Recognition Memory for Melody

Gabriel Riegner

University of Southern California
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Dr. Assal Habibi, Advisor
Dr. Irving Biederman, Committee Member

Abstract

Musical melodies are built from tones structured in time; and through general organizing principles, tones within a melody fall into hierarchies of perceived stability known as scales. Mental representations of tonal hierarchies are learned implicitly through passive exposure to music and explicitly through music training. Musical experience helps internalize the statistics of tonal systems, and since the crucial purpose of memory is to generate predictions, it follows that learning predictable tonal structures would improve domain-specific memory sensitivity.

This study manipulated these tonal structures by presenting 53 participants with unfamiliar tonal and atonal melodies played on *cello* and *oboe* and subsequently tested recognition memory on a series of *new* and *old* melodies presented on *piano*. Observers decided *new* or *old* based on the strength of their memory and indicated if they recollected a source detail (*cello* or *oboe*) from the first presentation. Post hoc measures of individual differences in musical experience (Goldsmiths Musical Sophistication Index) were used to classify participants into musician and nonmusician groups.

Recognition memory can be dissociated into two component memory processes as theorized by the dual-process model – a signal detection process where memory sensitivity depends on the strength of its familiarity and a source memory process that allows for the recollection of contextual information associated with the memory. Signal detection theory was used to measure familiarity while accounting for bias in the decision process, and the proportion of source hits (the melody and the instrument were correctly classified) was used a proxy for recollection.

The results show that active musical experience has specific positive effects on familiarity and not recollection. Conversely, tonality specifically improves recollection and not familiarity. In addition, since there are strong assumptions underlying these dual-process model measures, a proof of concept analysis shows that the data-generating process for recognition of melodies yields the same empirical receiver operating characteristic (ROC) curves as observed in other studies of recognition memory. In sum, this study shows a double dissociation between two memory processes subserving recollection of melodies, each independently sensitive to changes in tonality and musical experience.

Introduction

Musical melodies are built on simple elements yet create rich perceptions. Music, like all auditory stimuli, unfolds over time. Melodies engage a broad set of sensory and perceptual processes that help structure the relationships between tones over time. An example is the perception of tonal hierarchies—certain musical tones are more prominent, stable, and structurally significant than others. Tonal hierarchies likely have consequences on the formation of stable mental representation and subsequent memory retrieval. Thus, the tonal structure of music is of considerable interest for recognition memory research.

Tonality

The basic perceptual unit of a melody is the tone. Tones are composed from a set of simple acoustic features—frequency, onset, intensity, and timbre (Griffiths, 2003). Complex acoustic features arise from patterns of simple features as over time. The relationships between individual tones form the basis of musical processing and contribute to the encoding and recognition of melodies. Tonal hierarchies are internalized through hearing the relationships between tones in the environment and building increasingly complex mental representations of how tones are regularly organized into melodies. Listening to music is a complex task that includes the processing of contour (direction of pitch changes in a melody), interval (distance between two successive tones), and tonality (recognition of a particular scale in which a melody is written) (Peretz and Coltheart, 2003).

Tonal melodies establish a hierarchy of tones. They are an example of a highly structured system built around a limited number of elements. The Western tonal system is structured around a set of twelve tones, from which a subset of seven tones are used to create a scale. Hierarchies of functional importance exist among tones of a given scale (Tillmann et al., 2003), such that tones of the first, fourth, and fifth scale degrees are the most stable and come first in the hierarchy. The remaining scale tones are less related to the tonal center, and non-scale tones are the least related. Thus, every tone within a melody has a well-defined level of perceived stability with respect to these reference tones. This tonal hierarchal organization facilitates perception and memory by creating probabilistic expectancies, such that unstable tones resolve to stable tones (Peretz and Coltheart, 2003).

To the contrary, atonal music ignores the rules that govern tonality. An atonal melody is organized in a way to establish no hierarchy between pitches. Rather than writing a melody from a subset of seven tones (tonal music), the composer intentionally avoids anything that suggests tonality by sampling any one of the twelve musical tones seemly at random. There exists no tonal center, and thus no reference to a hierarchy between tones. The main idea is that atonal melodies do not allow for forming predictions on where that melody will lead.

Expectancy and memory

Expectancy is defined as the anticipation of upcoming information based on past and current experience (Schmuckler, 1997). Since music unfolds over time, the ability to predict what comes next in a musical melody is fundamental to its perception. Tonal music, based on a well-defined hierarchical structure, allows listeners to develop expectations about what tones will follow others. It is yet unknown what the impact is of tonality on expectancy formation for on-going musical processing and subsequent memory retrieval.

Some scholars have made the direct link between expectancy and memory, arguing that the crucial purpose of memory is to generate predictions based on experience (Hawkins and Blakeslee, 2005; Jones and Pashler, 2007). See *Albouy et al., 2013; Halpern and Bartlett, 2010; Schulze and Dowling, 2012* for a review of how expectancy impacts specifically musical memories. Overall, this work demonstrates that predictable tonal structures improve memory for melodies.

Passive exposure to music

From a psychological perspective, the hierarchical organization of a scale creates central reference tones which anchor other extraneous tones, creating expectancies and facilitating memory formation. The Western tonal system is built from a restricted set of tones, which always depend on the established scale. Through repeated exposure to music, listeners implicitly develop mental representations of these regularities (Krumhansl and Cuddy, 2010). Although scale structure differs from culture to culture, all musical scales are organized around focal tones and afford the building of tonal hierarchies (Balzano, 1982). Though tonal encoding seems to exploit musical predispositions—infants show enhanced processing for tonal scales (Trehub et al., 1999)—there are inevitably affects of experience and culture-specific schemata. The Western tonal system embodies strong regularities to which listeners become implicitly sensitive by mere exposure (Tillmann et al., 2003). Just as in language, where learners acquire passive knowledge of the systematic structures of their native language, we implicitly learn the structure of the musical systems.

Active exposure to music

Though musical experience is implicit, musical proficiency is highly variable across the population. Active exposure to music is distributed broadly, with musicians being the ideal model to investigate effects of experience on musical processing and subsequent memory performance. More specifically, auditory processing seems to be adaptive and subject to plastic changes through active exposure to music (Schlaug, 2003). Examples include enhanced frequency and temporal discrimination and decoding of speech prosody (Lima and Castro, 2011; Musacchia et al., 2008). There is also evidence that music training can influence brain plasticity as shown by functional differences in auditory brain areas (Habibi et al., 2016; Lappe et al., 2008), as well as structural changes (Hyde et al., 2009). However, the degree to which this experience advantage extends to more distant aspects of cognition, such as episodic memory, is not yet clear.

For long-term memory tasks, musicians generally perform better than nonmusicians in auditory learning and recall (Cohen et al., 2011; Franklin et al., 2008; Ho et al., 2003; Jakobson et al., 2008; Roden et al., 2012; Taylor and Dewhurst, 2017). However, these findings are not always reproducible (Halpern and Bartlett, 2010; Schiavio and Timmers, 2016). The differences between musicians and nonmusicians in recognition memory tasks varies as a function of stimulus type—melodic, verbal, or visual. A meta-analysis study on musical experience and memory suggests that musicians have better recognition memory for music than nonmusicians (Talamini et al., 2017), though they make clear that further studies are needed to define precisely what, within the broad context of recognition memory, shows experience-related plasticity.

Recognition memory

The dual-process model for recognition memory assumes that familiarity and recollection are two memory processes that underlie the ability to recognize an item as having been previously encountered (Jacoby, 1991; Mandler, 1980; Yonelinas, 2002). At retrieval, it is typical to first recognize *that* an item has been presented before, and second recognize *what* that item was—familiarity then recollection. Thus, familiarity is a fast process that involves the retrieval of information about the item per se but lacks any contextual information. Recollection is a slower process that involves retrieval of associated contextual information (Wixted et al., 2010; Yonelinas, 2002). When recollection succeeds, it can be experimentally characterized by high accuracy and high confidence; but when it fails, the accuracy and confidence depend on the strength of the familiarity signal. Assuming that recollection either occurs or does not, that it is categorical, is the basis for the dual-process model (Yonelinas, 1994). In music cognition research, no study has isolated parameter estimates of familiarity and recollection when considering the effects of tonality and musical experience.

Hypotheses

The aim of the first experiment is to determine whether expectancies generated by tonal melodies influence recognition memory and whether active exposure to music further improves memory performance. The general prediction is that memory accuracy would be better for melodies that respected musical hierarchies (tonal sequences) than for those that did not (atonal sequences). Likewise, accuracy would be higher for musicians compared to nonmusicians.

The next objective is to explore whether the independent variables, tonality and musicality, have specific effects on performance for two distinct recognition memory tests: 1. Accuracy for simple *old*/*new* recognition judgments (familiarity) and 2. Accuracy for more complex source memory judgments (recollection). Tonality is a manipulation of how a melody is composed—it is either tonal by establishing tonal hierarchies or atonal by avoiding tonal hierarchies. Musicality is a quality of the listener, measured by an survey of active musical experience.

The aim of the second experiment is to determine parameter estimates for familiarity and recollection. Under the assumption that recognition memory can be subdivided into two component processes, we predict that the above measures of 1. simple *old/new* judgments and 2. complex source judgments, test functionally distinct memory processes—familiarity and recollection respectively. This hypothesis is consistent with the dual-process model of recognition memory (Yonelinas, 2002).

Methods

Participants

Fifty-three college undergraduates were recruited from the experimental participant pool at the University of Southern California. Participants included 32 females and 21 males between the ages of 17 and 27 (mean age = 20.4). All but five participants had some degree of musical training: voice, piano, violin, guitar, percussion, etc. Critically, there were no experienced *cello* or *oboe* players as the experimental stimuli were recorded on these instruments. Likewise, everyone came from a background where they were primarily exposed to Western tonal music. They gave their informed consent according to the University's institutional review board and received course credit for completing the experiment.

Materials and design

Participants were asked to study a series of melodies for a later memory test. The melody pool was drawn from 200 five-second single-note melodies composed in a range of different major and minor keys, using a variety of rhythms, melodic contours, and articulation styles. All melodies were newly composed by Bruce Adolphe to be unfamiliar to the listeners and free from specific memory associations. Importantly, half of the melodies used were tonal while the other half were atonal. The notation software *Sibelius* was used to generate synthesized *oboe*, *cello*, and *piano* audio files. The experiment was run with *Matlab* and the *Psychophysics toolbox*. After the memory experiment, the *Goldsmiths Musical Sophistication Index* (Gold-MSI) questionnaire was administered—a psychometric construct that can refer to musical expertise, achievements, and other relevant music-related experience (Levitin, 2012; Müllensiefen et al., 2014). Using a mean split of the Gold-MSI scores, participants were placed into two groups: musicians (N=25) and nonmusicians (N=23).

Procedure

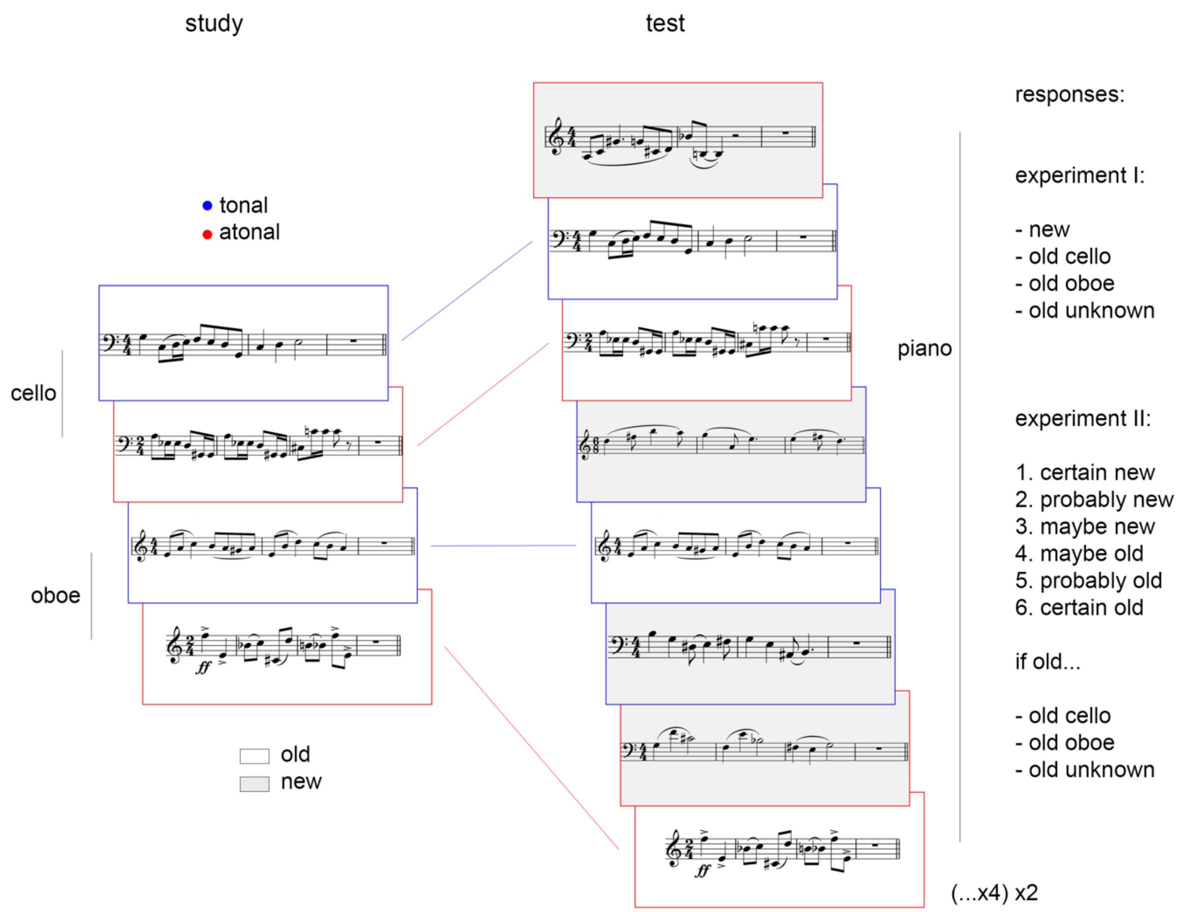

Figure. 1. Experimental procedure. Melodies were presented using a standard recognition memory test, with a study phase and a subsequent test phase.

Experiment I

Thirty-two novel melodies were presented during the study phase on either a *cello* or *oboe*. On a later recognition test, participants made an *old/new* decision for sixty-four melodies, half *old* and half *new*. To add a source-memory component, melodies were presented in a source-neutral fashion, all melodies were played on *piano*, and participants were asked to indicate if they could recollect the original instrument. After each melody, participants indicated if it was 1. *new* 2. *old cello* 3. *old oboe* or 4. *old unknown*? This task tests the ability to recognize *old* from *new* melodies as well as the ability to recollect the source detail (instrument) associated with the melody presented during the study phase. The option to respond *old unknown* helped to minimize guessing.

Experiment II

To dissociate familiarity from recollection, we needed parallel data that compared the relationship between confidence expressed in a recognition decision and source accuracy for that memory decision. Under that rationale, an additional three participants were tested on a paradigm very similar to Experiment I. During the test phase, each observer responded to 128 old and new melodies, but this time they gave a graded confidence judgement on their certainty that the melodies were *new* or *old*. Additionally, if they answered *old*, they made an associative source judgement for that decision— *old cello*, *old oboe*, *old unknown*.

Dependent measures

Detection theory

The signal detection model reflects how melodies are internally represented and describes how the decision process for categorizing a melody as *new* or *old*. This methodological tool was developed from perception research for separating response bias from signal detection (Macmillan and Creelman, 2004). It informs researchers whether a manipulation truly influenced memory or merely the bias for responding *old*.

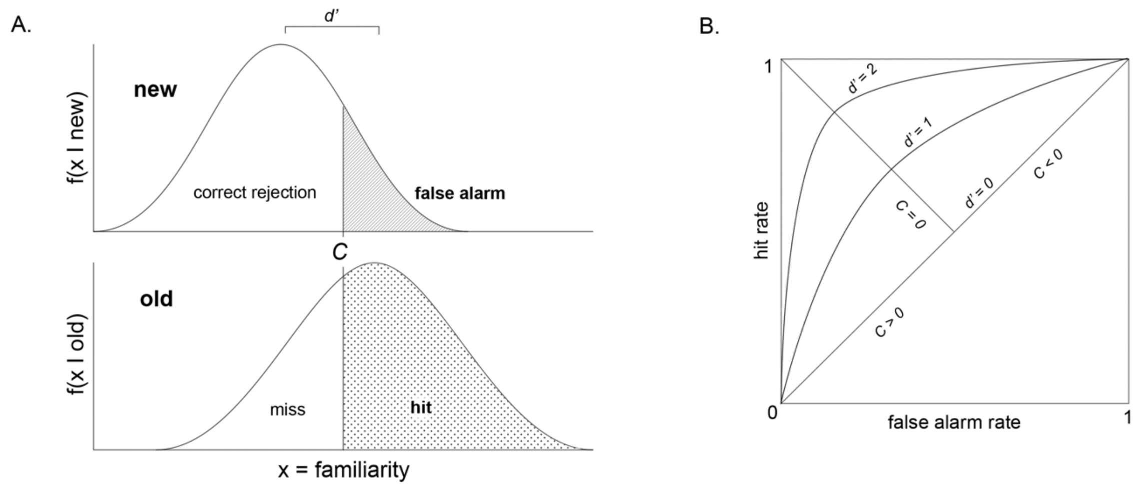

Figure 2. Detection theory

A. Theoretical memory distributions and the decision space for *new* and *old* melodies. The top curve shows an example distribution of memory strength or familiarity for *new* melodies. Decisions above the arbitrary criterion (*C*) lead to false alarms, those below to correct rejections. The lower curve shows a distribution of memory strength for *old* melodies where values above the criterion lead to hits, and those below to misses. Recognition memory sensitivity in the decision space (*d'*) is the difference between the means of the two distributions.

B. Receiver operating characteristic (ROC) curves across different memory sensitivity thresholds, *d'*. The chance line (major diagonal) is where *d'*= 0. An unbiased criterion (minor diagonal) is where $c = 0$. Negative c values indicate a bias towards an *old* decision, while positive c values indicate a bias towards a *new* decision. Note that SDT assumes a perfectly symmetrical ROC curve.

Familiarity continuum

Detection theory infers that participants are basing their memory judgments on familiarity. All melodies have some level of pre-experimental familiarity, based on perceptual features, and there is some variability from one melody to the next, so familiarity can be described by a normal distribution. Being presented with novel melodies in the study phase temporarily increases the familiarity of those melodies, which has the effect of shifting the distribution to the right. So, Fig. 2 (A) represents a hypothetical memory distribution during testing—the leftward distribution represents non-studied items, and the rightward represents studied items. It reveals the separation between the means of the non-studied (*new*) and studied (*old*) distributions and indicates how well participants can discriminate *new* from *old*.

Index of sensitivity (*d'*)

High sensitivity refers to good ability to discriminate, and low sensitivity to poor ability. Such a measure should increase when either hit rates increase or when false alarm rates decrease. The measure is *d'* and uses the normal-distribution *z*-transformation: $d' = z(H) - z(FA)$. Empirical *d'* measures for recognition memory typically correspond to values between 0.5 and 2.5 (Macmillan and Creelman, 2004). So, *d'* is a bias-free sensitivity index and treated as a proxy for memory performance.

Response bias (*c*)

Response bias measures a participant's tilt toward one response or the other—a positive bias is a tendency to say *new*, whereas a negative bias is a tendency to say *old*. It is assumed that the participant establishes a criterion at some point on a relevant internal dimension and uses it to partition the decision space into *new* and *old*. The measure for response bias is *c*: $c = -\frac{1}{2} * [z(H) + z(FA)]$.

Empirical ROCs

If a participant in a memory experiment produces a (false alarm, hit) pair that lies on a particular implied ROC, that observer should be able to display any other (false alarm, hit) pair on the same curve. However, this is typically not what recognition memory data suggest. In recognition memory experiments, observers can make graded reports about the degree of their experience by setting multiple criteria simultaneously. Participants judge an item as *new* or *old* and grade the confidence of each response.

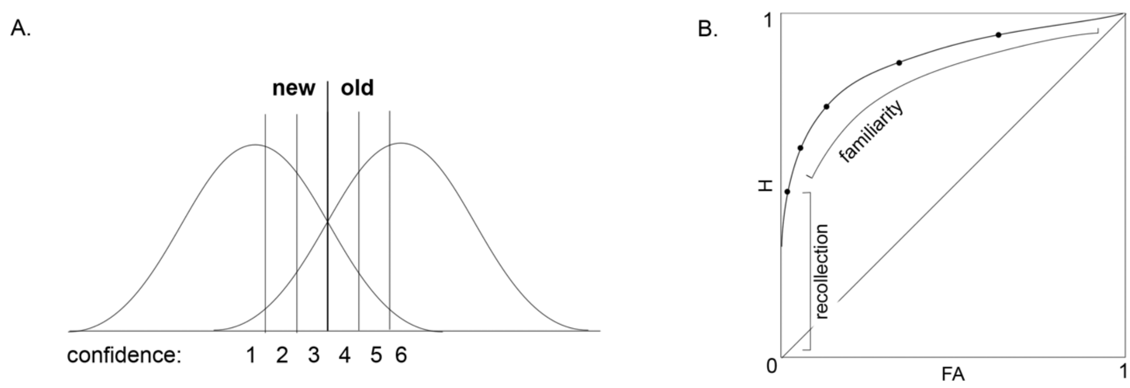

Figure 3. Empirical ROC curve

A. The detection theory model. It is assumed that participants use a different criterion for each confidence rating category. The probability of a hit and false alarm in each confidence bin is then calculated, and these values are incrementally summed to yield the points on the empirical ROC.

B. Empirical ROC curve from plotting false alarm rates against hit rates with rising endorsement of the standard response class *old*. Note that unlike the symmetrical ROC curve predicted by SDT, studies of recognition memory typically produce skewed ROC curves (Yonelinas, 1994). The left end of the curve is shifted upward, resulting in an asymmetrical function. A dual-process model (Mandler, 1980) suggests that both familiarity and recollection contribute to a recognition decision. In ROC space, the intercept provides a measure of recollection whereas the degree of curvilinearity provides a measure of familiarity.

Measures of multiple processes

With confidence judgments, empirical ROCs provide a complete picture of recognition memory. Unlike what is predicted by detection theory, recognition memory experiments produce data where changes in response bias (confidence judgments) show corresponding changes in memory sensitivity. Specifically, high-confidence responses have a higher hit rate than predicted by detection theory with no influence on the false-alarm rate (Yonelinas, 1994). To account for this there must be a separate internal parameter, apart from familiarity, influencing high confidence *old* responses. Many suggest a separate recollection process contributes to performance on standard memory tasks (Mandler, 1980; Yonelinas, 2002; Yonelinas and Parks, 2007). When recollection occurs, it is characterized by high confidence and high accuracy; when it fails, the confidence and accuracy of the decision depend on the strength of the familiarity signal (Wixted et al., 2010).

Source memory

Recollection is unique in that it involves remembering specific features about the episode in which the item (or melody) was encountered, whereas familiarity is largely devoid of source detail. Therefore, a source memory task isolates recollection to reveal not only that an item was studied but also contains content-specific information about the presentation. This is operationalized as stimulus-specific physical features—i.e., remembering that a melody, now played on the *piano*, was originally played on the *cello*.

Results

A threshold of $p < 0.05$ was used to determine statistical significance. Effect sizes are reported using Pearson's r, Cohen's d, and *Eta* squared. Error bars indicate standard error of the mean.

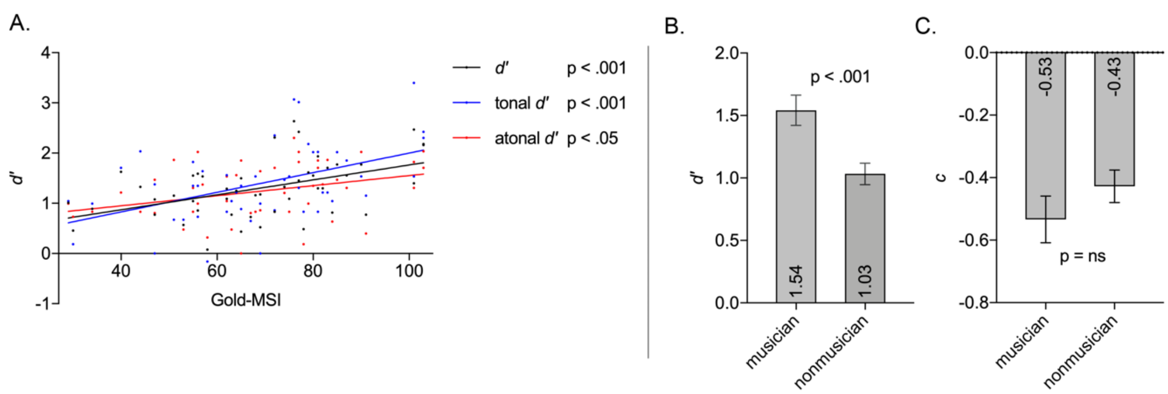

Figure 4. Musical experience and memory performance

A. Correlation between memory sensitivity (d') (range = 0.08 – 2.64) and musician experience indexed by the Gold-MSI questionnaire (range = 30 – 103). For all melodies, there was a significant positive correlation between musical experience and memory sensitivity ($p = 0.0007$, $r = 0.474$). For only tonal melodies, there was a significant positive correlation between musical experience and memory sensitivity ($p < 0.0007$, $r = 0.472$). For only atonal melodies, there was a moderate though significant positive correlation between musical experience and memory sensitivity ($p = 0.0223$, $r = 0.329$).

A mean-split of the Gold-MSI index (mean = 68.70, SD = 18.36) was used to separate participants into two groups: musicians (N = 25, mean Gold-MSI = 82.8, SD = 10.29) and nonmusicians (N = 23, mean = 53.39, SD = 11.57).

B. An independent samples *t*-test was used to determine the level of difference between memory sensitivity (*d'*) for musicians and nonmusicians. There was a significant difference between the music group (mean = 1.54, SD = 0.60) and the nonmusic group (mean = 1.03, SD = .41)—($t(42.46) = 3.43$, $p = 0.0007$, $d = 1.01$).

C. An independent samples *t*-test was used to determine the level of difference between response bias (*c*) for musicians and nonmusicians. There was a non-significant difference between the music group (mean = -0.53, SD = 0.37) and nonmusic group (mean = -0.43, SD = 0.23)—($t(42.07) = 1.17$, $p = 0.2489$, $d = 0.31$). This indicates that both groups had a slightly liberal bias towards an *old* recognition decision.

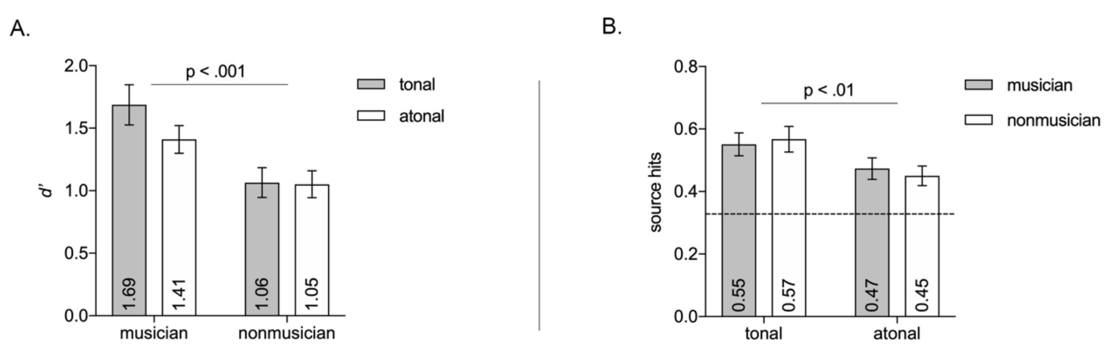

Figure 5. Parameter estimates of familiarity and recollection

A. As in Fig. 5 (B), there is an effect of musicality on memory sensitivity (*d'*), but does that effect differ across tonality? Memory sensitivity mean scores were compared across a 2(musician vs nonmusicians) x 2(tonal vs atonal) ANOVA to test the interaction between musicality and tonality. There was a main effect of musicality on *d'* (F (1, 92) = 14.82, p = .0002, $\eta^2 = 0.161$) and no effect of tonality or interaction between levels.

B. For every *old* response there were three options to identify the source attribute—either *cello*, *oboe*, or *unknown*. Source accuracy, measured as percent correct, were compared across a 2 (tonal vs atonal) x 2(musician vs nonmusicians) ANOVA. There was a main effect of tonality on the percent of correct source hits (chance levels .33) (F (1, 92) = 7.265, p = .0084, $\eta^2 = 0.079$) and no effect of musicality or interaction between levels.

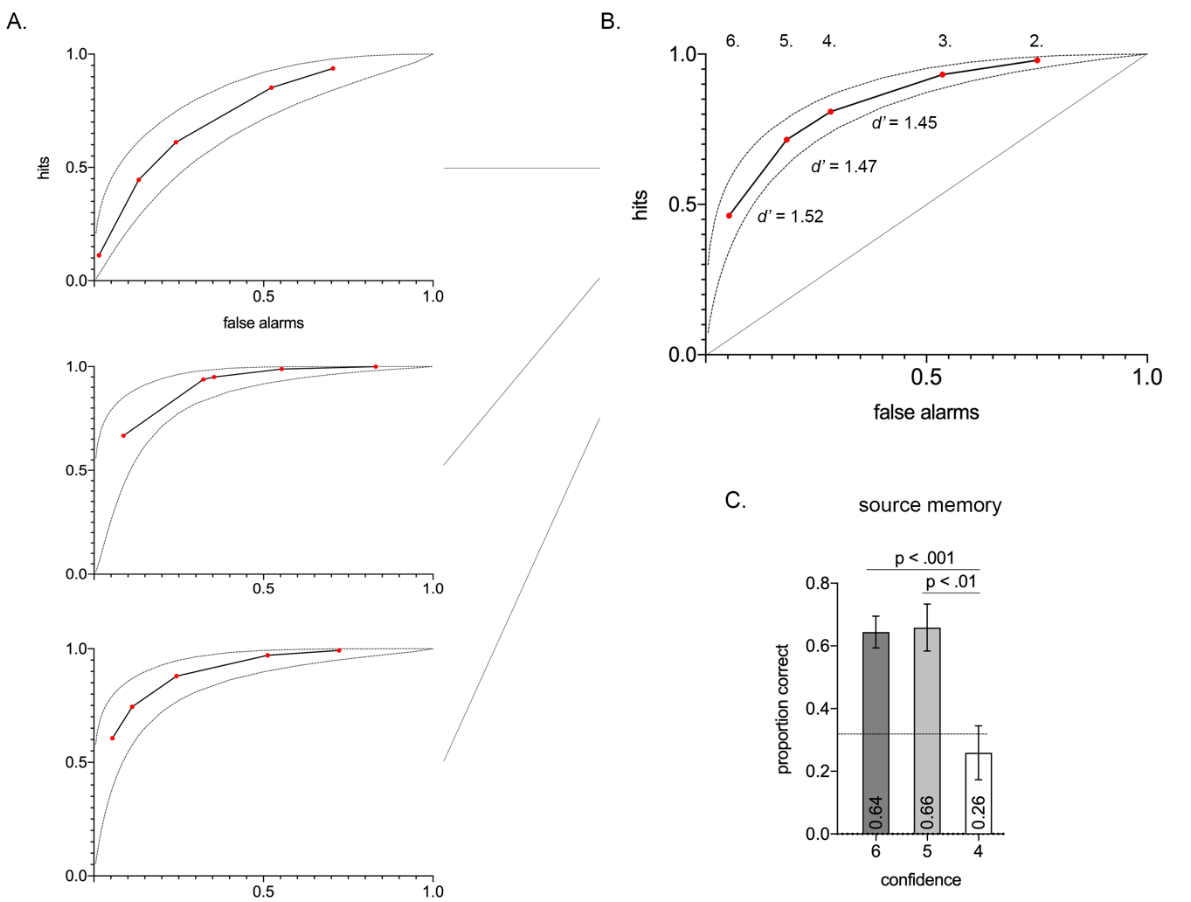

Figure 6. Proof of concept—parallel detection theory and source memory data

A. Individual fitted ROC curves with 95% confidence intervals for three participants.

B. Fitted ROC curve with a 95% confidence interval made from 384 responses between three participants. Each point (6 to 2) represents decreasing confidence to select *old* or an increasingly liberal criterion. In agreement with the dual-process model, the curve is asymmetrical with high confidence hits skewed upwards, and false alarms unaffected. That memory sensitivity (*d'*) is not constant across confidence levels suggests that a recollection process separate from familiarity strength is influencing highly-confident responses.

C. How confidence in ROC space (B) is related to the accuracy of a subsequent source recollection decision (C). Source accuracy plotted as a function of *old/new* confidence abruptly increases beyond chance levels (where chance is 0.33) when confidence reaches 5 and 6. Source memory data suggest that high confidence hit rates in ROC space are skewed upwards because of the contribution of recollection. Therefore, measuring source hits can be used as a reasonable proxy for recollection performance.

Discussion

Findings

The hypothesis that memory accuracy would be better for musicians over nonmusicians and for tonal over atonal melodies is consistent with our results; though unexpectedly, it depends on the type of recognition memory. Signal-detection tests of *old/new* discriminations are sensitive to musicality and are unaffected by tonality (fig. 5A), suggesting that active musical experience has specific effects on familiarity-based memories. Conversely, tests of source memory (recalling the melody and the instrument the melody was originally played on) are sensitive to tonality and unaffected by musicality (fig. 5B). This supports the idea that perceiving pitch hierarchies improves selectively source-based memories. Notably, since the two distinct recognition tests are sensitive to different variables, the underlying memory processes may be functionally distinct.

To further support this assumption, the confidence-based ROC curves (fig. 6) show the same upward skew as predicted by the dual-process model (Yonelinas and Parks, 2007). And parallel source memory accuracy drops to chance levels substantiating the claim that recollection is a threshold process (Harlow and Donaldson, 2013). From there we can determine with more assurance parameter estimates of familiarity (a signal-detection process) and recollection (a source memory process). Theoretically, our findings suggest that familiarity is sensitive to musicality and recollection is sensitive tonality. Another reason for getting estimates of familiarity and recollection is that there is an immense literature on the dual process model and its neural correlates, extending even to animal models (Fortin et al., 2004; Manns et al., 2003; Preston, 2002; Sauvage et al., 2008). This helps to put these results into a broader context.

Theoretical model

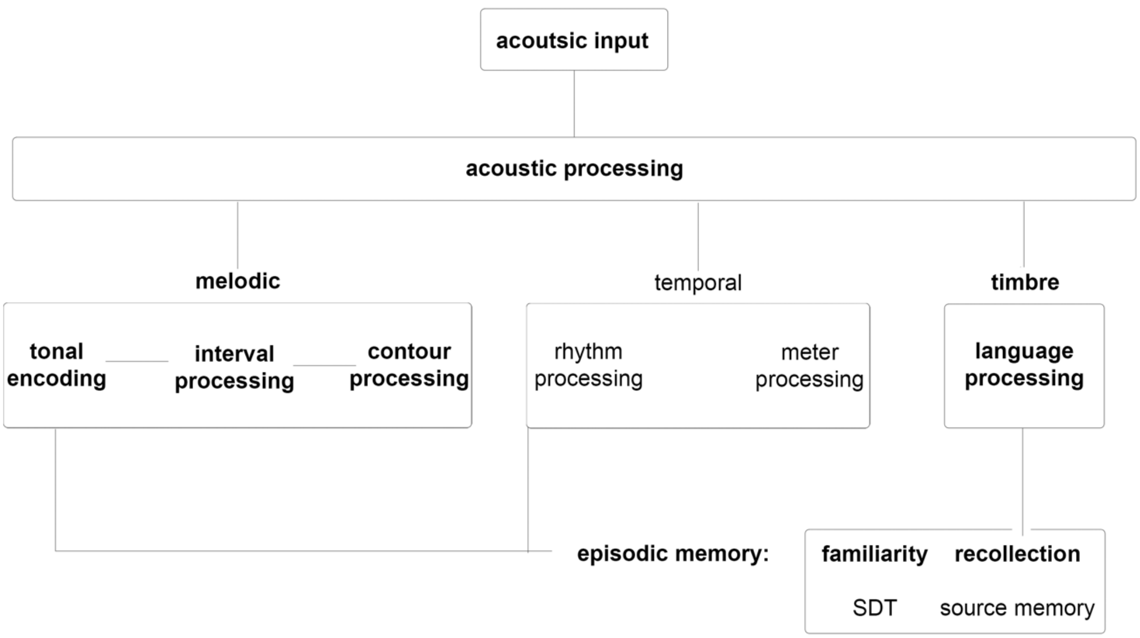

Figure 7. Perception modules and hierarchies for recognition memory for melodies. A module is a specialize processing unit that is devoted to the execution of some biologically important function and is related directly to the functional architecture of the human brain (Peretz and Coltheart, 2003). At successive stages in the hierarchical network, each processing module represents increasingly complex properties. Aspects of music perception essential to later recognition are processed by neural substrates common to all humans and located mainly in the superior temporal gyrus (Altenmüller, 2003). Areas essential to memory are located within the medial temporal lobe ((Eichenbaum et al., 2007).

As mentioned previously, the auditory system uses parallel processing of melodic and temporal information for perception and subsequent memory. In addition, timbre is a dimension of auditory perception which allows for the identification of a particular instrument, e.g. *cello* or *oboe*. Timbre or "sound quality" is a complex feature relying on the spectral shape of sound (Patel, 2003). In fig. 7, language processing is then crucial when forming the mental connection between melodies and their context (instrument), and it allows for the naming of that instrument on a later recognition memory test. So, a task that requires retrieving nonmusical information about a melody, naming the instrument in a source memory task, will require the retrieval of the melody along with a conceptual or linguistic label for instrument.

This ability is clearly dependent on a large network of brain regions, but most importantly the medial temporal lobe. Important to its organization is that the perirhinal and parahippocampal cortices project to the entorhinal cortex and the information then converges within the hippocampus (Eichenbaum et al., 2007). The perirhinal cortex seems to represent *that* a specific melody has previously occurred and is sufficient to support recognition based on familiarity alone (Ranganath, 2010). The parahippocampal cortex may represent information about the source in which these melodies were encountered (i.e. conceptual labels of *cello* or *oboe*)—the hippocampus then processes the bound representation of melodies and their context (Davachi, 2006; Eacott and Gaffan, 2005). The hippocampus disproportionally supports source recollection (Davachi et al., 2003; Ranganath et al., 2004). If the binding does not happen, memories can still be formed but based on perceptual features alone (familiarity). According to this view, the degree to which a memory task recruits relational versus familiarity processes determines its relative reliance on hippocampal versus nonhippocampal MTL structures. So, the psychological distinction between recollection and familiarity seems to be an organizing principle of the MTL, though most of this research is in the domain of vision (Diana et al., 2007 for a review). Future neuroimaging studies are needed to determine whether this holds true for auditory memory, and specifically musical memories.

Limitations

Of course, the correlational design of this study does not allow for comment on whether active musical experience causally enhances familiarity-based memories or whether other variables are responsible for the findings. In this study, musicians were identified by a standardized musical experience survey (Müllensiefen et al., 2014). From this it is impossible to comment on whether the memory differences observed were due to musical experience per se or other pre-existing traits favoring musicality. Future randomized controlled trails would help assess causal effects.

Secondly, the dual-process model of recognition memory remains a matter of considerable dispute. The model makes several strong assumptions about the behavioral nature and neural substrates of familiarity and recollection. Though well-supported in the literature, other models of recognition memory give an equally convincing explanation of empirical ROC curves. Notably, the unequal variance signal detection model and the mixture signal detection model (Jang et al., 2009). There is also disagreement on whether recollection is a categorical or continuous process (Mickes et al., 2009; Wixted et al., 2010). So, until the field arrives to an agreed upon model, it is not possible to make definitive claims about the nature of familiarity and recollection.

Conclusion

Understanding the interplay between passive exposure, active exposure, and the brain processes involved in music perception and memory was the goal of this project. Tonality appears to be a central aspect of all music, and passive exposure to Western tonal music sets up automatic mental representations specialized for that system (Peretz, 2006; Peretz and Coltheart, 2003; Tillmann et al., 2003; Zatorre and Peretz, 2001). The hierarchical structure of tonal music affords the opportunity to analyze the relationship between expectancy formation and subsequent musical memory. Likewise, people differ substantially in their active musical experience and training. We levered this distribution to better understand the role that experience plays in domain-specific memory formation. By using the tools of detection theory, we further disentangle perceptual familiarity-based and conceptual recollective-based memories, showing that familiarity is modulated by musicality and recollection by tonality.

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