Identification of concurrently sounding wind instrument tones

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Introduction

Timbre is a multidimensional perceptual attribute. Most studies in the field, so far, have mainly focused on the physical correlates of timbre (spectral, temporal, spectrotemporal) that are important in establishing a theoretical base. But, it is somewhat surprising that only a few of them looked at timbre-related issues through their relevance to the theory and practice of music. For example, perceptual identification of musical instruments when they are combined - consisting a complex auditory scene - has been under investigated up to this time. Besides, in most cases synthetic or hybrid material was used. McAdams (1987) point out that "Sloboda emphasizes above all, the importance of experimentation on real musical material that embodies the real complexities of music…". Studies that used recordings of real instrument tones usually refer to isolated situations and pose considerable methodological differences, thus presenting discrepancies on their results.

The starting point of this study is purely musical. As Boulez (1987) points out "up to the 19th Century, the function of timbre was primarily related to its identity…", contrary to the "flexibility", "mobility" and "temporality" of the modern orchestra. Furthermore, Sandell (1995) describes three "sonic goals" about concurrently sounding instrument tones, taken from the art of orchestration: "timbre heterogeneity", "timbre augmentation" and "emergent timbre" referring to the recognition of constituent instruments, to the predominance and strengthening of one instrument by another and finally to the creation of a new compound sound, respectively.

The main goal of this research, however, is to investigate timbre identification performance of musically trained listeners through an experimental paradigm where they were asked to identify tones of wind musical instruments that sounded concurrently in pairs. Primary focus is given at four intervallic combinations, very often used historically in musical praxis: unison, major third, octave and major tenth. The effect of instrument combination, pitch interval and their interaction, on listener's sensitivity in identifying the individual instrument timbres within each pair, is examined.

Finally, results are compared to previous related findings on musical instruments' identification [2]. The role of pitch in estimating timbral similarity [4] is also discussed.

Method

Stimuli

The main set of stimuli constructed from wind instrument tones (flute, oboe, Bb clarinet and Bb trumpet) of about 3.500 ms duration, which played individually by professional performers at four musical pitches (A4, C#5, A5, C#6).

Recordings were obtained in a recording studio (Laboratory of Electroacoustics, Aristotle University of Thessaloniki) using an AKG C460B-CK 61 condenser microphone, which was placed in front of the performer at an average height of 155 cm from the floor and at a distance of 90 cm from the instrument. Microphone's output was connected to a Pro Tools/HD2 system. Tunings were first made by an electronic tuner, then with oboe and finally using all instruments in ensemble performance. Loudness of all individual tones was equalized through an adaptive two alternatives forced-choice procedure (PEST), where forty–eight musicians (not participated in the present experiment) were asked to provide judgments of the relative loudness of the tones presented in pairs. Perceptual attack time was adjusted through careful listening by the researchers. The final set of stimuli formed all possible combinations (dyads) of instruments and pitches sounding concurrently -58 pairs in total.

Participants

Forty-two musicians, in their majority students at a University Music Department (School of Music Studies, Aristotle University of Thessaloniki) participated voluntarily in the experiment. Their ages ranged from 20 to 47 years (M = 29). All of them were experienced music performers having normal hearing.

Procedure

Before the main experiment, participants were subjected to a pretest procedure that examined their ability in identifying the isolated sounds (four instruments x four pitches). The entire set of stimuli was presented four times. Scores were registered and percentages of correct identifications were calculated. Special attention was given at A4. Participants that had achieved a high percentage of correct identification with reference to two predefined criteria (55% correct identification at all conditions plus 75% correct identification at A4) were allowed to participate in the main experiment. During the main procedure they listened to all possible combinations of paired stimuli which formed intervals of unison, major third, octave and major tenth, with a standard A4 tone. Participants were asked to name the individual instruments within each pair. Stimuli were presented in random order diotically -i.e. the sound stimulus presented at each ear was identical- through a pair of circumaural earphones (Sennheiser HD 545). Participants' responses were recorded through the use of a software interface displayed on a touch screen. The software was developed in National Instruments LabVIEW suite.

Results

Percentages of correct identifications (both instruments), semi-identifications (one of the two instruments) and no identifications were calculated from participants' responses. The first interesting thing to note is the tendency of participants to identify at least the one (whatever) instrument of the constituent dyad, compared to the no identification condition. Table 1, displays mean percentages of identification data, across four pair structure categories. Dyads within each category consisted of an oboe-A4, flute-A4, clarinet-A4 and trumpet-A4 tone respectively (fixed tone), paired with one of all possible combinations of instrument and pitch (variable tone - x). As we can see, for example, correct identification using an oboe-A4 as a fixed tone achieved a 44,11%, semi-identification of oboe (fixed tone) a 34,48%, semi-identification of whatever other instrument as variable tone a 19,57% and no identification the remaining 1,84%.

Table 1: Mean percentages of identification data. Rows represent pair structure categories. Columns illustrate discrete types of identification behaviour.

Pair structure	Percentage of correct identifications (%)		
	Both instruments identified	Fixed tone only	Variable tone only
OboeA4 – x	44,11	34,48	19,57
FluteA4 - x	41,58	33,28	23,65
ClarinetA4 – x	46,25	26,55	30,36
TrumpetA4 – x	43,24	22,71	33,37

In order to examine in detail the main effect of instrument and interval, as well as, their interaction on correct identification, a 4 (instrument) x 4 (interval) repeated - measures ANOVA was carried out, for each one of the four instruments used as fixed sounds.

The instrument had a significant influence on correct identification in all cases: "oboe–x" condition $F(2.9, 120.4) = 6.2$, $p < 0.05$, "flute–x" condition $F(2.7, 109.6) = 17.4$, $p < 0.05$, "clarinet–x" condition $F(2.8, 116.03) = 4.4$, $p < 0.05$ and "trumpet–x" condition $F(2.86, 117.36) = 34.01$, $p < 0.05$.

There was also a significant main effect of interval on correct identification in the "flute–x" condition $F(2.85, 117.01) = 16.8$, $p < 0.05$ and "clarinet–x" condition $F(2.85, 116.9) = 20.52$, $p < 0.05$. On the other hand, interval had not a significant main effect on correct identification in the "oboe–x" condition, $F(2.6, 104.9) = 1.3$, $p > 0.05$ and in the "trumpet–x" condition, $F(2.8, 116.6) = 0.77$, $p > 0.05$.

As regards the combined effect of instrument and interval, results indicated that instrument type had a significant effect on correct identification, depending on the interval that was presented to the participants. More specifically, when the oboe A4 was used as a fixed tone, there was a significant interaction effect between instrument and interval $F(6.4, 260.8) = 19.4$, $p < 0.05$, as well as when the flute A4 was used as a fixed tone, $F(6.6, 269.9) = 15.2$, $p < 0.05$. Similarly, in cases where a clarinet A4 tone and a trumpet A4 tone were used as fixed tones, there were also significant interaction

effects between instrument and interval $F(6.9, 285.3) = 22.3$, $p < 0.05$ and $F(6.8, 277.9) = 24.3$, $p < 0.05$ respectively.

Discussion and Conclusions

Results suggest that identification sensitivity of concurrently sounding wind instrument tones is greatly influenced by the specific timbres used in the pair, their pitch interval, as well as, by the interaction of those two factors.

A closer look at the analysis of the instuments' main effect showed that identities present the highest scores except for the clarinet – clarinet pairs.

Also, it appears that participants' judgments are affected by the interval only in the flute and clarinet conditions. In the remaining (oboe and trumpet) conditions, interval does not seem to affect correct identifications. Moreover, the highest identification scores were obtained on the interval of third (A4 - C#5) except for the oboe – x pairs.

Related previous research on the role of successively presented pitch intervals on timbre similarity judgments [4] has revealed that timbre was a prominent and independent from the pitch, at least for intervals smaller than an octave. However it is noteworthy, that no other study on identification of concurrently sounding wind instrument tones has been published yet, except that of Kendall et al., (1993). In general, our results are not directly comparable with theses of Kendall et al., since there are many differences in the experimental design, as well as the stimuli used. However, a common finding is that participants identify at least one (whatever) of the two instruments of the dyad, as contrasted to the no identification condition.

The lack of experimental data on that domain indicates that additional work is required which should also extent to comparative studies of similarity judgments in contrast with calculated timbral distance metrics provided by analyses of certain acoustic features of the stimulus tones. That work will enrich our knowledge on traditional orchestration practice for the wind family and lead to new insights for "meaningful" blending of different instrument timbres in contemporary music.

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