3pMU1. Timbre as a structuring force in music

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Most of the music we enjoy uses the musical qualities of different instruments to create specific perceptual and emotional effects that composers sculpt over time. Timbre is the auditory attribute that distinguishes different instruments. Research on timbre perception has demonstrated that it is multifaceted and contributes in many ways to the perceptual organization of musical structures. The art of structuring music with timbre is orchestration. A survey of orchestration treatises reveals the dearth of underlying theory, in sharp contrast to other traditional areas such as harmony and counterpoint, which have long theoretical traditions. We seek to develop a theoretical ground for orchestration practice starting with the structuring role that timbre can play in music. Many aspects of musical structuring are achieved by auditory scene analysis, the perceptual processes that result in unified events, integrated streams of events, groups of events segmented into phrases and sections, and larger-scale units extended over time that we call orchestral gestures. The roles that timbre plays in the manifestation of these principles in orchestration practice will be considered as potential elements of a theory of orchestration. How such principles might be incorporated into computer-aided orchestration systems and computer-aided orchestral rendering systems will also be examined.

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INTRODUCTION

Most music uses the musical qualities of different instruments to create specific perceptual and emotional effects that composers sculpt over time. The auditory attribute that distinguishes different instruments is called timbre, and research on timbre perception has demonstrated that it is multifaceted, can be linked to acoustic properties of instrument sounds (Caclin et al., 2005, 2007; Chiasson et al., 2010; Giordano & McAdams, 2010; Marozeau et al., 2003; McAdams, 1993; McAdams & Winsberg, 2000; McAdams et al., 1995; Peeters et al., 2011), and contributes in many different ways to the perceptual organization of musical structures (McAdams, 2013). The art of structuring music with timbre is orchestration.

A survey of orchestration treatises reveals the dearth of underlying theory. Their main focus is to provide examples of scoring the most appropriate pitch and register for a given instrument and common combinations of instruments. The presentation of this material most often resembles recipes with specific ingredients rather than aspects of theory that would allow a practitioner to generalize beyond the given example to create new sonorities in a principled way. This situation is in sharp contrast to the areas of harmony, musical form, voice leading, and counterpoint, which have long theoretical traditions. But even these traditional musical phenomena can be strongly affected by orchestration, and surprisingly the role of timbre in their perception is rarely addressed.

To begin to develop a theoretical ground for orchestration practice in Western art music, it would seem crucial to start with the structuring role that timbre can play in music. In line with a recent trend toward the incorporation of psychological principles and empirical research into what is now known as cognitive music theory, this ground could be sought in principles that govern how timbre affects perceived musical structure. Many of these principles can be derived from the theory of auditory scene analysis, which involves the perceptual processes by which musical information is structured into: 1) unified events, 2) integrated streams of events, 3) groups of events segmented into phrases and sections, and 4) larger-scale units extended over time that one might call orchestral gestures. Taken together and linked to other musical phenomena, these areas of inquiry can contribute to theoretical considerations of timbre as a form-bearing element in music (McAdams, 1989b, 1999; McAdams & Giordano, 2009; McAdams et al, 2004; Poulin-Charronnat et al., 2004).

TIMBRE AND AUDITORY SCENE ANALYSIS

Of the myriad issues that could be addressed in orchestration practice, the most powerful techniques are those that rely intuitively on processes related to auditory scene analysis, with particular focus on their interaction with timbre perception. Four topics that address different processes will be considered: concurrent grouping, sequential grouping, segmentational grouping, and the formation of orchestral gestures.

Concurrent Grouping

What combinations of instruments playing concurrently and what kinds of temporal structuring facilitate blending from which new timbres emerge, as in the parallel melodies by different instruments in Ravel's Boléro? Or conversely, what properties facilitate their segregation into distinct voices?

The creation of new timbres by orchestration necessarily depends on the degree to which the constituent sound sources are fused or blended (Brant, 1971; Bregman, 1990; Erickson, 1975; Esling & Agon, 2010; Marin & McAdams, 1991; McAdams, 1989a; McAdams & Bregman, 1979; Read, 2004). Sandell (1995) proposes three perceptual goals in combining timbres concurrently: timbral heterogeneity: the instruments retain their individual identities; timbral augmentation: the identity of one instrument is retained, but its timbre is embellished by the other; and timbral emergence: all timbres fuse into a new sound entity and lose their individual identities (Kendall & Carterette, 1993). Principles of concurrent auditory grouping (harmonicity, onset synchrony, parallel change in pitch and dynamics) all contribute to the process of perceptual fusion (McAdams, 1984), but the actual acoustic properties of the constituent sounds are also crucial, e.g., sounds with similar attacks and spectral properties are more likely to blend (Sandell, 1995; Lembke & McAdams, 2011; Tardieu & McAdams, 2012). Perceptual data concerning timbral blend have been incorporated into the computer-aided orchestration (CAO) environment Orchidée (Carpentier et al., 2010). However, little music analysis has addressed how these effects are actually created in music and what their formal and ornamental functions might be.
Sequential Grouping

How do relative similarities or differences in instrumental timbres favor their clear distinction as carriers of melodic and rhythmic information in settings in which the voices move independently, as in a wind quintet, as opposed to settings in which they are integrated into a common texture, as in a Barbershop quartet? To what extent does the creation of orchestral layers, as in Berlioz's Symphonie Fantastique or Takemitsu's How Slow the Wind, depend on timbral similarities within layers and timbral differences between layers? Which instrumental timbres or combinations are most likely to stand out in complex textures (creating foreground and background elements)?

Auditory streams carry melody and rhythm in music, and their perception depends on integrating the notes that form them into the same stream (Bey & McAdams, 2003; McAdams & Bertoncini, 1997; McAdams & Bregman, 1979). Timbral continuity is an important factor in auditory stream formation and timbral discontinuity in the segregation of notes into separate streams (Bregman & Pinker, 1978; Hartmann & Johnson, 1991; Singh & Bregman, 1997; Wessel, 1979). The degree of segregation is directly related to the degree of similarity between timbres (Bey & McAdams, 2003; Iverson, 1995). Timbre is also an important cue for following a voice that crosses other voices (Culling & Darwin, 1993; McAdams & Bregman, 1979) or hearing out a given voice in a polyphonic texture (Gregory, 1990; Janata et al., 2002). We have identified the acoustic cues involved in the perception of timbral salience (Chon & McAdams, 2012a,b). Some music-theoretic work has applied streaming principles to explain the rules of voice leading and polyphonic writing (Huron, 2001; Wright & Bregman, 1987), but with only cursory consideration of timbre (Huron, 2001). How such effects depend on timbre and actually operate in orchestral music has not been studied.

Segmentational Grouping

How are changes in instrumentation used to segment musical materials at specific points in time at the level of motifs or themes, such as the antiphonal contrasts resulting from patterns alternating between the strings and winds in the second movement of Beethoven's 9th Symphony? How do they work at the level of larger-scale musical sections, as in the succession of sections of brass, woodwinds/strings, strings, and then woodwinds at the opening of Sibelius' Finlandia?

Timbre is an important component in the perception of musical groupings at the segmentational level. Discontinuities in timbre (instrument change) can provoke segmentation of longer sequences of notes into smaller groups (Deliège, 1989) or of larger-scale sections delimited by significant changes in instrumentation and texture (Deliège, 1989). Repeating timbral patterns that are learned over sufficient periods of time can also create segmentation of sequences into smaller-scale timbral patterns (Tillmann & McAdams, 2004). Specific evaluation of the role that timbre plays in such structuring in real pieces of music is exceedingly rare in the literature.

Orchestral Gestures

What techniques are used to create higher-level auditory images that are perceived as gestures with timbral evolution, such as an orchestral swell or waning, a sudden “wall of sound” or “drop off”, or Klangfarbenmelodien (timbre melodies, Schoenberg, 1911)? Each of these “orchestral gestures” is composed of multiple instruments, but their perceptual cohesion gives rise to properties that emerge from the temporal shape of the whole and often creates a dramatic emotional impact in concert with other musical parameters (Goodchild et al., 2011, 2012).

There is very little music-theoretical or perceptual research on the topic of orchestral gestures. However, such gestures have been shown to contribute to peak emotional experiences in orchestral music (Guhn et al., 2007; Sloboda, 1991). While some orchestration treatises mention certain of these gestures, a major concern in this topic is the lack of a clear taxonomy of techniques and of a conceptual framework related to their musical function.

**COMPUTER-AIDED ORCHESTRATION AND ORCHESTRAL RENDERING**

For orchestral pedagogy, Denys Bouliane and Félix Baril at McGill University are developing a computer-aided orchestral rendering package, the Digital Orchestra SIMulator (DOSIM). This kind of tool can provide orchestral rendering of a score coded in the Finale notation software with remarkably compelling results. This kind of highly interactive tool will be crucial in the future for developing reorchestrations to test specific hypotheses about the various perceptual and cognitive phenomena researchers on orchestration may wish to study.
Carlos Agon and his team at IRCAM in Paris have developed the computer-aided orchestration environment *Orchidée* (Carpentier et al., 2010), which allows composers to specify instrumentation and abstract orchestral goals and to receive different proposals for possible orchestrations. This environment has been extended by Eric Daubresse and collaborators at the Haute Ecole de Musique de Genève with *Orchis* (Carpentier et al., 2012a,b) at HEMG and by Agon's team at IRCAM with Philippe Esling's ATO-MS (Esling & Agon, 2010, in press; Esling et al., 2010). These environments will be crucial for proposing reorchestrations to test specific hypotheses about the role of timbral characteristics in the various orchestration effects. By integrating the perceptual and cognitive results from psychological experimentation, perceptually relevant rules and principles can be embedded within these systems.

**CONCLUSIONS**

A true theory of orchestration will have a major impact on composers, orchestrators/arrangers, and teachers, as well as on people developing digital environments for such users. A clear theorizing of orchestral effects and their relation to more traditional aspects of music theory will launch an area of enquiry that has just barely been touched upon by the music theory community.

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**REFERENCES**


