment 2) most similar, second-most similar, and most dissimilar motives.

As illustrated, a significantly smaller proportion of listeners identified, within the musical context of *Anthèmes 2*, the most dissimilar motives from the Long Tone and Scale groups compared to the most similar motives in those two groups: p = .02 and p = .0002 (McNemar), respectively. A similar situation can be observed with respect to the Scale motives in *Anthèmes I*: p = .0004 (McNemar). Furthermore, the difference in recognition between the Long Tone model and the most dissimilar Long Tone motive in *Anthèmes 1* was near marginal statistical significance after applying the Bonferroni-Holm correction (p = .12, McNemar), suggesting a trend. Following this, in both pieces, the similarity relationship between the pairs of motives remained the same, suggesting that the internal dissimilarity structures of the Long Tone and Scale groups are quite robust to contextual effects. Note that it is also possible that the dissimilarity structure of the groups was further exaggerated by the musical context. Nevertheless, the important point is that members

of the group that are perceived as relatively different from each other when presented in the restricted context of their motivic family, are also perceived as relatively distant from each other when presented in the broader context of either version of the entire musical composition. It is in this sense that the perceived similarity relationships for these groups can be said to be similar in out-of-context and within-context situations. This idea is further supported by the equally high proportions (not only in statistical terms, but, most remarkably, in terms of the descriptives) of participants identifying the most similar and second-most similar Scale and Long Tone motives in both versions of *Anthèmes*. Finally, the differences between the musical features of the motivic instances in question are robust to the very different contexts provided by the two versions of the composition. Note that this idea is compatible with the equal recognition of Scale and Long Tone motives observed in connection with Figure 3.11.

This robustness to context appears to be an aspect of the Long Tone and Scale groups only. An examination of the results corresponding to the pairs of motives from the Trill group illustrated in the figure suggests that the musical setting in which the motives are presented can affect motivic similarity perception. A slight reversal in the identification proportions of the most similar motive with respect to the most dissimilar motive when presented in the context provided by *Anthèmes 1* suggests that the musical setting may have the potential to alter the perceived sense of belongingness of musical motives to their motivic family. When heard in the context of *Anthèmes I*, the motive that was perceived as the most dissimilar motive in the Trill group in the restricted and unordered context of the motivic family (Experiment 2) was more often identified as belonging to the Trill group than the motive that was perceived as the most similar motive in the family when presented out of the musical context of the piece. This contextual effect on the perceived internal structure of the Trill group can perhaps be further supported by a reversal in the perceived identification of the most similar and second-most similar motives from the Trill group during listening to *Anthèmes 2*.

Finally, an analysis of the recognition of the Melodic motives for the two compositions supports the idea that the similarity perception of motives can be affected by the specific musical context in which those motives are set. As illustrated in the right panel of Figure 3.12 (corresponding to *Anthèmes 2*), the motive that was perceived as the second-most similar motive in the Melodic group during the restricted context of Experiment 2 was perceived as a member of

the Melodic group by a significantly smaller proportion of participants than the most similar motive in the group, as revealed by the McNemar test: $p = .007$ In addition, the most-similar Melodic motive was recognized as a member of the Melodic group by a larger proportion of participants than the most-dissimilar Melodic motive: $p = .003$ (McNemar). Furthermore, none of the participants identified the most-dissimilar Melodic motive as a member of its group while listening to *Anthèmes 2*. These results suggest that the perceived motivic relationships for the Melodic group are either similar or enhanced (rather than disturbed) in out-of-context situations compared to certain within-context conditions. Nevertheless, this appears to be case for the musical context provided by the electronic work only. The two significant differences mentioned here are exclusive to *Anthèmes 2*, suggesting that the internal similarity relationships of the Melodic group are perceived differently in the two versions of the piece.

This subsection and the previous one aimed to demonstrate that the perception of the similarity relationships among the motivic materials is affected by the specific musical context in which those materials are set. It should also be clear from the description above that some motivic families are more robust to certain changes in musical context than are others. This implies that both the intrinsic (non-contextual) characteristics of the motivic materials and the specific context in which those materials are set affect (in general) the way listeners form motivic relationships among those materials. This idea will be explored in more depth in Chapter 4 during a more thorough comparison of the five experiments presented in this dissertation.

Even when the findings reported in the paragraphs above contribute to the understanding of the effects of context on motivic similarity perception, they do not provide information concerning the way listeners attend to the different levels of the formal hierarchy. It is in this respect that the analyses of the two versions of *Anthèmes* presented in Tables 3.1 and 3.3, as well as the analysis of the electronic effects in Tables 3.4 and 3.5, become relevant. In effect, these analyses reveal formal aspects and musical characteristics of the two compositions that, when studied in connection with the listener's identification of motivic variations, elucidate the specific musical settings that influence the perception of the motivic categories at different levels. More precisely, a study of the experimental results in light of the tables of the formal and timbral analyses of the compositions allows for an exploration of the ways in which the factors of the model of aspects of form perception proposed at the beginning of this chapter (*predictability*, *formal-unit*

blend, and *elapsed musical time*) affect motivic recognition, and, in turn, the perception of the formal hierarchy. This is examined in the next section.

Contextual effects on the perception of form

Figure 3.13 shows the proportion of motivic identification for each of the nine formal units in the two versions of the composition. The nine macro-level formal sections are shown along the x-axis, and the proportion of motivic recognition per section is shown on the y-axis. Four points can be immediately inferred from the figure. First, overall, the identification of motivic materials appears to decrease as formal units pass by, presumably suggesting that the evolution of the music in time—i.e., the musical form or, in other words, the temporal development and organization of the musical materials—has an effect on the motivic connections perceived by the listener. Second, this decreasing pattern appears to be interrupted by a relatively low motivic identification during section IV for both compositions. As will be discussed, this section presents all the motives in their highest degree of transformation (from a theoretical-analytical perspective) in both compositions. Within the scope of the rudimentary formal model shown in Figure 3.1, this highest degree of transformation can be interpreted as low predictability in the sense that the motives appear in forms that are either exclusive to that section of the piece or only rarely used throughout the two compositions. Third, the section characterized by the highest degree of formal-unit blend—VIc—has the lowest motivic identification. Lastly, motivic recognition is at its highest for the two sections characterized by the highest degrees of predictability in terms of motivic successions—Sections I and III. A closer examination of these four points along with a detailed study of the correspondence of diverse degrees of motivic recognition with specific features of the different formal sections of the two compositions sheds light on the ways predictability, formal-unit blend, and elapsed musical time (temporal evolution and organization of the musical materials) influence the listeners' formation of motivic connections and, in turn, their understanding of the different levels of the formal structure. The sections titled Formal-unit Blend and Predictability below address most directly research questions 2a and 2b (effects of context in relationship to the formal structure across and within the two versions of *Anthèmes* on motivic recognition), whereas the section titled Form as Temporal Development deals particularly with research question 2c (effects of the temporal development of the musical materials and their overall formal organization on motivic recognition) and question 5 (effects of repeated listening of

Anthèmes 1 on motivic recognition). Nevertheless, the discussion also incorporates observations that shed light on research questions 1a, 1b, 3a and 3b.

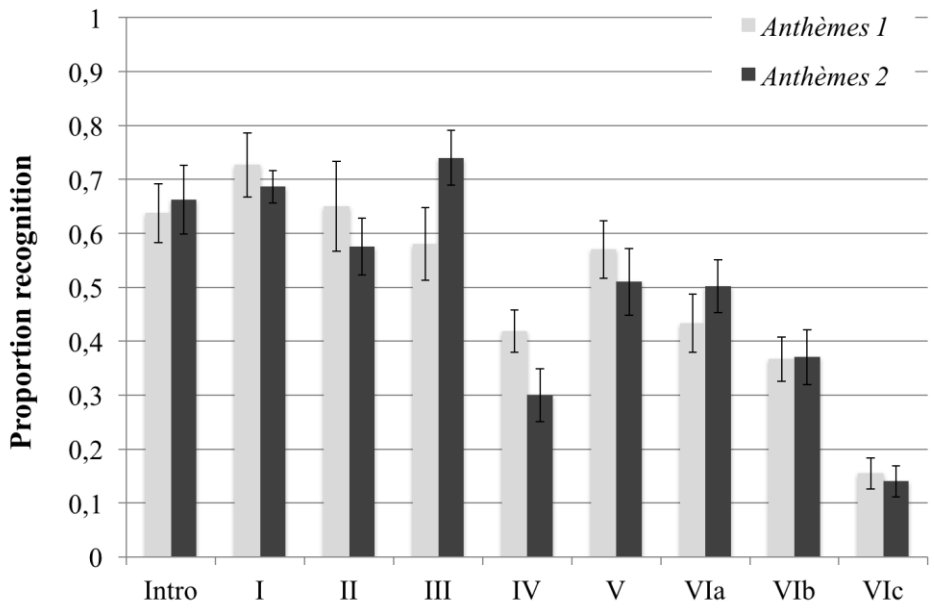


Figure 3.13: Motivic recognition per formal unit in the two compositions

The relationship between motivic identification and the perception of the formal hierarchy

A high recognition of motivic instances occurring at the local level of the formal structure, i.e., identification of motives presented as indivisible small units, can be linked to the listener's most direct attention to aspects of the small-scale structure. Because motivic materials tend to be the most basic (smallest) constituent blocks of larger formal segments, the proportions of motivic identification should relatively directly reveal information concerning the listener's attention to the local hierarchical level. Presumably, listeners focusing on musical processes taking place at higher levels should not instantly identify the motivic materials making up those processes. In this sense, the link between listeners' identification of motivic variations and their perception of the small-scale structure is quite direct. High recognition of motives should imply that listeners are primarily focusing their attention on local aspects of the music.

In the context of this project, a study of the perception of the large-scale structure is more complex, because Experiments 4 and 5 were designed to study the identification of musical motives, and, in that sense, the perception of relatively small levels of the formal hierarchy. The interpretation of the listeners' perception of high formal levels proposed in this dissertation is based on two assumptions: (1) listeners tend to pay relatively more attention to one level of the formal hierarchy at each given moment, rather than equally and concurrently dividing their attention among multiple levels; and (2) the levels of the formal hierarchy emphasized by the characteristics of the music are more likely to naturally capture the listeners' attention than other, less emphasized levels. These two assumptions are supported by previous literature reviewed below.

With respect to the first assumption, research has demonstrated that it is extremely difficult to divide attention while listening (e.g., Bregman, 1990; Kahneman, 1973). Specifically, this research has shown that listeners cannot separately focus on sound events occurring simultaneously (and at the same level). This suggests that listeners have difficulty separately processing aspects of music that occur concurrently. The levels of the formal hierarchy are concurrent (like the auditory layers associated with the divided-attention research) in the sense that they are organized (and presumably perceived) in a nested fashion. In line with this, it seems reasonable to propose that the ability of listeners to comprehend the formal hierarchy of music is at least partly dependent on their natural tendency to focus on different levels in an alternative fashion rather than simultaneously. Furthermore, assuming that listeners do not intuitively attend to different formal levels simultaneously and individually, it is possible that their capacity to alternatively focus on them is at least partly influenced by a set of equal factors acting in different ways. If listeners more naturally attend to one musical phenomenon over a concurrent one, it is likely that the attention mechanisms that regulate their tendency to focus on the attended phenomenon are the same as those regulating their tendency to focus on the unattended, concurrent phenomenon. A unique attention mechanism (or set of mechanisms) should have a capturing effect on the attended phenomenon and a distracting effect on the unattended phenomenon. It is important to note that even when the divided-attention hypothesis provides support for the idea that listeners cannot focus on more than one hierarchical level simultaneously, it does not confirm the notion that listeners focus on elements of larger hierarchical levels when they are not focusing on the elements of the local level. On one hand, it seems reasonable to propose that the formal hierarchy,

due to its nested nature, includes (more or less directly) all aspects of a musical piece. Following this, if listeners are focusing on the music, a lack of attention to local-level aspects should in principle imply greater attention to large-scale aspects. Favorably, this should account for the majority of listeners' responses in experimental situations where they are instructed to pay attention to the music at all times, as is the case for the experiments discussed in this chapter. On the other hand, it is possible that listeners momentarily distract their attention from all musical factors. In effect, attention is not an aspect of perception that can be totally controlled at all times (e.g., a listener could zone out from the music simply because he/she has had an exhausting day). In this case, a lack of attention to musical aspects of one hierarchical level would not imply a focus of attention on aspects from other levels.

In reference to the second assumption, it is likely that listeners would most naturally attend to the hierarchical level emphasized by the music. For instance, listeners would most naturally tend to focus on global, relatively large time spans (rather than on the moment-to-moment details) while hearing a piece whose formal structure consists of long sections that are both motivically unified and difficult to segment internally, such as minimal music or Wagner's dramas. Conversely, their attention would be more naturally focused on local, short time spans while listening to a piece whose formal structure is based on brief and contrasting musical motives, such as Stravinsky's *Symphony of Wind Instruments*. This idea is supported by the literature demonstrating that surface features play a central role in formal segmentation at any level of the hierarchy (e.g., Deliège, 1987, 1989; Lalitte et al., 2004) and that musical repetition (i.e., lack of musical change) tends to shift the listeners' attention to global levels of the structure (see Margulis, 2012, above). Following this reasoning, small musical motives sparsely presented within a context that emphasizes the higher levels of the structure are likely to be unattended by listeners, especially when the arrival of those motives does not imply a sudden and obvious contrast in the surface. In this situation, listeners would tend to focus on musical developments of larger scope.

This idea is linked to the formal-enlargement types associated with *Anthèmes 2* (formal analysis in Table 3.3). Given the larger proportions of the electronic piece, the extremely short motivic materials of the original composition are likely to merge into larger formal units. Type-1 formal enlargement (IME) extends the original motivic materials to proportions that are more concordant with the large dimensions of the electronic piece, and yet maintains the original internal

indivisibility of the materials. Type 3 (UAE) adds a large quantity of extra motivic materials that are still contrasting at the local level, considerably increasing and emphasizing the natural internal divisibility of a section at the local level where the motives take place. As a result, types 1 (IME) and 3 (UAE) highlight the local level of the formal structure. Conversely, type-2 formal enlargement (ILE) converts the original indivisible motivic materials into segmentable formal units of considerably higher hierarchical level that are internally homogeneous (not contrasting) in terms of motivic materials. Consequently, type 2 (ILE) emphasizes global levels of the formal structure. Furthermore, because the original materials affected by type 2 (ILE) are often stated in the middle or towards the end (rather than at the beginning) of these internally divisible and motivically homogeneous enlarged formal units, they are extremely likely to be less apparent from a perceptual standpoint as suggested by the previous research reported above.

In line with this thinking, the interpretation of the listeners' perception of the global structure proposed in the following sections is based on the proportions of motivic recognition for the two versions of *Anthèmes* as well as the processes of formal enlargement affecting the electronic piece. Specifically, high recognition of musical motives is associated with the listeners' attention to aspects of the local level of the formal hierarchy, whereas low recognition of indivisible musical motives is linked to the listeners' attention to aspects of the large level of the formal hierarchy. The following sections discuss the effects of formal-unit blend, predictability, and elapsed musical time on the listeners' identification of motivic variations throughout the two versions of the piece. The listeners' understanding of the formal hierarchy is interpreted in light of these effects and based on the two assumptions explained above.

Formal-unit blend

The effects of formal-unit blend are particularly obvious when examining the participants' responses for section VIc, identified in the theoretical analysis as the section with the highest degree of formal-unit blend. As mentioned, in this section the boundaries between motivic materials are relatively obscure, making the form more diffuse. The lack of clear segmentation points results from the lack of contrast in surface features—especially rhythm, register, articulation, and dynamics. In both versions of the piece, section VIc was associated with the largest number of statistically significant pairwise (across-section, within-piece) comparisons, meaning that it was the section for which motivic recognition was lowest overall. As shown by

Wilcoxon signed-rank tests, while listening to the electronic version of the piece, the proportion of motivic variations identified for section VIc was significantly smaller than that for all the other sections: $z \geq 3.29$, $p \leq .02$.

Wilcoxon signed-ranks test also revealed that the degree of formal-unit blend caused by the pure (acoustic) musical materials in *Anthèmes 1* significantly affected the participants' recognition of motivic variations during the final section. Listeners identified a significantly smaller number of variations for section VIc than for the Introduction and sections I, II, III, IV, V, and VIa (all sections except VIb): $z \geq 3.14$, $p \leq .04$. It is remarkable that the difference in identification of motivic variations between section VIc and the section built with successive (and difficult-to-segment) statements of the Pizzicato motive—section II—was no longer statistically significant when the recognition performance for all the successive versions of the Pizzicato motive was included in the data analysis. Furthermore, motivic recognition was significantly lower for section II than for section I when all consecutive motives were taken into consideration: $z = 3.55$; $p = .01$. This result supports the idea that the high recognition observed for section II (Figure 3.13) when disregarding consecutive Pizzicato motives is partly the result of the low formal-unit blend (high surface contrast) that characterizes the onset of the Pizzicato section and the Long Tone that ends that section. The mean recognition for the Pizzicato section when considering all consecutive Pizzicato motives was as low as $M = .36$, only .18 higher and .10 lower than motivic recognition in sections VIb and IV (sections with lowest and third-to-lowest motivic identification), respectively, and approximately the same as that in section VIb (section with second-lowest motivic identification). The importance of formal-unit blend for motivic recognition during section II can be further supported by the higher motivic recognition observed for the electronic version compared to the original piece when consecutive Pizzicato motives are disregarded (Figure 3.13). In effect, the electronic effects for the Pizzicato and Long Tone motives are quite contrasting to each other, presumably increasing listeners' natural tendency to identify the onset of the section and the arrival of the Long Tone. (Recall that the analysis of section II discussed here includes only the Pizzicato motive that starts the section, which is marked by the entrance of a new electronic effect, and excludes all the consecutive versions of that motive that are subsequently stated with the same electronic effect.) This along with the low motivic recognition associated with section VIc suggests that higher degrees of formal-unit blend, i.e., lack

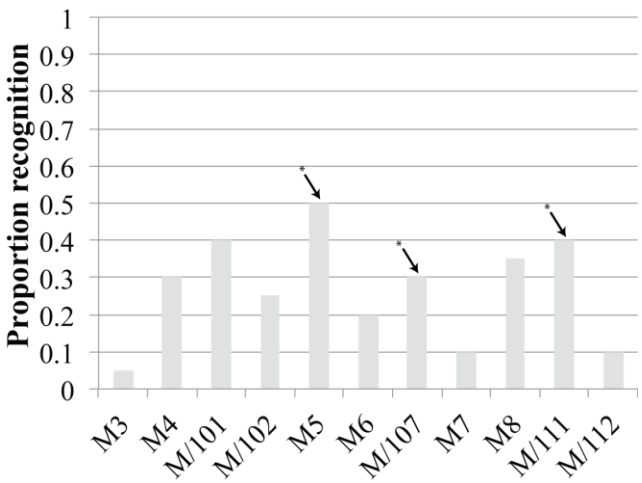
of clear segmentation points in the musical surface, interfere with motivic recognition, perhaps by naturally encouraging listeners to attend to more global levels of the musical structure.

An examination of the recognition of the Pizzicato group across its multiple motivic instantiations throughout *Anthèmes 1* further supports the idea that relatively high degrees of formal-unit blend interfere with the listeners' tendency to attend to the motivic, small-scale (indivisible) formal level. A Wilcoxon signed-rank test compared the recognition for all variations from the Pizzicato group that were stated in immediate succession with another motivic instance belonging to the same group, on the one hand, to the recognition for all variations from the Pizzicato group stated after contrasting material, on the other hand. The Pizzicato motives stated in immediate succession with one another (first group) correspond to all the Pizzicato motives in section II, with the only exception of the motive that starts the section. The Pizzicato motives stated after contrasting material (second group) correspond to all the Pizzicato motives in section VIb and the onset of section II. The results revealed that the listeners' tendency to identify motivic variations from the Pizzicato group was significantly larger when those variations followed contrasting material than when they came after material from the same motivic family: $z = 2.63$, $p = .008$.

The idea that musical passages that are easy to segment facilitate the listeners' identification of motivic variations can be further justified with the relatively high identification of motives observed in the Introduction in both compositions (Figure 3.13). Indeed, formal-unit blend is extremely low in the Introduction, where contrasting motives belonging to different families are juxtaposed and separated by musical rests. Furthermore, the different electronic effects applied to the motivic families in the Introduction (Table 3.5) perhaps emphasize the contrast between the motivic materials, presumably explaining the slightly larger proportion of motivic instances identified during the electronic version compared to the acoustic work.

Further support for the relevance of formal-unit blend for the model of form perception proposed in this dissertation comes from an analysis of the motivic variations identified by the largest number of listeners in the Melodic group in *Anthèmes 1* (where the musical features defining the formal segmentation can be observed separately from the electronic effects). An analysis of the musical setting of the motives in section VIa is particularly revealing. The identification of Melodic variations during this section is shown in Figure 3.14. Motives are shown

on the x-axis and the proportion of participants identifying those motives as variations of the Melodic group appears on the y-axis. As described in the formal analysis proposed at the beginning of this chapter, section VIa is mostly based on the alternation of motives from the Melodic and Trill groups. The section is subdivided by the Broken Arpeggio motives in staccato with a diminuendo dynamic profile leading to a musical silence (the score for the first instance is shown in Figure 3.2). The Melodic motives initiating each subsection following these Broken Arpeggio motives are M5, M/107, and M/111. The motivic instances initiating a subsection (marked in Figure 3.14 with arrows) were identified by relatively large proportions of listeners compared to the rest of the motivic instances.[16] Accordingly, contrasts in surface features, i.e., a sudden decrease in formal-unit blend, appear to shift the listeners' attention to the small-scale level, facilitating connections among motivic materials (in this case reflected in the identification of motivic variations).



* The arrows show motivic instances initiating a subsection (internal formal unit).

Figure 3.14: Identification of Melodic variations in section VIa

The link between low motivic recognition during highly formally blended sections and the participants' attention to global formal levels can be supported with a comparison of the

[16] M8 and M/107, which were also identified by a relatively large number of listeners coincide with the motivic model presented to the participants at the beginning of the trial and a considerable register shift, respectively.

proportions of motivic recognition obtained for sections IV and V in *Anthèmes 2* compared to *Anthèmes I*, in light of the formal enlargement procedures affecting the electronic work. As shown in Figure 3.13, motivic identification for sections IV and V was lower for the electronic than for the original composition. These sections along with section II (discussed above) gave the three largest differences in motivic identification for the original over the electronic piece. Even when the differences did not reach statistical significance, considering the low power of the statistical tests, it seems valid to include possible explanations for them. Furthermore, the fact that these differences in recognition can be explained by similar factors is encouraging. The lower motivic recognition for section IV for the electronic version compared to the original piece can be associated with the higher degree of formal-unit blend caused by the use of a unique and constant reverberating electronic effect and the enlargement procedures affecting the motivic materials. The uninterrupted infinite reverberation throughout the section and the use of the sampler to enhance all the motives that receive some kind of electronic treatment greatly merge the motives timbrally, presumably decreasing their capacity to create surface contrasts and, in turn, to instantly attract the attention of the listeners. As shown in Figure 3.6, the electronic version of section IV is 50% longer than in the original work. As listed in Table 3.3, the enlargement procedures affecting section IV are of type 1 (IME) and type 2 (ILE). More specifically, 33% of the motivic instances are affected by type-2 enlargement (ILE) and 11% by type 1 (IME). The overall extension of the section along with a relatively high proportion of motives affected by type-2 enlargement (ILE) is likely to lead the listeners' attention to the larger levels of the formal structure in ways that interfere with their ability to instantly recognize the many motivic materials occurring at smaller levels. Indeed, the 66% of motives that preserve their original proportions are likely to get lost in the midst of the formal enlargement. The difference in motivic recognition between the electronic version and the original piece observed for section IV can be statistically supported by the within-piece pairwise comparisons among the nine sections of the piece. In *Anthèmes 2*, section IV gave the second-largest number of statistically significant pairwise (across-section) comparisons associated with a section for which motivic recognition was low. This is to say, in statistical terms, section IV has the second-lowest motivic recognition for all the sections while listening to the electronic piece (see Figure 3.13). Specifically, motivic recognition was significantly lower for section IV than for the Introduction, section I, and section III: $z \geq 3.37$, $p \leq .02$. The situation was very different for *Anthèmes I*, where motivic recognition in section IV was only significantly lower than that in

section I: $z = 3.23$, $p = .03$. Furthermore, note that motivic recognition was better for section IV than for section VIb in *Anthèmes 1* (Figure 3.13).[17]

The lower motivic recognition during section V of *Anthèmes 2* with respect to *Anthèmes 1* can also be justified through an analysis of the procedures of formal enlargement, providing further support for the ideas suggested in the preceding paragraph. As illustrated in Table 3.3, this section is associated with enlargement procedures of types 1 (IME) and 2 (ILE). A recount of the motivic instances shows that 25% of the motivic instances are affected by type 1 (IME) and another 25% by type 2 (ILE). This implies that only 25% of the instances (some of which do not even belong to the five motivic categories studied here) are highlighted, whereas more than half of them either remain in their original dimensions (as in *Anthèmes I*) or become sections of formal units of clearly larger levels that are internally homogeneous, presumably getting lost in the expanded proportions of the electronic piece.

The discussion above is meant to provide support for the idea that low degrees of formal-unit blend (contrasts between musical units or sudden interruptions in the musical discourse) increase the listeners' tendency to attend to the local, indivisible level of the formal hierarchy. Conversely, high degrees of formal-unit blend interfere with the listener's ability to instantly and naturally form motivic relationships at the local level, presumably facilitating their understanding of large, divisible levels of the form. The next section explains how the degree of predictability given by repeating musical materials or constant features can influence listeners' attention to different levels of the structure.

Predictability

As hypothesized, musical passages that are more predictable tend to facilitate motivic connections for the listeners. The results of Experiments 4 and 5 suggest that there are two types of musical situations leading to higher degrees of predictability and, in turn, to the listeners' tendency to more naturally connect motivic materials: (1) sequences of motivic materials that return; and (2) musical features, including electronic effects, that are more frequently associated with certain motivic materials. The following sections describe and exemplify these two types.

[17] Section IV is further discussed in the section entitled Predictability of Musical Features.

Predictability of motivic sequences

According to the theoretical analysis presented above, section I is the most predictable section.[18] As shown in Figure 3.13, participants identified a larger proportion of motivic instances in section I than in any other section when listening to *Anthèmes I*. This relatively improved recognition for section I is supported by the statistically significant larger proportion of motivic recognition for that section with respect to most other sections. In effect, section I was the section with relatively high motivic recognition that gave the largest number of statistically significant pairwise comparisons—Wilcoxon Signed Rank tests—with respect to the remaining eight formal sections. Specifically, a significantly larger proportion of motivic variations were recognized in section I than in sections IV, VIa, VIb, and VIc: $z \geq 3.23$, $p \leq .03$. Presumably, the high motivic recognition associated with section I would be at least partly due to the repeating motivic patterns. As shown in Table 3.1 (column 2), the sequence of motives always follows the pattern Scale group, Trill group, and Grace Notes group during this section. This fixed order of motivic materials is likely to facilitate the identification of the arrival of the motives for the listeners, since those arrivals should be highly expected. Because in *Anthèmes 1* the motivic materials associated with section I take place at the smallest level of the formal structure (i.e., all motives are short and indivisible, and there is only one instance of two motives of the same class stated in succession), the relative ease with which listeners identify motivic transformations during that section can be interpreted as a result of a natural tendency to attend to that smallest level.

In *Anthèmes 2*, motivic recognition was higher for sections I and III (Figure 3.13). Section I gave the largest number of statistically significant pairwise comparisons across sections, and section III gave the second-largest number of such comparisons (along with the Introduction, which has already been discussed in the Formal-unit blend section). A larger proportion of motivic variations were identified for section I with respect to sections IV, VIa, VIb, and VIc: $z \geq 3.25$, $p \leq .02$. Similarly, a larger proportion of motivic variations were identified for section III with respect to sections IV, VIb, and VIc: $z \geq 3.88$, $p = .003$. According to the analysis proposed above, section III, like section I, is very predictable in terms of the succession of motivic materials.

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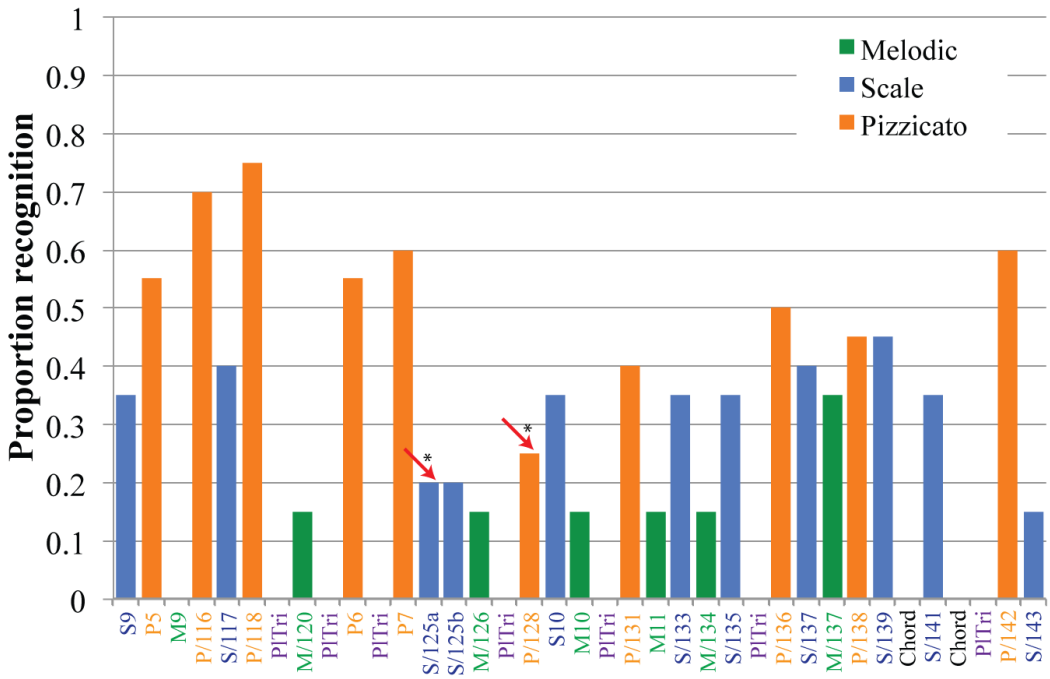
[18] Section III is also highly predictable, since it is based on the repetition of a unique sequence of motivic patterns. Nevertheless, in section I the same sequence of motivic materials is repeated 5 times, whereas in section III the same sequence of motivic materials is stated twice. In this sense, section III is less predictable than section I.

A study of the procedures of formal enlargement taking place in sections I and III indicates that the high proportion of motivic identification associated with these two sections could easily be due to musical features capturing listeners' attention to the small levels at which the onset of the motivic materials occur. As illustrated in Figure 3.13, motivic recognition for section III appeared to be higher for *Anthèmes 2* than for *Anthèmes I*. Furthermore, this difference in motivic recognition was the largest one found among all pairwise comparisons between the sections of the two versions of the piece. As shown in Table 3.3, the majority of the motives in section III are enlarged through type 1 (IME). Specifically, 67% of the motivic instances are enlarged through type 1 (IME), whereas 11% are enlarged through type 2 (ILE) (approximately 22% remains in their original dimension). This implies that the dimensions of the majority of the motives are augmented to become more concordant with the proportions of the piece (and the section) in a way that does not interfere with the internal structure of those motives (which remain indivisible units). As a result, the motives themselves are emphasized and, with them, the small level of the formal hierarchy at which they occur. In section I, approximately 5% of the motives are enlarged through type 1 (IME, see Table 3.3), whereas the remaining materials keep their original proportions. Perhaps, this would explain the slightly lower motivic recognition observed for section I in *Anthèmes 2* than for the same section in the original piece (Figure 3.13) (the enlargement procedure favors the perceptual salience of 5% of the motives only).

The discussion above attempts to convey the idea that easily predictable successions of contrasting classes of motivic materials facilitate the listeners' associations among the varied forms of each of those classes of motivic materials, particularly when the predicable successions take place at lower levels of the formal hierarchy. This in turn suggests that sections that are highly predictable lead the listener's attention to the local level of the form. An analysis of section IVb, particularly in connection with the original piece, supports the converse idea that classes of musical materials that are presented in an unpredictable succession are more difficult to instantly recognize. The significant differences mentioned above (in relationship to both pieces) involve a relatively small proportion of motivic variations identified for the most unpredictable section of the piece, i.e., section VIb. As shown in Figure 3.13, motivic recognition for section VIb is relatively low for both versions of the piece (around 37%). This relatively poor identification of motivic transformations in this section of *Anthèmes 1* is significantly lower than for section I, the most predictable sections in the piece, and for section V, which is also highly predictable (see Table

3.1): z = 3.85, p = .004, and z = 3.42, p = .02, respectively. In *Anthèmes 2*, motivic recognition for section VIb was significantly lower than that for the Introduction and sections I and III: z = 3.36, p = .02; z = 3.49, p = .01; and z = 3.92, p = .003, respectively. Note that two of these differences involve the two more predictable sections.

A detailed examination of the participants' motivic associations for section VIb while listening to *Anthèmes 1* provides further insights concerning the ways in which frequently encountered (relatively predictable) motivic successions facilitate motivic associations (recognition of motivic variations) for the listener. The x-axis of Figure 3.15 shows the succession of motives in VIb. The proportion of participants recognizing each motivic instance as a variation is shown for the motivic families studied in this dissertation (note that recognition data for the motives from the Plucked Trichord group are not available).



* The arrows show versions of the Scale and Pizzicato motives that follow a new succession of motives (with respect to previous statements of those two motives).

Figure 3.15: Recognition of motivic variations during section VIb

A close examination of the figure reveals that a motive is less likely to be recognized as a member of its motivic family when it is stated after a new sequence of motives. This is indeed

the case for the Scale and Pizzicato groups. The first time that the Scale and Pizzicato motives follow a relatively complex sequence of motives, a relatively small number of listeners identify those motives as members of their respective families. This is shown with the red arrows in the figure. The Scale motive (S/125) is here presented for the first time after the Plucked Trichord and Pizzicato motives. Note that the next appearance of the Scale motive (S10) follows that same motivic succession, presumably causing the observed increase in motivic recognition. Similarly, the proportion of musicians associating the Pizzicato motive with the Pizzicato group is notably reduced on the first time that this motive follows the relatively complex sequence of motives involving the Scale, Melodic, and Plucked Trichord groups (P/128). Once again, as the same sequence of motives repeats immediately afterwards, the proportion of participants associating the Pizzicato motive with the Pizzicato group increases (P/131). The motivic instances from the Melodic group appear to require more than two identical motivic successions in a row in order to cause an identification increase. This is consistent with the relative lack of internal consistency that characterizes the Melodic group (as discussed in Chapter 2). The only increase in motivic identification observed in connection with the Melodic group occurs with the statement of M/137, which coincides with the third time that an instance from the Melodic group comes after the Plucked Trichord, Pizzicato, and Scale groups (the first two times this motivic succession occurs end with the statement of M/126 and M10).

An analysis of the participants' perception of motivic relationships with respect to the Trill group provides another interesting example of how sequences of motives that are more frequently encountered throughout a composition can affect the way listeners form motivic relationships during listening. The motives from the Trill group have a special characteristic that distinguishes them from the motives of the remaining groups: the majority of trills are preceded by a motive from the Scale or Melodic group functioning as a pickup (anacrusis). As illustrated in Figure 3.11, the Trill group had the largest proportion of motivic variations identified with it while listening to both compositions. In addition to the inherent salience of trills as traditional musical ornaments and their relatively contrasting character with respect to the rest of the musical elements, it is possible that their recurrent anticipation through anacruses built with the Scale and Melodic groups facilitated their identification. Furthermore, an observation of the proportion of recognitions obtained for all the motivic instances in each of the five families suggests that the recognition of the Trill group was different from the other groups in that it was remarkably and

constantly high throughout the very many motivic variants (i.e., independently of subfamily and formal section). Presumably, the Scale or Melodic motive leading to the trill made the return of the trill more predictable and, consequently, easier to identify during listening.

The predictability factor discussed above is related to formal functions. In relationship with this, it seems reasonable to propose that motives that are frequently associated with a clear formal function would be more easily identified as members of the same family when they play such a function. This is indeed the case for the Scale group, in which most motivic instances have an initiating formal function (most frequently leading to a trill). An exact McNemar test (preselected motivic pair type 1: beginning-end) revealed that in *Anthèmes 1* a motive from the Scale group that initiated a formal section and phrase (leading to a trill—specifically S/90) was recognized as a variation from the Scale group by a significantly greater proportion of listeners than the only motivic instance (in the entire piece) from that group that ended a large-scale formal section (leading, after a pause, to a long tone in harmonics—specifically, S/96): $p = .007$.[19] As is the case for the Trill motives, the larger recognition of the Scale motive with initiating formal function discussed here can be related to a more predictable (frequently encountered) formal function associated with the motive. Nevertheless, there is an important difference between the formal function associated with the larger identification of variations in the Trill group, and those associated with the Scale group. Whereas in the Trill group the formal function anticipates the motive in question (i.e., the Trill motive is the goal of a scalar/melodic anacrusis), in the Scale group, the formal function is intrinsic to such a motive (i.e., the Scale motive is itself the anacrusis to another motive, usually a trill). In this sense, the formal function associated with the Trill group prepares the arrival of the motives from that group with a predictable musical setting. Trills are the goal of a motivic succession. On the other hand, the formal function associated with the Scale group is predictable only in the sense that it is a common feature of the members from the group.

[19] It is important to note that the motive ending a formal section that is included in this statistical test (S/96) is a descending scale, whereas the motive initiating the section (S/90) is an ascending scale. Ascending scales are more common throughout the composition. Furthermore, the motivic model played to the participants at the beginning of the experimental trial was an ascending scale. It is thus possible that the lower identification associated with the motive playing a closing formal function is related to the descending contour of the motive rather than to its rare formal function. Nevertheless, as will be discussed in Chapter 4, further statistical analyses revealed no difference in identification of motives from the Scale group according to pitch direction. This, along with the fact that the motives from the Scale group are almost exclusively associated with initiating formal functions, supports the proposed interpretation.

The specific motivic succession that results from the initiating function of the Scale motives should not affect the recognition of the Scale motives, because they constitute the initial point of the succession. Following this, the predictability associated with the initiating function of the Scale motives is of type 2 (related to musical features), because it refers to a commonly encountered feature and not to a specific sequence of musical events. A more thorough explanation of the second type of musical situation leading to higher degrees of predictability is proposed and exemplified under the following heading.

Predictability of musical features

Intuitively, musical features that are more frequently associated with certain motivic materials (predictability of type 2 above) should lead listeners to more frequently associate those materials with the same motivic family. This type of musical situation is more general than type 1 (predictability of motivic sequences) in that it does not refer to a repeating sequence of [several] musical events, but rather to a musical characteristic that is frequently associated with a motivic family. As observed in connection with the introduction of Figure 3.13, section IV has relatively low motivic identification for the two compositions. It is the section with the second-lowest and third-lowest proportion of identification of motivic instances of *Anthèmes 2* and *Anthèmes I*, respectively. The low proportion of motivic recognition that characterizes the section can be explained in light of its unconventionality in terms of motivic materials. The material of the section consists of motivic subfamilies that are quite different from their related subfamilies and from most of the material of the piece in general. In effect, the section contains the motives from the Trill and Melodic groups that were perceived as most dissimilar in their groups during Experiment 2 (specifically, M2 and T6), as well as motives that were not immediately grouped with most of their family members during Experiment 1 (specifically, S7, T5, and T7). Most obviously, in section IV, the Trill motives are attacked in multiple-stops, the Scale motives are slurred, and the Melodic motives are rhythmically very diverse, marking clear differences in terms of surface features—specifically, texture, articulation, and rhythm—with respect to the majority of the motives from those same groups throughout the rest of the piece. In line with the formal model proposed in this dissertation, it is possible that the listeners' ability to instantly identify motivic variations during section IV is due to the relatively extreme transformation of the members of the motivic families during that section. The arrival of motives in section IV has low predictability in the sense that it

coincides with a high degree of transformation (lack of consistency or repetition with respect to the materials heard prior to the section) of the features of those motives.

The predictability of musical features being discussed here can best be investigated in relationship with the electronic effects affecting the motivic families in *Anthèmes 2*. As noted along with the introduction of Figure 3.11, the recognition of the motives from the Long Tone and Scale groups was the least influenced by the formally enlarged and electronically enhanced context provided by *Anthèmes 2*. Assuming that the enlargement of the composition affects all motivic families in similar ways, the relative perceptual robustness of the motivic connections defining the Long Tone and Scale groups with respect to the musical context can partly be explained by the association of the motives from those groups with remarkably consistent electronic effects.[20] As shown in Table 3.5, the Long Tone motives are always enhanced with the ring modulator, the comb filter, and reverberation. Furthermore, they are the only motivic group passed through ring modulator and comb filter. Similarly, the majority of the Scale motives are associated with frequency shift, whereas the few remaining Scale motives are presented without electronic enhancement. The plain frequency-shift effect is exclusive to the scale motives. Presumably, the persistent connection of the Long Tone and Scale motives with the same (and quite unique) electronic effects facilitated the recognition of those motives during listening.

This idea is further supported with statistical analyses of the electronic vs. acoustic versions of the motives from the Scale and Melodic groups in *Anthèmes 2*, as revealed by McNemar tests performed on specific pairs of motivic instances (preselected motivic pair type 4': acoustic-electronic). With respect to the Scale group, a motive enhanced with frequency shifting (specifically, S3) was identified as a member of the motivic family by a significantly larger number of listeners than one of the few acoustic instances of the Scale group in the piece (specifically, S7): $p = .003$. Similarly, in reference to the Melodic group, where most of the motives are devoid of electronic effects throughout the piece, an acoustic instance (specifically, M/101) was identified

[20] The Pizzicato motives are also extremely consistent in terms of electronic effects. Nevertheless, their relatively low recognition can be explained in terms of distortion of surface features with respect to the motivic model that the participants heard at the beginning of the trial (see the section General effects of musical context, p. 148, for a complete explanation).

as a member of the motivic family by a significantly greater proportion of musicians than one of the few electronically enhanced instances of a motivic group (specifically, M2): $p = .02$.

An examination of the participants' identification of motivic variations for each section provides further support for the idea that consistency in the electronic effects applied to a motivic family increases the predictability of the members of that family and, in turn, listeners' tendency to conceive those motives as variations of the same motivic class. As mentioned above in connection with the explanation of the predictability of motivic successions, a significantly larger proportion of motivic variations in *Anthèmes 2* was identified in section I than in sections IV, VIa, VIb, and VIc and in section III than in sections IV, VIb, and VIc. Furthermore, the difference between section III and VIa was marginally significant statistically: $z = 3.02$, $p = .052$. As shown in Table 3.5, sections I and III are remarkably consistent in terms of the electronic effects applied to each of the motivic families. More importantly, these sections feature the electronic effects that are most commonly associated with each motivic family throughout the entire composition. Sections IV, VIa, and VIb are also consistent in terms of the electronic effects applied to the motivic categories; nevertheless, they feature electronic effects that are rare for most of the motivic families taking place in those sections (i.e., even when the electronic effects are consistent within the sections, they are also exclusive or almost exclusive to those sections). In section IV, the Scale motive is devoid of electronic effects—which is rare for this motivic family—and the Trill features a new and not frequently used electronic effect.[21] Similarly, section VIa presents the Scale group in its (rare) acoustic version and the Trill group with an electronic effect not used since the Introduction, where it was fleetingly used only once. Finally, section VIb features the first and only time that the Melodic motive is enhanced with the sampler without reverberation. Following this, the relatively large number of motivic variations recognized in sections I and III is presumably not only due to the high predictability of those sections in terms of the motivic successions that they repeatedly feature, but also due to the high predictability of the electronic effects associated with each motivic family.

[21] Recall also that the lower recognition of section IV is likely to be partly due to the relatively high formal-unit blend caused by the use of the same electronic effects across motivic families (see section Formal-unit Blend, p. 160, for details).

Form as temporal development: The effects of time on form perception

Based on previous literature and the importance of the temporal aspect of music, elapsed musical time constitutes a central element in the theoretical model of form perception proposed above. An analysis of the participants' responses throughout the nine sections of the two compositions suggests that local-level motivic associations decrease as the musical materials and formal sections unfold. In both versions of the piece, listeners' recognition of motivic variations decreased with each formal section, from the beginning to the end of the piece. Figure 3.16 shows the logistic regression line (trend in log-odds ratios—see below for a more intuitive explanation) representing this decrease. The dots in the figure represent the proportion of motivic recognition (y-axis) for each listener throughout the nine formal sections (x-axis) of *Anthèmes 1* (left panel) and *Anthèmes 2* (right panel).

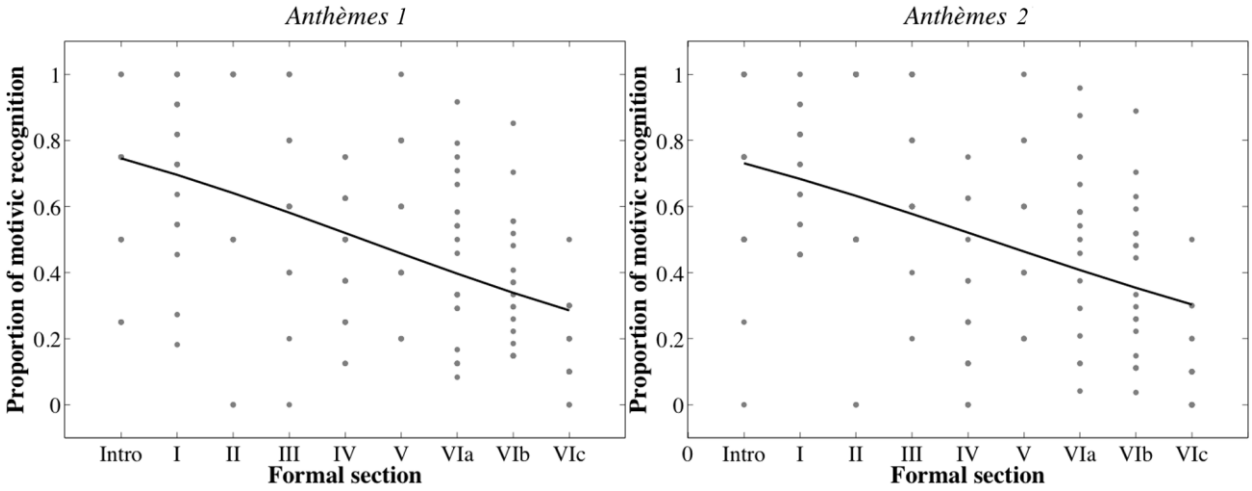


Figure 3.16: Identification of motivic variations throughout the nine sections.

Specifically, in *Anthèmes I*, a logistic regression analysis of the proportion of motivic identification (for each participant) on the nine formal sections showed that listeners were 22% (.44/.56 = .78 =

$e^{-0.25}$)[22] less likely to identify motivic variations within each formal unit with respect to the immediately previous one: $b = -0.25$, $p < .001$. This linear decrease in motivic identification across sections was remarkably similar for the longer version of the composition, where listeners were 21% (.446/.564 = .79 = $e^{-0.23}$) less likely to identify motivic variations within each formal unit with respect to the immediately previous one: $b = -0.23$, $p < .001$.

This effect of the temporal development of the music on the participants' association of motivic materials (decrease on motivic identification across sections) was statistically the same for the two compositions, as shown by the non-significant interaction term (Formal Section × Piece) of a multiple logistic regression analysis of proportion of motivic identification on Formal Section and Piece: $b = 0.02$; $p = .50$. These results support the idea that listeners gradually and more naturally shift their main focus of attention from local (indivisible) to larger (divisible) levels of the structure as formal sections and variations of motivic materials pass by. The similar effect obtained for the two versions of the composition in spite of their very different total temporal dimensions suggests that it is not the mere passing of time (nor that the participants got more distracted, tired, or bored due to the repetitiveness of the task), but rather elapsed musical time or the temporal evolution and organization of the musical materials that affect the identification of the motives and, presumably, the listeners' attention. In *Anthèmes 2*, where all the constituent formal units are enlarged, the participant's recognition of the motives is affected at a slower pace in real time (time as succession of seconds), yet at the same pace in musical time (time as succession of formal sections). At least this is the case in the sense that the same decreasing effect in motivic recognition takes more than twice as many minutes in *Anthèmes 2* than in *Anthèmes I*, yet spans the same number of formal units in both versions of the piece. It is the temporal evolution of the musical materials and the way they delineate the formal structure that influences the listeners' perception of those materials.

An analysis of the repeated listenings to *Anthèmes 1* during Experiment 4 is relevant for the study of the effects of the temporal experience of the music—specifically, repeated exposure—on motivic recognition. A within-subjects two-way (Motivic Family × Listening Time) ANOVA revealed that the participant's conceptualization of the motivic families did not change with the

[22] All this information is derived from the value of *b* reported belo (*e* is raised to the power of *b*).

three successive listenings of the piece. This was the case for all five of the motivic families studied here. Furthermore, a logistic regression analysis of motivic identification on Listening Time showed that motivic recognition was not affected by number of listenings to the piece. These results do not imply that the listeners' perception of the motivic structure does not vary with repeated exposure to a musical composition. In effect, such a conclusion would contradict previous findings (reviewed at the beginning of this chapter). It is more likely that a global effect of repeated exposure across the entire experiment—during which participants heard the piece a total of 15 times—minimized the effects of repeated listening within each of the motivic families.

The previous sections provided empirical evidence for the effects of formal-unit blend, predictability, and elapsed musical time on the recognition of musical motives. A link between motivic recognition and formal hierarchy allowed for conclusions regarding the listeners' attention to the two main levels of the hierarchical structure. The section below uses the interpretation of the empirical findings to validate and refine the model of form perception proposed at the beginning of this chapter.

A theoretical model of aspects of form perception

The results of Experiments 4 and 5 suggest that predictability, formal-unit blend, and elapsed musical time (as defined by the musical form) play an important role in the perception of form in post-tonal music. The empirical findings imply that these three factors operate in a dynamic way during music listening, contributing to the listeners' comprehension of the different levels of the form. Based on the interpretation of the results from Experiments 4 and 5, Figure 3.17 refines the model originally supported with the perceptual, theoretical, and compositional literature reviewed at the beginning of this chapter (model introduced in Figure 3.1). The refined version of the model further specifies the effects of predictability, formal-unit blend, and elapsed musical time as it adds information about the most predominant ways in which they affect the listeners' perception of the local (motivic or indivisible) and global (middle to large or divisible) levels of the musical form.

The findings of Experiments 4 and 5 support the idea that musical events that are more predictable (either due to repeating motivic successions leading to those events or to musical features very frequently associated with those events) or more salient on the musical surface

(associated with contrast in surface features or low formal-unit blend) lead the listeners' attention to the motivic, local level of the formal structure, allowing them to naturally and instantly discover the arrival of those musical events. Conversely, musical events that are quite unpredictable and highly blended within the formal structure lead the listeners' attention to higher, more global levels of the musical form, allowing them to better and more immediately comprehend the overall structure.

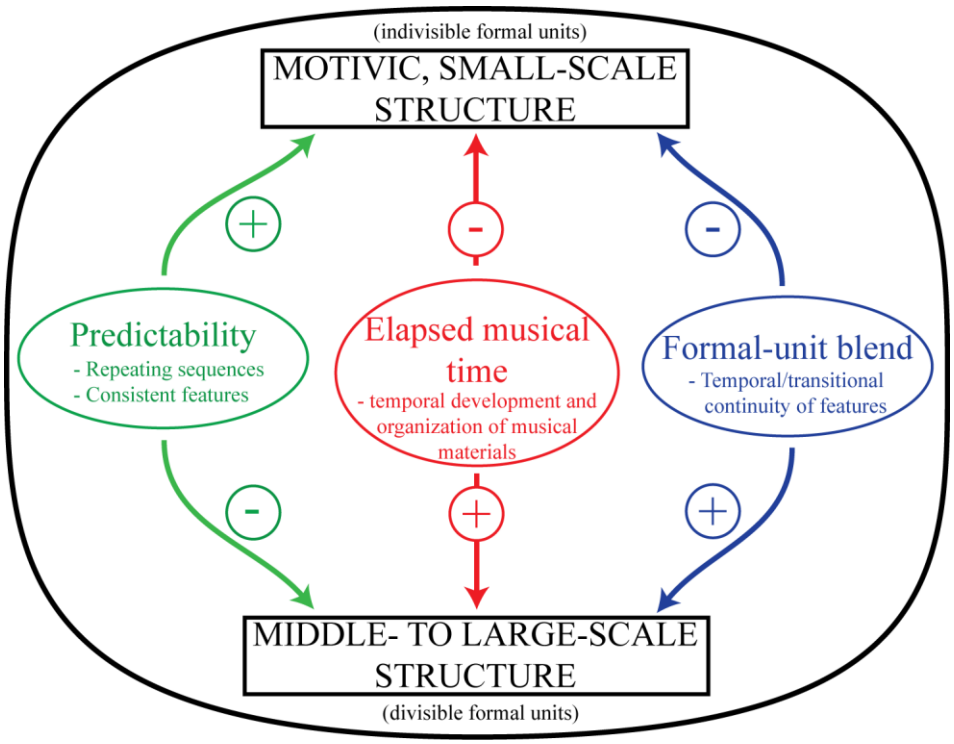


Figure 3.17: A theoretical model of form perception

It is important to note that the conception of the listeners' understanding of the formal hierarchy is the result of complex interactions that a simple model is incapable of explaining. It is likely that the conception of the diverse levels is itself in constant change during the listening experience, because those levels are defined by a multiplicity of musical factors that are continuously changing and interacting in numerous ways for a given listener and interpretation of the piece. In addition, as will be shown in Chapter 4, the effects of context on the perception of the motivic materials depend on the specific characteristics of those materials and the musical context in which they are set. In reference to *Anthèmes*, I will show that some motivic families (and

subfamilies) are more robust to context than others. Finally, the model proposed here is only intended to start illuminating the very complex ways in which listeners make sense of the formal hierarchy of music. The model is limited to the interpretation of previous findings and the results of the experiments reported here. It is extremely simple, certainly incomplete, and perhaps as unstable as the perception of musical form itself. In fact, that instability is precisely one of the aspects of musical form that this model attempts to convey.

Concluding summary

This chapter discussed the effects of musical context on the perception of motives and form. Theoretical studies were combined with empirical methods with the purpose of beginning to develop analytical tools that are both theoretically applicable and perceptually valid. The chapter started by proposing a theoretical model of musical form perception, based on intuitions and previous literature in the fields of theory and perception. The model was also elucidated with Boulez's own ideas about musical composition and form. A detailed motivic analysis and a formal interpretation for the two versions of Boulez's *Anthèmes* followed. These analytical studies were then used to interpret the results from two experiments that explored the identification of motivic variations while listening to *Anthèmes 1* and *Anthèmes 2*. When analyzed in light of the different contexts provided by these two versions of *Anthèmes* in terms of formal structure and musical features, the results of the empirical studies suggest that contextual effects play an important role in shaping the listeners' perception of the diverse hierarchical levels of the musical form. The theoretical model of form perception sketched at the beginning of the chapter was then refined based on the empirical data.

Finally, never intended to be an end in itself, the theoretical model proposed in this dissertation modestly aims to begin discovering the very complex ways in which the specific musical context affects how listeners perceive the many different aspects of the motivic and formal structure of musical works. Perhaps more importantly, the model attempts to convey the dynamism that characterizes musical form when it is conceived as a listening experience:

> Listening is ultimately something other than the mere act of hearing contained in understanding. It means the capacity to hear differently, to discover in oneself new antennae,

new sensors, new sensibilities; to discover one's own alterability and use it to resist the unfreedom which it uncovers. (Lachenmann, 2003, 29).

Chapter 4
Final discussion and conclusions

By way of conclusion, this chapter starts with a comparative discussion of the results obtained in the experiments presented in this dissertation. The discussion aims to offer insights into the complex interaction that takes place (at a perceptual level) between the relatively fixed features of more or less defined musical objects (motivic families, in this case) and the constantly changing characteristics of the unfolding musical context. I conclude that the effects of context on motivic-similarity perception depend on both the nature of the context and the perceptual robustness of the musical motives to contextual changes. First, changes in the context in which a musical motive is set can alter the perception of that motive. Second, certain musical features intrinsic to the motives are perceptually more robust (resistant to perceptual alteration) to contextual characteristics than other features. I then incorporate these ideas into the theoretical model of aspects of form perception introduced in Chapter 3. Finally, in a concluding section, I address the relevance of this study, its limitations, and future directions.

Motivic-similarity perception in different contexts

In this section, I compare the results from Experiments 1, 2, 4 and 5 with the purpose of investigating the perception of motivic similarity in different contexts.[1] These experiments are associated with four clearly different contexts as defined by the musical stimuli available to the participants. In Experiment 1, participants heard most motives from each of five representative families as many times as they wanted, forming motivic families according to their own criteria.

[1] Experiment 3, in which participants choose the motive that best represents each motivic family, is excluded from this discussion for the following reasons: (1) the experiment studied aspects of perceived similarity only indirectly and in terms of their relationship to the notion of best representative; (2) the interpretation of the meaning of the results of this experiment in terms of the perception of similarity relationships is contentious due to the broadness of the question asked to the participants—a broadness that was necessary in order to avoid biasing the participants to favor traditional definitions of prototype, stereotype, or model, which are themselves complex and controversial across music sub-disciplines; (3) the context in which the motives were presented to the participants of Experiment 3 is similar to that of Experiment 2—the same selection of motives was presented within the restricted context of each motivic family— as discussed in Chapter 2.

In Experiment 2, participants listened to pairs made from a set of motives selected from the motives of all families used in Experiment 1, organized per motivic family. The pairs were played a maximum of two times and participants rated the dissimilarity of the motive played second with respect to the one that was played first and was presented as the reference. In Experiments 4 and 5, participants first heard a motive representing each of the five motivic families several times, subsequently identifying all variations of that motive as they listened to *Anthèmes 1* and *Anthèmes 2*, respectively.

Following this, the contexts provided by the four experiments can be sorted from the most restricted (narrowest) one to the broadest or most largely modified, as follows:

1. in Experiment 2, the context is limited to pairs of motives from *Anthèmes I*—heard by the participants one (possibly two) time(s) only—taken from a restricted selection of motives representing five families;
2. in Experiment 1, the context is broadened to include a larger selection of motives (that contains most motivic variations stated in *Anthèmes I*) from the five families, which participants could hear as many times as they wished and in any order across all families;
3. in Experiment 4, the motives in all their variations are presented only once in the actual context of the original composition; and
4. in Experiment 5, the motives themselves are often electronically enhanced as they are presented (once) in the context of the expanded form and electronically modified version of *Anthèmes 2*.

A comparison of the perceptual data from these four experiments in connection with the musical contexts associated with the experimental tasks contributes to the understanding of the ways in which the perception of specific intrinsic features of the musical materials interacts with the constantly changing characteristics that define the unfolding musical context.

Table 4.1 attempts to summarize how several intrinsic motivic features differentiating (defining) subgroups (subfamilies) of motives within a single family are perceived in the varying contexts provided by the four experiments. Because these intrinsic features directly refer to either similarities or differences between any two motives of a family, the table can be more generally seen as an analysis of the perception of motivic similarity in different contexts.

Table 4.1: Effects of context on the perception of intrinsic motivic features according to the results of Experiments 1, 2, 4, and 5

Family	Intrinsic motivic features defining subfamilies	Most restricted within-family context (Exp. 2)	Broader across-family, atemporal context (Exp. 1)	Full within-piece context provided by *Anthèmes I* (Exp. 4)	Electronically modified and enlarged context provided by *Anthèmes 2* (Exp. 5)
Long Tone	**Glissando (with vs. without)**	Internal subdivisions likely supported: the only motive featuring a single note and no gliss. (L7) was the most dissimilar in the entire Long Tone family.	Internal subdivisions at different levels, including highest-order level.	Motives representing the two different subfamilies were perceived differently: recognition is significantly different statistically z=2.46, *p*= .028	Motives representing the two different subfamilies were perceived differently: recognition is significantly different statistically z=3.52, *p*= .0008
	Number of notes (1 vs. more than 1)		Highest-order subdivision	Motives representing the two different subfamilies were perceived equally: recognition is statistically equivalent.	Motives representing the two different subfamilies were perceived equally: recognition is statistically equivalent.
Melodic	**Character (*brusque* vs. non-*brusque*)**	Subdivision possibly supported. All motives are quite dissimilar to each other. Two motives that are opposite in terms of these three characteristics (M11, M14) have two of the highest dissimilarity means in the family.	Highest-order subdivision	Motives representing the different subfamilies were perceived equally.	Motives representing the different subfamilies were perceived equally.
	Texture (clearly compound vs. non-compound)				
	Speed (slower vs. faster)		Subdivisions at different levels, including highest-order level.		Motives representing the different subfamilies were perceived differently (t=4.39, *p*= .001)
Scale	**Articulation (slurred vs. *jeté/ricochet*)**	Likely subdivisions: the only two motives that are slurred (S8, S11) showed the highest dissimilarity means in the group.	Highest-order subdivision	Motives representing the different subfamilies were perceived differently (z=3.57, *p*= .001)	Motives representing the different subfamilies were perceived differently (t=7.32, *p*= .00001)
	Texture (single vs. double-stops)	Possible subdivisions, but not clear: the two motives with double-stops and downward contour (S9, S10) have relatively high dissimilarity means. (There are no examples of single line with downward contour).	Third- highest order level (second- highest order refers to register contrast, which in the context of the piece was difficult to determine—not clear where to put the limits).	Motives representing the different subfamilies were perceived equally.	Motives representing the different subfamilies were perceived equally.
	Direction and texture (single *jeté* down vs. double-stops in both directions)				Motives representing the different subfamilies were perceived differently (t=3.61, *p*= .006)
	Direction and texture (single *jeté* up vs. double-stops in both directions)			Motives representing the different subfamilies were perceived differently (z=3.82, *p*= .001)	Motives representing the different subfamilies were perceived differently (t=4.62, *p*= .008)
	Direction (up vs. down)		Subdivisions at lowest to third- highest levels	Motives representing the different subfamilies were perceived equally.	Motives representing the different subfamilies were perceived equally.
Trill	**General texture (polyphonic vs. monodic)**	Likely subdivisions: the only two motives that are monodic (T9, T13) showed the lowest dissimilarity means in the group.	Second- highest-order subdivision (highest-order subdivision not tested because one subgroup contained only one motive)	Motives representing the different subfamilies were perceived equally.	Motives representing the different subfamilies were perceived differently (t=3.3, *p*= .008)
	Polyphonic subtype (two-part counterpoint vs. attacks in multiple-stops)	Possible subdivisions, but not clear. The motives in these subgroups have relatively high dissimilarity means, but there is no pattern concerning multiple-stops vs. two-voice counterpoint.	Third- and fourth-highest-order subdivisions.		Motives representing the different subfamilies were perceived equally.

A detailed description of the contents of the table should clarify its analytical aims.

The *motivic families* from *Anthèmes* identified in Chapter 2 are shown in *column 1*. *Intrinsic musical features defining subfamilies* for the Long Tone, Melodic, Scale, and Trill groups are listed in *column 2*.The Pizzicato group is excluded from the table because it cannot be subdivided into clear subfamilies on the basis of specific musical features.[2] Note that each musical feature defines two subfamilies. For example, the feature presence/absence of glissando defines the subfamilies of the Long Tone motives with and without glissando. The *selection of intrinsic musical features* that define the subfamilies was based on the analyses and experimental results reported in Chapter 2. Accordingly, most of these features define the subfamilies suggested by the clustering analysis obtained from the categorization data of Experiment 1 (Figure 2.11, p. 38) along with its interpretation in light of the theoretical analysis presented in Table 2.3 (p. 42). The remaining features correspond to lower-level subdivisions of the hierarchical tree obtained from Experiment 1 that involve a relatively large proportion of motives from the same family. With the purpose of making more plausible observations, subfamilies were built to contain a relatively large proportion of motivic variations (from all variations appearing in the piece according to the theoretical analysis). It is important to highlight that the subfamilies listed account for all the motives within each family.

Whereas columns 1 and 2 refer to intrinsic aspects of the motives, columns 3 to 6 are concerned with the effects of context on those intrinsic characteristics. Columns 3 and 4 describe aspects of motivic similarity perception out of the musical context of *Anthèmes*. Columns 5 and 6 analyze aspects of motivic similarity perception in the context of the two versions of the composition. Specifically, columns 3, 4, 5, and 6 correspond to results from Experiments 2, 1, 4 and 5, respectively. Following this, the table sorts the experiments from *narrowest to broadest context*. *Column 3* contains descriptive observations concerning the dissimilarity means of the motives of each subfamily in the within-family context of Experiment 2. The perceived dissimilarity between the two subfamilies defined by an intrinsic feature is interpreted on the basis

[2] The most important (internal) difference among the Pizzicato motives is whether they are presented immediately after another motive from the same group or after contrasting motivic material. Because the within-family consecutiveness or lack thereof is an aspect exclusively related to the contextual effects studied in Experiment 4, those differences (which correspond to the data analysis 4 associated with the Pizzicato group) are discussed in Chapter 3.

of the dissimilarity means among the motives of each subfamily with respect to all motives in the group (see Figure 2.19, p. 62). This interpretation is based on the idea that motives with different degrees of overall resemblance to their family as a whole are likely to mark relatively strong perceptual subdivisions within that family. Conversely, two motives that are very similar to each other should have relatively equal similarity relationships with respect to all the other motives in the group. Due to the small number of stimuli used in Experiment 2, it is often the case that a single motive is the only representative of subfamilies defined by different intrinsic features (across rows in the table). Consequently, the observations indicated in column 2 often refer to more than one intrinsic feature. For this reason, a number of within-family rows are merged in column 3. For example, Long Tone motive L7 is the motive with the highest dissimilarity mean in Experiment 2. Because L7 was the only Long Tone motive representing the single-note and without-glissando subfamilies of the Long Tone family in Experiment 2 and also the motive with distinctively highest dissimilarity mean for its group, column 3 indicates that both the presence/absence of a glissando and the number of notes were important features for similarity ratings of pairs of motives from the Long Tone family. *Column 4* refers to the perceptual divisibility of the families—separability or independence of the subfamilies from one another—in terms of the clustering analysis associated with the across-family atemporal[3] context of Experiment 1. Explicitly, the annotations in the table indicate the hierarchical level at which the subdivision of a family occurs in the clustering analysis of Figure 2.11 (p. 38). These annotations assume that the participants' categorization of the motives reflects their perception of similarity relationships among the motives. Motives that were grouped together by a relatively large proportion of participants in Experiment 1 should form a subfamily whose members were perceived as similar to each other. Therefore, subfamilies represented at relatively higher-order distinct subdivisions in the clustering analysis should be perceptually different from one another. No statistical analyses of motivic subfamilies were conducted with respect to Experiments 1 and 2, due to the extremely limited number of motivic variations representing each subfamily. Given the small number of data points available, descriptive observations seemed more cogent than inferential statistics. Furthermore, in Experiment 2, the subfamilies listed in Table 4.1 were often represented by one motive only.

[3] The temporal order in which the motives are heard in Experiment 1 is chosen by the participants.

Columns 5 and *6* indicate whether the musical features defining the various subfamilies were equally relevant for the listeners' identification of the variations of the motivic model while listening to *Anthèmes 1* and *Anthèmes 2*, respectively. Assuming that the identification of motivic variations involves the perceptual comparison of intrinsic features from those variations, columns 5 and 6 refer to the perceived similarity of the intrinsic features of the motives in piece-specific musical contexts. The *shading* in these two columns illustrates the results from statistical analyses testing for differences in motivic recognition between any two subfamilies associated with an intrinsic motivic feature, while listening to *Anthèmes 1* and *Anthèmes 2*. These differences were tested using pairwise contrast tests and controlling for multiple comparisons (see data analysis 4—subfamilies—in Chapter 3). The statistical significance of the differences between the recognition of paired subfamilies associated with an intrinsic motivic feature is shown with the shading: white indicates a significant difference and grey a non-significant difference. Statistics for subfamilies of motives that were recognized in significantly different proportions are reported in parentheses.[4] .White cells indicate that the participants related the motivic members of one subfamily to the parent family in general and to the motivic model in particular more than the members of the paired subfamily. In other words, motivic recognition was different for the two subfamilies representing an intrinsic motivic feature. Conversely, grey cells signify that listeners recognized the members of a subfamily in equal proportions as the members of the paired subfamily. In other words, motivic recognition was the same for the two subfamilies representing an intrinsic motivic feature. In this sense, grey cells refer to intrinsic motivic features that do not interfere with the identification of motivic variations while listening to the musical composition, whereas white cells illustrate intrinsic motivic features that are perceptually crucial for performing the same task.

Three main observations can be drawn from the analysis presented in Table 4.1: (1) the results of Experiments 1 and 2— columns 4 and 3—are quite similar to each other and can thus be interpreted holistically; (2) the perception of intrinsic motivic features is affected by the addition of a musical context provided by the composition with respect to out-of-musical-context situations—columns 5 and 6 vs. columns 3 and 4; and (3) the perception of intrinsic motivic

[4] All the p-values reported throughout this chapter are corrected for multiple comparisons.

features is affected by the specific characteristics of the added musical context—column 5 vs. column 6. These three observations are discussed under three separate headings below.

OUT-OF-MUSICAL-CONTEXT SITUATIONS (JUSTIFICATION FOR HOLISTIC INTERPRETATION OF EXPERIMENTS 1 AND 2)

The internal subdivisions of the motivic families listed (subfamilies associated with the intrinsic motivic features) are evidently supported by the clustering data analysis corresponding to Experiment 1, because the subfamilies were defined on the basis of such analysis. Note, however, that column 4 (description of results of Experiment 1) provides more specific information in this respect, because it indicates the level of the clustering analysis at which the subdivisions occur. The descriptions in column 3 suggest that these subdivisions are manifested to a certain extent in Experiment 2 as well. Subfamilies defined at lower levels of the clustering analysis of Experiment 1 also appear to be less clearly defined in terms of the dissimilarity ratings obtained in Experiment 2. For instance, both the description of the dissimilarity ratings obtained in Experiment 2 and that of the clustering analysis obtained in Experiment 1 concerning one textural feature of the Trill motives (whether the texture of the motives consists of two-part counterpoint or multiple-stops) refer to weak subdivisions. This is shown in Table 4.2, which reproduces columns 1 to 4 of the last row of Table 4.1. Similarly, subfamilies defined at higher levels of the clustering analysis of Experiment 1 also appear to be clearly defined in terms of the dissimilarity ratings obtained in Experiment 2.

Table 4.2: Example of subfamilies defined similarly according to the results of Experiments 1 and 2.

Family	Intrinsic motivic features defining subfamilies	Most restricted within-family context (Exp. 2)	Broader across-family, atemporal context (Exp. 1)
Trill	**Polyphonic subtype (two-part counterpoint vs. attacks in multiple-stops)**	Possible subdivisions, but not clear. The motives in these subgroups have relatively high dissimilarity means, but there is no pattern concerning multiple-stops vs. two-voice counterpoint.	Third- and fourth-highest-order subdivisions.

The number of notes in the Long Tone motives is a clear example of an intrinsic feature associated with perceptually distinct subfamilies according to the results of Experiments 1 and 2. Finally, according to Table 4.1, in Experiments 1 and 2 all the motivic subfamilies appear to be justified in similar degrees. Consequently, the discussion below considers the results of Experiments 1 and 2 (columns 4 and 3) together, comparing them to those of Experiment 4 (column 5) and Experiment 5 (column 6).

This section has suggested that the results of Experiments 1 and 2 are similar enough to be considered together. In addition, the two experiments represent musically non-contextual situations in the sense that the participants heard the motivic materials out of the context of *Anthèmes*. The section below compares the musically non-contextual situation of Experiments 1 and 2 with the musically contextual situation of Experiments 4 and 5, aiming to elucidate the effects of musical (piece-specific) context on the listeners' perception of the similarity of intrinsic motivic features.

EFFECTS OF ADDING A MUSICAL CONTEXT (EXPERIMENTS 1 AND 2 VS. EXPERIMENTS 4 AND 5)

A comparison of columns 4 and 3 as a whole (or more simply, column 3) with columns 5 and 6 suggests that the presence of a musical context affects the perception of motivic similarity. Some motivic subfamilies corresponding to highest-order subdivisions in Experiment 1 were not perceived as clearly distinct from each other when heard in the musical contexts provided by the compositions. In effect, the Long Tone subfamilies associated with number of component notes as well as the Melodic subfamilies defined by differences in character and texture are indicated as highest-order subdivisions in column 4 (meaning that the subfamilies were perceptually distinct during the categorization task of Experiment 1), but are shaded in columns 5 and 6 (meaning that the subfamilies were not perceptually distinct while listening to *Anthèmes*). This is illustrated in Table 4.3, which reproduces rows 3 to 5 of Table 4.1.

Conversely, some motivic subfamilies corresponding to relatively lower-order subdivisions in Experiment 1 were heard as very different from each other in the context of the pieces. This was the case for the presence/absence of the glissando in the Long Tone motives. This feature was certainly not the most relevant (highest-order subdivision) feature considered by the

listeners when forming groups of motives out of the musical context of the composition (indeed, the most relevant feature in that situation was the number of component notes).

Table 4.3: Examples of intrinsic motivic features that lead to differentiation among motivic subtypes (family subdivisions) out of the context of the piece only

Family	**Intrinsic motivic features defining subfamilies**	**Most restricted within-family context (Exp. 2)**	**Broader across-family, atemporal context (Exp. 1)**	**Full within-piece context provided by *Anthèmes I* (Exp. 4)**	**Electronically modified and enlarged context provided by *Anthèmes 2* (Exp. 5)**
Long Tone	**Number of notes (1 vs. more than 1)**		Highest-order subdivision	Motives representing the two different subfamilies were perceived equally: recognition is statistically equivalent.	Motives representing the two different subfamilies were perceived equally: recognition is statistically equivalent.
Melodic	**Character (*brusque* vs. non-*brusque*)** **Texture (clearly compound vs. non-compound)**	Subdivision possibly supported. All motives are quite dissimilar to each other. Two motives that are opposite in terms of these three characteristics (M11 and M14) have two of the highest dissimilarity means in the family.	Highest-order subdivision	Motives representing the different subfamilies were perceived equally.	Motives representing the different subfamilies were perceived equally.

As shown in column 3 of Table 4.4 (which reproduces the second row of Table 4.1), the presence or absence of the glissando is represented at multiple levels of the hierarchical analysis obtained in Experiment 1. Nevertheless, Long Tone motives with glissando were perceived differently from Long Tone motives without glissando while listening to *Anthèmes 1* and *Anthèmes 2* (columns 5 and 6 are white).

Table 4.4: Example of intrinsic motivic feature that lead to clear differentiation among motivic subtypes (family subdivisions) within the context of the piece only

Family	**Intrinsic motivic features defining subfamilies**	**Most restricted within-family context (Exp. 2)**	**Broader across-family, atemporal context (Exp. 1)**	**Full within-piece context provided by *Anthèmes I* (Exp. 4)**	**Electronically modified and enlarged context provided by *Anthèmes 2* (Exp. 5)**
Long Tone	**Glissando (with vs. without)**	Internal subdivisions likely supported: the only motive featuring a single note and no gliss. (L7) was the most dissimilar in the entire Long Tone family.	Internal subdivisions at different levels, including highest-order level.	Motives representing the two different subfamilies were perceived differently: recognition is significantly different statistically $z=2.46$, $p= .028$	Motives representing the two different subfamilies were perceived differently: recognition is significantly different statistically $z=3.52$, $p= .0008$

The discussion above considered the differences with regard to similarity perception between musically contextual and non-contextual listening situations. The effects of the specific musical contexts associated with each version of *Anthèmes* on the perception of similarity of intrinsic motivic features are discussed below.

EFFECTS OF PIECE-SPECIFIC MUSICAL CONTEXT (EXPERIMENT 4 VS. EXPERIMENT 5)

Certain musical features seem to be perceptually more robust to (less affected by) a particular context than to other contexts. This is reflected in the differences in the participants' recognition of variations representing the (preselected) motivic subfamilies across the contexts provided by the two versions of the composition. A detailed study of the differences between the results of Experiments 4 and 5 provides specific information about the robustness of certain musical features to different contextual factors. Based on Table 4.1, the subfamily-defining features studied here can be classified into two groups according to their relative degrees of robustness to the different contexts provided by the two versions of *Anthèmes*: (1) more robust to the electronically enhanced and/or formally expanded context provided by *Anthèmes 2* than to the musical context of *Anthèmes I*, and (2) equally robust—or non-robust—to the musical context of *Anthèmes 1* and *Anthèmes 2.* In Table 4.1, the first group is represented by white cells in column 6 that are shaded in column 5, whereas the second group is represented by equal shading (white = robust, and grey = non-robust) in columns 5 and 6. These two groups along with the fact that there were no differences in recognition of subfamilies exclusively associated with *Anthèmes 1* imply that the perception of the similarity of musical motives depends on specific characteristics of the context in which those motives are stated. In simpler terms, the listeners' perception of the internal structure of the motivic families (specifically, their perceptual association of the subfamilies to the parent family) appears to be different when listening to the original composition compared to the electronic version.

Intrinsic motivic features more robust to the context of Anthèmes 2 than to context of Anthèmes I

With respect to the first group of features that define subfamilies, speed for the motives of the Melodic group, specific combinations of direction and texture (monodic with downward direction vs. double-stops in both directions) for the motives of the Scale group, and texture

(polyphonic vs. monodic) for the motives of the Trill group, appear to be heard as clearly distinctive features only in the context of *Anthèmes 2*. Specifically, musicians identified a larger proportion of faster than of slower Melodic motives, of monodic descending Scale motives in *jeté* than of double-stop Scale motives (in any direction) in *jeté*, and of monodic than of polyphonic Trill motives in *Anthèmes 2* than in *Anthèmes I*. By doing this, listeners favored motives with characteristics that were clearly present in the model heard at the beginning of each experimental trial. Indeed, the Melodic, Scale, and Trill models consisted of a relatively fast short melody, a monodic scale, and a monodic (regular) trill, respectively.

None of these differences in the participants' relationships of the subfamilies to their perception of the parent family for one version of the piece with respect to the other can be directly associated with different electronic effects applied to the diverse subfamilies. Most obviously, as shown in the analysis of the electronic effects in Table 3.5 (p. 134), all Scale motives in *jeté* (single- or double-stops) are associated with the same electronic effect throughout the entire composition, and yet participants heard the monodic descending Scale motives differently from the Scale motives in double-stops. This suggests that it is not the electronic effects themselves, but rather their influence on the perception or performance (and then perception) of certain musical features from the motives that plays an important role in the listeners' formation of motivic relationships. In line with this reasoning, the differences in the results of recognition of the subfamilies in the two versions of the composition can be interpreted as consequences of two factors indirectly related to the effect of the electronics on (*electronic-effects indirect factors*): (1) the perception of specific musical features, and (2) temporal aspects of the performance, which in turn affect the temporal structure of the composition. Factor 1 appears to be at least partly responsible for the difference observed in the perception of the Trill and Scale subgroups. Factor 2 can explain the differences in perception related to the Melodic subgroups.

The participants' difference in the perception (in *Anthèmes 2* but not in *Anthèmes I*) of monodic descending Scale motives compared to Scale motives in double-stops with one voice consisting of a repeated note and the remaining voice of a scale in any direction can be justified by the electronic transformation of the motives played in double-stops (electronic-effects indirect factor 1: perception of specific features). Specifically, it is likely that the frequency shifting perceptually emphasized the two-voice texture in the double-stop motives of *Anthèmes 2*, making

it more salient compared to that of *Anthèmes* I. In the original composition, the repeated-note line is very difficult to segregate and the moving line is perceptually much more salient. As a result, the difference between monodic and two-voice scalar patterns might not be obvious. In the electronic piece, the addition of frequency shifting is likely to facilitate the segregation of the repeated-note line, leading to a perceptually more evident two-voice texture.

The participants' more evident difference in recognition of polyphonic vs. monodic Trill motives in *Anthèmes 2* than in *Anthèmes I*, in spite of the similar (and multiple) electronic effects applied to each subfamily, further supports the idea that the electronic effects by themselves are not crucial to the participants' motivic associations. As illustrated in Table 3.5 (p. 134), some single trills are associated with a scalar pattern produced by the sampler whereas others are associated with sampler plucked chords modified with the harmonizer. Furthermore, these plucked chords are also associated with two-voice Trill motives, whereas Trill motives in multiple stops are played with added reverberation in the sampler and often modified through a pitch-randomization process. As a result, some of the monodic and polyphonic Trill motives share certain electronic effects, whereas other motives share other electronic effects. In this sense, the textural aspect of the Trill motives is remarkably robust to (multiple) electronic modifications. The better recognition of monodic with respect to polyphonic Trill motives in *Anthèmes 2* than *Anthèmes 1* can be explained by a perceptual interference resulting from the extra layer of textural complexity added by the electronic effects (electronic-effects indirect factor 1: perception of specific features). In all cases, the electronic versions of the Trill motives are polyphonically very intricate. Naturally, the level of added complexity increases as the texture of the acoustic (original) motives (input passed through the electronics) involves more simultaneous layers. In line with this, electronically enhanced trills might be easier to instantly recognized when they are input as monodic material. In other words, the electronic effects applied to the Trill motives are more likely to disturb the perception of the most important feature of those motives when the original motives are polyphonic than when they are monodic.

Finally, with respect to the subdivision of the Melodic group based on speed, the slower Melodic motives (recognized less often than the faster ones as variations of the Melodic model) appear in the final section (VIc). In this section, the added electronics (sampler, reverberation, and randomization of pitches as reported in Table 3.5, p. 134), and in particular the reverberation

combined with a continuous (and originally relatively fast) rhythmic pattern, demand a slower performance tempo than all other sections (electronic-effects indirect factor 2: temporal aspects of performance). Note that in section IV, where the electronic effects are the same as those applied to section VIc, the rhythmic diversity and complexity of the Melodic motives allows for a faster tempo. (In effect, the Melodic motives from section IV are included in the faster subfamily for the analysis discussed here.) This result suggests that it is not the added reverberation but its combination with the regular rhythmic pattern of the motives in section VIc that leads to the slower tempo in this final section (and in turn to the lower identification of the motives as variations of the model, which is played at a faster speed). In addition, as mentioned in the Formal Blend section, the high degree of formal blend that characterizes section VIc is likely to be an important factor for the lower association of the slower motives with the Melodic group. Indeed, given the characteristics of the contexts in which the faster and slower Melodic motives appear, it is impossible to tease apart the effect of speed from that of formal blend. In other words, it is uncertain whether the participants' relatively low tendency to associate the slower motives with the Melodic group is due to the speed of the motives or to the characteristics of the section in which they appear, because all the slower motives and none of the faster motives appear in the section featuring the highest degree of formal blend.

Intrinsic motivic features equally robust (or non-robust) to the contexts of Anthèmes 1 and Anthèmes 2

The group of subfamily features that are equally robust (or non-robust) to the musical contexts of both *Anthèmes 1* and *Anthèmes 2* (group 2 above) can be subdivided into two subgroups (*equal-robustness subgroups*): (1) features that are equally robust in both compositions—features that lead to a large difference in recognition between subfamilies, and (2) features that are not robust in both compositions—features that do not lead to a difference in motivic recognition between subfamilies. With respect to the first subgroup, presence/absence of the glissando for the motives of the Long Tone group, and articulation and a specific combination of texture and direction for the Scale family play an important role. Not surprisingly, once again a distinctive characteristic of the motivic models seemed to affect musicians' ongoing formation of motivic relationships with respect to that model. Specifically, participants related a larger proportion of Long Tone motives with glissando than without glissando to the Long Tone family. It is likely that the great contrasting (thus easy-to-perceive in all contexts) nature of the very few features that

define the Long Tone motives (and in particular the model) led participants to naturally perceive the variations of the motives that did not include all the characteristics of the model as members of clearly distinct sets. These findings suggest that the very slow sustained tones and the glissando that characterized most of the Long Tone motives are extremely robust to different musical contexts. This result is compatible with Boulez's intention to use the Long Tone motives as formal markers.

With respect to the Scale motives associated with equal-robustness subgroup 1 (features equally robust in both compositions), listeners recognized *jeté* or *ricochet* Scale motives (in any direction and texture) and ascending monodic Scale motives in *jeté* as variations of the Scale model more often than slurred Scale motives and double-stopped Scale motives (also *jeté*) moving in both directions, respectively. These findings imply that *jeté* articulation was a relevant defining feature for the Scale group. Nevertheless, they do not provide clear information concerning the importance of pitch direction and texture for the identification of variations from the Scale group. It is only when analyzing the results of the second equal-robustness subgroup of intrinsic motivic features non-robust to the contexts of *Anthèmes 1* and *Anthèmes 2* that conclusions can be drawn in this respect.

Moving on to this second subgroup (features not robust in both compositions), differences in terms of direction for the Scale group, number of notes for the Long Tone group, character for the Melodic group, and at least one textural feature for all four groups did not lead to differences in recognition while listening to either version of *Anthèmes*. These results indicate that differences in texture do not affect motivic recognition in general.

Interaction between intrinsic motivic features and contextual factors within the proposed model of form perception

The differences in recognition of the motives belonging to the diverse subfamilies discussed above suggest that the perception of some specific features from certain musical motives is affected by characteristics of the musical context or lack thereof. This implies that the effects of (musical or non-musical) context on the perceptual associations among musical materials result at least partly from the interaction of two factors (*context-features interaction factors*): (1) the characteristics of the context and (2) the intrinsic, non-contextual musical features of those musical

materials. With respect to the first factor, the results reported above demonstrate that the same musical feature (of a given motivic type) can be perceived differently in a variety of musical settings. For instance, the difference in recognition of Trill motives based on texture between *Anthèmes 1* and *Anthèmes 2* suggests that diverse musical contexts alter the perception of textural aspects of the Trill motives in different ways. Trill motives with different textural properties were perceived as different from one another when they were heard in the context provided by *Anthèmes 2*, but not while listening to *Anthèmes 1* (as already mentioned in connection with the first group of intrinsic motivic features). This is shown in Table 4.5, which reproduces columns 1, 2, 5 and 6 of the twelfth row of Table 4.1. The characteristics of the different contexts (in this case, the characteristics defining the acoustic and electronically enhanced contexts) are thus partly responsible for the perceptual differences regarding the texture feature of the Trill motives.

Table 4.5: Example of the effects of the characteristics of the context on the perception of intrinsic motivic features

Family	**Intrinsic motivic features defining subfamilies**	**Full within-piece context provided by *Anthèmes I* (Exp. 4)**	**Electronically modified and enlarged context provided by *Anthèmes 2* (Exp. 5)**
Trill	**General texture (polyphonic vs. monodic)**	Motives representing the different subfamilies were perceived equally.	Motives representing the different subfamilies were perceived differently (t=3.3, *p*= .008)

With respect to the second context-features interaction factor (intrinsic features of the musical materials), some intrinsic features of the motivic materials are perceptually less affected by music contextualization than other features. This is to say that a musical context can alter the perceived similarity of certain features (and in turn of musical materials) while leaving that of other features intact. For instance, the *jeté/ricochet* articulation profile of Scale motives was perceptually highly robust to musical contextualization. In effect, the motives with *jeté/ricochet* articulation were more naturally perceived as variations of the Scale family than were the slurred Scale motives, both out of the context of the compositions and in the many musical settings provided by them. This is reflected in the higher-order subdivision between slurred and *jeté/ricochet* Scale motives obtained in Experiment 1, and in the statistically significant higher

proportion of recognition of *jeté/ricochet* Scale motives in Experiments 4 and 5. This is shown in Table 4.6, which reproduces the seventh row of Table 4.1.

Table 4.6: Example of feature that is perceptually robust to a wide range of contextual situations

Family	**Intrinsic motivic features defining subfamilies**	**Most restricted within-family context (Exp. 2)**	**Broader across-family, atemporal context (Exp. 1)**	**Full within-piece context provided by *Anthèmes I* (Exp. 4)**	**Electronically modified and enlarged context provided by *Anthèmes 2* (Exp. 5)**
Scale	**Articulation (slurred vs. *jeté/ricochet*)**	Likely subdivisions: the only two motives that are slurred (S8 and S11) showed the highest dissimilarity means in the group.	Highest-order subdivision	Motives representing the different subfamilies were perceived differently (z=3.57, p= .001)	Motives representing the different subfamilies were perceived differently (t=7.32, p= .00001)

Conversely, the feature referring to the number of notes constituting the Long Tone motives was perceptually affected by (lowly robust to) musical contextualization, inasmuch as differences in the number of notes constituting the motives led to apparently strong perceptual motivic disassociations in out-of-musical-context situations that faded away in the contexts provided by the two versions of *Anthèmes*. This can be seen in the highest-order subdivision of the Long Tone motives obtained in Experiment 1 with respect to the statistically equivalent recognition of Long Tone motives of single and multiple component notes during listening of either version of the composition in Experiments 4 and 5 (Table 4.7, which reproduces the third row of Table 4.1).

Table 4.7: Example of feature that is affected by the addition of a musical context

Family	**Intrinsic motivic features defining subfamilies**	**Most restricted within-family context (Exp. 2)**	**Broader across-family, atemporal context (Exp. 1)**	**Full within-piece context provided by *Anthèmes I* (Exp. 4)**	**Electronically modified and enlarged context provided by *Anthèmes 2* (Exp. 5)**
Long Tone	**Number of notes (1 vs. more than 1)**	Internal subdivisions likely supported: the only motive featuring a single note and no gliss. (L7) was the most dissimilar in the entire Long Tone family.	Highest-order subdivision	Motives representing the two different subfamilies were perceived equally: recognition is statistically equivalent.	Motives representing the two different subfamilies were perceived equally: recognition is statistically equivalent.

The first context-features interaction factor (characteristics of the context) is defined in terms of different contextual settings. The factor is best exemplified by the first group of subfamily-defining features described in the previous section under the first subheading (features

that are perceptually more robust to the context of *Anthèmes 2* than that of *Anthèmes I*), since that group refers to perceptual changes of invariable motivic features caused by the modification of the musical contextualization of those features. The second factor (intrinsic features of the musical materials) is defined in terms of intrinsic motivic features, and, consequently, it is less directly related to one of the groups of subfamily-defining features presented above. In effect, the second factor equally includes both groups of subfamily-defining features in their entirety (features that are perceptually more robust to the context of *Anthèmes 2* than that of *Anthèmes I*, and features that are equally robust or non-robust to the context of both versions of *Anthèmes*), inasmuch as it refers to the perceptual robustness of features to musical contextualization overall. Indeed, this perceptual robustness should be an aspect common to all features to some degree and in differing amounts.

Whereas the two groups of subfamily-defining features presented in the previous section (under separate subheadings) refer exclusively to the perceptual robustness of a predetermined set of features to the effects of context associated with *Anthèmes 1* and *Anthèmes 2*, the two context-features interaction factors presented in this section attempt to more broadly and theoretically account for the reciprocal influence between a (given) musical context and the intrinsic features of a musical material set in that context. Finally, a study of the effects of context on the perception of any musical feature is at the very least controversial, even if the context is clearly predefined. Instead, an examination of the effects of a given context on the perception of a specific musical feature seems more plausible. This is to say that a controlled empirical investigation of contextual musical effects would need to control for both the characteristics of the context and the intrinsic (fixed) features of the materials that are being set in that context, since the effects of the same context on the perception of an intrinsic feature could vary depending on the feature. In sum, the very complex ways in which a musical context interacts with the perception of musical materials can only be understood in light of the intrinsic features defining those materials.

This interaction between the characteristics of the context and the intrinsic features of the motivic materials contributes to a better understanding of the model of aspects of form perception proposed in Chapter 3. The model linked high and low motivic recognition with the listeners' attention to local and larger levels of the structure, respectively. In light of this and based on the differences in motivic identification among subfamilies reported in the present chapter, diverse

intrinsic motivic features would have different effects on the listeners' attention to the levels of the formal hierarchy. Furthermore, the hypothesis proposed in this chapter suggests that at least the magnitude of that effect is determined by both the characteristics of the context and the intrinsic motivic features. As justified in the paragraphs below, the three factors of the model proposed in Chapter 3, i.e., predictability, formal-unit blend and elapsed musical time, encompass in their very definition aspects associated with the intrinsic features of the motives and their musical surroundings. Accordingly, the perceptual robustness of intrinsic motivic features to contextualization should mediate (to a greater or lesser extent) the effects of all these factors on the listeners' attention to the formal hierarchy.

With respect to predictability, in Chapter 3, consistent musical features and repeated motivic successions were proposed as predictability factors affecting the perception of the different hierarchical levels of the formal structure. According to the findings reported in that chapter, musical features that remain constant throughout the many instantiations of a motivic model facilitate the listeners' connections between those instantiations and the model, presumably leading their attention to the motivic, indivisible level of the formal hierarchy. Similarly, repeating successions of motives provide a predictable musical context for listeners, leading their attention to the indivisible level of the form. The analysis along with the rationale proposed in the present chapter further suggests that certain musical features facilitate the perception of motivic connections better than others (context-features interaction factor 2: intrinsic features of the musical materials), and that the ability of a motivically intrinsic and relatively fixed musical feature to facilitate those connections is itself affected by the characteristics of the context, which in terms of the predictability factor consists of the specific succession of motives (context-features interaction factor 1: characteristics of the context). In accordance with the model presented in Chapter 3, consistent features that are perceptually more robust to musical contexts and/or highly predictable motivic successions that do not considerably interfere with the perception of the intrinsic motivic features would lead listeners to more naturally attend to the motivic, indivisible level of the formal hierarchy.

With regard to formal-unit blend, the model of aspects of form perception proposed in Chapter 3 referred to formal-unit blend as the transition between successive musical units. More specifically, formal-unit blend was directly associated with the way in which the musical features

of one unit (e.g., motive or section) were changed (more or less abruptly) into those of the immediately following unit. Consequently, the degree of formal blend between two units is dependent on the perceived similarity between the features defining those units and the rate at which the features of the first unit change into those of the second unit. The contrast in surface features that implies formal segmentation (and thus grouping) results from a sudden and relatively radical change of musical features. In line with the findings discussed in the previous chapter, the higher the degree of formal-unit blend, the less naturally the listeners focus on the motivic, indivisible level of the form, and presumably, the more naturally they focus on the large, divisible level of the form. In light of the context-features interaction hypothesis proposed in this chapter, this effect of formal-unit blend on the perception of the formal hierarchy (or at least the magnitude of this effect) would be regulated by the in-context perceptual similarity between the features of the formal units delineating the formal transition (context-features interaction factor 2: intrinsic features of the musical materials), and the rate at which those features are transformed (context-features interaction factor 1: characteristics of the context). More precisely, the more similar the features of the first unit are to those of the second unit and the more gradual the rate at which the former are changed into the latter, the higher the formal-unit blend between the units, and, thus, the more naturally the listeners will attend to large-scale formal processes (the less naturally they will segment the music in local-scale units).

Lastly, elapsed musical time was defined in Chapter 3 as the development of the musical materials over time. Intrinsic motivic features play a central role in the theoretical and perceptual definition of musical materials (motives, in this case) and, in that sense, they are an aspect of elapsed musical time. Chapter 3 proposed that the development of the musical materials over time leads listeners to naturally attend to the large-scale levels of the form. In light of the findings presented in the present chapter, this effect of elapsed musical time on the listeners' perception of the hierarchical structure would be mediated by the tendency of the intrinsic features of the musical materials to be more or less affected by the precise ways in which the music develops over time. Specifically, features that are perceptually robust (context-features interaction factor 2: intrinsic features of the musical materials) to the temporal developments of a musical form (context-features interaction factor 1: characteristics of the context) would shift the listeners attention from local to global levels of the formal hierarchy much more gradually than musical features whose perceptual similarity (context-features interaction factor 2: intrinsic features of the musical materials) is

greatly affected by the ongoing musical processes (context-features interaction factor 1: characteristics of the context).

To conclude, the influence of predictability, formal-unit blend and elapsed musical time on the listeners' perception of the formal hierarchy appears to be mediated by the perceptual robustness of intrinsic motivic features to the context and by the specific characteristics of that context. The degree of perceptual robustness of intrinsic motivic features and the characteristics of the context contribute to the very definition of the three factors of the model. In effect, the factors of the model are themselves determined by both the relatively invariable features of the motivic materials and the characteristics of the musical context. The listeners' most immediate attention to different hierarchical levels of the musical form, their tendency to focus on the details or to integrate musical information within large-scale musical processes results from very complex interactions between the intrinsic features of the musical materials and their contextual development.

Relevance, limitations, and future directions

Particularly relevant for the fields of music perception and cognition as well as music theory and analysis, this dissertation proposes a model of form perception for post-tonal music based on previous literature in cognition and theory as well as an interpretation of the results of five experiments in light of theoretical analyses. Empirical research has demonstrated that form perception is shaped by the interaction of different hierarchical levels and the temporal evolution of musical features. Similarly, music theory commonly distinguishes between two types of formal models: static or hierarchical and dynamic or processual. Both the perceptual and theoretical literature highlight the importance of formal hierarchy. Nevertheless, perceptual research has shown that listeners are sensitive to many hierarchical levels of post-tonal forms and that surface features are essential to form perception, whereas post-tonal theories have tended to disregard large-scale hierarchical levels and emphasize local-level abstract structures (e.g., pitch-class sets) instead of surface events. This marks an important disconnect between perceptual and theoretical research agendas. Through the interdisciplinary character of their very genesis, the principles regulating the theoretical model of form perception proposed in this dissertation can serve as basis for the development of post-tonal formal theories that are both perceptually valid and theoretically

applicable. More specifically, this dissertation has shown that theoretical analyses of a musical composition in terms of motivic sequences (predictability), consistency of musical features (predictability), formal segmentation (formal-unit blend), and formal development (elapsed musical time) can provide information concerning the way listeners attend to the formal hierarchical levels of that composition. In this sense, the model of form perception proposed in this dissertation is a theoretical predictor of the listeners' attention to formal hierarchy, beginning to concretely fill the gap that separates perception and theory in the scholarship of post-tonal music. Furthermore, the model links formal hierarchy with divided attention and, in turn, with musical recognizability. Formal hierarchy is a concept that originated and developed within the field of Music Theory and for which attempts to validate it by empirical research have been insufficient. Divided attention and musical recognizability are concepts that have belonged almost exclusively to the field of Music Perception. Accordingly, the model is theoretically and perceptually founded. Given that hierarchy is often at the core of music theories and analyses and that recognizability is perhaps one of the most essential aspects of music perception, a further understanding of the relationships between these two concepts could perhaps serve as a way of integrating research in both Music Theory and Analysis, on the one hand, and Music Perception and Cognition, on the other, to the advantage of a more comprehensive and deeper understanding of music as a structured art to be heard.

The experiments and theoretical analyses focus on the two versions of a composition by Pierre Boulez: *Anthèmes 1* for solo violin (1992) and *Anthèmes 2* for violin and electronics (1997). Three aspects make this musical work ideal for a study of motivic similarity and form that aims to bring closer together the fields of theory and cognition: (1) Boulez's explicit intent to reconcile composition and perception, (2) his view of the form of *Anthèmes* in terms of constantly changing yet clearly recognizable, local-scale musical motives and surface features acting as large-scale perceptual cues, and (3) the use of a common set of motivic families in the two timbrally and formally differentiated musical contexts given by the two versions of the composition. This study has musicological value and validity, in the sense that it explores relationships between empirical and theoretical-analytical findings and Boulez's conception of music, form, and perception. It illuminates the correspondence between the composer's compositional practice, his theoretical thinking, and the audience reception of his work. Furthermore, given the consistency of the empirical results with Boulez's ideas, some of the findings reported in this dissertation could

potentially become useful compositional tools. For instance, a composer could use certain musical features to either attract the listeners' attention or intentionally release it. More specifically, if the model of form perception proposed here is valid, composers should presumably be able to relatively consciously and systematically consider aspects of structural repetition, segmentability, and formal development to manipulate, to a certain extent, the way listeners would most naturally perceive the hierarchical structure of their musical works.

In addition to bringing closer together different fields of music research, this study is relevant in terms of the experimental methods on which it is based. The empirical results along with their interpretation contribute to the unexplored area of the listeners' perception of aspects of post-tonal musical forms while listening to pieces from the repertoire from beginning to end (in relatively normal listening conditions). Much of the previous general perceptual literature is built on atypical music listening situations and the perceptual research dealing with post-tonal music is clearly underrepresented.

Following all of the above, the two greatest values of this dissertation can perhaps be summarized as (1) its attempt—achieved to a certain extent—to bring together perceptual and theoretical/analytical approaches of post-tonal music while incorporating the composer's very own ideas about music, and (2) its use of complete post-tonal pieces of music taken from the repertoire as the basis for the investigation of perceptual processes. However, the kind of systematization that makes studies in music perception scientifically valid is in many ways incompatible with the principles underlying the aesthetical value and perceptual reality of most musical works. Modern compositional techniques are indeed often systematic. To provide an extreme example, serial techniques are commonly regarded as strictly controlled compositional systems. Nevertheless, controlled compositional techniques tend to be systematic in ways that are not necessarily obvious from a perceptual perspective in the final product (the specific aspects of the systematization of the musical parameters are most commonly not obvious to the listener). More importantly, those techniques do not aim for controlled musical situations in the same manner as empirical research does. Empirical studies seek control in terms of absolute balance. For example, in relationship with this study, an investigation of the effects of motivic-sequence repetitiveness (predictability) on motivic recognition would require musical stimuli that state exactly the same motivic material in multiple, yet carefully counterbalanced, contextual situations. This would imply setting the same

musical motive to a clearly predetermined set of contexts differing from each other in quantifiable, methodical, and proportional ways (e.g., changing only one pre-determined aspect of one parameter of the context at a time, keeping the remaining contextual features constant). These situations are certainly not common among musical repertoires (including post-tonal music). Musical works that are based on controlled compositional techniques do not aim for perfectly balanced musical situations. Furthermore, composers most often control compositional techniques in ways that avoid obvious balance in the musical product. Due to this natural yet essential difference between the kinds of systematization associated with empirical stimuli and musical compositions, the strengths of this study are its very own limitations.

First, the experiments discussed in this dissertation investigate the effects of context on the perception of musical objects without controlling in any way for the changes taking place in both the context and the objects being studied. Even when the characteristics of the motivic and formal structure of the two versions of *Anthèmes* might appear ideal for the study presented here, they are far from providing the level of balance that is necessary to make definitive empirical observations. To provide an extreme example in this respect, the statistical analyses comparing the recognition of the motivic subfamilies in Experiments 4 and 5 (discussed above) involve subgroups that differ greatly in terms of musical context. Furthermore, the analyses compare groups of motives that are quantitatively very different. The results reported in this dissertation ignore this kind of unbalance, and, in that sense, their scientific validity is questionable. Second, the conclusions are limited to the investigation of two versions of one piece by a single composer and thus all the generalizations proposed are merely conjectural as concerns their application to other pieces. Third, largely as a consequence of the first two limitations, the interpretation of the empirical data is in a few cases based on recurrent patterns observed in descriptive statistics rather than on significant differences obtained from inferential statistics. The interpretations concerning these cases are theoretically and analytically supported, and, in that sense, reasonably valuable. The interpretations are indeed valid explanations for perceptual trends. However, it is important to consider that these few interpretations are not justified with inferential statistics. Further empirical studies are needed in that respect.

Some of the limitations could be overcome in future studies addressing similar issues in other post-tonal works and increasing the number of participants in order to reach more plausible

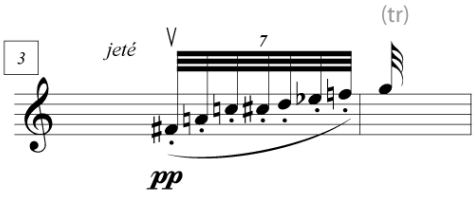
conclusions (since the conclusions are based on proportions of responses). Empirical studies using artificial (specially composed) works to investigate the ways in which specific musical features are perceived in controlled musical contexts should contribute as well. Finally, intuitively, it seems possible that many of the conclusions concerning the perception of motivic similarity and form in post-tonal music that are proposed in this dissertation could be valid for and applicable to many Western musical genres and styles. Furthermore, as reported in Chapter 2, tonal patterns linked to traditional formal functions seem to lead to an asymmetrical perception of motivic similarity. Perceptual studies of motivic similarity and form in tonal musical contexts should be extremely valuable in this respect.

Finally, I hope that the contributions of this dissertation will be regarded more than its limitations, inspiring future research to discover the many ways in which music scholarship can benefit from interdisciplinary approaches. As is the case for any human experience, music is too complex to be completely understood or modeled in a set of theories. Nevertheless, by its very human nature, this complexity is perhaps the very essence of the artistic quality of music and it is thus a critical component in the elucidation of all musical phenomena.

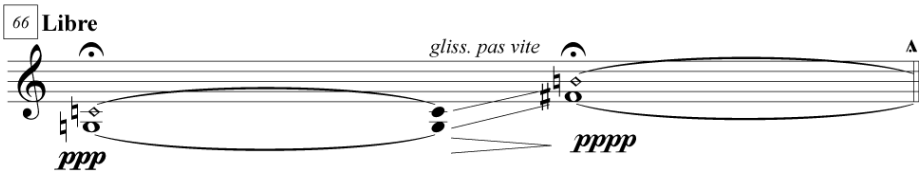
> What really interests me (and it is there that actual form may give a work its maximum effectiveness) is a work that contains a strong element of ambiguity and therefore permits a number of different meanings and solutions … In today's music and today's means of expression it is possible to investigate this ambiguity, giving the work multiple meanings that the listener can discover for himself … Contemporary music in fact demands the intelligent participation of the audience, which is 'making' the work at the same time as the author. (Boulez, 1986, 462).

Appendix A: Motivic models from groups used in the experiments

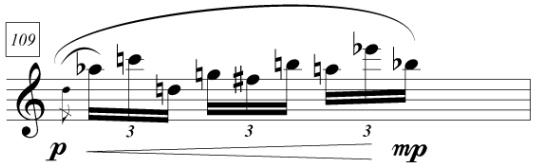
Scale motive



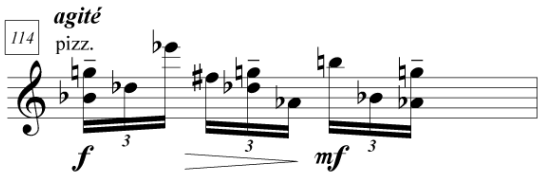
Long Tone motive



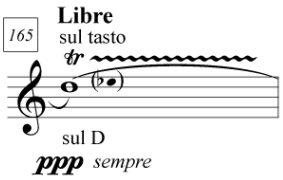
Melodic motive



Pizzicato motive

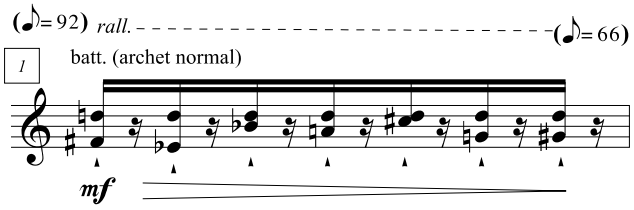


Trill motive

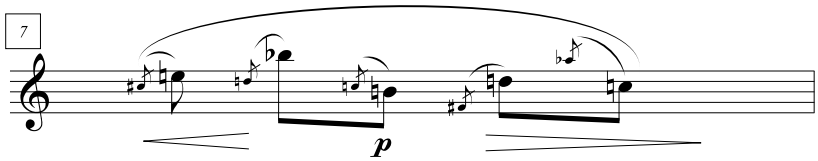


Appendix B: Examples of motives from groups excluded from the experiments

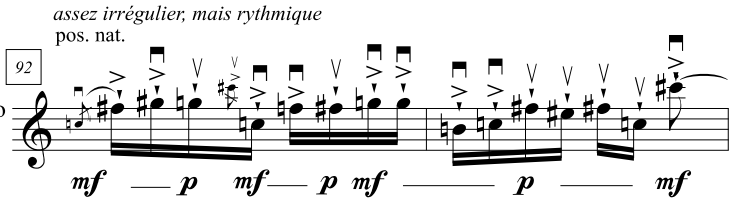
Battimento motive



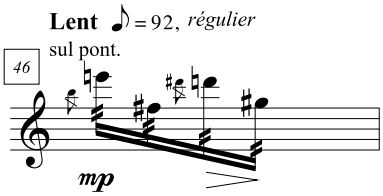
Grace Note motive



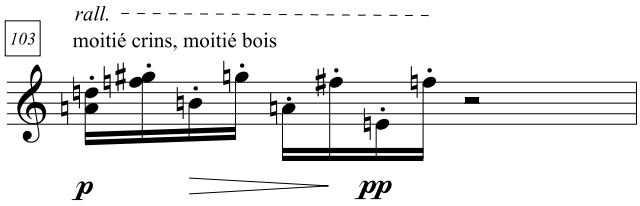
Staccatissimo motive



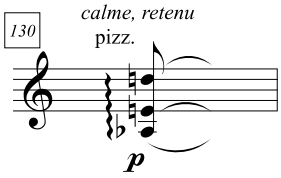
Tremolando motive



Broken Arpeggio motive



Plucked Trichord motive



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