Beyond (the cave of) pitch/loudness-equalization: A Commentary on Reymore (2021)

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ABSTRACT: Traditional approaches in timbre research have often equalized sounds according to pitch, loudness, duration in order to study timbral differences across instruments. In a compact case study of the semantic qualities of the oboe and French horn, Reymore (2021) takes a different approach and considers timbral differences within musical instruments, which arise due to the covariation of timbre with the musical parameters of fundamental frequency (pitch) and playing effort (dynamic level). The study constitutes a timely contribution to a growing body of work on the covariation between timbre, pitch, and loudness. After providing a background and summary of important aspects of the target article, I elaborate on results from a recent complementary study that analyzed acoustical signal properties regarding that matter. Finally, I address three important issues in this context that appear to be worthy of future research.

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WHEN musicians play on their instruments, they seamlessly decide on how to simultaneously sculpt a number of parameters of musical sound production, including fundamental frequency (F0, or more casually *pitch*), playing effort (i.e., dynamic level), articulation, and duration. Many but not necessarily all of these parameters affect the timbre or perceptual quality of the sound beyond just pitch and loudness, such that these parameters may be conceived of as collectively spanning a high-dimensional array or tensor that can potentially affect timbre perception. Due to the fundamental differences between the physical means of sound production across instruments from the Western orchestra, it seems plausible that the covariance between production parameters and timbre perception can be specific to individual instrument classes. In other words, it would be rather surprising to find similar acoustical patterns of covariance between these parameters for a Bosendorfer grand piano and a piccolo flute.

Busy characterizing the multidimensional nature of timbre perception itself, empirical research has long ignored the lurking curse of dimensionality based on the multiple potential associations between musical production parameters and perceptual subcomponents of timbre. Perhaps for these reasons, many previous studies have used operationalizations of timbre that focused on the perceptual differences that arise between sounds from different instruments equaling in pitch, loudness, and duration. The limitations of this approach (that is often blamed on the infamous ANSI definition of timbre, ANSI, 1960/1994) have been discussed elsewhere (e.g., Plomp, 1970; Krumhansl, 1989; Bregman, 1990; Siedenburg & McAdams, 2017). Equalizing loudness, pitch, and duration yet meant that participants in the sound booths were often presented only with low-dimensional slices of the blooming and buzzing variety of timbre of the real world—just as prisoners in Plato's allegory of the cave only perceive the shadows or low-dimensional projections of real-world objects.

In the present target article, Lindsey Reymore addresses semantic aspects of timbre perception as a function of arguably the two most basic production parameters, pitch and dynamic level. Reymore's work is part of a broader development in the community that moves beyond the restrictions of equalization for pitch and loudness. Studying the ways in which musical production parameters—musicians' bread and butter—affect

timbre perception is an important step for timbre research. In fact, starting to understand and, at some point, *explain* the nature of instrument-specific sound characteristics and the intricate ways in which these characteristics map onto semantics is a critical step for beginning to make timbre research relevant for musical practice.

MAPPING TIMBRE SEMANTICS OF INDIVIDUAL INSTRUMENTS

Focusing on two instruments, the main contribution of the target article consists of the detailed depiction of the semantic qualities of sounds from the oboe and French horn. For this purpose, Reymore used a set of 20 semantic scales, denoted as *timbre traits*, that were developed in a previous publication (Reymore & Huron, 2020). Note that previous empirical studies on timbre semantics (e.g., Zacharakis et al., 2015; see Saitis & Weinzierl, 2019, for a review) have provided semantic spaces condensed to three latent dimensions or so for the description of instrument sound. In comparison to this body of work, the set of timbre trait scales provides a redundant and overcomplete semantic description of musical instrument timbre, that yet appears to be well-suited to capture nuanced timbral differences as arising within single musical instruments. In the present experiment, participants rated instrument tones from semitone clusters of different F0-registers and three different dynamic levels on the 20 scales. Thus, the approach is similar to work by McAdams et al. (2017), who measured affective qualities of instrument tones across a wide range of F0s. The resulting rating profiles were interpreted qualitatively. The obtained patterns suggest that some semantic scales did not seem to be affected by F0-register or dynamic level, such as *ringing/long decay*, *percussive*, and *open*. Other scales were clearly affected by changes across F0-register, such as *direct/loud*, *shrill/noisy*, and *rumbling/low*. Some scales such as *soft/singing* showed patterns specific to one of the two instruments: for the oboe, trends indicated an inverted U-shaped pattern across register with *pp* and *mm* dynamic levels reaching their highest ratings for mid 1 and mid 2 registers. For the French horn, however, ratings for the *mm* dynamic level increased monotonically over registers. Observations such as these suggest that it indeed makes sense to study instruments on an individual basis, and that the functional relation between timbre and the production parameters of F0 and dynamic level can differ across instruments. For these reasons, the present study serves as a timely and valuable point of departure for researchers interested in semantic qualities of individual instruments.

Because the study is of exploratory nature and no specific hypothesis was tested, it may be hard to condense the results into a concise summary. In the author's own words,

> The results illustrate the potential complexity of within-instrument timbral variability. Some trends were approximately linear, others demonstrated different patterns, and some timbre qualia dimensions displayed interactions between register and dynamics. While certain trends were shared between the oboe and French horn, others seem to be unique to each instrument. (Reymore, 2021)

Given these intricate patterns of covariation between semantic scales, F0-register, and dynamic level, the target article is certainly beyond criticism of not taking care of the details. However, the critical reader may raise doubt as to whether this type of conclusion—perhaps polemically paraphrased by *anything-goes*—is parsimoniously describing the data. More critically, one could argue that the present study is limited by its lack of statistical summary measures that could have helped to more rigorously break down the complexity and allow for quantitative statements. Qualitative approaches are certainly warranted in this domain but may be complemented by statistical analyses (e.g., polynomial regression as a function of F0 and dynamic level). It would have also been interesting to consider and compare the underlying dimensionality of ratings on the 20 scales by means of dimensionality reduction (e.g., principal component analysis), given that the original scales were developed to account for a more diverse set of sounds from many more instruments. Do listeners' ratings perhaps only inhabit a semantic subspace, given that only two instruments were tested?

In any case, the timeliness of the approach of the target article is highlighted by the circumstance that together with colleagues, I have been working in parallel—perhaps guided by the timbral *Zeitgeist*—on an acoustical analysis of around 5000 orchestral instrument sounds from 50 different instruments, with a particular focus of the effects of F0-register and dynamic level (Siedenburg et al., 2021). The latter study complements the target article by illustrating the acoustical effects of variation along F0 and dynamic level. More specifically, results from the mentioned study indicate that the shape of the spectral envelope and its position along the

frequency axis are most consistently affected by dynamic level, and that independence of F0 and spectral envelope position is the exception rather than the norm. Specifically, the study demonstrates the extraordinarily strong effect of dynamic level on the spectral envelope of the French horn, which also appears to be recognizable in the perceptual ratings of the target article. Accordingly, it does not seem far-fetched to speculate that the association of timbre trait profiles, F0-register, and dynamic level is directly grounded in acoustical properties of instrument tones, which naturally invites for further acoustical modeling of the present data.

QUESTIONS FOR FUTURE RESEARCH

As research on timbre is starting to explore shelterless territory beyond the Platonian cave, we might be dazzled by the vividness and complexity of auditory phenomena under study. For a notion as general as the umbrella of timbre, there are a plethora of interesting research avenues to pursue. Accordingly, several issues are raised by the current target article that deserve further scrutiny. A first issue concerns individual differences between participants. An interesting challenge regarding this topic would be to try to map out group-specific idiosyncrasies of timbre semantics. Do oboists have a refined perception and vocabulary for sounds from their own instrument? Given Reymore's 20 semantic traits, would the profiles of oboists look different from profiles of hornists? It only seems logical, if groups of highly specialized individuals (such as oboists) developed specialized vocabulary in order to more specifically deal with their daily musical business. To the best of my knowledge, such demonstrations regarding the flexibility of timbre semantics have not been published, although a domain-specificity would certainly fit into the general picture of the "messy, pluralistic world of musical semantics" (Noble et al., 2020, p. 214).

A second important issue that deserves consideration concerns the timbral variability based on fine-grained changes of F0. The present study averaged data across clusters of three neighboring semitones to explicitly avoid note-to-note idiosyncrasies and only displayed F0-register-dependent variation of semantic ratings. Sometimes, however, averaging means missing out. More detailed analyses of note-to-note perceptual differences, potentially even collected for sounds generated by different instruments and players, would serve as an important contribution to the literature. Such pursuits could also serve as an empirical grounding for so-far solely theoretical proposals on instrument-specific absolute pitch (Reymore & Hansen, 2020). In fact, we know that there is approximate absolute pitch for musicians and nonmusicians (Levitin, 1994; Frieler et al., 2013), which, paired with F0-specific idiosyncratic timbral nuances, could provide a candidate set of auditory features that instrument-specific absolute pitch could be based on.

Finally, there is the question whether empirical data provides support for the traditional notion of F0-registers, which supposedly each encompass individual timbral properties. A review of orchestration excerpts suggests that reported F0-registers are relatively stable across treatises and historic periods (Reuter, 2002). Concerning acoustical properties, Siedenburg et al. (2021) did not observe pronounced differences in the association of spectral centroids and F0 in the different F0-registers of brass instruments, but a much more diverse pattern emerged for several other instrument classes. More specifically, however, it is not at all clear that traditional F0-register boundaries can be derived in a straight-forward manner from the acoustical properties of instrument sounds. Concerning the resulting perceptual differences between traditional registers, I am not aware of conclusive evidence, say, beyond the well-known example of the clarinet (Barthet et al., 2010), to support the notion that F0-registers each have their distinct timbral characteristics and that there are clear boundaries rather than graded transitions. The so-called "rule of thumb for timbre invariance" suggested that instrument identity can easily be discriminated for pairs of sounds with F0 differences below an octave but not any more for pairs with greater F0 differences (Handel & Erickson, 2001). Yet, it was later shown that the F0-effect are much weaker for musically trained participants (Steele, 2006). Future research may differentiate two questions in this context. First, does there exist a strict partitioning of the F0 range of musical instruments into regions that have distinct timbral characteristics? If yes, secondly, do these regions coincide with the traditional notion of F0-register as characterized in the orchestration and acoustics literature? A healthy amount of skepticism towards the traditional notion of F0-register and an awareness of the F0-dependency of timbre perception may guide us towards a deeper understanding of the perception of musical instrument sound.

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NOTES

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