Effect of spectrum and attack properties on the evaluation of concurrently sounding timbres[1]

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Abstract

The perception of concurrently-sounding musical timbres underlies musical orchestration, but current knowledge about psychological attributes of timbre emphasizes successive comparison (e.g., similarity, analogy). The psychological attribute "blend" was investigated by having eight listeners use a ten-point scale (a continuum of "separated" to "fused") to rate all possible simultaneous presentations of synthesized instrumental tones used in an earlier study [J. Grey, J. Acoust. Soc. Am. 61, 1270-1277 (1975)]. Following Grey's three-dimensional model, the data was analyzed for the effects of harmonic synchrony, spectrum content (centroid), and attack characteristics. The latter two attributes showed a significant relationship to blend: in general, "dark" instruments and instruments with quick, clean attacks tended to blend well. The amount of blend reported for such instruments decreased as their pairs increased in brightness or attack length, and pairs of bright or noisy-attack instruments did not blend well. The results found here corroborate some of the recommendations for desirable blends in traditional orchestration manuals.

I'm going to present the results of an experiment I ran to investigate a possible perceptual mechanism underlying musical orchestration. Orchestration is a time-honored musical art, and clearly is the domain within the traditional division of musical disciplines in which timbre comes to bear, but it rarely (if ever) has been the focus of a perceptual study. Orchestration manuals, as the primary repository for attitudes and values about timbre throughout history, suggest several possible areas of investigation. Rimsky-Korsakov's 1913 treatise of orchestration devotes an entire chapter to advising the student on obtaining effective blends when combining more than one type of instrument on a single melodic line. In an orchestration context, "blend" appears to be an auditory fusion phenomenon: the idea is to combine different timbres in such a way that none of the individual

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instruments are heard separately, but fuse to form a hybrid timbre. Orchestration treatises instruct this practice entirely by example, as in the warnings "strings do not blend so well with the brass, and when the two groups are placed side-by-side, each is heard too distinctly" and "the middle notes of the horn resemble those of the bassoon and the two instruments blend well together." (These are both quotes from Rimsky-Korsakov's treatise.) A goal of experimental research in orchestration should be to generalize these observations into abstract principles, leading to a more systematic approach to orchestration.

(slide 1) Two brief musical examples illustrate blended combinations of instruments. In the example from *Parsifal*, Wagner has orchestrated a single melodic line with a changing instrumentation in which brighter instruments are added to darker ones to emphasize the dynamic arch of the melody. (taped example 1) That was cut short in the interest of time. (slide 2) Another example shows an even more rapid change of blends, by Schoenberg. (taped example 2)

(slide 3) The present study investigated blend by playing sounds of musical instruments in simultaneous presentation to a group of listeners, who were asked to judge their blend. The instrumental sounds were the well-known Stanford collection of tones that have appeared in studies by Grey, Wessel, and Gordon. These are brief tones (about 300 msec) sounding at around 311 Hz, or E-flat above middle-C, which were originally recorded from live performers. Each trial in the experiment consisted of a single sound, which was one of the 120 possible pairs of instruments, played simultaneously. A ten-point rating scale was used. They were told that if the two sounds seem to blend into one, fused sound, they were to give it a high number. If the two sounds seemed to separate into two kinds of sounds, then they were to give it a low number.

(slide 4) This graph presents two physical properties of the tones which played a primary role in determining the judgments. On the left hand side of the graph we see the centroids of the tones. Centroid captures the spectral center of gravity of the tone and expresses it as a frequency. A low frequency, such as in the french horn, corresponds to a dark sound, and a high frequency, such as the muted trombone, corresponds to a bright sound. On the right hand side is the attack time of the tones. Single reeds tend to have longer, noisier attacks, whereas brass and double reeds tend to have shorter, cleaner attacks.

(slide 5) This graph shows the data for just 15 of the 120 trials, the trials which included the bassoon. Each point on the ordinate shows the rating for the instrument that was paired with the bassoon. On the abscissa we see the centroid, and the two axes show that the darker the instrument, the higher the blend rating. This was typical for most of the instruments. (slide 6) This graph generalizes the data so that each point is the average rating for the named instrument. For example, the point indicated by the muted cello is the averaged blend rating for all trials that included that instrument. Its position on this dimension indicates its centroid value as being especially dark. As we consider all the instruments this way, we see an approximately linear relationship. What this means is that the presence of any dark instrument appears to lead to a good blend. The best blend is obtained between two dark instruments, while pairs of bright instruments do not blend. (slide 7) As an aid to orchestration, we might hazard the following rule of thumb: to predict the blend, sum the centroids of the tones; the lower the number, the more likely the tones are to blend. Of course, like all rules of thumbs, its only a rough approximation: this graph actually plots blend judgments against centroid sums, and there is considerable scatter. The trend is apparent nonetheless.

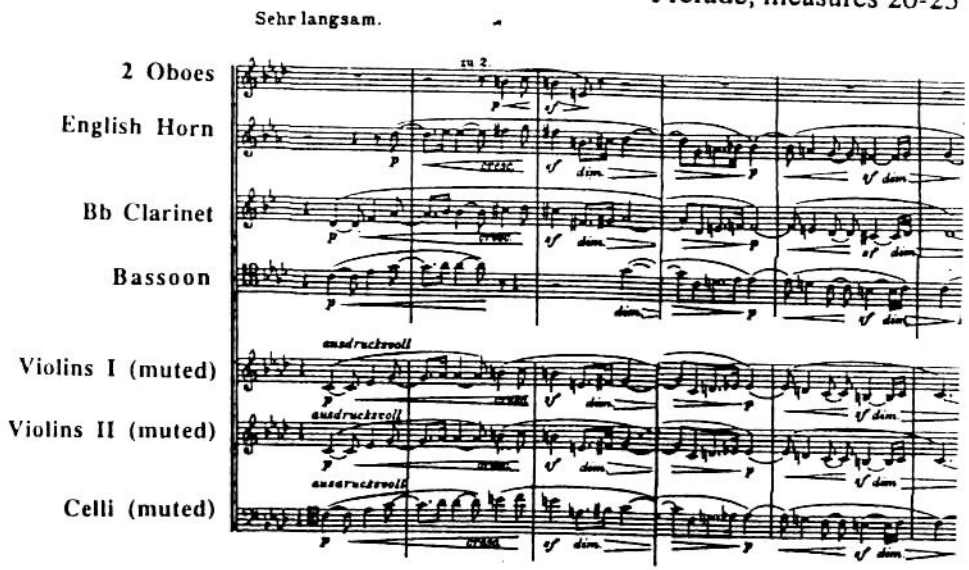
As I said before, the attack duration of tones also played a role in determining blend. Essentially, short attacks led to good blends, in exactly the same way that low

centroids led to good blends. The best blend tended to come from pairs of instruments with short attacks, and any pair containing one instrument with a short attack obtained a better blend than pairs of long-attack instruments. However, the effect was not as strong for attack as it was for centroid.

[**Presented only if time allows:**] (slide 8) I will give you the opportunity to hear some of the individual trials. This chart shows the pairing which received the highest average blend judgment at the top, the lowest average blend judgment at the bottom, and selections of pairs which received ratings along a continuum in between these two extremes. You'll notice that there is a tendency for dark instruments to populate the blended end and brighter instruments to populate the unblended end; to a lesser degree you can observe short-attack instruments on the blended end and long-attack instruments on the unblended end as well. The tape plays all thirteen trials in a row; let me warn you, these are brief sounds.

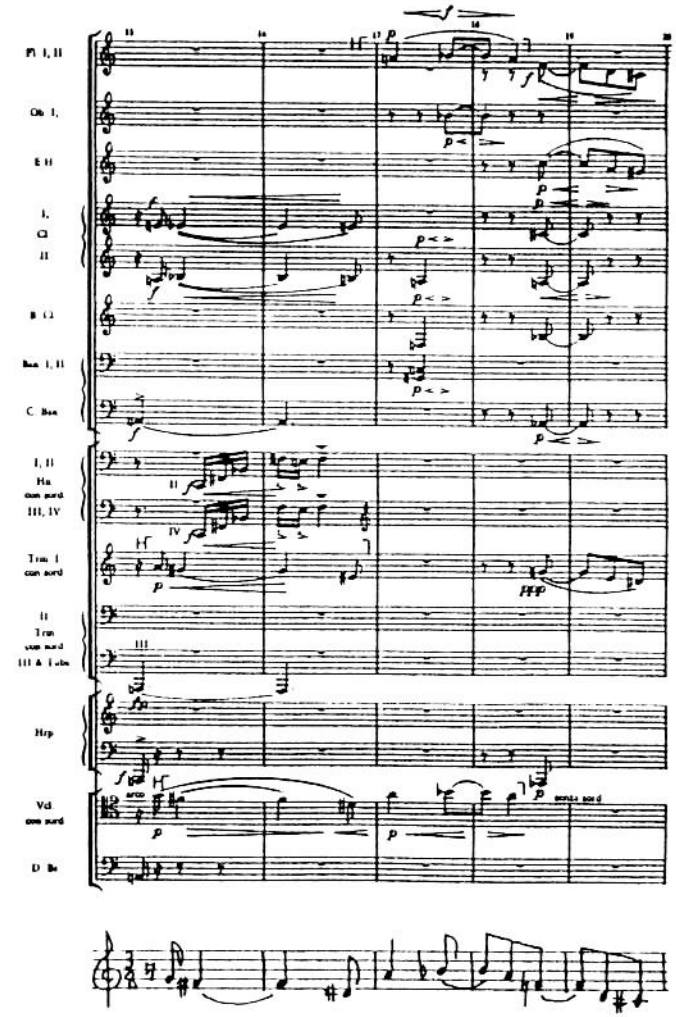
[**Conclusion; if time allows:**] In actual music, the french horn and the bassoon (both dark instruments with quick attacks) are frequently seen combined with many instruments, because they blend so well with instruments having of widely varying degrees of brightness and methods of production. The french horn is seen equally often paired with strings, woodwinds, and brass, while the bassoon is paired with the woodwinds, low strings or low brass. Brighter instruments such as the oboe and trumpet tend to be used more soloistically, or when combined with other instruments, as elements of dynamic emphasis (as in the Wagner example). The findings of this experiment, therefore, offer a generalized approach to obtaining blend, while reinforcing the statements of traditional orchestration manuals and actual musical practice.

Richard Wagner, *Parsifal* (1882)
Prelude, measures 20-25



Slide 1

Arnold Schoenberg
Five Pieces for Orchestra, Op. 16
Movement I, measures 15-19 (1949 version)



Slide 2

Instrument	Short Name
flute	flute
oboe	oboe2
English horn	englhorn
eb clarinet	ebclar
bass clarinet	bassclar
soprano saxophone	sopsax
alto saxophone (played *mf*)	tsax1
alto saxophone (played *f*)	tsax2
bassoon	bassoon
French horn	frhorn
trumpet	trumpet
muted trombone	trombone
cello (bowed *sul ponticello*)	sulpontcello
cello (bowed normally)	normcello
muted cello (bowed *sul tasto*)	mutecello

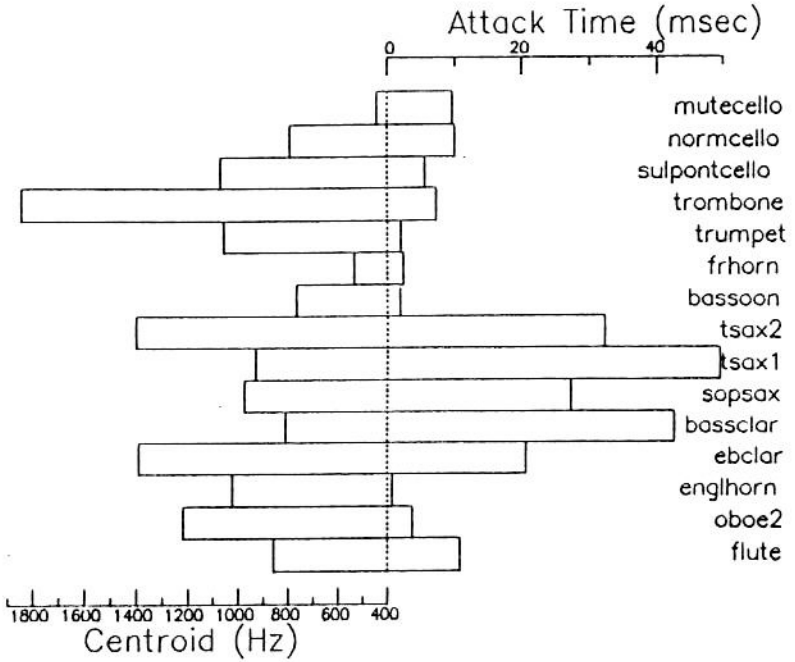
Pitch: Eb^5 Duration: .3 seconds

Total number of trials: 120

flute-flute		
flute-oboe2	oboe2-oboe2	
flute-ebclar	oboe2-ebclar	ebclar-ebclar
flute-bassclar	oboe2-bassclar	ebclar-bassclar
.	.	.
.	.	.
.	.	.
flute-mutecello	oboe2-mutecello	ebclar-mutecello
15	**14**	**13**

+ + ...etc.

Slide 3



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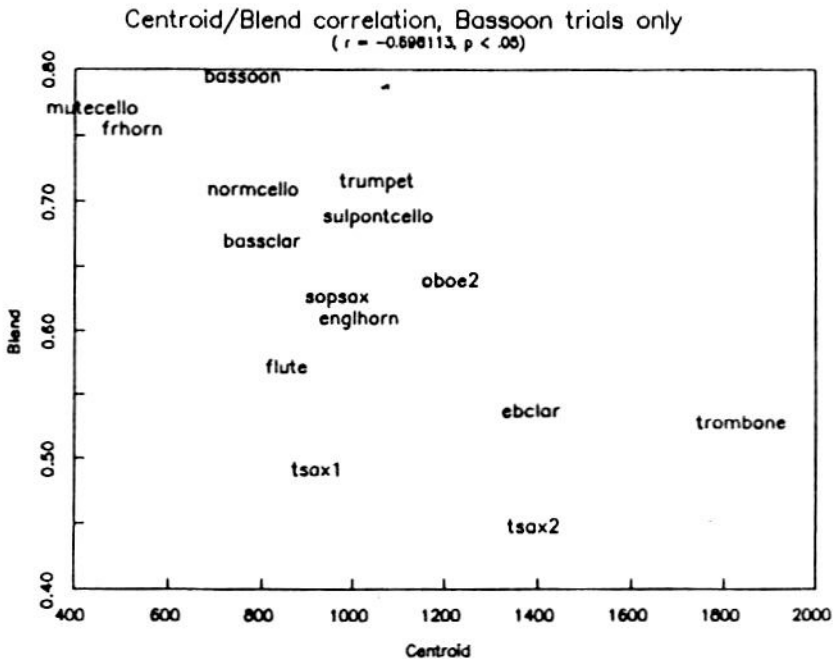

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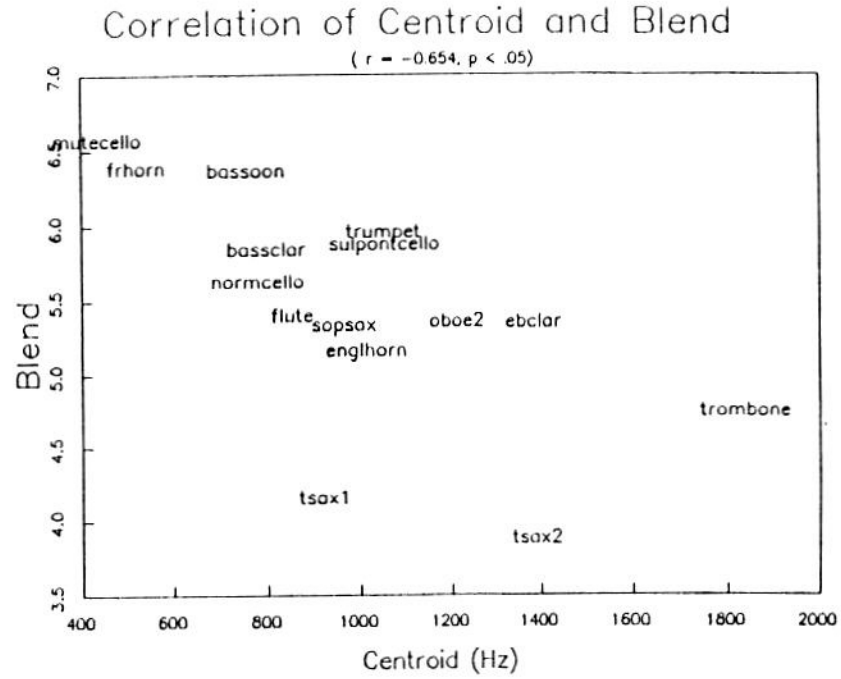
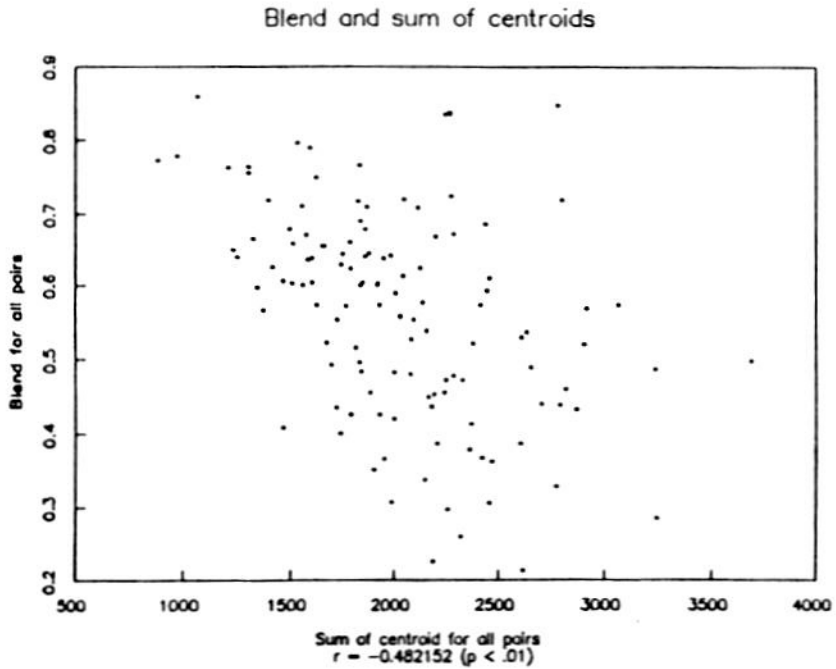


Slide 6



Slide 7

Instrument Pair	Rating
french horn and french horn	8.5
french horn and bassoon	7.5
muted cello and trumpet	6.7
cello and flute	6.5
bassoon and soprano sax	6.2
french horn and eb clarinet	6.0
english horn and eb clarinet	5.7
muted trombone and bassoon	5.3
muted trombone and bass clarinet	4.9
english horn and flute	4.5
cello (*sul ponticello*) and alto sax	4.2
soprano and alto saxes	3.5
alto sax and oboe	2.1

Low <----------Perceived Blend ----------> High

Slide 8