



The perception of size in four families of instruments; brass, strings, woodwind and voice

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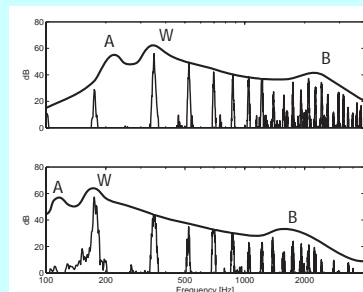
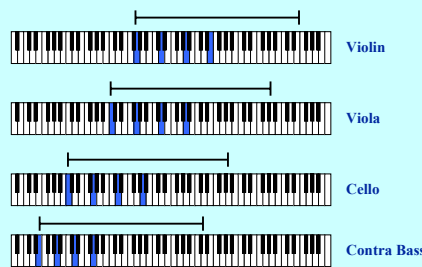
Abstract

The size information in musical sounds is carried by a) the pitch of the note, which is correlated with instrument size, and b) the scale of the impulse response of the instrument, which is also correlated with instrument size.

We performed a psychophysical study to determine whether subjects are able to discriminate between relative sizes of the instruments within the musical families of cello, saxophone, French horn and baritone voice.

Physical aspects of size information in musical instruments

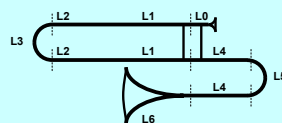
- Within a family of instruments there are instruments with different sizes
•Pitch is correlated with size
•Scale of impulse response is correlated with size: If a violin and cello play the same note, it is still possible to tell which is the larger instrument
•The impulse response of an instrument reveals the natural, resonant frequencies of vibration which decrease as the size of the instrument increases



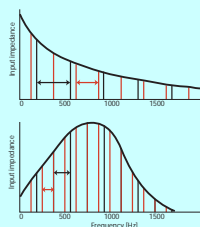
The top and bottom panels show the power spectra of notes produced by bowing a viola and a cello, respectively. The instruments are playing the same note (pitch). The hypothetical solid lines plotted above the harmonics in the panels represent resonance curves for the two instruments.

Some instruments change in size during playing, for example brass instruments, which suggests that it would be difficult to judge the size of these instruments. In the example below we show that playing different notes on a brass instrument will not cause a shift of the spectral envelope of the sound, and thus listeners can use this cue to judge its size.

The figure on the right shows a stylized picture of a trombone. The total length that the air passes through is the sum of the length of the mouthpiece, the tubes and the bell. The length of L2 is variable due to the slider. The length of the tube determines the spacing between the harmonic resonant frequencies.



A change in size within an instrument does not always result in a shift of the spectral envelope. In the case of the trombone changes in body length contribute to the pitch of the note, and the spectral envelope is mainly determined by the mouthpiece and bell.



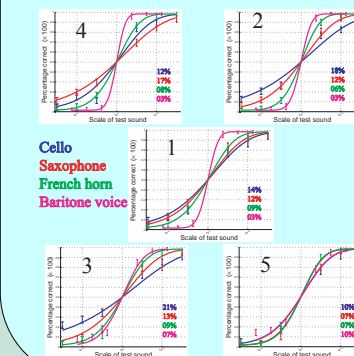
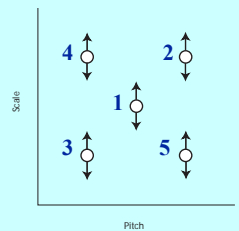
The figure on the left shows the harmonic resonances of a brass instrument. In the top panel the harmonic resonances are shown for the tube alone. The bottom panel shows the harmonic resonances of a complete brass instrument.

In summary, playing different notes on a brass instrument will not cause a shift of the spectral envelope of the sound, and thus listeners can use this cue to judge its size. Similar arguments apply for woodwind instruments, such as the saxophone and clarinet.

Perception of size in musical instruments

We investigated whether listeners are able to discriminate between relative sizes of musical instruments. We measured the just noticeable difference (JND) in the size of four instruments: cello, tenor saxophone, French horn and baritone voice.

- A high-fidelity database of musical instrument sounds recorded by Real Computing World (RCW) database (Goto et al., 2003) was used for the experiment to extract individual sustained notes for families of instruments
•The onset of the recorded instrument was included to preserve important characteristics of the sound of the instrument
•The instrument sounds were modified in size and pitch by the muocoder STRAIGHT (Kawahara et al., 1999)
•In the pitch-size space (figure right) 5 initial settings were used for determining the JNDs. The arrows show the direction in which the JND was measured
•A 2AFC was used to determine just noticeable differences (JNDs) between sounds played by an instrument of two different sizes
•The subject was presented two random tonal melodies played by an instrument of two sizes and was asked to indicate the interval which contained the smaller instrument



- In the figure on the left the psychometric functions are shown for the five conditions
•The location of the five panels in this figure corresponds to the five points shown in the figure above
•The JND's for the baritone voice are the smallest, being as low as about 3 %. These are excellent results, keeping in mind that JND's for most perceptual dimensions (except pitch) are usually around 10 %
•Conversely, we observe that the JND's measured for the cello are the largest, increasing to as much as 21 % for the condition in the bottom left panel
•The measured JND's across conditions within each of the instruments vary no more than about a factor of two. This indicates that the performance across conditions for each instrument is reasonably uniform

Conclusions

We investigated the perception of scale in musical instruments. In the first part, we have shown that for the string, woodwind, brass and voice families, a change in the scale of the impulse response is correlated to the perceived size of the instrument. In the second part, we demonstrated that listeners were able to make discriminations about musical instrument size. The JND's across conditions within an instrument are reasonable close. The listeners' performance was excellent in discriminating the relative sizes of the baritone voice, and they had most difficulty in discriminating the relative size of the cello.

Acknowledgements

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