

# CAN SILENCE AFFECT PERCEPTION? DURATION AND FREQUENCY OF OCCURRENCE IN PERCEIVED PITCH STRUCTURE

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## 1. INTRODUCTION

Walsh's (2003) theory of magnitude states that attributes of events such as duration and frequency of occurrence act upon a single mechanism that in turn increments a magnitude accumulator. However, Lantz and Cuddy (1998) found that, within a sequence of tones, longer tones were judged more salient than shorter but more frequent tones. The finding suggests that the duration of an event has perceptual priority over the frequency of occurrence of the event, and brings into question Walsh's (2003) theory of magnitude. Duration should not increment a magnitude accumulator more than frequency of occurrence.

In the current study, we further investigated the nature of duration. A possibility is that a longer duration allows rehearsal, essentially increasing the frequency of occurrence of the event through self-generated repetitions (Johnson, Taylor, & Kaye, 1977). If such is the case, it should not matter whether the event continues throughout the full duration or whether a shorter duration is followed by a period of silence equalling the full duration.

Duration and frequency of occurrence are both elemental in music. In our study, we manipulated the duration and frequency of occurrence of tones, as well as the silence between tones, to understand how they affect the perceived organization or pitch structure of tone sequences.

Listening to a melody establishes a pitch structure or a "sense of key" so that we can easily tell when a tone does not fit, or sounds "sour". In order to measure perceived pitch structure, we used the probe-tone technique (Krumhansl & Shepard, 1979). A sequence of tones is played to the listener, followed by a probe tone, one of the 12 chromatic divisions of the octave. The listener rates how well the probe tone fits the sequence just heard. The sequence is then repeated, followed by a different probe tone until all 12 chromatic tones have been presented and rated. The resulting probe-tone profile of 12 ratings is then examined for evidence of perceived pitch structure. Key-defining sequences yield a hierarchically structured profile that matches Western music-theoretic proposals concerning the relative salience and function of tones within a key (Krumhansl & Kessler, 1982). Nonkey-defining sequences

yield a perceived pitch structure organized according to the surface properties within the sequence, such as the duration (Lantz & Cuddy, 1998) or frequency of occurrence (Oram & Cuddy, 1995).

We asked whether a silence following a tone could affect the perception of pitch structure of a tone sequence. In the current study, three types of sequences were created—an original sequence in which there were shorter but more frequent tones, and two modifications of the original sequence. In one modification, the long tones were shortened and followed by silence so that the duration of the tone plus silence equaled the duration of the long tone in the original. In the other modification, long tones were shortened and followed immediately by the next tone (i.e., no intervening silence). Long tones were expected to receive higher probe-tone ratings than short tones, as in Lantz and Cuddy (1998). More frequent tones were expected to receive higher ratings than less frequent tones, as in Oram and Cuddy (1995). The outcome of particular interest was whether a tone followed by silence would be rated as highly or higher than the more frequent tones.

## 2. METHOD

### 2.1 Participants

Twenty-four listeners from an Introductory Psychology class took part for course credit. Half the listeners had achieved at least Royal Conservatory of Music (Toronto) grade VIII music training or equivalent. The rest of the listeners had much less music training, no more than they had received in grade or high school music classes.

### 2.2 Sequence Construction and Apparatus

Sequences were generated from six-tone tonesets. Each toneset contained the tones of two major triads from maximally distant keys so that tonesets did not correspond to any key of the Western tonal system. Three sequence conditions were created from the tonesets. In Condition 1, the tones of one major triad (Triad Du) were longer than the other tones (2000 ms vs. 125 ms), whereas the tones of the other major triad (Triad Fr) were shorter but occurred more often (12 occurrences vs. 3 occurrences). In Condition 2, the first sequence was modified so that long Triad Du tones were shortened to the 125 ms duration of Triad Fr tones and immediately followed by silence such that the tone plus

silence equaled the duration of the long tones in Condition 1. In Condition 3, the original sequence was again modified such that long tones were shortened and followed immediately by the next tone (i.e., no intervening silence).

Sequences were Musical Instrument Digital Interface (MIDI) files. Presentation of sequences and collection of responses were controlled by a Zenith Z-200 computer. All tones were pure tones in the range C4 to B4 generated by a Yamaha TX802 FM tone generator. Sequences were delivered to the listener through Sennheiser 480 headphones in a sound-attenuated chamber.

### 2.3 Procedure

Listeners were tested individually with the probe-tone technique. Each of the three sequences was heard 14 times in succession. The first two trials were practice with the probe tone selected randomly. The 12 experimental trials were each followed by one of the 12 chromatic tones in random order. Listeners rated how well each probe tone 'fit' with the sequence on a scale of '1 – fits very poorly' to '7 – fits very well'. Listeners then filled in a form about their music training.

## 3. RESULTS AND DISCUSSION

Ratings from each listener for each condition were ordered according to (1) the three tones of Triad Du, (2) the three tones of Triad Fr, and (3) the six tones not in the tonal set. A 12 x 3 x 2 (Probe Tone X Condition X Group) mixed factorial ANOVA with orthogonal contrasts was conducted. The contrasts of concern compared ratings for Triad Du to ratings for Triad Fr. Overall, there was no difference in ratings for Triad Du and Triad Fr,  $F(2, 22) = 0.28, p > .60$ . However, there was a significant interaction across conditions that can be seen in Figure 1,  $F(2, 22) = 9.49, p = .006$ . The long tones of Triad Du received the highest ratings in Condition 1, and the more frequent tones of Triad Fr received the highest ratings when Triad Du had no duration bias in Condition 3. As expected, duration had priority over frequency of occurrence, although frequency of occurrence had an effect on perception when duration was removed as a cue to pitch structure. Of more interest is that a short tone followed by silence had an effect on the ratings of Triad Du in Condition 2. If silence had no effect on perceived pitch structure, then ratings for Triad Fr should have been higher than ratings of Triad Du. However, neither group rated Triad Fr higher than Triad Du. The musically trained group rated Triad Du higher than Triad Fr, just as they had when the tone had been played throughout the full duration. The musically untrained group rated Triad Du just as highly as Triad Fr.

Silence clearly had an effect on perceived pitch structure, with an increase in ratings for Triad Du for the short duration followed by silence compared to ratings for Triad Du tones of the same duration but without subsequent

silence. Those with music training perceived the tones with silence to be just as important as the long tones of Condition 1. The musically untrained group perceived the tones with silence to be just as important as the more frequent tones in Condition 2.

The improved ratings of a tone with silence may be due to rehearsal (Johnson et al., 1977), echoic memory, or to placement at the end of a phrase, with the silence indicating a phrase boundary. In any case, the results are problematic for Walsh's (2003) theory of magnitude. Any accumulator must increment the magnitude of tones even in the absence of the sounding of a tone.

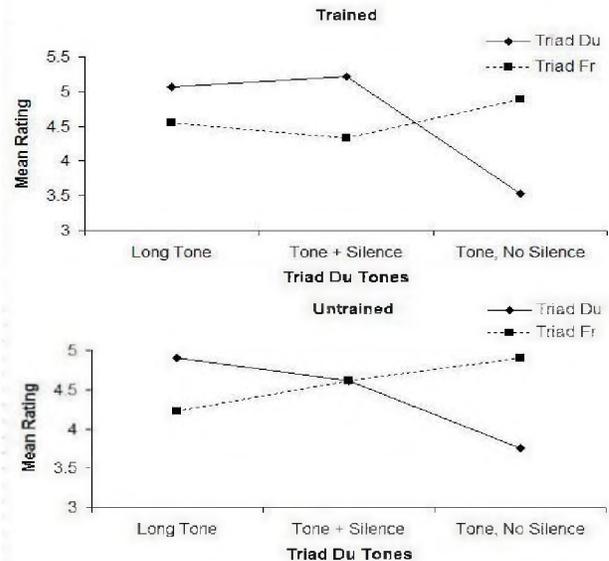


Fig. 1. Mean ratings for Triad Du and Triad Fr across the three conditions: Triad Du tones played for a long duration, a short duration followed by a silence, and a short duration without subsequent silence. The two panels show ratings from musically trained listeners (top) and musically untrained listeners (bottom).

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