**The perceptual magnet effect is not specific to speech prototypes:**

**new evidence from music categories**

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In the fields of linguistics and cognitive psychology, the perceptual magnet effect is a prominent discovery (Kuhl, 1992) of language-specific prototypical phenomena, and has been regarded as a central property of neural map formation. It is a relational mapping system between an acoustic variability in a speech signal and the stable linguistic categories that a listener reports to hear without effort. Incoming speech sounds are identified by reference to the category prototype acting as a perceptual magnet because they are absolutely or relatively indistinguishable from it. This led to research on prototypicality in music with a study by Acker et al., (1995) in which professional musicians were given discrimination tasks in the context of both prototypical and non-prototypical C-major chords. The highest and lowest rated exemplars served as the prototype and non-prototype in a discrimination task involving 30 prototypical and non-prototypical chords. The research concluded that opposite to speech prototypes, music prototypes act as perceptual anchors rather than magnets. The studies conducted by Acker et al. although seemingly conclusive, are fundamentally flawed because they account for a small subset of the population who have extensive training in the recognition of in-tune and out-of-tune musical chords.

Seeing this, Barrett investigated whether the performance of such musically trained subjects is representative of the average listener’s perception of music categories by conducting Acker et al.’s experiment and adding non-musicians into the second discrimination task involving the absolute prototype and relative non-prototypes determined in the first portion of the experiment. The goal behind this experiment was to isolate each individual musician’s less representative example of a C-Major chord to be used as the non-prototype in a subsequent discrimination task involving both musicians and non-musicians. Barrett replicated Acker et al.’s experiment in which musicians were asked to provide a “goodness” rating allowing her to determine the 50% crossover point on a given C-major chord. Determining this threshold would allow Barrett to develop the non-prototypical representatives of a C-major chord that would be used with non-musicians in the second experiment. Barrett appropriately used a prototypical C-major chord that matched as closely as possible, that of the prototypical C-major chord used by Acker et al (261.6 Hz [C]; 329 Hz [E]; 392 Hz [G]), establishing a commonality between the musicians and non-musicians. Musicians may have different preferences for where they place the perceptual boundary between a major and minor chord (similar to the varying pronunciation of speech sounds). This consideration which was also made by Acker et al. and Kuhl in their previous studies, led Barrett to an averaging function to produce the resulting non-prototype used in the subsequent experiment. In keeping with the parameters set by Acker et al., Barrett used a group of 10 subjects (5 males, 5 females) each of which had at least 10 years of musical training and were between the ages of 20 to 26. Although Barrett takes certain measures to ensure that the parameters set in Acker et al.’s experiment are replicated, there is one crucial adaptation made which may account for unequivocal results. In Acker et al.’s study, the synthesized 3-note chord is modulated along two parameters (1st, 5th). Both the C and G frequencies vary along a continuum that digresses from a prototypical C-Major chord to uncharacterized non-prototypical C-Major chords. Barrett on the other hand provided a similar stimulus (3-note synthesized chord) but modulated only along the E frequency, evolving from a prototypical C-Major chord to a prototypical C-Minor chord in 12 equal steps of 1.5 Hz increments. This is however not the most questionable decision in regards to Barrett’s choice in parameterization.

Barrett chose to represent the frequencies using the Hertz measurement system as opposed to representing the non-prototypical to prototypical chords as frequency ratios (interval size) or cents. Cents are a fundamentally more intuitive measurement of tuning because they match our logarithmic hearing patterns. By using hertz, it is hard to get an accurate understanding of where the ‘threshold’ of C-Major lies. Simply stating that it is at 321.5 Hz means nothing in relation to the prototypical 329 Hz frequency, where as by performing the calculation for cents, the resulting value of 27.7 cents easily shows that the threshold is approximately one quarter of an equal tempered semitone different then that of the prototypical chord. Barrett also required the participants to make their identifications out loud as the experimenter recorded the responses on a sheet of paper. It seems quite apparent that there would be problems associated with this practice as results can often be skewed when participants overhear others answers. Nevertheless, this was the decision made and although unelaborated, it perhaps was simply done to better replicate the experiment conducted by Acker et al.

The intentions behind the second experiment come in two parts. First, Barrett wanted to confirm Acker et al.’s findings that musicians have enhanced discrimination in the context of a prototypical chord rather than a non-prototypical chord. Second, the experiment determined whether or not non-musicians (those receiving no formal music training) would show a similarly enhanced discrimination ability near the prototypical chord. As previously mentioned, the non-prototypical C-Major chords determined for each individual musician in the first experiment were used – being averaged and increased in frequency by 5 Hz to ensure that it would fall within the category of a C-Major chord despite not being the most preferred C-Major to some. Kuhl’s original study had been criticized for using least preferred exemplars as the non-prototype because it is often too close to the category boundary to ensure that all comparison exemplars in the discrimination task are from the same category. Barrett’s experiment however must be criticized again for its use of hertz rather than cents. ‘Padding’ the non-prototype with 5 Hz was done to avoid the criticism that Kuhl received, but as stated, hertz are not logarithmic and so the ability to discriminate an additional 5 Hz to a frequency will be reduced as the frequency is raised. In Barrett’s case, the stimuli for the non-musicians was set to 326.5 Hz. The comparison chords were synthesized in equal steps of 1.5 Hz from the prototype and non-prototype in both sharp and flat directions. For the discrimination task, subjects heard a randomised series of pairs of chords. There were 60 ‘same’ trials in which the prototype or non-prototype was paired with itself, and 60 ‘different’ trials where they were paired with one of the 6 comparison chords. Subjects judged whether the two chords were the ‘same’ or ‘different’ and made their response by clicking the mouse on one of two panels on a button box on the computer screen.

The results of the experiment revealed some promising information in the attempt to prove the warping of perceptual space near prototypical chordal centers (as in phonemic category centers). The first experiment concluded that the 50% crossover point for musicians in their ability to distinguish between a major and minor chord ranged between 320 – 322.5 Hz. To avoid the criticism that Kuhl received in his research on the perceptual magnet effect in linguistics, a 5 Hz buffer was added to this crossover point, after its averaging, resulting in a non-prototypical frequency of 326.5 Hz. The result of the second, more substantial experiment was scored within a framework of signal detection theory developed by Macmillan & Creelman. For all 10 of the non-musicians, discrimination was significantly worse when placed near the prototype than non-prototype (opposite to Acker et al.’s findings). Within the 10 musicians, there was no significant difference between discrimination around the two references, however two trends emerge in the musician’s data which might account for this non-significant finding. For 6 of the 10 musicians, discrimination is reduced near the non-prototype and for the remaining 4 musicians the opposite is true. Barrett however lists the varying musical experience of the 10 musicians and it can be seen that 4 musicians are in fact much less experienced and were even noted as not being involved with musical practices during the time of testing. It can be concluded that prototypes have an adaptive significance that can allow them to be distinguished if needed. Barrett’s aim to investigate Acker et al.’s experiment proves to be successful and quantitatively demonstrate the fluctuating property of the perceptual magnet effect in music. It is an exciting development and furthers our understanding in musical and categorical perception.

**Experiment Replication**

I was interested in exploring the performance of musically trained subjects in such a discrimination task and to determine whether these subjects are representative of the average listener’s perception of music categories as originally stated by Acker et al. In keeping with Barrett’s experiment, I included non-musicians into the second discrimination task involving the same/different representation of the absolute vs. relative non-prototypes.

I began with Barrett’s replication of Acker et al.’s experiment in which musicians were asked to provide a major/minor response to represent the chord that is played – both ascending and descending versions of a prototypical C-Major/C-Minor chord moving to a prototypical C-Minor/C-Major chord in 1.5Hz increments totalling 12 chords. In preparing for this experiment, I realized another criticism that can be made towards Barrett’s attempt. Asking participants to provide a major/minor response to a given chord diminishes the choices when in fact a chord may sound neither major nor minor. It would perhaps be more accurate if just one more option to the participants was provided so that they can determine whether the chord is major, minor or indistinguishable and this would at least provide the 50% crossover point of each participant as opposed to having to average one for the group. In any case, my interest was in replicating and providing critique rather than attempting to improve Barrett’s experiment.

In keeping with Barrett’s parameters, I used a prototypical C-Major chord described in Barrett’s paper (261.6 Hz [C]; 329 Hz [E]; 392 Hz [G]), but my chosen sample size was half that of Barrett’s; 5 musicians and 5 non-musicians. I chose to use saw tooth signals as opposed to the square waves used in Barrett’s experiment because they would produce less electronic sounding chords. I also had participants write down their responses on paper as opposed to responding out loud with the group. I felt like this was another flaw in Barrett’s experiment and doing so would allow me to organize the responses more accurately.

The second portion of the experiment would confirm Acker et al.’s findings that musicians hear non-prototypical chords as perceptual anchors (enhanced discrimination) in reference to a prototypical C-Major chord, and show how non-musicians discriminate in the context of a prototypical to non-prototypical C-Major chord. The stimuli in my experiment was set to 325.5 Hz. The comparison chords were synthesized in equal steps of 1.5 Hz from the prototype and non-prototype in both sharp and flat directions. Participants heard a randomised series of pairs of chords. There were 24 ‘same’ trials in which the prototype or non-prototype was paired with itself and 24 ‘different’ trials where the prototype or non-prototype was paired with one of the 6 comparison chords. Subjects judged whether the two chords were the ‘same’ or ‘different’ and wrote down their responses on a piece of paper provided to them.

The results of my replicated experiment matched closely the results of Barrett’s experiment. The first experiment concluded that the 50% crossover point for musicians in their ability to distinguish between a major and minor chord ranged between 320.5 Hz or 31.4 cents below 329 Hz. I also added a 5 Hz buffer to the crossover point (an 18.57 cent increase as opposed to Barrett’s 18.51 cent increase), resulting in a frequency of 325.5 Hz or 12.83 cents below 329 Hz. The 10 non-musicians had significantly worse discrimination when compared to a prototypical C-Major chord (as found in Barrett’s conclusion). Within the group of musicians, there was one ‘amateur musician’ who did exhibit an enhanced discrimination when the non-prototype reference was used, which also echoed the results found in Barrett’s experiment.

This suggests that within the category of ‘musician’, the amount of individual training in music can vary and significantly affect the performance of the individual subject on certain discrimination tasks and that this experiment is more dependent upon the nature of the subject’s prior training than with the nature of the prototype under investigation. The lesser trained musicians, which Barrett labels ‘amateur musicians’ react similarly to the non-musicians in using the prototype as a perceptual magnet whereas professional musicians use the prototype as a perceptual anchor. The prototype’s role at a given point in time seems to depend entirely upon the needs of the listener and consequently, on the amount of attention that must be paid to the prototype by the listener (attention even affects the discrimination of young infants [Jusczyk et al.]). If a lot of attention is paid to the prototype, there will be a stretching in the perceptual space (enhanced discrimination) and the prototype will be easily discriminated from similar-sounding variants of the same category.

**A module for syntactic processing in music?**

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The term ‘syntax’ was likely coined to refer to the structural organization in language but in a broader definition syntax is the organizational structure of events. Language has a very clear syntax, but many systems contain an organizational structure that can be thought of as the syntax of that system. Music, for instance, contains a clear organizational structure of events that can be looked at similarly to language. It is however well documented in linguistics that the brain performs syntactic computations for language, could the same be assumed of the brain with regards to music?

In ‘A module for syntactic processing in music’, Bigand et al. state that as linguistic syntax is rooted in the abstract computation between words, the rules that govern musical syntax instead lay their roots in the psychoacoustic properties of sound. The rules for syntactic computations in language appear to evolve from natural phenomena – abilities (and lack of) that are true for all humans and so it seems quite intuitive that the model for syntactic computations in music be derived from the natural phenomena that exist in music, which are defined as psychoacoustic properties. They determined that syntactically related events are related on a sensory level and involve only weak acoustical deviance by observing the pitch commonality values of various chords. It was observed that in tonic and dominant chords, whose succession typically form the most fundamental syntactic unit of western tonal music, the pitch commonality values were 2 times higher than less related dominant and supertonic chords.

Music syntax and psychoacoustic properties seem to be so entangled that the cognitive and psychoacoustic attempts to model musical syntax produce highly accurate accounts of musical structures for western music. Psychoacoustic models however, appear to be more frugal as they challenge the long-standing evidence for syntax-like processing in music. Cognitive components linked to musical syntax processing can overrule sensory components in music processing but these studies account for the predominance of sensory factors during early the early processing stages. A question that remains is whether or not a more abstract computation occurs beyond this sensory processing. A cognitive model for short-term memory, operating on echoic images of pitch periodicity can account for the musical functions of tones in tonal contexts. Bigand et al. suggests that this brings up a prominent issue of evaluating syntactic processing in music and observing its level of contribution. The observation is made that there is in fact only a minor contribution if any as suggested by psychoacoustic approaches. This leads to the conclusion that the cognitive model of syntactic computation may not contribute as greatly to musical syntax as it does to linguistics and understanding the processing of language.

The paper states that in order to reach a conclusion to a syntactic module for music processing, studies in neuroscience should be conducted to observe manipulations in orthogonal syntactic and acoustical outliers of various musical stimuli and confirm that these manipulations produce distinct neural signatures. There have been previous studies that evaluate neural correlations in response to a combination of musical and acoustic irregularities, but they lack sufficient evidence to conclude that the effects produced by these irregularities reflect a purely syntactic processing module. Bigand et al. notes that Koelsch and Siebel have conducted very promising studies but determining a module for musical syntax processing is still premature.

Experiment to determine whether or not there exists a perceptual magnet effect (PME) in music as it does in linguistics.

Appendix 1 Paper Provided for Experiment Responses

**PART 1:** Determine whether the chord is major or minor. Participants will hear a series of chords played for a duration of 1 second both descending and ascending, moving from a prototypical C Major chord to a prototypical C Minor chord. Identify whether the chord is major or minor by writing this appropriate response on the given line (M, m).

Descending

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_
5. \_\_\_\_\_
6. \_\_\_\_\_
7. \_\_\_\_\_
8. \_\_\_\_\_
9. \_\_\_\_\_
10. \_\_\_\_\_
11. \_\_\_\_\_
12. \_\_\_\_\_

Ascending

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_
5. \_\_\_\_\_
6. \_\_\_\_\_
7. \_\_\_\_\_
8. \_\_\_\_\_
9. \_\_\_\_\_
10. \_\_\_\_\_
11. \_\_\_\_\_
12. \_\_\_\_\_

**PART 2:** Determine whether the pairs of chords are the same or different. Participants will hear pairs of chords played successively with a 2 second interval before each set. Identify whether the two chords are the same (equal pitch) or different by writing the appropriate response on the given line (same, diff).

1. \_\_\_\_\_\_\_\_\_\_
2. \_\_\_\_\_\_\_\_\_\_
3. \_\_\_\_\_\_\_\_\_\_
4. \_\_\_\_\_\_\_\_\_\_
5. \_\_\_\_\_\_\_\_\_\_
6. \_\_\_\_\_\_\_\_\_\_
7. \_\_\_\_\_\_\_\_\_\_
8. \_\_\_\_\_\_\_\_\_\_
9. \_\_\_\_\_\_\_\_\_\_
10. \_\_\_\_\_\_\_\_\_\_
11. \_\_\_\_\_\_\_\_\_\_
12. \_\_\_\_\_\_\_\_\_\_
13. \_\_\_\_\_\_\_\_\_\_
14. \_\_\_\_\_\_\_\_\_\_
15. \_\_\_\_\_\_\_\_\_\_
16. \_\_\_\_\_\_\_\_\_\_
17. \_\_\_\_\_\_\_\_\_\_
18. \_\_\_\_\_\_\_\_\_\_
19. \_\_\_\_\_\_\_\_\_\_
20. \_\_\_\_\_\_\_\_\_\_
21. \_\_\_\_\_\_\_\_\_\_
22. \_\_\_\_\_\_\_\_\_\_
23. \_\_\_\_\_\_\_\_\_\_
24. \_\_\_\_\_\_\_\_\_\_
25. \_\_\_\_\_\_\_\_\_\_
26. \_\_\_\_\_\_\_\_\_\_
27. \_\_\_\_\_\_\_\_\_\_
28. \_\_\_\_\_\_\_\_\_\_
29. \_\_\_\_\_\_\_\_\_\_
30. \_\_\_\_\_\_\_\_\_\_
31. \_\_\_\_\_\_\_\_\_\_
32. \_\_\_\_\_\_\_\_\_\_
33. \_\_\_\_\_\_\_\_\_\_
34. \_\_\_\_\_\_\_\_\_\_
35. \_\_\_\_\_\_\_\_\_\_
36. \_\_\_\_\_\_\_\_\_\_
37. \_\_\_\_\_\_\_\_\_\_
38. \_\_\_\_\_\_\_\_\_\_
39. \_\_\_\_\_\_\_\_\_\_
40. \_\_\_\_\_\_\_\_\_\_
41. \_\_\_\_\_\_\_\_\_\_
42. \_\_\_\_\_\_\_\_\_\_

Chords and Chord Pairs Used in First Experiment Replication

Appendix 2 Chords and Pairs Used in Experiment Replication

Ascending

1. 216.600 311.500 392
2. 216.600 313.000 392
3. 216.600 315.500 392
4. 216.600 317.000 392
5. 216.600 318.500 392
6. 216.600 320.000 392
7. 216.600 321.500 392
8. 216.600 323.000 392
9. 216.600 324.500 392
10. 216.600 326.000 392
11. 216.600 327.500 392
12. 216.600 329.000 392

Descending

1. 216.600 329.000 392
2. 216.600 327.500 392
3. 216.600 326.000 392
4. 216.600 324.500 392
5. 216.600 323.000 392
6. 216.600 321.500 392
7. 216.600 320.000 392
8. 216.600 318.500 392
9. 216.600 317.000 392
10. 216.600 315.500 392
11. 216.600 313.000 392
12. 216.600 311.500 392

Randomised Pairs of Prototypical and Non-Prototypical E Frequencies for C-Major Chords

1. 324.0:329.0
2. 325.5:325.5
3. 329.0:329.0
4. 325.5:325.5
5. 329.0:329.0
6. 327.0:329.0
7. 325.5:325.5
8. 329.0:329.0
9. 325.5:332.0
10. 325.5:325.5
11. 325.5:327.5
12. 329.0:332.0
13. 329.0:329.0
14. 325.5:325.5
15. 329.0:329.0
16. 329.0:329.0
17. 329.0:324.5
18. 325.5:325.5
19. 325.5:333.5
20. 329.0:327.5
21. 329.0:329.0
22. 325.5:325.5
23. 327.0:325.5
24. 328.5:329.0
25. 329.0:330.5
26. 321.0:325.5
27. 325.5:326.0
28. 325.5:325.5
29. 328.5:325.5
30. 325.5:330.5
31. 329.0:326.0
32. 324.0:325.5
33. 329.0:329.0
34. 325.5:325.5
35. 330.0:329.0
36. 329.0:329.0
37. 330.0:325.5
38. 329.0:329.0
39. 325.5:325.5
40. 329.0:329.0
41. 322.5:325.5
42. 329.0:333.5
43. 325.5:325.5
44. 321.0:329.0
45. 329.0:329.0
46. 325.5:325.5
47. 322.5:329.0
48. 325.5:324.5