Thoughts on the Music Task- David Cremins, August 2015

In the next several paragraphs, I will assess three questions- 1) are there non-superficial reasons to believe the proposed parallels regarding the neural processing of language and music based on similar syntactic-structures in each domain?, 2) if so, how certainly can we design a task that will causally assess this claim?, and 3) what does our task look like so far? I hope this is useful, I would also be interested eventually in how well my ideas/interpretations hold up under the scrutiny of yourself, Dr. Monti, and/or a musicologist. For the moment, I am still viewing this as a work in progress, mainly to summarize for you some of the issues and justifications that have struck me most in revisiting the papers you gave to me and our experiment after about a month of inactivity. Again, I apologize for how long it has taken even to send this, it has been weighing heavily on my ~~soul~~ mind (thanks, Debby) how to get this thing, which is fairly outside my comfort zone/expertise, right. The article citations can be found in a document in our shared TMS study Dropbox.

1.

There have recently been attempts to provide formal, rule-based accounts of the phrase-structure hierarchies which may govern diatonic- think "Western"- harmonic progressions (Rohrmeier 2011). Parsing trees, found commonly in linguistics, are increasingly being used to map the interdependencies of chords in musical passages*, while simultaneously many insist that the grammatical similarities between language and music are just that— non-substantive similarities with little empirical basis. Klein and Jacobsen (2008-12) point out that not even all Western tonal music prescribes to the same harmonic rules that some scientists have equated with a sort of idiomatic musical grammar (eg. compare the rules governing jazz music with those of Mozart). Furthermore, our understanding of the "syntax" of music can be shown to be manipulated by the timbre, pitch, and dynamics of the notes, unlike in speech- so is it possible to still provide a consistent, verifiable hierarchical account of harmony, even just within the Western canon? The neuroscientific literature indicates that there is still some reason to think so.

In Fitch and Martins 2014 review, they discuss event related potential and MEG studies which link Broca's area, and the left inferior frontal gyrus (IFG) generally, to harmonic syntax, but note that the related fMRI data is as of yet unclear and occasionally conflicting. Nevertheless, it is promising to repeatedly find that chords which are predicted to be inappropriate in their harmonic context- musical violations, in short- do indeed induce measurable brain responses, usually activating an early right-anterior negativity (ERAN) (Maess 2001). Perhaps the most direct and useful evidence comes from Sammler, who in 2009 showed similar patterns of lateral activation after subjects detected both musical and linguistic syntax violations. And, in 2010, Sammler et al. carried out a lesion-comparison study which used EEG to show significantly less ERAN activation in patients with damage to left fronto-temporal regions encompassing Broca's area (inferior Brodmann's 44) compared with patients with damage in other areas or no lesions. These left IFG patients were also worse at judging the regularity or irregularity of musical passages ending with harmonically expected or unexpected chords. Although the behavioral differences observed were relatively small (an issue to be addressed in the next sections) and there still may be other regions of overlap in play, it is important to note that the most-impaired patient out of seven in the experimental group was the one who had the least amount of time pass

since the onset of their lesion lesion affecting Broca's area, indicating that, at least initially, language processing areas may play a necessary role in the detection of harmonic syntax violations, a result consistent with the idea that Broca's area may process syntax in a "domain-general way".

If the above is true, there is already, thankfully, theoretical and lab work focused on explaining how and why music and language might rely on the same regions. In 2003, Patel proposed the Shared Syntactic Integration Resource Hypothesis, outlining how even though cognitive *representations* of music and language are distinct, the hierarchically structured discrete elements which comprise each domain can still be *processed* in overlapping areas. Proof of this shared neural architecture could prove that that neural language processes are not modular, and, by extension, that even the disorders of aphasia and amusia may be connected phenomena. In a clever 2011 experiment, Hoch et al. supported Patel's theory by showing that inserting unexpected chords within a musical progression that played alongside a complex sentence interfered with participant's ability to effectively *process* linguistic syntax, but, crucially, there was no effect on the semantic *representations* of the language's meaning.

The upshot from this evidence is that even if there are still plenty of holes to be poked in the specific formalized theories that predict the existence of generative musical grammars embedded in our cognition, there is still some evidence that music and language are neurally connected. How much of this connection can be attributed directly to shared processing mechanisms in Broca's area? I believe the evidence is as of yet too mixed and sparse of strong causation, and there are too many critics, to comfortably say that the perceived syntactic parallels between the domains of musical harmony and natural language are necessarily representations of a functional cognitive reality. However, that makes it all the more crucial to design further behavioral tasks which could potentially definitively link both music and language processing to Broca's area.

*Most of the evidence and theories here are naturally over-simplified (hopefully not excessively so), but for a more in-depth explanation I would suggest Koelsch et al. from 2013- *Processing of hierarchical syntactic structure in music*. This paper describes Western tonal music as a mixture of short term, local relationships as well as a complex assortment of nested, nonlocal dependencies which stretch over long ranges of music. The Generative Syntax Model they describe also attempts at giving explicit rules for harmonic syntax creation, and there are examples of the type of stimuli manipulations (ie. transposing the ending of a phrase to make it incongruous with the initial context 50% of the time) very similar to those used in many other studies, including potentially ours. The Koelsch paper also very cleverly makes the point that, just like in natural language, most people neither possess nor require explicit structural knowledge of the underlying syntax of a phrase (eg. extensive lessons in English grammar or music theory) in order to implicitly know whether it is resolved or not.

2.

One paper that shaped my thinking a lot in both designing a behavioral task that will tap into harmonic syntax processing and understanding the necessary theory behind it is in fact the oldest of the bunch, Bigand and Pineau from 1997 (previously emailed to you). This is the earliest good example* of a scientist explaining how our seemingly inherent knowledge of musical idiom and tonal-harmonic hierarchy relates to connectionist models of cognition and theories of global versus local systems arising from studies of language. What is most important from this paper, though, is the paradigm employed, which is outlined well enough in their abstract:

"The effects of global harmonic contexts on expectancy formation were studied in a set of three experiments. Eight-chord sequences were presented to subjects. Expectations for the last chord

were varied by manipulating the harmonic context created by the first six: in one context, the last chord was part of an authentic cadence (V-I), whereas in the other, it was a fourth harmonic degree following a full cadence (I-IV). Given this change in harmonic function, the last chord was assumed to be more expected in the former context, all the other local parameters being held constant. The effect of global context on expectancy formation was supported by the fact that subjects reported a lower degree of completion for sequences ending on an unexpected chord (Experiment 1), took longer to decide whether the last chord belonged to the sequence when the last chord was unexpected (Experiment 2), and took longer to decide whether the last chord was consonant or dissonant when it was unexpected (Experiment 3). These results are discussed with reference to current models of tonal cognition."

I recorded these sequences with the help of my piano-playing friend Sophia Sun (who, if this all pans out, really deserves some credit at some point), and they are in an audio file named BigandPineau97- the "prime sequences" correspond to the less stable/unexpected I-IV ending mentioned above. I will defer to the authors for fuller explanation, but I am convinced from these experiments that keeping the relationship between the penultimate and final chord the same is necessary to ensure that the overall harmonic priming of the phrase is being tested instead of just the immediate local context. Therefore, a two-chord "target" will be used after a four-chord "cue" (chosen to account for possible time constraints while still allowing for a full progression that will well-establish the initial key and harmonic dependencies and expectancies within it).

I have made this choice also in the face of the fact that most similar studies from this century choose to manipulate only the last chord of the sequence, usually replacing the stable tonic chord with a less-stable double dominant or neapolitan sixth chord in order to induce brain reactions to this harmonic violation measurable by EEG or MEG techniques. However, these methods limit the variability of targets available to us, tend to ignore the subtleties of previous musical and cognitive theories of harmonic syntax closely attended to in the 1997 paper and others in favor of relying, as prove of their efficacy, on significant activation results, and may be partially responsible for the lack of recent convincing behavioral data (ie. musically naive subjects are bad at making conscious judgments based on just one irregular chord).

One piece of advice that may be worth taking from more recent papers, though, for example from the Sammler 2010 discussed above, is using professional software to create the musical stimuli that avoids confounds such as acoustical deviance or pitch repetition within adjacent chords— basically, many modern research teams try and ensure that participants are responding just to the musical syntactic elements and not sensory features of the sounds, like unintended deviance or similarities between chords. While these fears may be overblown (we generally learn the implicit rules of Western music by listening to real, imperfect musicians, not dry computer sounds, and successful studies in the past have not relied on these programmatic techniques, after all), it possibly presents an issue that would be easy for a reviewer to latch onto. I believe we should both read and consider Koelsch and Sammler from 2008 when time permits.

To stay within the realm of harmonic syntax and to avoid any possible confounds with musical "semantics", or the feelings elicited by different modes, I believe any stimuli should remain within the diatonic major keys (ie. avoid minor chords, even if they are often closely related from a composer's point of view). This is a point I could definitely reconsider, though.

In conclusion, there is already enough history and conflict in this line of research to make it practically impossible to attend to every variable and theory. However, with the proper pilot testing and reliance on some of the ideas from myself and many others touched upon here, we should be able to design a task which is at least as effective as any other domain-task in our experiment and those which have come before.

*Of course, this is not the earliest work which draws analogies between music and language. I'm currently watching the composer Leonard Bernstein's famous Norton series of lectures at Harvard from 1972, in which he relies heavily on the ideas of Chomsky's universal grammar to explore the language of music through the vocabulary of phonology, syntax, semantics, etc. Although these talks were given primarily for the purpose of connecting art to wider disciplines and making it more intellectually accessible to people without a deep understanding of music, I intend to watch a good deal of the series in order to better understand the original ideas which have fueled this general area of inquiry.

3.

Lastly, there's the actual work of making something with fits somewhat into the overall design of this TMS experiment. I probably do not need to outline again every detail of what we have been considering for this task (see if you still have the excel document I sent entitled "final_stimuli", please, I think it maps out the potential layout of every stage of the experiment well), except to remind that the biggest hurdle is designing two levels of difficulty in this task. Here is the part you really care about, and I am going to write it in a less-formal way, because of course some of it is still up in the air. I could only figure out how to send the audio files as MP3, and a couple other less useful formats, out of GarageBand, I hope that still allows for easy enough listening.

(Side note: I have just thought of a possible explanation for why designing this task has been so difficult and why behavioral data of this type seems to be so scarce and unconvincing. See *)

The cues = I-IV-V6/5-I (pretty standard four-chord progression familiar to anyone who has heard pop music). A ~one-second pause following the cues (which will be played more metronomically precisely and quickly in the final version in order to keep them within ~five seconds) should be assumed for now…possibly with instructions to think about the sounds which the participant just heard during this caesura?

The targets = cadences (two-chord sequences that signify the end of a musical phrase), so far just in D major but replicable in each of the 12 major keys. The cadences which work are the traditional V-I and IV-I endings, which would limit us to 24 possible combinations. However, something else like an inverted I-I sequence could work to bump that up to 36. I'll talk it over more with smarter people than myself, but it shouldn't be too difficult to have more versions of targets that will either match congruously or not with a given cue.

Another consideration = We could just have 12 versions of the same target ending (V-I cadence) but instead mix up the progression of the cues for more variety in order to hit an assumed goal of 36 unique musical trial phrases. I can't remember if there's a good reason not to do it this way besides it further limiting the uniqueness of the targets (this method would result in the same cadence being heard 12 times when taking into account both levels of difficulty and incorrect and correct matchings, if my understanding is correct, but never with the same cue). The argument could be made that since we already agreed that the independent factor in this domain is the cue and not the target, unlike the others, this might even be a more internally consistent way to do it.

First difficulty level:

correct pairing = the cue and target are in the same key. For an example, listen to “Dmaj-Dmaj”. It’s an older example so the target is four-chords long, but it gets the point across.

incorrect pairing = the cue key shares no common notes, the difference should be noticeable to most listeners, despite the fact that the two ending chords are always going to sound correct, even pretty, when listened to just by themselves (will have to train against that). ex. - “Dflatmaj-Dmaj(IV-I)”

Second difficulty level:

correct pairing = the cue and the target are in related keys that share common stable chords. not as theoretically easy. ex. - “Gmaj-Dmaj(IV-I)”

incorrect pairing = the target chords do appear in the cue key but are not harmonically stable elements of it. this is probably the most difficult case to design/ascertain. What I have so far as an example may require some prerequisite knowledge because of its relative subtlety. ex. - “Bflatmaj-Dmaj(V-I)”

The potential questions = Was the phrase initiated by the cue chords completed by the target chords? or Were the target chords (harmonically) congruous with the preceding cue chords?

* It would be consistent with Patel’s theory that a normal, naive musical listener could both exhibit the anticipated EEG ERAN response when exposed to harmonically unexpected chords because of a disruption of what Broca’s area is expecting to be *processed,* and still remain consciously unaware of such a temporary change in brain state because at the *representational* level we are used to being exposed to new ideas, even new grammars in music, much more so than in language, because it is a non-literal mode of expression. There are even of course large subsets of musical listeners who seek out and appreciate creative compositions that defy expectation, even if they are modern, atonal, or dissonant works that are completely obviously “not correct” in the Western musical idiom— it is far less likely for people to appreciate works of literature which completely discard the rules of normal, intelligible syntax (except possibly with Joyce or some poets). I believe it’s possible that language and music rely on many or all of the same neural structures in order to be processed, but what separates the domains in our everyday experience is our willingness to “go with the flow” with the inventiveness of musical syntax more. I am sure I am not the first person to think of this and there is much more thinking to be done on it, but it strikes me now that this might explain how subjects with no lesions in the left IFG can bolster the robustness of brain wave monitoring data and still barely perform at above chance level when consciously attending to whether musical passages are “irregular” or not.

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Please comment back/ask for clarification etc. when possible. I’ll make a point in the coming next semester to always leave some time for this project if you need. If in the end it is better to rely on either asking other researchers to replicate or use their stimuli, or relying upon the expertise of someone else entirely, I would not be bothered by that. My main goals this summer were to learn a lot and be useful in some capacities in advancing something, and I’m relatively satisfied in both those “domains” as long as you UCLA folks are! Thank you for reading this much :)