INTER-PARAMETRIC ANALOGY AND THE PERCEPTION OF SIMILARITY IN MUSIC

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ABSTRACT

Background: Music theorists and psychologists have described musical processes as bipolar changes in "intensity". This notion implies that analogous intensity contours would be perceived as akin, even when expressed by different parameters. These may include basic parameters of sound, as well as music-specific parameters like the size of pitch intervals or harmonic progressions. One underlying assumption is that these analogies are mediated through the perception of musical tension (Berry, Hopkins, Meyer). Relevant studies notwithstanding, the validity of this hypothesis has yet to be studied systematically.

Aims: We set out to examine the relationship between the perceived affinity among musical stimuli sharing similar intensity contours, and the perceived tension in the same stimuli.

Method: 59 college students (26 musically trained) rated the degree to which members of pairs of musical stimuli were akin in character to a "standard" – a crescendo on a repeating tone. One member of each pair presented an "increase" in a specific musical parameter, while the other presented a "decrease" (e.g., ascent vs. descent). Parameters investigated were: melodic direction and attack rate and all their combinations, pitch interval size, motivic pace, and harmonic progressions. In the second part of the experiment participants were asked to determine whether tension in each figure increases, decreases, or remains unchanged.

Results: In most parameters examined, the intensifying figure was rated as more akin to the standard and significantly higher in the tension-change scale than its abating counterpart. In both types of rating, this relationship was stronger for attack rate, motivic pace, and melodic direction than for the music-specific parameters - interval size and harmonic progressions. The harmonic dimension influenced mainly ratings of musically trained participants who were also more sensitive to changes in attack rate. When two parameters (melodic direction and attack rate) were coupled, their effect depended on the degree to which they correlate suggesting an additive effect.

Conclusions: Our results suggest that listeners perceive intensity contours in different parameters as analogous via concomitant perceived changes in musical tension. However, this process is not shared by all listeners some of which associate intensity with tension but do not use this measure in their similarity ratings. This may reflect different cognitive approaches to the issue of similarity in music: a "gestural" holistic approach versus a more analytic one.

1. BACKGROUND

The question of how listeners categorize musical events in terms of their degree of similarity is crucial to our understanding of musical processing. Categorization processes (Rosch and Mervis, 1975) enable listeners both to parse musical sequences into smaller chunks and to create a network of associations across sections (Deliege, 2001). Nonetheless, whereas the processes underlying similarity on the tone to tone level (grouping) have been widely studied (Bregman, 1990), the principles governing the perception of similarity among longer musical units such as motives are much less well understood (for a theoretical model see Zbikowski, 1999).

The term "motive" is customarily used is music theory to denote a relatively small-scale melodic, harmonic, or rhythmic pattern, whose varied repetition presumably contributes to a composition's coherence. Most music theorists (e.g. Reti, 1951; Schoenberg, 1934-5; Schachter, 1983) view pitch relationships –intervals, scale degrees, or voice-leading patterning – as the main attributes defining similarity and variance of musical motives, with proportional IOI patterning coming a close second. However, music-theoretical studies (Berry, 1976; Hatten, 1997-2001; Rink, 1999; Eitan, 1997) and empirical work on music and motion (see Shove and Repp 1995, for a survey), suggest an additional source of motivic similarity: intensity contours.

Intensification, one of the most basic and effective processes used in music, may be realized in different parameters, both basic parameters of sound, like dynamics (increased "intensity" in the acoustic sense), IOI, melodic direction, or increased density, as well as music-specific parameters like the size of pitch intervals or tonal harmonic progressions. Each of these parameters may be conceived as bi-directional, one direction "increasing" (crescendo, accelerando, pitch rise, etc.), the other "decreasing." A major reason intensity changes in different parameters are presumed to be analogous is that they are all related to the dimension of perceived musical tension: intensifications supposedly increase tension and instability, while abatements alleviate tension and move toward stability and closure (Berry, 1976; Hopkins, 1990; Meyer, 1989).

Despite the importance of intensification contours in music, there is currently, to the best of our knowledge, no systematic study of the perceived relationships among similar intensity contours using various musical parameters, and the perceived tension level. Consequently, in our study we examined three main hypotheses: (a) Similar intensity contours in different musical

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parameters enhance the perceived affinity between musical stimuli (b) This enhanced affinity is based, at least partially, on concomitant perceived changes in musical tension, and (c) Due to the importance of intensification processes in our physiology, our acoustical environment as well as in music, there would be only small differences in the perception of various intensity contours between musicians and non-musicians.

2. METHOD

Participants: 59 college students (mean age 24.2, 27 males, 32 females) participated in the study. 26 of the participants had at least 7 years of formal musical training ("musicians"), whereas the remaining 33 listeners had little or no musical training ("non-musicians").

Materials: Musical materials (EITAN_GRANOT3.PDF; EITAN_GRANOT.MID) consisted of a "standard" motive, which included 9 isochronous monotones increasing gradually in intensity from *ppp* to *fff*. This standard (Ex. 1) was followed by pairs of brief melodic figures. One member of each pair presented an "increase" in a specific musical parameter, while the other presented a "decrease" (e.g., ascent vs. descent, accelerando vs. ritardando). Other parameters were held constant for each pair. Parameters investigated were: melodic direction (e.g., Ex. 2-5), pitch intervals size (Ex. 6-9), attack rate, Inter Onset Interval (IO) of a repeating tone figure (Ex. 10-11), motivic pace (progressive changes in a group's duration, Ex. 12-13), harmonic progression[1] (Ex. 14-15) and motion towards more or less dissonance (Ex. 16-17), as well as all possible combinations between melodic direction of a melodic sequence (upward vs. downward motion) and attack rate (Ex. 18-29). Stimuli were produced using the *Sibelius 1.2* notation software in a pseudo piano timbre and recorded on a CD.

Procedure: Participants were tested in small groups of 4-8 participants, each group presented with a different random order of stimuli. In the first part of the experiment the standard was presented four times for general acquaintance. Following this presentation participants were asked to rate which of two musical figures in each pair was more akin in its character to the standard (which was presented again before each pair). Next, the pair was presented again, and participants were asked to rate the degree of affinity of each of its members with the standard on a 1-7 point scale. In the second part of the experiment all the stimuli (including the standard) were presented again in a new random order, disregarding the pairing of stimuli employed in the first part. Participants were asked to determine whether tension in each figure increases, decreases, or remains unchanged, and then rate the tension change in each stimulus on a -3 to +3 scale (increase: 1 to 3; decrease: -1 to -3; unchanged: 0). Participants were given ~ 15 seconds to fill in their answers. Stimuli in both sessions were presented at a tempo of 160 b/m.

[1] The intensifying harmonic stimulus was a sequence of "ascending" (strong) root progressions, as defined by Schoenberg (1983, p. 119-123), moving from tonic to dominant, and the abating stimulus – its retrograde, moving from dominant to tonic through "descending" (weak) root progressions.

Statistical Methods: The hypothesis that the choice of the motive in each pair, closer in character to the standard motive is made at random, was tested by chi-squared goodness of fit tests and by Wilcoxon test for paired samples. These tests were carried out for the entire study population and separately for musicians and non-musicians. The intensifying and abating motives in each pair were compared and contrasted for musicians and non-musicians using repeated measures analysis of variance. This analysis was applied to all pairs in a single model, to each pair individually and also to groups of motives that differ with respect to particular musical parameter. Whether the tension increased, decreased or did not change was compared across motive pairs using McNemar's test. For each pair of motives, it was hypothesized that the choice of which motive was closer to the standard would be reflected in the assessment of change in tension given to the same motives in the second part of the study. This hypothesis was tested by using McNemar's test on the tension assessments for the two motives. For each pair of motives, change scores were computed for the differences in closeness to the standard and level of tension between the motives. Pearson correlation coefficients were used to assess the degree of correlation between the change scores and paired t-tests were used to examine whether there was an overall difference between the two change scores. For each pair of motives, the association of the tension ratings to the choice of which motive was closer to the standard, was examined by conducting a chi-squared goodness to fit test, separately for each choice, under the hypothesis that the higher tension rating was made at random between the two motives. For motives taken from a common source, differences in ratings among the motives were analyzed and related to whether or not the subject was a musician by analysis of variance with repeated measures. The false discovery rate (Benjamini and Hochberg 1995) was used to account for multiple testing.

3. RESULTS

1. Intensity contours and tension. In most parameters examined (melodic direction, IOI, motivic pace, harmonic progression, and harmonic dissonance), the intensifying figure was rated significantly higher in the tension-change scale than its abating counterpart, suggesting that parametric intensification indeed correlates with perceived increase in tension. Z values are highest when differing intensity contours involve accelerando vs. ritardando, somewhat smaller for melodic direction, followed by the harmonic parameter all of which yield significant p values [EITAN_GRANOT TABLE1+2.PDF]. The association of the two harmonic dimensions (harmonic progression and dissonance) with tension-change, however, is relatively weak, and limited to musicians (harmonic dissonance is the only feature in which tension ratings were significantly different for musicians and non-musicians, $p<0.005$). The effect of pitch-interval size is even weaker presenting no correlation with tension such that increases and decreases in this domain are not significantly different with regard to tension change (although they are marginally so for ascending contours). Interestingly, when both pair members present non-congruence between parameters (attack rate and pitch contour), tension ratings are roughly identical suggesting that intensification in one parameter was annulled by abatement in the other. Note however, that the trend for musicians was to rate the descending figure with increasing IOIs higher than the

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ascending figure with decreasing IOIs. This may indicate that in the musically trained participants, the parameter of attack rate was somewhat stronger than melodic direction. In contrast, when different parameters support each other, the difference in tension ratings is extremely significant, suggesting an additive effect**.**

2. Intensification and motivic affinity. For most parameters, perceived motivic affinity was indeed enhanced by analogies of intensity contours across parameters. The affinity of intensifying figures with the standard stimulus (a crescendo) was rated significantly higher than that of their abating counterpart for melodic direction, pitch interval size (in ascent only, as in the tension ratings), motivic pace, and harmonic dissonance (see Table 2). There was no significant difference between intensifying and abating figures for descending pitch intervals and for consonant harmonic progressions. For attack rate (IOI), significant differences were found only when coupled with change in pitch (both ascent and descent). This result however, was carried mainly by the non musicians who rated both acceleration and deceleration in the repeating tone motive (whose pitch was an octave higher than that of the standard, Ex. 10-11) as similar to the standard (Wilcoxon test, $p < 0.005$). In contrast, the musicians were less influenced by pitch similarity and more sensitive to the increase in IOI. Finally, the musicians' data also revealed an interesting trend in the responses to the interaction between contour and interval size ($p = 0.077$) such that convex contours (increasing intervals in ascent and decreasing intervals in descent) were rated as more similar to the standard as opposed to concave contours. This trend which mirrors the tension ratings is consistent with some models of musical tension proposed by music theorists (e.g., Cohen and Wagner, 2000).

3. The relationship between intensity contours and tension. In all pairs of stimuli but one the stimulus rated as more akin to the standard was also rated, on average as more tense. In order to test whether these parallel ratings were given by the same participants, we created a dummy variable so that if the tension rating given by each subject to the intensifying figure was higher than that given to its abating counterpart, a (+1) score was assigned, and if the rating given to the abating figure was higher, a (-1) score was assigned. We then tested our hypothesis separately for participants who marked the intensifying figure as more akin to the standard, and for participants who marked the abating figure as more akin to the standard. In general, participants who marked the intensifying figure as more akin to the standard also rated the same stimulus as more tense. This was highly significant ($p \leq 0.0001$) for all stimuli except for those in which intensification was based on increasing interval size, harmonic progressions (both "strong" progressions and dissonance), and noncongruence between melodic direction and IOI (ascending in ritardando vs. descending in accelerando). In contrast, participants who marked the abating figure as more akin to the standard did not rate the same stimuli as more tense but rather rated, as the first group, the intensifying member in each pair as more tense. This pattern was consistent across all stimuli except for ascending, increasing and decreasing intervals, and ascending in ritardando vs. descending in accelerando. This trend was statistically significant for only some of the pairs due to the small number of entries in the relevant cells (similar results were obtained when using Mcnemar's test). Overall, this proposes a more complex relationship between the two dimensions examined in our study – affinity and tension – than the one proposed by the theoretical mode. This relationship will be discussed in the following conclusions.

4. CONCLUSIONS

The results reported above suggest that listeners are indeed able to perform a "leap" across musical domains, and perceive intensity contours in different parameters as analogous, these analogies affecting their perception of motivic affinity. Results also indicate that listeners strongly associate intensifications and abatements in diverse parameters with tension rise and fall. Perceiving the latter relationship, however, does not always lead to the former: listeners who fail to relate intensity contours and motivic affinity still tend to associate intensity with tension. In other words, some listeners did not use their measure of perceived tension as a basis for similarity judgments. This fact may indicate different cognitive approaches to the issue of similarity in music: a "gestural" holistic approach, which would take into account analogies among different domains (musical and perhaps extra musical as well), and the resulting overall tensional shape of a musical figure, and a more analytic approach ignoring such cross-domain analogies and consequently disassociating perceived tension and measures of similarity.

Analogies between intensity curves across musical parameters, and their association with perceived tension, are least effective in the music-specific parameters of harmonic progression and size of pitch intervals. In these parameters cross-parametric analogies relationships were perceived, if at all, mainly by musicians. In contrast, domains shared by music and other sound phenomena such as dynamics and pitch contour, and dynamics and attack rate (IOI) lend themselves more easily to analogies. The former relationship may be related to Doppler-like effects, associating change of distance (itself related to perceived loudness) and perceived pitch change (see Neuhoff et al. 1996, 1999 for recent demonstrations of the interaction of loudness and pitch perception). The latter relationship may stem from associating both loudness and temporal density with the degree of "energy" or force produced or invested: louder sounds are usually a sign of a more forceful action, and faster sounds are presumably produced by faster actions which are more energetic. As Todd and McAngus (1992) propose, such associations may arise not only from experience with environmental stimuli, but from shared physiological mechanisms. Furthermore, loudness, duration, and "vocal effort" (related to pitch contour) were used "successfully" by Stevens (e.g., 1975), in cross modal matching tasks. According to his interpretation all sensory magnitudes are coded somewhere in the nervous system as firing rates of neural pulses. This intensity information is supposedly carried to a common "intensity locus" in the forebrain. Note however, that in our study we did not use a magnitude estimation task. Furthermore, our results extend beyond simple stimuli to more complex patterns such as harmonic dissonance or motivic pace.

Differences between musically trained and untrained listeners were found, in addition to the music-specific domains of pitch interval size and harmony, in stronger tendencies to associate IOI and loudness intensity contours. This may be yet another indication of the effect of musical training on sensitivity to temporal processes, and specifically to the relationships of temporal changes to changes in other parameters.

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An important though preliminary finding is the additive effect of intensity curves in different parameters. Coupling intensifications in two different parameters (IOI and pitch contour), results in higher tension ratings, and higher ratings of affinity with the standard; in contrast, non-congruence between parameters lowers both ratings. This finding seems to suggest that changes of intensity in different domains are indeed processed in an integrated way, as Todd (1992) suggests. For music analysis, these results suggests the validity of applying integrated intensity contours to describe processes of tension change in music, as Rink (1999), Berry (1976) and others have suggested.

Cross-domain intensity contours in music have been the subject of both psychological and music-theoretical studies. This study has tried to investigate whether such analogies affect our sense of similarity among musical figures; in other words, whether musical "gestures," based on curves of intensification and abatements (psychologically interpreted as tension contours), can be generalized across parameters. Our results indicate – though cautiously – that this might be the case. They thus suggest that quasi-motivic similarity in music may be sought not only among patterns similar in their specific pitch or rhythmic construction, but among patterns which, though they may be dissimilar in particular melodic, rhythmic or harmonic qualities, may share a global, cross-domain intensity "shape".[2]

5. REFERENCES

1. Benjamini, Y. and Hochberg, Y. (1995). Controlling the false discovery rate: A practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society*, Series B, 57, 289-300.
2. Berry, Wallace. (1976). Structural Processes in Music. Englewood Cliffs, N.J.: Prentice-Hall.
3. Bregman, A. S. (1990). *Auditory Scene Analysis: The Perceptual Organization of Sound* Cambridge, MA, USA: M.I.T. Press.
4. Cohen, D., and Wagner, N. (2000). Concurrence and nonconcurrence between learned and natural schemata: The case of J.S. Bach's Saraband in C minor for cello solo. *Journal of New Music Research*, 29, 23-36.
5. Deliège, I. (2001). Similarity perception, categorization, cue abstraction. *Music Perception, 18*, 233-43.
6. Eitan, Z, (1997). *Highpoints: A Study of Melodic Peaks* (Philadelphia: U of Pennsylvania Press)
7. Hatten, R, (1997-2001). *Musical Gesture: On-line Lectures* (Cyber Semiotic Institute, University of Toronto), URL:http://www.chase.utoronto.ca/epc/srb/cyber/ hatout.html
8. Hopkins, Robert G. 1990. *Closure in Mahler's Music: The Role of Secondary Parameters.* Philadelphia: University of Pennsylvania Press.
9. Meyer, Leonard B. (1989). *Style and Music: Theory, History, and Ideology*. Philadelphia: University of Pennsylvania Press.
10. Neuhoff, J. G., & McBeath, M. K. (1996). The Doppler Illusion: The influence of dynamic intensity change on perceived pitch. *Journal of Experimental Psychology: Human Perception and Performance.* *22* (4) 970-985.
11. Neuhoff, J. G., McBeath, M. K., Wanzie, W. C. (1999). Dynamic frequency change influences loudness perception: A central, analytic process. *Journal of Experimental Psychology: Human Perception and Performance.* *25* (4), 1050-1059.
12. Reti, R. (1951). *The thematic process in music*. New York: Macmillan.
13. Rink, J. (1999). Translating Musical Meaning: The Nineteenth-Century Performer as Narrator. In Nicholas Cook and Mark Everist (ed.), *Rethinking Music* Oxford & New York: Oxford University Press, pp. 217-238.
14. Rosch, E., and Mervis, C. B. (1975). Family resemblance: Studies in the internal structure of categories. *Cognitive Psychology 7,* 573-605.
15. Schachter, C. (1983b). Motive and text in Four Schubert songs." In Beach, D. (Ed.). *Aspects of Schenkerian theory* (pp. 61-76). New Haven: Yale University Press.
16. Schoenberg, A. (1934-36/1995). *The musical idea and the logic, technique, and art of its presentation.* (P. Carpenter S. Neff, Eds. and Trans). New York: Columbia University Press.
17. ------. (1983). *Theory of Harmony.* Translated by R. Carter. Berkeley: Univ. of CA Press.
18. Shove, P., and B. Repp, (1995). Musical Motion and Performance: Theoretical and Empirical Perspectives in John Rink (ed.), *The Practice of Performance: Studies in Musical Interpretation* (Cambridge: Cambridge UP), 55-83.
19. Stevens, S. S. (1975) *Psychophysics*. New York: Wiley.
20. Todd, Neil P. McAngus. (1992). The dynamics of dynamics: A model of musical expression. *Journal of the Acoustical Society of America*, vol. 91 no. 6 , 3540-3550.
21. Zbikowski, L. (1999). Musical coherence, motive, and categorization. *Music Perception, 17/1,* 5-42.

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