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Abstract

Research on the acquisition and use of communicative categories in domains such as language and music is largely divided between approaches suggesting innate cognitive constraints on domain-specific communicative forms, and approaches suggesting domain-general mechanisms through which specific communicative forms are learned. The present study investigates the effect of greater or lesser enculturation in the communicative system of Western tonal music on peoples' ability to discriminate culturally familiar and culturally unfamiliar pitch categories. The results indicate that while prior musical training affects peoples' overall approach to pitch discrimination, the advantage is dependent on the familiarity (in both pitch and timbre) of the aural stimulus, and is negligible under conditions of maximal musical unfamiliarity. Observed differences in pitch discrimination ability therefore appear to result from enculturation effects of exposure to Western music, not from a relationship between musical training and innate perceptual categories.

Keywords: Auditory perception; auditory representation; music cognition; categorical perception; learning; enculturation

Introduction

Do people with extensive Western musical performance training differ in their ability to discriminate tones that vary in pitch frequency from people without such training? To what extent are differences between these groups a function of the familiarity of the frequencies (i.e., musical scale system) and timbres (i.e., musical instrument) in which sounded tones are presented?

One possibility is that musical training tunes a person's perceptual system to the continuous dimension of pitch. On this view, one would expect that people who are musically trained would outperform people who are untrained in their ability to discriminate small variations in pitch, irrespective of the familiarity of the tones. A second possibility, however, is that musical training facilitates the development of prototypical sound categories, such as the 12 pitch classes of Western tonal music. On this latter view, one would expect that musically trained participants would outperform untrained participants only in tasks in which they were asked to discriminate variations in pitch from familiar prototypes.

These two hypotheses represent opposing answers to the underlying theoretical question: does perceptive and performative training within a communicative system facilitate the emergence of an innate faculty for discrimination of domain-specific communicative categories (Chomsky, 1965; Lerdahl, 1992), or does it facilitate selective perception of learned communicative categories (Cutting & Rosner, 1974; Tomasello, 2008)?

Existing research on pitch perception suggests that people with extensive professional musical training recognize and reproduce culturally familiar pitch-class sets better than people without such training (Smith et al., 1994). That is, musical training has been shown to facilitate discrimination between a prototypical pitch and a pitch that deviates slightly from this prototype. While this finding supports the hypothesis that musical training tunes people to familiar prototypical pitches, it does not rule out the possibility that musical training facilitates unfamiliar pitch discrimination as well (i.e., that musical training tunes people to variation in pitch more generally).

The Present Study

To investigate how musical training affects the perception of pitch, we recruited people from two populations — one with extensive musical performance training and one without — for participation in a pitch discrimination task. In the task, participants were asked to identify sounds that deviated from a designated set: in some cases, the set included culturally familiar pitches (i.e., notes from the Western major scale); in others, the set included culturally unfamiliar pitches (i.e., notes from the scales used on Javanese pelog gamelans).

Prior research utilizing a similar paradigm has shown that Western trained musicians outperform an untrained sample even on culturally unfamiliar pitches (Lynch et al., 1990; Lynch & Eilers, 1991, 1992). However, this research utilized small sets of tones within the context of a musical melody. We expended on this paradigm by broadening the number of tones, eliminating the melodic context (i.e., randomizing the order of presented pitches and standardizing the inter-stimulus interval), and adding a variable for timbre: in some cases sounds were presented in the musically familiar timbre of a violin, while in others the tone quality was flattened to a sine wave (Remez et al., 1981, 1994). The present study, therefore, is better able to address whether musically trained individuals are sensitive to deviations in pitch from an unfamiliar prototype when listening to isolated musical sounds.

Method

Participants

Fifty Oberlin College and Conservatory students participated in the study in exchange for course credit. Of these, 26 were students from the College of Arts and Sciences enrolled in an introductory psychology course and 24 were students from the Conservatory of Music enrolled in an introductory musicology course.

To confirm that our samples differed with respect to musical experience, everyone was asked to complete the Musical Experience Questionnaire (MEQ) (Werner, Swope, & Heide, 2006) at the end of the experiment. The MEQ revealed strong differences between the two sample groups in three of the six sub-dimensions of the scale: commitment, $t[48] = 4.731$, $p < 0.001$; innovative musical aptitude, $t[48] = 4.736$, $p < 0.001$; and positive psychotropic effects, $t[48] = 3.557$, $p < 0.001$. The MEQ revealed marginally significant differences for the other three sub-dimensions: social uplift, $t[48] = 1.878$, $p = 0.07$; affective reactions, $t[48] = 0.152$, $p = 0.08$; and reactive musical behavior $t[48] = 1.701$, $p = 0.10$. In every case, the trained musicians reported scores higher than the untrained sample. These results help to confirm that our sample differed in important ways with respect to musical experience.

Procedure

There were four blocks of the pitch discrimination task: one for each of the tone types (violin major, sine major, violin pelog, and sine pelog), presented in random order. The pitch discrimination task consisted of familiarization and discrimination phases. In the familiarization phase, participants passively listened to a set of eight prototypical tones. In the discrimination phase, participants were instructed to press the spacebar when they heard a tone that deviated from those played during the familiarization phase ("even very slightly").

In the discrimination phase 80% of the tones matched one of the eight prototypes from the familiarization phase and 20% deviated. There were two levels of deviation: small (an 0.8% increase or decrease in absolute frequency from the prototype) and large (a 2.4% increase or decrease in absolute frequency from the prototype). In both phases, tones played for 1,000 ms and were followed by 800 ms of silence. The task was continuous, so each subsequent tone began 1,800 ms after the previous, regardless of the participant's behavior.

Each block was designed such that people were presented with approximately two minutes of familiarization, followed by two minutes of discrimination, followed by a minute of familiarization, followed by two minutes of discrimination (see Table 1).

BLOCK 1	BLOCK 2	BLOCK 3	BLOCK 4
Violin MS	Sine MS	Violin PS	Sine PS
2 minutes of familiarization (80 tones)			
2 minutes of discrimination (80 tones): 20% of the tones deviated from those presented in the familiarization phase			
1 minute of re-familiarization (40 tones)			
2 minutes of discrimination (80 tones): 20% of the tones deviated from those presented in the familiarization phase			
Distractor Task: Lexical decision task with 80 self-paced trials (50% words; 50% non-words)			

Table 1. Design of the experiment (block types presented in random order).

The end of each block included a lexical decision task, which served as a buffer between blocks of the auditory perception task. In the lexical decision task, participants were shown strings of letters on the screen serially and were asked to identify, as quickly and accurately as possible, whether the string was an English word or not. Fifty percent of the letter strings were English words and 50% were non-words.

At the end of the experiment, participants were asked to fill out the abridged MEQ (Werner, Swope, & Heide, 2006).

Results

Data Processing

Recognition Trials. In the auditory discrimination task, responses faster than 500 ms from the stimulus onset were trimmed. This cutoff is roughly two standard deviations below the mean response time (RT) ($M = 1{,}184.89$, $SD = 356.98$) and included less than 1% of the trials (0.79%). These responses likely reflect errant responses or slow reactions to the preceding trial. Since RTs are calculated from the onset of the tone, a participant who responded at 500 ms is reacting mid-tone and is unlikely to have had a chance to make a decision and respond to the present trial.

Deviation Direction for Recognition Trials. Large upward and large downward deviations were grouped into a single category of "large" deviations; small upward and small downward deviations were similarly grouped. Separate two-way (sample X block type) repeated measures ANOVAs found no difference by deviation direction. For large deviations, there were no differences in performance by sample, $F[1,191] = 1.67$, $p = 0.20$, block type, $F[3,191] = 1.83$, $p = 0.14$, or interaction between sample and block type, $F[3,191] < 1$. Similarly, for small deviations, there were no differences by sample, $F[1,191] = 3.82$, $p = 0.05$[1],

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[1] There was a marginal effect of population such that the untrained participants performed slightly better on upward deviations (by 2.7 percentage points) whereas the musicians showed no advantage for

condition, $F[3,191] = 1.97$, $p = 0.12$, or interaction between sample and condition $F[3,191] < 1$.

Block Order for Recognition Trials. The participants' performance on the auditory discrimination task was not affected by block order, $F[3,79] < 1$, nor was there an interaction between block order and block type, $F[9,79] < 1$.[2]

Perceptual Discrimination Task

Response data were transformed to a comprehensive measure of performance, d', which accounts for sensitivity to the signal (correct responses) while controlling for the noise (false alarms). Because of the structure of the task, deviating tones were treated as the "targets" and responding on a "target" trial was coded as a "hit"; responding to a prototypical, non-deviating, tone was coded as a "false alarm." For each scale and instrument condition, we normalized "hit" distributions separately by "small" and "large" deviation groups, averaged these scores and then subtracted participants' normalized false alarm rate from the normalized hit rate (see Figure 1).

A repeated-measures ANOVA revealed a main effect of training, $F[1,195] = 13.479$, $p < 0.001$, and an interaction between training and scale, $F[1,195] = 5.901$, $p < 0.05$. We found no effect of timbre, $F[1,195] < 1$ or interaction between timbre and sample , $F[1,195] < 1$.

Post-hoc tests revealed that trained musicians were better at the task overall, $t[48]=3.64$, $p < .001$, Cohen's $d = .922$. This difference was larger for tones from the major scale, $t[48] = 3.45$, $p < .01$, Cohen's $d = .884$, than for tones from the pelog scale, $t[48] = 2.22$, $p < .05$, Cohen's $d = .606$.

Indeed, when block types were coded by familiarity (in order from most familiar to least familiar: major violin, major sine, pelog violin, pelog sine) and included as a linear predictor with sample population in a repeated-measures ANOVA we find an interaction between familiarity and sample , $F[1,195] = 6.156$, $p < .05$. That is, the difference between groups shrank as the tones became less familiar (see Figure 1).

Specifically, trained musicians outperformed non-musicians on major violin, $t[48] = 3.418$, $p < 0.01$, major sine, $t[44] = 2.880$, $p < 0.01$, and pelog violin, $t[48] = 2.041$, $p < 0.05$, but not on the pelog sine trials, $t[48] = 1.151$, $p = 0.256$.

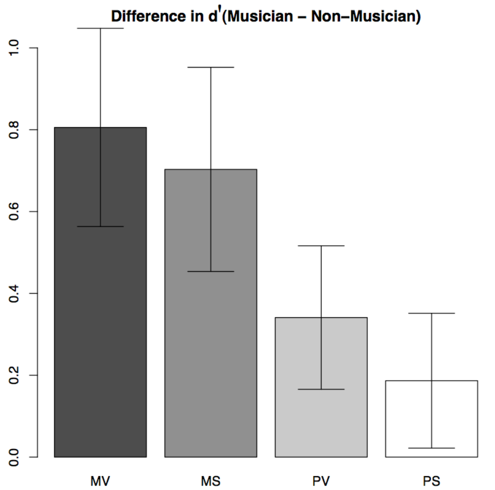

Figure 1. The difference in performance between the trained musicians and untrained non-musician samples by block type. Error bars reflect the standard error of mean.

These finding leave open the possibility that the trained musicians' performance on the tone recognition task is in part aided by their practice of fine motor tasks (e.g. repetitive, precision-oriented hand movement during musical practice), improved attention to relevant stimuli or overall improved signal detection. In order to evaluate these questions, an analysis of the lexical decision task results for both groups was performed.

Results of Lexical Decision Task

Overall, participants performed well on the lexical decision task with a correct response rate of 91.53%. In analyzing data from the lexical decision task relative to the auditory perception task, we found an interaction in performance, $F[1,95] = 6.478$, $p < .05$. The sample of musically trained participants performed better on the auditory recognition task whereas the sample of musically untrained participants performed better on the lexical decision task (see Figure 2).

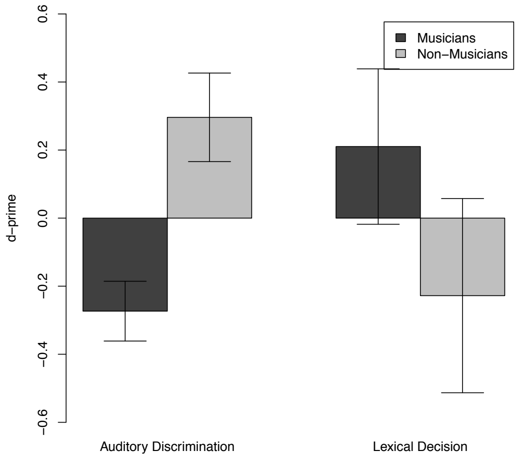

Figure 2. Mean d' for trained musicians and non-musicians on the auditory discrimination and lexical decision tasks. Error bars reflect the standard error of mean.

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deviations in either direction (a difference of < .01 percentage points).

[2] Due to a coding error, a substantial portion of the non-musician participants received the same block order: Pelog Violin, Major Violin, Pelog Sine, Major Sine.

General Discussion

The data generated in this study supported the initial hypothesis regarding effects of enculturation: that while prior musical training predicted better performance on the pitch discrimination task, the resulting advantage depended closely upon the familiarity of the pitches and timbres presented. Not only did familiarity show a positive correlation with accuracy of identification and a negative correlation with reaction time, but these effects were more marked for participants with substantial musical training, which reduced the utility of subjects' musical training as a signal to predict their performance under conditions of low familiarity. In fact, the demonstrated advantage resulting from musical training was altogether absent for tone discrimination of pelog sine prototypes and of pelog violin and pelog sine large deviations. These results are in agreement with previously established enculturation effects in pitch discrimination, which suggest a learned rather than generative aspect of communicative category formation.

The interactions between sample (trained vs. untrained) and familiarity suggest that while the two groups may approach the frequency discrimination task in fundamentally different ways, these differences become insignificant as the aural input becomes inconsistent with sound patterns for culturally familiar musical sound. This result holds true across not only the variable for pitch but also the variable for timbre — where without accounting for musical enculturation, the richness of overtones within the violin timbre compared to the sine wave would presumably lead to greater difficulty in distinguishing fundamental frequencies. As a result, we can infer that what sets trained musicians apart is the salience of cognitive schemas established through the enculturation of familiar musical pitches and timbres, rather than a heightened and innate faculty for the discrimination of pitch frequencies.

The richness of the data set offers several promising approaches for future analysis beyond what is presented in this paper. Data from the musical experience questionnaire given to each participant includes not only ordinal responses on propositions relating to various facets of musical experience, but also qualitative responses for the time, intensity, and instrument(s) of participants' musical experience. Integrated into the main analysis, this data could offer any number of ways to parse musical experience beyond the trained/untrained binary provided by subjects' institutional and academic backgrounds, allowing for quantitative differentiation between multiple variables in musical experience and their influence on pitch discrimination.

In addition to further analysis on existing data, additional experimentation within similar paradigms could build off of existing research on the effects of linguistic interference tasks on learned categorical perception (Winawer et al, 2007). If variable performance on pitch discrimination tasks depends largely upon enculturation of specific sound categories, interference tasks designed to impede the utilization of complex cognitive schemas should have similar effects on pitch discrimination as on discrimination of categories in other domains, such as colors and phonemes. Furthermore, these effects should show significant variation in keeping with the varied extent of subjects' prior musical enculturation.

Demonstrating such effects on pitch category discrimination would provide further support for theories of domain-general communicative category formation, underscoring an important consistency between the present research and broader research directions within cognitive science and cognitive linguistics (e.g. Evans & Levinson, 2009; Tomasello, 2014).

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