**The Melodicon: Representing Melodic Relationships Using Network Science Methods**

**Abstract**

Semantic memory is represented as networks of words and their defining linguistic features. In semantic networks, related words are represented “closer” to each other than unrelated words, reflected in higher relatedness judgements and faster reaction times. While much research has investigated cognition underlying improvisation, the nature of improvisers’ knowledge structure has not been characterized. The current study examined whether network science can model the relationships between melodic sequences in improvised music. Using melodic sequences extracted from a large corpus of transcribed jazz improvisations, we sought evidence for melodic networks by asking participants to judge the relatedness of sequence pairs. We found that as distance increased, participants judged melodic sequences as less related. Moreover, the relationship between distance and reaction time was quadratic: participants slowed in RT up to distance four, then were quicker, a parallel finding to research in language. This study provides preliminary evidence for the existence of a melodic network, akin to semantic networks in language.

**The Melodicon: Representing Melodic Relationships Using Network Science Methods**

<< There will be a verbose and insightful introduction section here >>

**Method**

**Participants**

62 participants (30 men, 32 women; mean age 25.9 (*SD* = 8.38)) were recruited using the online study recruitment platform Prolific, filtering to individuals who lived in the US and Europe with high proficiency in English. 30 of these participants were specifically recruited as musicians, using the filtering criterion of having played an instrument for 5 years or more. 2 participants were excluded from analysis due to low-quality data; our final sample consisted of 27 musicians (defined as individuals who currently play an instrument) and 31 non-musicians (individuals who do not currently play an instrument). Participants received $9 USD/hour via Prolific’s payment system.

**Materials**

***Network calculation.*** Our network was calculated from the Weimar Jazz Database (WJD; Pfleiderer, 2017). The WJD corpus is a large collection of 456 annotated improvisation recordings and transcriptions by expert jazz musicians (e.g. Charlie Parker, John Coltrane, Miles Davis). << Insert technical details on how this was accomplished by James >>. We converted the WJD to a network by considering each 5-note sequence a “node” and continuations to other sequences as “edges.” We then calculated sematic distances by considering the number of “steps” between nodes and created samples of pairs with distances from 1-20.

***Stimuli.*** The 5-note sequence pairs calculated from the network were converted into MIDI format played with a piano sample via MATLAB, then written to WAV files using Winamp v5.8. Each pair was presented using one audio file at a tempo of 3 notes/second with an arrhythmic 2-second pause between the sequences (making each stimulus 5 seconds long). Stimuli were presented for distances 1, 2, 3, 4, 6, 10, and 20.

***Melodic relatedness task.*** We adapted the Semantic Distance Task (SDT; Kenett, Levi, Anaki, & Faust, 2017) for use with the melodic pairs. The task consisted of 7 conditions (1-, 2-, 3-, 4-, 6-, 10-, and 20-step distances), each containing 40 pairs. After listening to each pair, participants made a binary (yes/no) relatedness judgement as a response to the prompt “Are these sequences related?”. We considered the pairs for distances 1-4 as a-priori related, as these pairs contained overlapping note content (e.g. pairs with a distance of 1 only differed by one note with a 4-note overlap, pairs with a distance of 4 differed by four notes with a 1-note overlap).

***Survey.*** We created a survey to collect information about music listening habits and musical background, including items specifically related to jazz listening and experience improvising (Appendix 1). Several of these items, primarily related to musical training and education, were collected for exploratory analysis prior to conducting future studies that target professional musicians, but we report effects of music listening and musicianship here.

**Procedure**

Participants registered for the study using Prolific and were administered the tasks online following collection of informed consent via Qualtrics. Participants were instructed to complete the study in a quiet location, wearing headphones, and on a laptop or desktop computer that was connected to the Internet (the study would not run on a tablet or mobile device). The melodic relatedness task was administered using Pavlovia. Participants were given instructions, permitted to adjust their volume to a comfortable level, and provided 5 practice examples of the task. In the melodic relatedness task, each trial began with an 80 ms fixation cross appearing in the center of the screen. Next, the stimulus pair played for 5 s. Following the presentation of the stimulus pair, the participant decided whether the melodies were related to each other by pressing the “s” key to indicate “yes”, or the “k” key to indicate “no”. Once the participant pressed the key, the next trial was immediately initiated. Stimulus pairs were randomly presented in blocks of 50, with the opportunity to take a break between each block. This task took between 40 – 50 minutes to complete. After completion of the melodic relatedness task, participants were redirected to Qualtrics to complete the musical background survey. After completing the survey, participants were redirected back to Prolific to indicate study completion and eligibility for payment.

**Results**

***Melodic similarity analysis.*** Visual inspection of the mean responses (Fig. 1) revealed that, contrary to our initial predictions, on average participants judged the distance 20 pairs as related in 64.4% of trials, with all other distances being judged as expected. We believe that this finding warrants further investigation, i.e. a follow-up study that presents stimuli between 10- and 20- steps apart. We excluded trials with distance-20 stimuli from our main response and reaction time analyses and conducted a brief melodic similarity analysis to determine whether distance-20 stimulus pairs shared melodic content. Hannah needs to consult Martin on what the contour column means and then add like three sentences here.

***Responses.*** Responses to the melodic relatedness task, which were binary, were analyzed using logistic regression via the glm() function in R *v.3.5.1.* To determine the most predictive model, musician status and music listening parameters taken from the survey were serially added to an intercept-only model in the order shown using ANOVA model comparisons. Many survey questions about musical training and experience were only presented to participants who were musicians, so these variables were examined in a separate exploratory analysis that only included these participants.

A logistic regression analysis with five predictors (*distance, musician status, distance\*musician status, hours a week spent listening to music, hours a week spent listening to jazz*) tested whether participants judged pairs of melodic sequences as related at distances 1, 2, 3, 4, 6, and 10 (removing trials where they judged the distance 20 stimuli). Overall, this model provided a significantly better fit than an intercept-only model, χ2 (5, *N* = 15248) = 691.17, *p* < .001. The model correctly classified approximately 57.6% of trials.

Controlling for other variables in the model, a 1-unit increase in distance decreased the odds a participant would judge a pair as related by a factor of .86, *z* = -18.71, *p* < .001, 95% CI [.85, .88]. Holding other variables constant, each additional self-reported hour spent listening to music increased the odds a participant would judge a pair as related by a factor of 1.01, *z* = 8.32, *p* < .001, 95% CI [1.005, 1.008]. Holding other variables constant, each additional self-reported hour spent listening specifically to jazz decreased the odds a participant would judge a pair as related by a factor of .97, *z* = -4.89, *p* < .001, 95% CI [.96, .98]. Controlling for other variables in the model, whether or not the participant was a musician was not reliably associated with the relatedness judgement, OR = 1.07, *z* = 1.05, *p* = .29, 95% CI [.96, .98]. The interaction between musicianship and distance was not significant, *z* = 1.91, *p* = .056. Taken together, these results indicate that for distances prior to 10, relatedness judgements decrease with increases in distance. Additionally, music listening habits are a more important factor in these judgements than musicianship at lower distances.

***Musician responses.*** For participants who were musicians, information on their musical background was collected. As above, we analyzed these traits (*primary instrument proficiency, proficiency at improvising, hours currently spent playing music per week, hours spent playing jazz per week, percentage of playing time spent improvising*) for distances below 10. For distances 1-10 in the musician group, a logistic regression with these predictors, controlling for distance, tested how the musician group made relatedness judgements. This model provided a significantly better fit than one that just included distance, χ2 (5, *N* = 7109) = 128.89, *p* < .001. Holding other variables constant, each one-unit increase in self-rated proficiency on their primary instrument increased the odds a participant would judge a pair as related by a factor of 1.10, *z* = 5.31, *p* < .001, 95% CI [1.06, 1.14]. Holding other variables constant, each one-unit increase in self-rated proficiency in improvisation decreased the odds a participant would judge a pair as related by a factor of .93, *z* = -3.43, *p* < .001, 95% CI [.89, .97]. Holding other variables constant, each one-hour increase in hours spent playing music per week decreased the odds a participant would judge a pair as related by a factor of .95, *z* = -5.82, *p* < .001, 95% CI [.93, .97]. Holding other variables constant, each one-hour increase in hours spent improvising per week increased the odds a participant would judge a pair as related by a factor of 1.17, *z* = 8.65, *p* < .001, 95% CI [1.13, 1.21]. Percentage of total playing time dedicated to improvising was not significantly related to the relatedness judgement, OR = .99, *z* = -.69, *p* = .49.

***Reaction time.*** As in the language studies conducted by Kenett and colleagues (2017), prior to examining the reaction time data, trials were excluded from analysis if they were “incorrect” and did not align with whether the stimulus pair actually shared notes. For distances 1-4, trials with a response of “no” were excluded from the reaction time analysis, while for distances 6 and 10, “yes” trials were excluded.

Inspection of the reaction time data revealed a likely quadratic relationship between distance and reaction time. A quadratic regression was performed to quantify the relationship between distance and reaction time with the added predictors musician status, hours per week spent listening to music, and hours per week spent listening to jazz. A quadratic model including these predictors fit the data significantly better than a linear model, *F*(5, 8905) = 33.1, *p* < .001, PRE = .018. Analysis of individual predictors revealed that I have no idea how to report this model, help.

lm(formula = RT ~ distance + distancesq + musicianYN + hoursWeekListen +

hoursWeekListenJazz, data = masterCorrectNo20)

Omnibus ANOVA

SS df MS EtaSq F p

Model 71.503 5 14.301 0.018 33.103 0

Error 3846.990 8905 0.432

Corr Total 3918.493 8910 0.440

RMSE AdjEtaSq

0.657 0.018

Coefficients

Est StErr t SSR(3) EtaSq tol CI\_2.5 CI\_97.5 p

(Intercept) 1.654 0.023 70.599 2153.217 0.359 NA 1.608 1.700 0

distance 0.035 0.010 3.490 5.263 0.001 0.053 0.015 0.054 0

distancesq -0.004 0.001 -4.109 7.292 0.002 0.053 -0.005 -0.002 0

musicianYNNonmusicians -0.063 0.015 -4.310 8.025 0.002 0.911 -0.092 -0.034 0

hoursWeekListen 0.001 0.000 4.321 8.067 0.002 0.923 0.001 0.002 0

hoursWeekListenJazz 0.021 0.003 7.364 23.424 0.006 0.853 0.015 0.026 0

**Discussion**

<< Equally verbose and compelling discussion section here >>

References

Figures

Chart

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***Figure 1.*** Plot of mean responses (y-axis) against distance (x-axis) for the melodic relatedness task, including distance 20 trials.

***Figure 2.*** Will be a really cool plot of the logistic regression fit, excluding distance 20 trials.

***Chart

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***Figure 3.*** Plot of quadratic fit of reaction time (y-axis) against distance (x-axis) for the melodic relatedness task, grouped by musician status, excluding distance-20 trials.

Appendix

\*\*\*Survey

\*\*\*Task repo

\*\*\*Link to github repo? Make an open science framework repo? Both?