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# A study of confusions in identifying concurrently sounding wind instruments

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## ABSTRACT

**Background**

Our ability to identify musical instruments from attributes of their sound constitutes a major component of human auditory object perception and relies critically on the perception of musical timbre. Previous scientific research regarding instrument identification tasks showed that, in general, specific instrument combinations preserve their individual timbral identities, while other combinations lose their "personality" either in part or completely (Kendall and Carterette, 1993).

**Aims**

The present study aimed at investigating listeners' instrument identification efficiency when pairs of wind instrument tones play concurrently and at various interval relationships. More specifically, we investigate the potential effect of various parameters of the presented instruments' combinations, such as the pair's constituent instruments ("type-of-instrument"), the width of the pitch interval ("interval") and the assignment of each of the intervals' pitches at each instrument tone ("pitch-ordering-of-instruments"), on the listeners' ability to correctly identify the individual timbres within each pair. Given, also, that the Response Time in psychophysical tasks could be typically considered as an indicator of processing load, we additionally examined whether this factor associated with the listeners' confidence and efficiency in the specific identification task.

**Method**

*Participants*

Forty two musically experienced listeners - in their majority students from the School of Music Studies (Aristotle University of Thessaloniki) - participated voluntarily in the experiment. Their ages ranged from 20 to 47 years. Participants' experience in playing a musical instrument extended uniformly over several families of instruments (winds, strings, percussions, etc.).

*Stimuli*

Single notes at selected musical pitches (A4, C#5, A5, C#6) were played individually by professional performers on a flute, oboe, Bb clarinet and Bb trumpet, and recorded in a typical recording studio room. The duration of each note was about 3.5 sec. All recorded tones were tuned and loudness-equalized (Klonari et al. (2010) and Klonari et al. (2011)). The final set of stimuli consisted of concurrently sounding tone pairs at four intervals (unison, major third, octave and major tenth) based at A4, with each pair containing any possible combination of "type-of-instrument" and "pitch-ordering-of-instruments". Thus, finally, the experiment's constructed listening set contained 58 different pairs of concurrently sounding wind tones, with each pair repeated 5 times, creating (in total) a test battery of 58 x 5 presentations of random order.

*Procedure*

Before participants entered the main experimental procedure, they completed a preliminary test in order to assess their ability in identifying the experiment's instrument timbres when they were presented isolated (4 instruments x 4 pitches). Participants who achieved a minimum 80% of overall correct identification were finally admitted to the main experiment.

In the main experiment, listeners were presented with each sound through earphones (Sennheiser HD 545) and were asked to identify only the sounding instruments' timbres, namely combinations of Oboe, Clarinet, Flute or Trumpet. Both stimulus presentation and collection of participants' responses were administered through a custom computer-based application based on National Instruments LabVIEW.

**Results**

A repeated-measures ANOVA on the mean correct identification score (with minimum value equal to 0, meaning totally incorrect identification and maximum equal to 2, meaning correct identification of both wind instrument timbres) of each of the 58 different pairs of tones was carried out in order to examine the effect of "interval", "type-of-instrument" and "pitch-ordering-of-instruments" factors. The results suggest that mean identification score is affected significantly by all three factors ["type-of-instrument": $F(5.10,209.23)=9.45$, $p=.000$, $\eta^2=0.19$, "interval": $F(3,123)=26.46$, $p=.000$, $\eta^2 = 0.39$, "pitch-ordering-of-instruments": $F(1,41)=11.93$, $p=.001$, $\eta^2=0.23$], as well as their interactions ["type-of-instrument"*"interval": $F(11.89,487.25)=22.57$, $p=.000$, $\eta^2=0.35$, "interval"*"pitch-ordering-of-instruments": $F(2.53,103.82)=7.70$, $p=.000$, $\eta^2=0.16$, "type-of-instrument"*"pitch-ordering-of-instruments": $F(3.95,161.99)=13.54$, $p=.000$, $\eta^2=0.25$ and "type-of-instrument"*"interval"*"pitch-ordering-of-instruments": $F(10.11,414.65)=13.43$, $p=.000$, $\eta^2=0.25$].

The above analysis suggests that "interval" shows a pronounced impact on mean identification score. An analysis of contrasts reveals a consistent reduction of mean identification scores with increasing "interval" (from unison to major tenth), namely unison shows larger mean identification scores as contrasted to the corresponding mean scores of major tenth (mean diff.=0.165, $p=.000$). There are also significant mean identification scores differences for the remaining intervals of

unison-major third (0.048, $p$=.023), unison-octave (0.138, $p$=.000), unison-major tenth (0.165, $p$=.000), major third-octave (0.090, $p$=.000) and major third-major tenth (0.117, $p$=.000). On the contrary, in the case of the small intervallic difference of octave-major tenth, difference of mean identification score is not statistically significant (0.027, $p$ = .147). Applying a Bonferroni correction, the significance of differences is mostly interpreted by the intervallic movement of major third-octave.

Additionally, the examination of contrasts showed another interesting observation, which was also observed from confusions' matrices including percentages of full identification (both instruments), partial identification (one of the two instruments) and misidentification, namely unisons of identical pairs (oboe-oboe, flute-flute, clarinet-clarinet and trumpet-trumpet) show the smallest erroneous identification scores. Actually, this was expected since there is no timbral or intervallic differentiation in this case. All other "interval" combinations of identical pairs (oboe-oboe versus flute-flute, oboe-oboe versus trumpet-trumpet, oboe-oboe versus clarinet-clarinet, flute-flute versus clarinet-clarinet, flute-flute versus trumpet-trumpet and clarinet-clarinet versus trumpet-trumpet) did not show statistically significant contrast differences. Dissimilar instruments' pairs showed various tendencies.

Mean Response Times highlight possible manifestations of subjects' response confidence levels. The average Spearman correlation coefficient was of the order of -0.35, indicating a reverse relationship of mean identification score and Response Time, suggesting, as expected, that correct identifications are performed in shorter periods.

**Conclusions**

This study is a systematic attempt to investigate the identification of tones presented to musically trained listeners concurrently in pairs and at specific intervallic relationships. Results demonstrated the diversity and complexity even within a limited subset of wind musical instruments. The identification of individual instrument timbres is affected significantly by the pair's constituent instruments ("type-of-instrument"), the width of the pitch interval ("interval") and the assignment of each of the intervals' pitches at each instrument tone ("pitch-ordering-of-instruments"). Identification seems to degrade with increasing pitch difference of tones. Pairs of identical musical instruments (unisons) with no timbral or intervallic differentiations show the smallest erroneous identification scores, contrary to the other combinations.

A negative correlation of mean identification score with mean Response Time highlights the subjects' response confidence levels.

Interpretation of results and further extensive investigation might prove useful especially in the fields of orchestration or music synthesis, wherein tonal and timbral combinations of musical instruments are extensively considered.

**Keywords**

Timbre perception, identification, confusions of musical instruments, response time.

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