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Michael W. Weiss[a], Patrícia Vanzella[b], E. Glenn Schellenberg[a] & Sandra E. Trehub[a]

[a] Department of Psychology, University of Toronto Mississauga, Mississauga, ON, Canada

[b] Department of Music, University of Brasília, Brasília, Brazil

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Rapid communication

Pianists exhibit enhanced memory for vocal melodies but not piano melodies

Michael W. Weiss[1], Patrícia Vanzella[2], E. Glenn Schellenberg[1], and Sandra E. Trehub[1]

[1]Department of Psychology, University of Toronto Mississauga, Mississauga, ON, Canada
[2]Department of Music, University of Brasília, Brasília, Brazil

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Nonmusicians remember vocal melodies (i.e., sung to *la la*) better than instrumental melodies. If greater exposure to the voice contributes to those effects, then long-term experience with instrumental timbres should elicit instrument-specific advantages. Here we evaluate this hypothesis by comparing pianists with other musicians and nonmusicians. We also evaluate the possibility that absolute pitch (AP), which involves exceptional memory for isolated pitches, influences melodic memory. Participants heard 24 melodies played in four timbres (voice, piano, banjo, marimba) and were subsequently required to distinguish the melodies heard previously from 24 novel melodies presented in the same timbres. Musicians performed better than nonmusicians, but both groups showed a comparable memory advantage for vocal melodies. Moreover, pianists performed no better on melodies played on piano than on other instruments, and AP musicians performed no differently than non-AP musicians. The findings confirm the robust nature of the voice advantage and rule out explanations based on familiarity, practice, and motor representations.

Keywords: Memory; Melody; Timbre; Music training; Absolute pitch.

What makes a melody memorable? Relevant features include discernible rhythms (Hannon, Soley, & Ullal, 2012), familiar musical styles (Demorest, Morrison, Beken, & Jungbluth, 2008), distinctive motives (Müllensiefen & Halpern, 2014), expressive performances (Juslin, 2003), engaging lyrics (Peynircioğlu, Rabinovitz, & Thompson, 2008), and specific timbres (Weiss, Schellenberg, Trehub, & Dawber, 2015; Weiss, Trehub, & Schellenberg, 2012). After hearing initially unfamiliar melodies sung to *la la* or played on piano, banjo, or marimba, adults and children from 7 years of age recognize vocal versions more readily than instrumental versions (Weiss et al., 2012, 2015). Why? Although the simplest explanation implicates a preference for vocal renditions, adults and children actually rate sung versions less favourably than instrumental versions, perhaps because of the syllabic repetition.

An alternative explanation involves predispositions for attending to conspecific vocalizations (e.g., Braaten & Reynolds, 1999), resulting in enhanced encoding and more robust representations. In line with this view, preferential processing is evident for species-specific vocalizations and for vocal over instrumental sounds (Fecteau, Armony, Joanette, & Belin, 2004). For example,

Correspondence should be addressed to Glenn Schellenberg, Department of Psychology, University of Toronto Mississauga, Mississauga, ON, Canada L5L-1C6. E-mail: g.schellenberg@utoronto.ca

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nonlinguistic vocalizations elicit greater and more distinctive cortical activation than other complex signals in infants (Blasi et al., 2011) and adults (Belin, Zatorre, Lafaille, Ahad, & Pike, 2000).

Vocal production experience may also activate cortical regions associated with the planning and execution of vocal movements. For example, listening to sung rather than synthesized melodies results in earlier and more robust electroencephalography (EEG) responses in energy bands associated with sensorimotor activity (Lévêque & Schön, 2013). Moreover, transcranial magnetic stimulation (TMS) in laryngeal motor areas has greater impact on the categorization of natural human vocalizations than on the categorization of electronically distorted versions (Lévêque, Muggleton, Stewart, & Schön, 2013). In short, distinctive behavioural and cortical responsiveness may underlie the memory advantage for vocal melodies.

The voice is also more *familiar* than any instrumental timbre. If familiarity contributes to the processing advantage for vocal melodies, then high levels of instrumental training should generate processing advantages and better memory for melodies presented in the trained instrument. While listening to musical stimuli, musicians exhibit greater oscillatory gamma band activity, which is correlated with perceptual and cognitive function, than nonmusicians, with the largest enhancements evident for the timbre of training (Shahin, Roberts, Chau, Trainor, & Miller, 2008). Instrument-specific responses in the auditory cortex, as measured by magnetoencephalography (MEG), have also been documented for violinists and trumpet players (Pantev, Roberts, Schulz, Engelien, & Ross, 2001).

Perceptual and motor systems are tightly coupled in highly trained instrumentalists (Zatorre, Chen, & Penhune, 2007). For example, cortical representations of digits are enhanced on the left hand, but not the right, for violinists compared to nonmusicians, and the magnitude of the effect is related to the age of onset of training (Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1995). When listening to piano melodies, highly trained pianists exhibit greater activity than nonmusicians in regions near the primary (Haueisen & Knösche, 2001) and secondary (Baumann et al., 2007) motor areas. Enhanced auditory–motor networks (i.e., shared activation elicited by separate sound-only and motor-only musical tasks) are also evident for pianists relative to nonmusicians on auditory and motor tasks involving the piano (Baumann et al., 2007). On the basis of these findings, one would expect musicians to exhibit timbre-specific enhancement of memory for melodies.

In the present study, we assessed memory for melodies presented in vocal, piano, banjo, and marimba timbres, as in earlier research (Weiss et al., 2012, 2015), but with a focus on comparisons between nonmusicians and musicians, particularly pianists and musicians with absolute pitch (AP). Musicians outperform nonmusicians on some music-cognition tasks (e.g., Banai, Fisher, & Ganot, 2012; Dowling, Kwak, & Andrews, 1995, Experiments 6 and 7; Schellenberg & Moreno, 2010) but not others (Dowling et al., 1995, Experiments 1–5; Halpern, Kwak, Bartlett, & Dowling, 1996; McAuley, Stevens, & Humphreys, 2004). We know of no instances, however, in which nonmusicians performed better than musicians, and musically trained individuals routinely outperform their untrained counterparts on tests of memory for nonmusical auditory and visual stimuli (for a review, see Schellenberg & Weiss, 2013). Thus, we expected musicians to have better memory for melodies than nonmusicians. Moreover, if high levels of training have instrument-specific effects on memory, then professional pianists should remember piano melodies better than melodies played on other instruments. By contrast, other instrumentalists and nonmusicians would be expected to exhibit the vocal-memory advantage observed previously while exhibiting no differences among melodies in untrained instrumental timbres.

Exceptional pitch memory, as observed in musicians with AP, could also affect performance. AP refers to the ability to identify or produce isolated tones (e.g., middle C, concert A) without a reference tone. It is evident in only a small minority of musicians (Takeuchi & Hulse, 1993) and has been linked to enhanced cortical connectivity (Loui, Li, Hohmann, & Schlaug, 2011), facilitation on tone memory tasks (for a review, see

Deutsch, 2013), and interference with relative pitch processing (Miyazaki, 1993, 1995). In general, musicians with AP find it easier to identify tones presented instrumentally—especially in familiar timbres—than as sine-wave tones (Miyazaki, 1989; Schlemmer, Kulke, Kuchinke, & van der Meer, 2005). Presumably, the multiple frequency components of complex or instrumental tones (e.g., 200 Hz, 400 Hz, 600 Hz, and so on) facilitate performance because the harmonics, as integer multiples of the fundamental frequency, increase pitch salience (Oxenham, 2013).

Although sounds that are spoken or sung also have harmonics at integer multiples of the fundamental frequency, AP possessors have more difficulty naming vocal tones (natural or synthesized) than piano tones or pure tones (Vanzella & Schellenberg, 2010). In any event, it is unclear whether AP possessors would exhibit a memory advantage or disadvantage for vocal over instrumental melodies when there is no requirement for naming notes. In principle, the vocal disadvantage for note naming could offset the vocal advantage for melodic memory.

EXPERIMENTAL STUDY

Method

Participants

Participants were recruited in São Paulo and Brasília, where the second author is a faculty member. They included 38 musicians (19 male) and 20 nonmusicians (6 male) matched in age (musicians: $M = 28.3$ years, $SD = 9.3$; nonmusicians: $M = 27.4$ years, $SD = 7.4$). Nonmusicians had less than two years of music training ($M = 0.4$ years, $SD = 0.7$, range = 0–2 years), which ended more than four years before testing. All musicians were musically active, with at least five years of Western-style conservatory training on their primary instrument ($M = 14.3$ years, $SD = 6.6$, range = 5–40 years).

The musicians were current or former undergraduate or graduate students in music. Undergraduate music programmes in Brazilian universities tend to resemble those in North America. For most participants, "training" meant weekly individual lessons on their speciality instrument. In addition, the musicians in our sample had a history of training in music theory (including solfège, usually fixed-do), harmony, counterpoint, ear training, music history, analysis, and so on.

The musicians were recruited so that AP designation (AP or non-AP), primary instrument (piano or other), and professional status (professional or amateur) were balanced (i.e., $ns = 19$ in each group) but not counterbalanced. According to self-report, 16 had AP, 17 did not, and 5 were unsure, but actual AP skill (AP or non-AP) was determined objectively (see below, $ns = 19$). Piano was the primary instrument for half of the musicians, and half of the musicians were professionals (i.e., employed as musicians). There were four to six participants in each of eight cells (Piano/Other × AP/Non-AP × Professional/Amateur). A series of chi-square tests of independence revealed that these three dichotomous variables were statistically independent, $ps > .7$. Table 1 provides background information for the subgroups of musicians. One additional musician was excluded because of recognition performance more than two standard deviations below the overall group mean, which implied inattention to the task. The pattern of results was unaffected by inclusion or exclusion of this individual.

Apparatus and stimuli

The stimuli were 48 British or Irish folk melodies performed by amateur musicians, including the 32 used by Weiss et al. (2012) and 16 additional melodies. Each melody was recorded in four different timbres (voice, piano, banjo, marimba). Performance timing across timbres was matched by recording to a backing track, and vocal melodies were pitch-corrected without artefacts by means of Melodyne (Celemony, Inc.) software. Melodies differed in length (13–20 s), tempo (75–130), time signature (3/4, 4/4, 6/8), number of notes (20–57), and mode (major/minor). An untrained singer sang the vocal renditions in her most comfortable (alto) range. Further details about melody

Table 1. *Descriptive statistics for subgroups of musicians*

Variable	*Pianist*		*Absolute pitch*		*Professional*		
	Yes (n = *19*)	*No* (n = *19*)	*Yes* (n = *19*)	*No* (n = *19*)	*Yes* (n = *19*)	*No* (n = *19*)	*All* (n = *38*)
Gender (males)	7	12	9	10	7	12	19
Age (years)	25.21 (8.30)	31.37 (9.35)	29.79 (10.88)	26.79 (7.28)	30.74 (9.74)	25.84 (8.29)	28.29 (9.26)
Training (years)	12.84 (4.13)	15.74 (8.33)	16.84 (7.35)	11.74 (4.81)	16.58 (7.37)	12.00 (5.05)	14.29 (6.65)
Instrumental experience (years)	15.47 (8.28)	18.16 (10.13)	20.21 (10.62)	13.42 (6.15)	18.42 (8.76)	15.21 (9.63)	16.82 (9.23)
Performances per year	24.68 (44.20)	51.21 (32.90)	32.84 (31.44)	43.05 (48.62)	56.00 (47.63)	19.89 (21.23)	37.95 (40.71)
Practice (hours per day)	2.97 (1.74)	3.50 (1.83)	3.11 (1.48)	3.37 (2.08)	4.00 (1.88)	2.47 (1.34)	3.24 (1.79)
Onset of training (age)	8.11 (2.21)	9.74 (4.21)	7.89 (3.56)	9.95 (3.03)	8.84 (2.59)	9.00 (4.16)	8.92 (3.42)

Note: Noninteger values are means. Standard deviations are in parentheses.

production and recording are provided in Weiss et al. (2012). Customized software created with PsyScript (Slavin, 2007) on an Apple laptop computer presented melodies over Sony MDR-710 headphones and recorded responses, with instructions in Portuguese.

Musicians were tested for AP with Vanzella and Schellenberg's (2010) method. The stimuli were audio files, each 1 s in duration, corresponding to a note in the 24-note range (chromatic scale) from A3 (3 semitones below middle C) to G#5. Each of the 24 notes was presented in four timbres (real voice, synthesized voice, piano, sine wave) for 96 stimuli in total.

Procedure

Participants were tested individually in a quiet room with the experimenter present. There was an *exposure* phase, when participants listened to the target melodies, and a *test* phase, when they judged the melodies as old (targets) or new (foils). For each participant, the 48 melodies were assigned randomly to the four timbres (12 per timbre). For each listener and each timbre, half of the melodies were assigned at random to be old ($n = 6$ targets in each of four timbres) or new ($n = 6$ foils in each of four timbres). Order of stimulus presentation in the exposure and test phase was randomized separately for each listener.

In the exposure phase, participants heard the 24 target melodies, rating their liking of each melody on a 5-point scale (1–*dislike* to 5–*like*). In contrast to Weiss et al. (2012), each exposure melody was presented once rather than three times. During a 5- to 10-minute break, participants completed a background questionnaire. The test phase followed, during which participants heard all 48 melodies (24 targets and 24 foils intermixed) and rated each melody as old (i.e., heard in the exposure phase) or new on a 6-point scale (1–*definitely new* to 6–*definitely old*).

Following the memory test, musicians completed a test of AP. (Nonmusicians are unable to name notes.) They heard a note every 3 s and were required to identify it by clicking on a keyboard image on the screen. The 12 notes on the keyboard (corresponding to notes of the chromatic scale) were labelled with note names. Brazil uses a fixed-do system, so the notes were labelled *do*, *do#*, *re*, and so on, instead of letter names (C, C#, D, and so on). Stimuli were presented in separate blocks for each timbre. The order of blocks and of notes within blocks was randomized separately for each listener.

Results

Absolute pitch

For each musician, four scores were calculated based on the number of correct responses (maximum = 24) for each of the four timbres in the AP test (real voice, synthesized voice, piano, sine wave). Semitone errors were considered correct (following Miyazaki, 1988; Vanzella & Schellenberg, 2010). AP musicians were required to have 19 or more correct responses on one or more of the timbres, and non-AP musicians needed to have 17 or fewer correct responses for each of the four timbres. Mean performance across timbres was 20.49 correct ($SD = 2.45$) for the AP group and 7.86 correct ($SD = 3.24$) for the non-AP group, which corresponded well with musicians' self-reports. Self-reported non-AP status was confirmed in all cases, and only one self-report of AP was disconfirmed. Four of five musicians who were unsure of their AP status were found to have AP.

Because semitone errors were considered correct, 3 of 12 possible responses were correct on each trial, such that chance performance on 24 trials was 6 correct. For each participant, a score of 11 or greater exceeded chance performance, as determined by a one-tailed normal approximation to the binomial. Individually, then, AP musicians performed better than chance across timbres, whereas non-AP musicians were typically at chance levels. Nevertheless, a one-sample *t*-test revealed that performance of non-AP musicians as a group exceeded chance levels (6 correct), $t(18) = 2.50$, $p = .022$, in line with reports that many musicians without AP exhibit residual or quasi-AP (Levitin & Rogers, 2005), often for only one pitch class (e.g., C or *do*). The findings are also consistent with evidence that pitch memory varies on a continuum rather than being strictly bimodal (Schellenberg & Trehub, 2003).

Response patterns on the AP task were examined further with a two-way mixed-design analysis of variance (ANOVA), with timbre as a repeated measure and AP status as a between-subjects variable. Descriptive statistics are illustrated in Figure 1. Although there was no two-way interaction, $F < 1$, there were main effects of timbre, $F(3, 108) = 5.69$, $p = .001$, $\eta_p^2 = .14$, and AP status (guaranteed by the grouping criteria). Three planned orthogonal contrasts confirmed that note-naming performance was similar for the natural and synthesized voice, $p > .5$, and for the piano and sine-wave timbres, $p > .2$, but worse for the two vocal than the two nonvocal timbres, $t(37) = 4.03$, $p < .001$, Cohen's $d = 0.65$ (d calculated from difference scores). For AP musicians, average performance was 19.84 correct ($SD = 2.89$) for the vocal timbres and 21.13 correct ($SD = 2.32$) for the nonvocal timbres. For non-AP musicians, the means were 7.11 ($SD = 2.79$) and 8.61 ($SD = 4.01$), respectively. These findings replicate Vanzella and Schellenberg's (2010) report of AP musicians having more difficulty naming notes in vocal than in nonvocal timbres. They also extend earlier work by revealing that non-AP

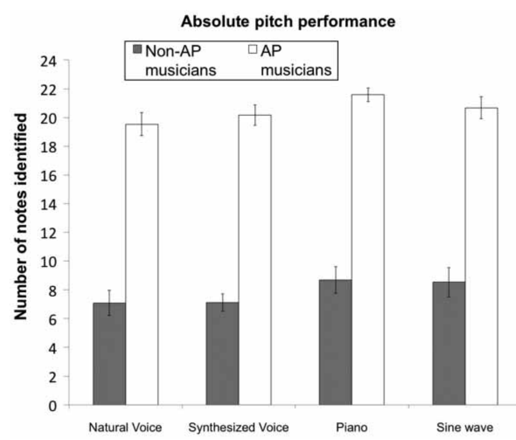

Figure 1. *Performance on the absolute pitch (AP) task as a function of timbre and whether the participant was an AP or non-AP musician. For both groups, performance on the vocal timbres was worse than performance on the nonvocal timbres. Error bars are standard errors of the mean.*

musicians also have greater difficulty naming notes presented vocally.

Melody recognition

In the recognition phase, each participant made responses to six melodies in each of eight cells (old–voice, new–voice, old–piano, new–piano, etc.). Across participants, a substantial proportion of cells (115 out of 464) were perfectly differentiated as either "old" or "new", defined as all ratings of 3 or lower for new cells and all ratings of 4 or higher for old cells. The small number of melodies per cell probably contributed to this pattern. A d' analysis was deemed inappropriate because of the high proportion of cells with perfect performance (i.e., indeterminate d' scores) and the need to transform the informative 6-point scale to a binary response. Instead, we analysed recognition ratings as in previous research (Weiss et al., 2012). For each participant, eight scores were formed by averaging the ratings for each timbre (voice, piano, banjo, marimba) separately for targets and foils, with each score derived from six original ratings. Higher scores for old than for new melodies indicated memory for the melodies, with no difference representing chance performance.

Preliminary analyses used one-sample t-tests (two-tailed) to compare scores with the midpoint of the rating scale (3.5). Because there were eight tests (4 timbres × 2 exposures) for each group of participants, we corrected for multiple tests using the Holm–Bonferroni method. (The same method was applied in subsequent analyses.) In all instances and for all groups of participants (musicians, nonmusicians, primary instrument piano or other, musicians with or without AP, professionals, and amateur musicians), new melodies received ratings lower than the midpoint for all four timbres, $p\text{s} < .005$. For musicians overall and all musician subgroups, old melodies were rated higher than the midpoint for all four timbres, $p\text{s} < .05$. For nonmusicians, old melodies were rated higher than the midpoint for the voice, piano, and banjo, $p\text{s} < .05$, but not the marimba, $p > .1$.

The main analysis was a three-way mixed-design ANOVA that included timbre (voice, piano, banjo, marimba) and exposure (old, new) as repeated measures and musicianship (20 nonmusicians, 38 musicians) as a between-subjects variable. Descriptive statistics are illustrated in Table 2. There was no three-way interaction among musicianship, timbre, and exposure, $F < 1$, and no two-way interaction between musicianship and timbre, $F < 1$. Two-way interactions between exposure and timbre (Figure 2, upper panel), $F(3, 168) = 9.72$, $p < .001$, $\eta_p^2 = .15$, and between exposure and musicianship (Figure 2, lower panel), $F(1, 56) = 10.22$, $p = .002$, $\eta_p^2 = .15$, qualified the main effects of exposure, $F(1, 56) = 288.38$, $p < .001$, $\eta_p^2 = .84$, and timbre, $F(3, 168) = 17.35$, $p < .001$, $\eta_p^2 = .24$.

The interaction between exposure and timbre was followed up with separate analyses of the four timbres. The exposure effect (i.e., the difference between old and new melodies) was significant in all instances, $p\text{s} < .001$, with the interaction con-

Table 2. *Descriptive statistics for mixed-design ANOVA with musicians and nonmusicians*

	Musicians		*Nonmusicians*	
Timbre	*Old melodies*	*New melodies*	*Old melodies*	*New melodies*
Voice	4.88 (0.65)	2.24 (0.74)	4.61 (0.76)	2.74 (0.71)
Piano	3.99 (0.73)	2.04 (0.72)	3.83 (0.56)	2.43 (0.67)
Banjo	4.31 (0.81)	2.39 (0.63)	4.18 (0.60)	2.73 (0.83)
Marimba	4.04 (0.92)	2.14 (0.74)	3.77 (0.74)	2.74 (0.76)

Note: Values are mean recognition confidence scores (standard deviations in parentheses) along continuum from "1–definitely new" to "6–definitely old". ANOVA = analysis of variance.

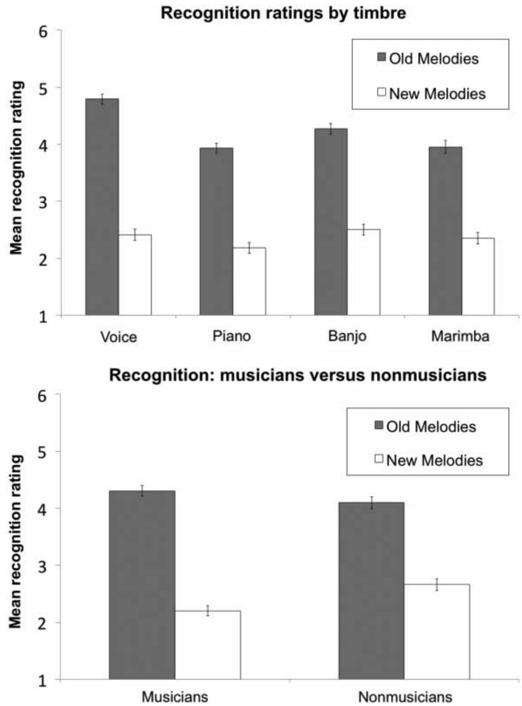

Figure 2. *Recognition scores as a function of exposure level and timbre (upper panel), and exposure level and whether the participant was a musician or nonmusician (lower panel). The difference between old and new melodies was greater for the vocal melodies than for the instrumental melodies, and for musicians than for nonmusicians. Error bars are standard errors of the mean.*

firming that the effect was significantly greater for the voice ($M_{\mathrm{Diff}} = 2.37$, $SD = 1.18$) than for the piano ($M_{\mathrm{Diff}} = 1.75$, $SD = 0.97$), banjo ($M_{\mathrm{Diff}} = 1.76$, $SD = 0.98$), or marimba ($M_{\mathrm{Diff}} = 1.60$, $SD = 1.10$), $p\mathrm{s} < .01$. The difference between old and new melodies was similar across the three instrumental timbres, $p\mathrm{s} > .2$. We also conducted separate analyses of old and new melodies. For old melodies, the timbre effect was highly significant, $F(3, 168) = 23.07$, $p < .001$, $\eta_p^2 = .29$, with the voice receiving higher ratings than the piano, banjo, and marimba, $p\mathrm{s} < .001$. The banjo also received higher ratings than the piano and marimba, $p\mathrm{s} < .05$, which did not differ. For new melodies, there was a much smaller difference among timbres, $F(3, 168) = 3.22$, $p = .024$, $\eta_p^2 = .05$, which stemmed from lower ratings for the piano than for the banjo, $p < .01$.

The interaction between exposure and musicianship was followed up with separate analyses of musicians and nonmusicians. Both groups differentiated old from new melodies, $p\mathrm{s} < .001$, with the interaction revealing that musicians ($M_{\mathrm{Diff}} = 2.10$, $SD = 0.82$) outperformed nonmusicians ($M_{\mathrm{Diff}} = 1.44$, $SD = 0.62$). Separate analyses of old and new melodies revealed that the groups provided similar ratings for old melodies, $p > .1$, but the musicians provided lower ratings for new melodies, $p < .01$.

Because there was no three-way interaction, the results can be summarized as follows: (a) The voice advantage was similar for musicians and nonmusicians, stemming from higher ratings for old vocal melodies, and (b) musicians had better memory than nonmusicians across timbres, with the effect resulting from lower ratings for new melodies (i.e., more confident rejections).

Differences among subgroups of musicians were examined with three mixed-design ANOVAs, with timbre (voice, piano, banjo, marimba) and exposure (old, new) as repeated measures and group as a between-subjects variable. The grouping criterion was different in each ANOVA: (a) primary instrument (piano or other), (b) AP status (AP or non-AP), and (c) amateur or professional status. For ease of interpretation, difference scores (old melodies − new melodies) are illustrated in Figure 3. In each ANOVA, the interaction between timbre and exposure was significant, $p < .001$, with pairwise comparisons revealing better memory (i.e., better differentiation of old and new melodies) for vocal than for instrumental melodies, $p\mathrm{s} < .01$, and no differences among the three instrumental timbres, $ps > .9$. More crucially, pianists and non-pianists did not differ in overall recognition (i.e., no interaction between exposure and primary instrument), $p > .2$, and the vocal advantage was similar between groups (i.e., no three-way interaction), $F < 1$ (Figure 3, upper panel). In other words, extensive piano experience did not affect the vocal melody advantage or memory for piano melodies. Similarly, differences in musician's AP status did not interact with exposure, $F < 1$, and voice-recognition was similar between groups, $F < 1$ (Figure 3, middle panel). Although AP

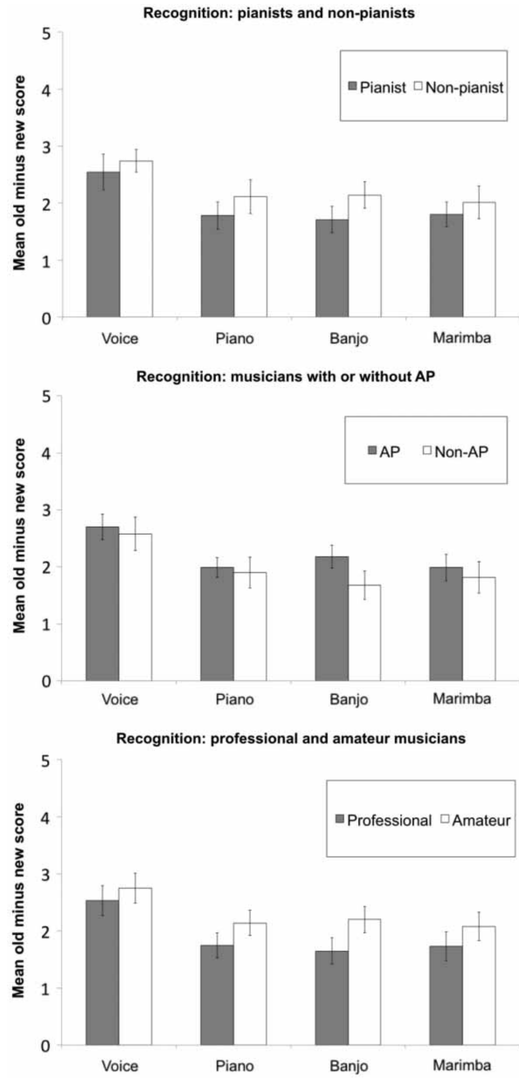

Figure 3. *Difference scores (recognition of old melodies – recognition of new melodies) as a function of timbre and whether the musician was pianist or nonpianist (upper panel), absolute pitch (AP) or non-AP (middle panel), and professional or amateur (lower panel). Nonmusicians were excluded. In each comparison, the voice advantage was evident and was similar for both groups. Error bars are standard errors of the mean.*

musicians had difficulty naming notes presented vocally, they exhibited the typical vocal advantage in melody recognition. Finally, there was no two-way interaction between amateur or professional status and exposure, $p > .1$, and both groups had virtually identical voice-recognition advantages, $F < 1$ (Figure 3, lower panel). This null finding is surprising because professional and amateur musicians differed in multiple ways (see Table 1). Professionals had more daily practice, $t(36) = 2.89$, $p = .007$, $d = 0.94$, more public performances annually, $t(36) = 3.02$, $p = .005$, $d = 0.98$, and more years of formal training than amateurs, $t(36) = 2.23$, $p = .032$, $d = 0.73$, but the groups did not differ in age, $p > .1$, years of instrumental experience, $p > .2$, or age of onset of training, $p > .8$.

A final analysis revealed that musicians' voice advantage on the recognition test (voice average minus instrumental average) was uncorrelated with their voice disadvantage on the AP test (average on piano and pure tones minus average on natural and synthesized voices), $p > .2$. We also used multiple regression to predict the musicians' voice advantage from four dummy-coded variables: gender, primary instrument, AP status, and professionalism. The model was not significant, $p > .9$, and none of the four predictor variables made a significant contribution to the model, ps $> .5$.

Liking

Musicians and nonmusicians could differ in hedonic evaluations of musical stimuli that promote differences in recognition. To test this possibility, liking ratings for melodies heard at exposure were formed for each timbre so that each participant had four scores, with each score averaged over six original ratings. A mixed-design ANOVA evaluating liking as a function of timbre (voice, piano, banjo, marimba) and musicianship (musician, nonmusician) revealed a main effect of timbre, $F(3, 168) = 3.88$, $p = .010$, $\eta_p^2 = .07$. Participants liked the voice significantly less than the banjo, $p = .011$, marginally less than the piano, $p = .075$, but no differently than the marimba, $p > .9$, and their liking ratings were similar for the three instrumental timbres, ps $> .3$. There was no difference in overall liking between musicians and nonmusicians, $p > .2$, and no interaction between timbre and musicianship, $p > .3$. In short, all participants liked the vocal melodies less than the instrumental melodies, in line with previous research (Weiss et al., 2012, 2015).

An item analysis confirmed that greater liking of individual melodies was related to more confident recognition. Two scores were calculated for each of the 48 melodies: average liking rating at exposure and average recognition rating at test for old presentations only. Calculated in this manner, there was a significant positive association between liking and recognition, $r(48) = .67$, $p < .001$, and separate correlations for each timbre yielded positive correlations that were significant or marginally significant. In sum, our test of the vocal-memory advantage was particularly conservative because greater liking was predictive of improved recognition, yet the vocal melodies were least favoured.

Discussion

The results of the present study revealed (a) better memory for melodies presented vocally rather than instrumentally, (b) a similar voice advantage for musicians and nonmusicians, (c) no advantage for highly trained pianists on piano melodies, (d) better memory for musicians than nonmusicians, and (e) no difference between AP musicians and non-AP musicians in memory for melodies or the voice-recognition advantage.

On the basis of instrument-specific processing advantages (Pantev et al., 2001; Shahin et al., 2008) and enhanced auditory–motor coordination (Zatorre et al., 2007) in musicians, we expected pianists to recognize piano melodies better than banjo and marimba melodies. They did not, however, which rules out motor representations as the principal source of the vocal-memory advantage. In principle, familiarity could contribute to the advantage for vocal melodies because the voice is the most familiar timbre as well as being the dominant musical timbre during the formative years, even among pianists. Nevertheless, the failure of extensive piano training and practice to enhance memory for piano melodies reduces the likely contribution of familiarity. Instead, whatever underlies the vocal-memory advantage may be specific to vocal processing or it may depend on exposure beyond that of experienced professional musicians. The voice is unique among musical timbres because it is not primarily musical. Rather, it is a biological signal that elicits distinctive processing across the lifespan (Belin et al., 2000; Blasi et al., 2011). Repetition of the syllable *la* may also have engaged communication or language networks, enhancing attention to the voice and facilitating the encoding of acoustic details.

Absolute pitch (AP) was neither advantageous nor disadvantageous for melodic memory. The contention that AP interferes with relative pitch processing (Miyazaki, 2004) arises from AP musicians' poor performance on relational processing tasks involving judgements of interval size—the pitch distance between two tones (Mito, 2003; Miyazaki, 1993, 1995). AP has also been linked to *better* performance on some listening tasks (Dooley & Deutsch, 2011; Ziv & Radin, 2014). Whereas previous studies focused on analytical music listening, the present melody-recognition task provided a more ecologically valid test of relative pitch processing because it was relevant to listeners regardless of training. The absence of memory differences between AP and non-AP musicians casts doubt on the notion that AP interferes with relative pitch processing in the context of everyday listening.

The AP test revealed that musicians more readily identified piano and sine tones than vocal tones, as they did in previous research (Vanzella & Schellenberg, 2010). This finding also mirrors the "vocal generosity effect" (Hutchins, Roquet, & Peretz, 2012), which refers to listeners' greater difficulty detecting out-of-tune notes in vocal than in instrumental contexts. The vocal tones in the present AP task consisted of real and synthesized voices (i.e., controlling for acoustic features like vibrato), so one possible explanation of poorer vocal pitch naming is that the voice is processed first as a biological signal and subsequently as an instrument with tonal characteristics. It is interesting that the voice impairs pitch processing in tasks involving note naming (Vanzella & Schellenberg, 2010) or tuning judgements (Hutchins et al., 2012), but it enhances memory for melodies (Weiss et al., 2012, 2015). For musicians in the current study, the voice disadvantage in the AP task did not correlate with the voice advantage in the memory task. Vocal material may confer local processing disadvantages, as in pitch-naming and pitch-judgement tasks, and global processing advantages, as in melodic processing and memory tasks.

Long-term memory for novel melodies was better for musicians than nonmusicians, a finding consistent with previous reports of musicians' enhanced long-term memory for prose (Jakobson, Cuddy, & Kilgour, 2003), lyrics (Kilgour, Jakobson, & Cuddy, 2000), word lists (Brandler & Rammsayer, 2003; Chan, Ho, & Cheung, 1998; Chin & Rickard, 2010), environmental sounds (Cohen, Evans, Horowitz, & Wolfe, 2011), and music (Cohen et al., 2011; Wee Hun Lim & Goh, 2013; Weiss et al., 2012). This finding has no bearing on the contentious issue of causation (Schellenberg & Weiss, 2013). In principle, Brazilian musicians could have been more familiar than their nonmusician counterparts with the genre or even with some specific melodies, although there was no indication that this was the case. Nevertheless, our finding confirms that musicians outperformed nonmusicians, as expected, and that the sample size provided the requisite statistical power.

It is possible that the vocal advantage in memory for melodies differs across subgroups of musicians, but larger sample sizes would be necessary to evaluate this possibility. Because differences between groups of musicians were at chance levels for all comparisons (i.e., pianists vs. nonpianists, AP vs. non-AP, professional and amateurs, all Fs < 1 in tests of the interaction between group, exposure, and timbre), any such differences, if evident in future research, are likely to be trivial in magnitude. In any event, the present vocal-memory advantage in musicians and nonmusicians and the comparable advantage in nonmusicans tested with digital or real instrumental melodies (Weiss et al., 2012, 2015) confirm the profound influence of the voice on music processing and on melodic memory in particular.

One promising direction for future research involves nonvocal timbres that share features with the voice. The instruments tested to date—piano, banjo, and marimba—have percussive amplitude envelopes and notes with fixed, stable pitches, two major differences from notes that are sung. Sung melodies could be compared with violin or saxophone melodies, which have amplitude envelopes similar to the voice. Moreover, the voice could be digitally manipulated to reduce spectral variation, in line with instrumental timbres. Finally, vocal melodies could be morphed into instrumental melodies by means of cross-synthesis procedures that use the features of one timbre to model a different timbre or instrument (Jehan & Schoner, 2001). A recognition advantage for hybrid (vocal/instrumental) melodies over instrumental melodies would shed light on the contribution of acoustic features to the vocal melody advantage.

As in previous research (Weiss et al., 2012, 2015), listeners remembered vocal melodies better than instrumental melodies, but they liked them less, indicating that hedonic preferences do not underlie the memory advantage. Nevertheless, hedonic preferences for specific melodies contributed to their memorability. It is possible that presentation of the vocal melodies in a more natural or fluid singing style (e.g., continuous *ah* vs. *la la*) would lead to higher liking ratings and an even greater vocal advantage.

In conclusion, the current findings highlight the robust processing advantage for vocal melodies (Weiss et al., 2012, 2015), which was comparable for musicians and nonmusicians. For highly trained pianists, vocal melodies were more memorable than piano melodies, which were no more memorable than melodies in other instrumental timbres. The vocal advantage is likely to implicate enhanced attention arising from processing predispositions for conspecific vocalizations. Whether vocal melodies automatically recruit greater attention than instrumental melodies regardless of age and experience remains to be determined.

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