Pitch-Distance and Contour Complexity in the Recognition of Short Melodies

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Abstract

This study investigated how people recognize short melodies. Participants completed a musical training questionnaire and were randomly assigned to a retention interval (3, 6, or 9 s). The experiment consisted of 32 trials. For each trial, an original melody was heard, a silent retention elapsed, and then two successive melodies were presented – the original (the target) and a novel melody (the distracter). Targets and distracters were either played in the original key or they were transposed. Recognition did not differ based on retention interval. Participants were better at recognizing targets played in their original keys than when they were transposed. Musical training contributed to recognizing transposed melodies but did not affect recognition of melodies that were not transposed. Melodic contour information was needed to recognize transposed melodies. Lastly, pitch-distance, and not key-distance, was observed to influence melody recognition. The results are discussed as they relate to models of music perception.

Keywords: music perception, melody recognition, pitch, contour

Investigating how people recognize melodies is important for understanding how people process auditory information in general. Melody recognition is a complex process involving several factors. Auditory information goes through many different stages before it becomes a conscious precept. In recent years, models of music perception have been developed based on neurobiological evidence. A modular model based on observations of neurologically impaired individuals (Peretz & Coltheart, 2003) indicates that acoustic input (both music and speech) is parsed into separate streams comprising pitch and temporal information. Another model based on auditory event related potentials associated with processing aspects of the auditory stream has identified the sequence that different auditory properties are processed (Koelsch & Siebel, 2005). In the first 100 ms, the acoustic stream undergoes feature extraction. Pitch, timbre, and amplitude are initially processed at this stage. In the next 100 ms, an auditory Gestalt is formed by processing melodic and rhythmic grouping aspects of the auditory stimuli. This is the point at which melodic contour is analyzed. Meter is processed 180-400 ms after contour. The sequence of processing influences how we recognize previously heard melodies. Since pitch interval is processed before melodic contour, attentional resources directed toward recognizing pitch would impact the perception of contour.

Melody recognition is usually experimentally studied by testing how well people recognize a melody played in a different key than it was previously heard (Bartlett & Dowling, 1980; Egmond & Povel, 1996). This change of key is referred to as transposition. Melodies may be transposed to keys that are either higher or lower in pitch than they were initially played. Transpositions may be either exact or inexact (Egmond & Povel, 1996). A pitch alteration that results from an exact transposition changes the pitch so that it becomes consistent with the new key of the transposition. Thus, the quality of the melodic intervals stays the same with exact transpositions (e.g., a major third remains a major third). Inexact transpositions, on the other hand, maintain the basic interval structures of the original melody but the quality of intervals may change (e.g., a major third may become a minor third). In this case, the melody not only starts on a different tone, but also has one or more of the melodic intervals changed.

Two additional aspects of transposition are key-distance and pitch-distance (Egmond & Povel, 1996). The relationship between keys in tonal music is represented by the circle of fifths (See Figure 1). One step clockwise or counterclockwise on the circle of fifths results in the same key-distance. For example, the closest to C major are F major are G major; the next closest keys are Bb major and D major, etc. Pitch-distance, on the other hand, is the distance from an initial melody to a transposition measured in semi-tones (Bartlett & Dowling, 1980). A melody in C major that is transposed upward to F major or downward to G major results in a pitch-distance of five semi-tones, while a melody that is transposed upward to D major or downward to Bb major results in a pitch-distance of two semi-tones.

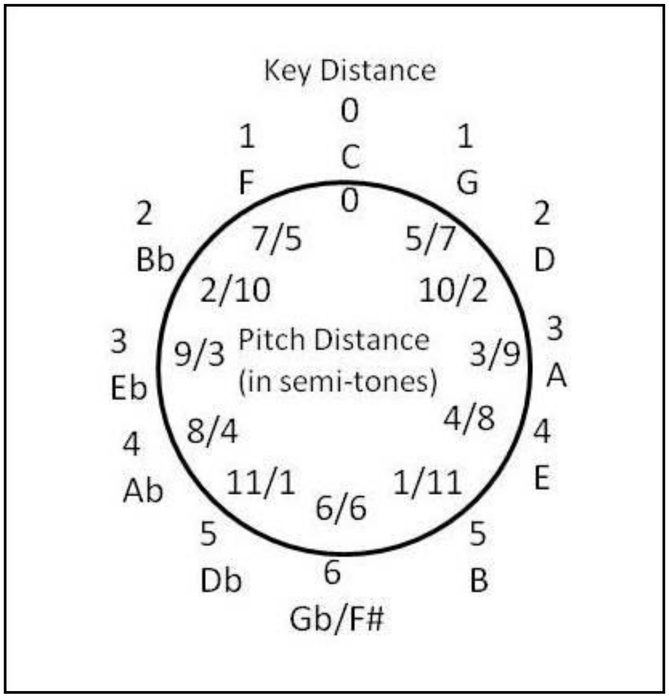

Figure 1. The circle of fifths with C major as the reference key. Every step on the outside of the circle corresponds to an increase in key-distance. Pitch-distance is shown inside the circle. The first number in each pair corresponds to the pitch-distance in semi-tones of a downward transposition; the second number in each pair refers to the pitch-distance in semi-tones of an upward transposition.

Pitch information is comprised of contour, interval, and scale degree information (Cuddy, Cohen, & Mewhort, 1981; Dowling & Fujitani, 1971; Dowling, 1978). Contour refers to the pattern of rising and falling pitches in a melody, while interval refers to the pitch-distance between successively heard tones. The contour representation consists of information about the up and down pattern of pitch changes. If a melody moves in an ascending manner and then descends, the change in direction is a melodic reversal. The number of reversals in a melody is a function of the complexity of its contour. Melodies with few reversals have a simple contour, while melodies with more reversals are complex (Croonen & Kop, 1989; Croonen, 1994). Listeners primarily use melodic contour information to identify melodies after retention intervals up to 5 s, while melodic interval information is used to identify melodies after retention intervals of 30 s or longer (Croonen, 1994). The tonal structure of a melody also influences the degree to which contour will influence recognition. Melodies that have a strong tonal structure are more salient than those with weaker tonal structure. There is some evidence that contour does not influence recognition if a melody has a strong tonal structure (Croonen & Kop, 1989; Croonen, 1994).

Musical training also has a bearing on how well people can identify individual pitches and melodies. Musicians can draw upon more cognitive schemata related to musical pieces, pitch discrimination, and identification of several other aspects of music than non-musicians. Musical training enhances the automatic encoding of melodic contour and interval structure (Fujioka, Trainor, Ross, Kakigi, & Pantev, 2004). The pitch intervals of unfamiliar melodies are also better perceived by trained than untrained musicians (Trainor, Desjardins, & Rockel, 1999; Peretz & Babai, 1992). A review of psychological research using musically inexperienced listeners (Smith, 1997) indicates that many of the musical abilities detected in musicians are not present in non-musicians to the same degree. Non-musicians generally cannot recognize musical intervals, make categorical decisions about pitch, or recognize common musical structures with the same fluency as musicians.

Memory studies typically involve an experimental design where participants are exposed to a stimulus, a retention interval elapses (which may include some kind of task), and then a recognition test is given. The recognition test usually presents the original stimulus (the target) and a novel stimulus which serves as a distracter. This design can easily be generalized to melody recognition. However, the key of the target melody may vary. The target melody may be played in the same key as the first time it was heard or it could be transposed to a different key.

The duration of the retention interval also varies according to the nature of the stimulus being tested (i.e., visual, auditory, etc.). Retention intervals may be filled with a task or some kind of stimulus that directs attention away from the test material or they may be silent meaning a task is not present. Information in short-term memory decays quickly if strategies such as rehearsal are not used to keep the information available for a longer time. The advantage of using a filled retention interval is that participants cannot rehearse the information. However, in situations involving very short time periods, using a filled retention interval may not always be practical.

Studies of auditory short term memory incorporating the two-tone methodology, in which a tone is presented and then a comparison tone is played after a silent interval, have shown that memory for pitch fades in 10 to 15 s (Cowan, Winkler, Teder, & Näätänen, 1993; Crowder, 1982; Winkler & Cowan, 2005; Winkler et al., 2002). Two studies testing melody recognition with a silent retention interval of 9 s resulted in recognition rates of 84% and 83% on trials in which the target melody was played in the same key as it was previously heard (Reiner, 2006; Reiner, 2007). The question arises as to whether a recognition ceiling effect would result if the duration of the silent retention interval were decreased from 9 s.

The purpose of the present study was to determine how pitch and contour interact in the process of recognizing short melodies. This study incorporated the typical paradigm for testing melody recognition which includes presenting a melody, having a retention interval elapse, then presenting the original melody (now called the target) and a novel melody (the distracter) and having listeners decide which melody was the same as the first melody. Specific hypotheses were tested based on the observations of Koelsch and Siebel (2005) that pitch processing precedes contour processing. A first hypothesis was proposed for when the target was played in the same key as it was previously heard and the distracter was played in a different key. The key of the distracter, along with the contours of the target and distracter, were not expected to interfere with recognizing the target. Listeners would not need any information other than pitch to recognize the target. However, a different situation arises if the target was transposed to a different key and the distracter was played in the original key. In this case, it was hypothesized that contour information would be needed to recognize the target melody.

Based on these hypotheses, the analysis focused on pairwise comparisons involving the interaction of pitch matching condition, pitch interval, and melodic contour. There was also interest in identifying the point at which a ceiling effect occurs with short novel melodies. The current study tested melody recognition with 9, 6, and 3 s silent retention intervals. The 9 s retention interval was chosen as a sort of baseline so that comparisons could be made to prior studies (Reiner, 2006; Reiner, 2007) and the two other retention intervals were chosen so that each delay decreased by each increments. Listener accuracy was expected to increase as the duration of the retention interval decreased from 9 to 3 s. The effect of musical training was also of interest. It was also expected that listeners who reported more years of prior musical training would demonstrate greater accuracy than those who reported fewer years of prior musical training.

Method

Participants

Ninety undergraduate psychology students, all with normal hearing, from the University of West Florida (ages 18-44 years, $M = 22.6$, $SD = 5.0$) participated in this experiment and received partial course credit in exchange for their participation. Based on their responses to a music training questionnaire, participants reported an average of 2.7 years ($SD = 2.2$) of prior musical training which ended 4.1 years ($SD = 6.9$) prior to the experiment. The *Music Training Questionnaire* is shown in the Appendix.

Apparatus

Audio was played back on computer workstations through 16-bit sound cards. Participants listened to the audio stimuli via Sony MDR-V150 headphones. The experiment was presented to participants by having them run a Visual Basic application installed on each laboratory computer workstation that stepped them through each experimental trial.

Melodies

Sixty-four melodies were used, each a succession of seven tones played in the timbre of an acoustic piano. Melodies were tonal and did not include any altered tones from the scales they were derived. Each melody was comprised of six tones of equal duration followed by a seventh tone that was twice the duration of the first six. In a musical sense, the melodies were equivalent to four measures in common time (4/4) with two half notes in each of the first three measures and a whole note in the fourth measure. Examples of melodies used in the study are shown in Figures 2 and 3.

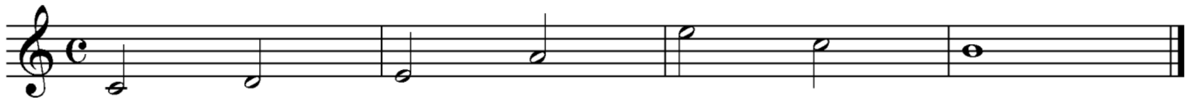

Figure 2. Example of a melody with a simple contour.

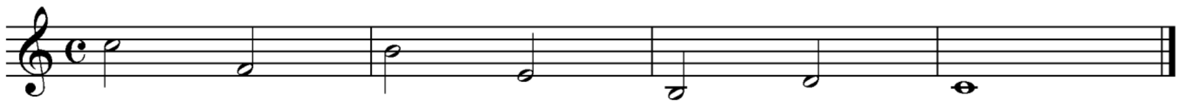

Figure 3. Example of a melody with a complex contour.

Melodies were equated for loudness, pitch range, and rhythm so that the effects of pitch and contour could be more closely examined. Each melody had a tempo of 150 beats per minute and was 6.4 s in duration. Stimuli were input into a standard music notation program and digitally recorded at a constant dynamic level as audio files on a PC with a Pentium 4 processor. Audio stimuli were recorded at a 44.1 kHz sampling rate with a 16-bit amplitude resolution.

Thirty-two melodies were designated as original/target melodies and 32 were distracter melodies. Targets were identical to originals and were either heard in the same key as they were played initially or they were transposed to a major second or a perfect fourth. The transpositions in the current study were “exact” so key relationships were maintained. Half of the transpositions were upward and half were downward. Distracters were different from originals on each trial and were either heard in the same key as the original or they were played in a key that was either a major second or a perfect fourth from the pitch of the original in a given trial.

Another variable of interest was “pitch-matching condition.” Pitch matching condition corresponded to the keys that the target and distracter were played in on a given trial. If the target was played in the original key, then the distracter was heard in a different key (referred to as a target-same trial). Conversely, if the target was heard in a key other than the original key, then the distracter was heard in the original key (referred to as a target-different trial). Pitch matching condition was counterbalanced across trials. The specific keys that correspond to each comparison melody were also counterbalanced across trials. Refer to Table 1 for a listing of the keys that correspond to each comparison melody in each pitch matching condition.

Table 1. Key of Each Melody by Pitch Matching Condition.

	Pitch Matching Condition	
	Target-Same	Target-Different
Original	Key 1	Key 1
Target	Key 1	Key 2
Distracter	Key 2	Key 1

Procedure

Each experimental session was run in the same manner. Participants were randomly assigned to a memory retention interval before they showed up for their session. Participants were given a one-page document to read that explained the purpose of the study. After reading the document, participants provided informed consent to be in the study. Participants then completed a short music training questionnaire. After that, the experimenter described the procedure of the experiment they were going to do on the computer. The experimenter explained that they were going to be asked to identify melodies they would hear during each trial, but that the melodies might be played at a higher or lower pitch than the first time they heard them.

Participants put on audio headphones and worked through the experiment on computer workstations. The experiment consisted of 32 trials. Each trial started with a V-I chord progression in C major to induce the key. The G major chord was played for 1 s followed by the C major chord played for 3 s. After the initial cadence, a 6.4 s melody designated as the "original" was heard. This was followed by a picture of the Grand Canal of Venice on the computer screen. The duration of the picture on the screen corresponded to the particular retention interval which each participant was randomly assigned (3 s, 6 s, or 9 s).

After the picture was shown, participants were given a two-alternative forced choice test (2AFC). Two melodies were heard successively with a 500 ms inter-stimulus interval. One of the two melodies was designated as the "target" and one was a new melody referred to as the "distracter." The presentation order of target and distracter sequences was counterbalanced across trials. Participants were instructed to choose the melody that matched the one they heard at the beginning of the trial. After they made their choice, participants were instructed to rate their level of confidence in their choice on a 5-point Likert scale ranging from "Not at all Confident" to "Extremely Confident." Higher numeric ratings corresponded to greater confidence.

Musical Keys

Original melodies were always played in the key of C major. The starting tone for melodies that initially ascended in pitch was middle C. The starting tone for melodies that initially descended in pitch was the "C" an octave above middle C. Targets and distracters played a major second above the original melodies were in D major; melodies heard a major second below originals were in Bb major; melodies heard a perfect fourth above originals were in F major; and melodies heard a perfect fourth below originals were in G major.

Melodic Contour

The melodic contour of the target and distracter in each trial was varied in the experiment. Melodies with one or two reversals were considered as having a simple contour and those with three or four reversals were considered as having a complex contour. The contour of the target and distracter in each trial was combined. There were four possible target-distracter contour complexity combinations: simple-simple, simple-complex, complex-simple, and complex-complex.

Results

An analysis of covariance was conducted to assess the effects of retention interval, musical training, pitch matching condition, pitch interval, and melodic contour on melody recognition. Retention interval was a between-subjects factor, while pitch matching condition, pitch interval, and contour complexity were within-subjects factors. The number of years of prior musical training that each participant reported was included as a covariate. The dependent variable was the number correct on a series of 2AFC tests. All pairwise comparisons reported here were performed with Bonferroni correction. The mean accuracy rates, standard deviations, and sensitivity measures (d' values) for each retention interval, pitch matching condition, pitch interval, and contour complexity combination are shown in Table 2.

Table 2. Mean Accuracy Rates, Standard Deviations, and d' Values for Each Retention Interval, Pitch Matching Condition, Pitch Interval, and Contour Complexity Combination

	n[a]	*M*	*SD*	*d'*
Retention Interval				
3 seconds	30	.78	.13	1.09
6 seconds	30	.80	.14	1.18
9 seconds	30	.78	.16	1.09
Pitch Matching Condition				
Target-Same	90	.87	.11	1.59
Target-Different	90	.71	.17	0.78
Pitch Interval				
Major 2nd	90	.82	.26	1.29
Perfect 4th	90	.77	.29	1.04

Contour Complexity Combination				
Simple-Simple	90	.80	.21	1.18
Simple-Complex	90	.79	.22	1.14
Complex-Simple	90	.84	.20	1.40
Complex-Complex	90	.74	.23	0.91

[a]*n* refers to the number of people in each condition.

The effect of pitch matching condition was significant [$F(1, 86) = 53.45$, $p < .001$, partial $\eta^2 = .38$], with listeners identifying target melodies more often when they were in the original key ($M = .87$) than a different key ($M = .71$). Pitch interval was significant [$F(1, 86) = 9.18$, $p = .003$, partial $\eta^2 = .10$.], with listeners demonstrating greater recognition when targets and distracters were played a major second from the original key ($M = .82$) than a perfect fourth ($M = .77$). Contour complexity was also significant [$F(3, 258) = 5.83$, $p = .001$, partial $\eta^2 = .06$], with listeners recognizing target melodies more often when the contour combination of the target and distracter was simple-simple, simple-complex, or complex-simple than when it was complex-complex (M = .80, .79, .84, and .74, respectively).

In addition, the covariate was significant [$F(1, 86) = 4.73$, $p = .03$, partial $\eta^2 = .05$] but it accounted for very little overall variance in the dependent variable. A closer examination showed that the correlation between years of musical training and accuracy was not significant for target-same trials [$r(90) = .14$, $p = .20$] but it was for target-different trials [$r(90) = .24$, $p = .02$]. This was verified by performing separate F tests by pitch matching condition: the effect of the covariate was not significant on target-same trials ($p = .16$) but it was for target-different trials ($p = .04$). Prior musical training did not affect melody recognition unless listeners needed to identify the target in a different key than it was originally heard.

Lastly, the effect of retention interval was not significant. Participants had very similar recognition rates for target-same trials vs. target-different trials by each retention interval (3 s: $M = .88$ vs. $M = .69$; 6 s: $M = .86$ vs. $M = .73$; 9 s: $M = .86$ vs. $M = .72$). This suggests that the original melody was still accessible in auditory short-term memory after a duration of 9 s.

The interaction between pitch matching condition and pitch interval was significant [$F(1, 86) = 5.57$, $p = .02$, partial $\eta^2 = .06$]. On target-same trials, the pitch of the distracter did not influence recognition. However, greater recognition was observed on target-different trials when the target was played a major second from the original key than a perfect fourth away. The interaction between pitch interval and contour complexity was significant [$F(3, 258) = 11.03$, $p = <.001$, partial $\eta^2 = .11$]. When either the target or distracter was heard a major second from the original key, every contour pair except complex-complex produced greater recognition. Additionally, when targets and distracters were heard a perfect fourth from the original key, complex-simple contour pairs produced greater recognition than any other contour combination. The interaction between pitch matching condition and contour complexity was significant [$F(3, 258) = 5.76$, $p = .001$, partial $\eta^2 = .06$]. With target-same trials, greater recognition was observed for every contour combination except complex-complex. For target-different trials, complex-simple contour pairings evoked greater recognition than any other contour combination. The mean accuracy rates, standard deviations, and d’ values for each pitch interval and contour complexity combination by each pitch matching condition are show in Table 3.

Table 3. Mean Accuracy Rates, Standard Deviations, and d' Values for Each Pitch Interval and Contour Complexity Combination by Pitch Matching Condition.

	Pitch Matching Condition					
	Target-Same			Target-Different		
	M	*SD*	*d'*	*M*	*SD*	*d'*
Pitch Interval[a]						
Major 2nd	.88	.22	1.65	.76	.30	1.00
Perfect 4th	.86	.24	1.52	.67	.34	0.62
Contour Complexity Combination[b]						
Simple-Simple	.91	.15	1.89	.68	.26	0.66
Simple-Complex	.89	.18	1.73	.67	.26	0.62
Complex-Simple	.87	.17	1.59	.81	.23	1.24
Complex-Complex	.79	.20	1.14	.67	.25	0.62

[a]Each pitch interval occurred eight times in each pitch matching condition.
[b]Each contour complexity combination occurred four times in each pitch matching condition.

The interaction of pitch matching condition, pitch interval, and contour complexity was also significant, $F(3, 258) = 6.19$, $p < .001$, partial $\eta^2 = .07$. When the distracter was heard a major second from the original pitch, listeners were better able to recognize the target when the contour pair was either simple-simple (*M* = .94), simple-complex (*M* = .89), or complex-simple (*M* = .89) than when it was complex-complex (*M* = .78). The combination of the close pitch-distance and complex contour of the comparison melodies created a situation that interfered with recognition. When the distracter was heard a perfect fourth from the original pitch, there was no difference in listener recognition based on which contour combination was heard. The greater pitch-distance of the distracter from the target made the melodies more discernible from each other. As a result, the distracter served as less of a distracter and the target was easy to identify.

When the target was heard a major second from its original pitch, a similar pattern of results was found as when the distracter was heard a major second from the original key. Listeners were better able to recognize the target when the contour pair was simple-simple (*M* = .81), simple-complex (*M* = .78), or complex-simple (*M* = .84) than when it was complex-complex (*M* = .59). The complex contour of the distracter, along with the complex contour of the target, appears to have again interfered with recognition.

When the target was heard a perfect fourth from the original pitch, listeners demonstrated greater recognition for complex-simple (*M* = .78) and complex-complex (*M* = .76) contour pairs compared to simple-simple (*M* = .57) and simple-complex contour pairs (*M* = .58). This is a different pattern of results than when the distracter was a perfect fourth from the original key. The greater pitch-distance of the target from the original key, along with the distracter being played in the original key, enabled listeners to identify the target more when it had a complex contour rather than a simple one.

It is important to note that even though the covariate was significant, none of the interactions involving the covariate were significant. The partial eta square value associated with the covariate indicates that only 5% of the total variation in the dependent variable was accounted for by prior musical training. Inclusion of the covariate allowed for greater experimental control and served to reduce the overall size of the error term associated with the dependent variable, but it did not contribute to any of the interaction effects revealed in the analysis.

Sensitivity Analysis

Signal detection theory is used to analyze data where there is a level of uncertainty. A typical scenario involves having participants respond "yes" or "no" as to whether a stimulus is present on a given experimental trial. This results in two indices, a sensitivity index (d') which measures how well participants are able to detect that the stimulus is present, and a response criterion index (c) which measures the extent that participants are biased toward reporting that a stimulus is either present or not present. The 2AFC design is an alternative to the single interval "yes-no "signal detection paradigm in which the stimulus is present on every trial. This forces all participants to adopt the same decision criterion. As such, only the sensitivity index can be calculated. The d' value calculated for target-same trials was above threshold (d' = 1.59), as defined by d' > 1.0 (Macmillan & Creelman, 2005). However, the d' value calculated for target-different trials did not reach threshold (d' = 0.78) indicating that participants were less able to discriminate between the target and distracter on these trials. This finding replicates earlier work by Dowling and Fujitani (1979) which showed that listeners are better able to recognize a previously heard melody when it is played in the same key as the first time it was heard.

Confidence Rating Analysis

Bivariate correlations were calculated between participants' melody choice and confidence rating on each trial to determine if there was a relationship between confidence and accuracy. Correlations were also calculated for pitch interval, contour complexity combination, and the number of years of musical training with confidence and accuracy. The correlational analysis for each pitch matching condition is reported separately.

Target-same condition. Higher confidence ratings were associated with greater accuracy, $r(1440) = .31$, $p < .001$. The pitch of either the target or distracter was not associated with confidence [$r(1440) = -.04$, $p = .18$] or accuracy [$r(1440) = -.03$, $p = .24$]. Increasing contour complexity combinations (simple-simple, simple-complex, etc.) were associated with lower confidence ratings [$r(1440) = -.20$, $p < .001$] and less accuracy [$r(1440) = -.12$, $p < .001$]. More years of prior musical training were associated with greater confidence, $r(1440) = .19$, $p < .001$. However, there was no relationship between the number of years of prior musical training and accuracy, $r(1440) = .05$, $p = .09$.

Target-different condition. Higher confidence ratings were associated with greater accuracy, $r(1440) = .26$, $p < .001$. Hearing the melody played a major second from the original key than a perfect fourth resulted in greater confidence [$r(1440) = -.08$, $p = .02$] and accuracy [$r(1440) = -.10$, $p < .001$]. There was no relationship between contour complexity combination and confidence [$r(1440) = .005$, $p = .85$] or accuracy [$r(1440) = .02$, $p = .39$]. Lastly, more years of prior musical training were associated with greater confidence [$r(1440) = .21$, $p < .001$] and accuracy [$r(1440) = .09$, $p = .001$].

Discussion

The primary aim of this study was to investigate how retention interval, prior musical experience, pitch interval, and melodic contour influence how people recognize short temporally invariant melodies. Different retention intervals were tested to identify the point at which a ceiling effect would be observed. However, there were no differences in melody recognition by retention interval. Regardless of how long the retention was between the initial exposure and testing, listeners were much better at recognizing targets on target-same trials than target-different trials, which supports Koelsch and Siebel's (2005) neurocognitive model of music perception. Since listeners were not engaged in an activity during the retention interval, they were able to keep the auditory information available in short-term memory.

Prior musical training did not account for much overall variance in this study. This reflects that fact that most participants did well on target-same trials, regardless of how much musical training they reported. Musical training only affected melody recognition on target-different trials. However, the key of the melody that was different from the original key in each trial did contribute to recognition. Participants recognized the target more often when it was a major second from the original key than when it was a perfect fourth away. This indicates that pitch-distance was more influential in the recognition process than key-distance with these particular stimuli.

As predicted, melodic contour did not impact recognition on target-same trials. Distracters heard a perfect fourth from the original key were easy to discern, so contour did not affect recognition on those trials. A distracter played a major second from the original key was also easily identifiable as long as the contour combination of the target and distracter was not complex-complex. The net effect of the complex contour of the comparison melodies is that it interferes with recognition in conjunction with a close pitch-distance.

On target-same trials, participants were more confident when they chose the correct melody. Lower confidence ratings might suggest that participants were guessing, which is a possibility with a 2AFC design. However, higher confidence ratings for correct choices, along with greater d' values, provide evidence that participants were not guessing on these trials. Pitch was not associated with confidence or accuracy on these trials. Participants did not need to attend to pitch information since the target was heard in the same key as it was initially heard.

Greater contour complexity was associated with lower confidence and accuracy on target-same trials. Recognition of temporally invariant melodies was easier when simple contours were presented. This finding seems counterintuitive since more information has been found to make the memory trace more elaborate and memorable. It may be that unless the additional contour information was distinctive it would interfere with processing the auditory information. More years of musical training were associated with greater confidence but not accuracy. Being involved in musical training for an extended amount of time, like most activities humans engage in, increases confidence in one's abilities. However, greater confidence does not always guarantee that accurate judgments or decisions will be made based on one's increased confidence.

Participants were also more confident in their choices when they chose the correct melody on target-different trials. This again provides evidence that participants were not guessing when they made correct choices, but since the d' values for these trials did not reach threshold, participants clearly had a more difficult time detecting the target when it was transposed. Hearing the target played a major second from its original key produced higher confidence and accuracy than when it was a perfect fourth away. This gives support to the notion that melody recognition is influenced more by pitch-distance than key distance.

The contour complexity combination of the target and distracter was not associated with confidence or accuracy on target-different trials. This is counter to the prediction that contour information would be needed to attend to transposed targets. It appears that participants were attending more to pitch information than contour on these trials since the target was played in a different key than its original one. More years of musical training were also associated with both greater confidence and accuracy suggesting that increased musical experience facilitates the recognition of transposed melodies.

Implications

This study provided evidence, within the present experimental paradigm, that melody recognition with short delays is determined by the interaction of melodic contour and the pitch-distance from an original melody. Melodies that are near in pitch and that have complex contours can be difficult to process as distinct percepts. It is easier to discern between melodies that are farther apart in pitch, regardless of their contours. Music educators could make use of these findings by emphasizing that students attend to the contour of melodies when they engage in ear training exercises. This could be of particular importance since melodies that are farther from a home tone (i.e., the tonic) are perceived as being less similar to each other than those closer to the home tone. Another application would be for ensemble musicians to attend to contour when their musical lines are close in pitch. This could be beneficial when they perform music that has intricate counterpoint or interleaving between musical voices.

The present study also provided behavioral support for Koelsch and Siebel's (2005) model since contour information was not needed to recognize melodies on target-same trials but it was necessary for recognizing melodies on target-different trials. Melody recognition at the feature extraction stage is the same for everyone when all that is necessary is to identify a melody played in the same key as it was heard previously. Musical training only contributes to the recognition of transposed melodies. When musical stimuli become more complex and sophisticated, experienced musicians can draw upon contextual cues and prior knowledge to assist with recognizing melodies. This area of research can inform us as to how musical training changes our ability to recognize musical stimuli. Future research involving pitch and contour could provide additional information about the nature of melody recognition by testing additional retention intervals and pitch-distances.

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Appendix

Music Training Questionnaire

1. What is your gender? male_____ female_____
2. What is your age? _______
3. Are you left-handed or right-handed? left_____ right_____
4. Are you a music major? yes_____ no_____
5. Are you enrolled in or have you ever had a class in music theory? yes_____ no_____
6. Have you had any previous formal musical training? (Be sure to count things like piano lessons and school band.) yes_____ no _____

If you answered "yes", then continue to question #7.

7. How many years of previous formal musical training have you had? ________ years
8. How long ago was your musical training? (write "ongoing" if you are still involved in formal music training) _____________ years