Instrument-Specific Effects of Musical Expertise on Audiovisual Processing (Clarinet vs. Violin)

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A large body of evidence has shown that musicians' brains differ in many ways from nonmusicians' brains due to the particularly intense and prolonged sensorimotor training involved. Not much is known about the effects of the specific musical instrument played on brain processing of audiovisual information. In this study the effect of musical expertise was investigated in professional clarinetists and violinists. One hundred and eighty videos showing fragments of musical performances played on a violin or a clarinet were presented to musicians of G. Verdi Milan Conservatory and age-matched controls. Half of the musicians were violinists, the other half were clarinetists; event-related potentials (ERPs) were recorded from 128 scalp sites and analyzed. Participants judged how many notes were played in each clip. The task was extremely easy for all participants. Over prefrontal areas an *anterior negativity* response was found to be much larger in controls than in musicians, and in musicians for the unfamiliar over the familiar musical instrument. Furthermore, a *later central negativity* response showed a lack of note numerosity effect in the brains of musicians for their own instrument, but not for unfamiliar instrument. The data indicate that music training is instrument-specific and that it profoundly affects prefrontal encoding of music-related information and auditory processing.

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The last two decades of neuroimaging and electromagnetic studies have provided solid evidence that being a musician (particularly when music training started early in childhood) is associated with important differences in brain connectivity (Fauvel et al., 2014; Kühnis, Elmer, & Jäncke, 2014), volume (Bermudez, Lerch, Evans, & Zatorre, 2009; Luders, Gaser, Jäncke, & Schlaug, 2004; Oechslin, Descloux, et al., 2013; Schlaug, 2001; Schlaug, Jäncke, Huang, Staiger, & Steinmetz, 1995; Sluming et al., 2002), and functioning (Oechslin, Van de Ville, Lazeyras, Hauert, & James, 2013) with respect to nonmusicians.

These differences concern motor performance (e.g., Bengtsson et al., 2005; Jäncke, 2009; Rüber, Lindenberg, & Schlaug, 2013; Zatorre, Chen, & Penhune, 2007), music reading and note coding (Proverbio, Manfredi, Zani, & Adorni, 2013), visuomotor transformation (Gaser & Schlaug, 2003; Harris and de Jong, 2014), callosal inter-hemispheric transfer (Lee, Chen, & Schlaug, 2003; Oztürk, Tasçioglu, Aktekin, Kurtoglu, & Erden, 2002), sound and speech processing (Chobert, François, Velay, & Besson, 2014; Chobert, Marie, François, Schön, & Besson, 2011; Elmer, Meyer, & Jäncke, 2012; Elmer, Hänggi, Meyer, & Jäncke, 2013; Gaab et al., 2005; Kraus & Chandrasekaran, 2010; Kühnis, Elmer, & Jäncke, 2014; Kühnis, Elmer, Meyer, & Jäncke, 2013; Parbery-Clark, Tierney, Strait, & Kraus, 2012; Strait & Kraus, 2011), and audiomotor integration (Baumann et al., 2007; Meyer, Elmer, & Jäncke, 2012). The related neuroplastic changes concern both gray matter and white matter architecture (Schmithorst & Wilke, 2002) and myelination (Bengtsson et al., 2005). It has also been demonstrated that music studying positively affects language processing. For example, through N400 analysis of event related potentials, François, Jaillet, Takerkart, & Schön (2014) showed that musicians were faster than controls at speech segmentation. Specifically, musicians showed an early increase in N400 amplitude (supposedly indicating phoneme segmentation), followed by a positivity indicating phoneme recognition. As for language reading, Proverbio et al. (2013) showed that music training occurring in childhood (from age ~8 years) modifies neural mechanisms of word reading. The electrophysiological neuroimaging study involved a letter (within word) detection task. While letter processing was strongly left-lateralized in controls, the fusiform (BA37) and inferior occipital gyri (BA18) were activated in both hemispheres in musicians for both word and music processing. The different neural activation pattern was associated with faster response times to target letters and fewer errors in letter detection in musicians compared to controls.

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Besides these more general effects of music training on cognition and intelligence, being a musician obviously affects the way the brain processes sounds and music. For example, musicians outperform nonmusicians in the ability to discriminate minor/major chords (Virtala, Huotilainen, Partanen, & Tervaniemi, 2014), as evidenced by mismatch negativity amplitude data. The electrophysiological investigation by Mikutta, Maissen, Altorfer, Strik, and Koenig (2014) showed that professional musicians exhibit a different pattern of brain activation than controls while listening to classical music (e.g., Ludwig van Beethoven's 5th symphony). In their study, larger mid frontal activity (and posterior alpha) was found in musicians compared to controls. The ERP study by Kaganovich et al. (2013) — in which subjects listened to sounds consisting of a male and a female voice saying [a], and of a cello and a French Horn playing an F3 note — showed that musicians had larger N1 ERP responses than controls to vocal sounds and to their (never before heard) spectrally-rotated versions. The authors concluded that music training is associated with a general improvement in the early neural encoding of complex sounds.

Although very interesting, these studies do not address the issue of whether music training enhances music-related visuomotor information in an instrument-specific manner; that is, depending on the musical instrument/s on which musicians were specifically trained. While some electrophysiological and neuroimaging studies have shown instrument-specific effects of music training on auditory (listening) and motor (execution) processing in musicians (see Tervaniemi, 2009, for a review), cross modal effects on the visual modality and on the action recognition systems (e.g., while attending a concert) remain relatively unexplored. For example, Pantev and colleagues (Pantev & Herholz, 2011; Pantev, Roberts, Schultz, Engelien, & Ross, 2001) investigated whether cortical representations for tones of different timbre (violin and trumpet) were enhanced compared to sine tones in violinists and trumpeters, preferentially for timbres of the instrument on which the musicians were trained. Participants in both groups had practiced their instrument for 15 years on average, and had never practiced the respective other instrument. Analysis of the N1 ERP component — recorded for violin and trumpet tones of corresponding pitches — showed a clear timbre specificity effect in the musicians' brains.

As for the obvious motor specialization of musicians, some clear instrument-specific effects have been demonstrated. For example, Bangert and Schlaug (2006) found a motor-related specialization in hand dominance, with keyboard players showing a left and string players showing a right hemisphere advantage. This suggests a differential brain adaptation depending on the instrument played. Elbert and colleagues' magnetic source imaging influential study (1995) revealed that the cortical representation of the digits of the left hand of string players was larger than that of controls. Interestingly, the amount of cortical reorganization in the representation of the fingering digits was correlated with the age at which the person had begun to play. Likewise, Halwani, Loui, Rüber, and Schlaug (2011) found that individuals with intensive vocal music training (compared to instrumental musicians) had larger tract volume (but lower functional anisotropy) in the left dorsal arcuate fasciculus, connecting the superior temporal gyrus back and forth with the inferior frontal gyrus. This effect was probably related to long-term vocal training.

Evidence of a more specialized crossmodal sensory processing in musicians over nonmusicians has been offered by recent literature on audiovisual integration (Lee & Noppeney, 2011; Paraskevopoulos et al., 2014). For example, in a combined psychophysics/neuroimaging study, Lee and Noppeney's (2011) subjects had to judge the audiovisual synchrony of speech sentences and piano music at 13 levels of audiovisual stimulus onset asynchronies. While piano practicing did not significantly affect audiovisual asynchrony processing in speech perception, the temporal integration window was narrower for musicians than nonmusicians for music material. Crucially, compared to nonmusicians, musicians showed enhanced asynchrony effects in left superior precentral sulcus (anterior premotor cortex), right posterior STS/middle temporal gyrus (MTG), and left cerebellum, suggesting that piano practicing improves fine tuning of audiovisual temporal binding and synchrony perception. Likewise, in a combined MEG/EEG study, Paraskevopoulos et al. (2014) investigated the ability to combine novel audiovisual stimuli (tones and numbers) in musicians vs. nonmusicians. Musicians showed increased differences between congruent and incongruent stimuli in the left superior frontal gyrus, thereby indicating that music expertise may affect multisensory comparative judgments.

Therefore, as previously mentioned, while instrument-specific effects (such as timbre preference or finger/hand/vocalization skills) have been shown for auditory and motor processing, scarce knowledge has been provided so far about the crossmodal effects of musical expertise on the visuomotor (mirror) processing of musical executions performed by other musicians. Do musical skills also modify visual processing of actions (musical playing)?

In a previous study, Proverbio, Calbi, Manfredi, and Zani (2014) investigated the neural basis of music learning and the existence of complex multimodal sensory/motor circuits. The authors provided evidence that violinists and clarinetists reacted quite differently to audio/visual musical incongruences with respect to the musical instrument mastered, thanks to mirror neural systems reflecting their specific motor expertise on the observed scene.

The aim of the present study was to shed light on this issue by presenting short musical videos in which a violinist and clarinetist played simple musical fragments, and participants (both musicians and controls) were required to detect whether each measure contained one or two notes. The task was sufficiently easy for each participant, but we hypothesized that the motor and acoustic expertise of musicians for their own instruments would permanently modify the way their brain would process the incoming information.

On the basis of previous literature on the role of prefrontal cortex in stimulus coding (Tulving, Markowitsch, Kapur, Habib, & Houle, 1994), also indexed by the FN400 old/new memory effect (Yu & Rugg, 2010), we expected to find a larger anterior negativity response over prefrontal areas of nonmusicians, due to their relative inexperience with music performance, as well as instruments' technicality and timbre.

We also expected to find a differential effect in the amplitude of anterior negativity as a function of music training, and — within the musician group — as a function of the specific familiarity with the two instruments (violin vs. clarinet). Indeed, several studies have shown a strong enhancement of prefrontal activity while processing novel compared to old items, thus reflecting their degree of visual or auditory familiarity (Evans & Wilding, 2012; Yonelinas, Aly, Wang, & Koen, 2010; Yonelinas, Otten, Shaw, & Rugg, 2005). For this reason the anterior negativity response represents a precious tool in determining the effect of expertise on brain information processing. For example, Shigeto, Ishiguro, and Nittono (2011) investigated the effects of visual stimulus complexity on ERPs and viewing duration in a free-viewing task. They found that the more complex the stimulus, the larger the anterior negativity response and the longer the viewing duration. Likewise, a family of anterior negativities have been described in ERP experiments on linguistic violations (Erdocia, Laka, Mestres-Missé, & Rodriguez-Fornells, 2009; Linares, Rodriguez-Fornells, & Clahsen, 2006; Osterhout & Nicol, 1999). These long lasting negative potentials are thought to directly reflect the amount of effort required for processing violations, irrespective of whether they are semantic, syntactic, or morphological ones. Again, an increased negativity for the processing of sentences needing more resources in terms of working memory has been described both for the visual (Müller, King, & Kutas, 1997; Federmeier, Kluender & Kutas, 2002) and the auditory modality.

The music score was created especially for the current study; each measure was repeated only once and sounds or sound combinations were never repeated. The performers and the music were unknown (totally novel) for both musicians and controls. Therefore, we assumed that any observed expertise-related ERP modulation would not reflect familiarity processes (for the musicians or the music played), but an effect of instrument-specific expertise (or lack of it) on stimulus encoding.

Method

PARTICIPANTS

Participants included 10 right-handed musicians graduates of Milan Conservatory Giuseppe Verdi (2 male, 8 female, age range = 21-32 years, $M = 25.8$, $SD = 2.6$) and 10 university student controls (1 male, 9 female, age range = 21-26, $M = 24.2$, $SD = 2.7$). Individual musicians' characteristics are shown in Table 1. The mean age of acquisition of musical ability (AoA= age at which they started the study of violin or clarinet) was 8 years for musicians. EEG data of three controls and one musician were excluded for excessive EEG artifacts and ocular movements.

All subjects had normal or corrected to normal vision and normal hearing. They reported no history of neurological illness or drug abuse. The handedness and lateral preference of participants was assessed through the administration of the Italian version of the Edinburgh Handedness Inventory. The experiment was conducted with the understanding and written consent of each participant according to the Declaration of Helsinki (*British Medical Journal*, 1991, *302*, 1194) and in compliance with APA's ethical standards for the treatment of human volunteers. The ethical committee of the University of Milano-Bicocca approved the experimental protocol. The whole experiment lasted about two hours and participants were paid 20 euros for their participation.

STIMULI AND PROCEDURE

Stimuli were the same as those used in Proverbio et al.'s (2014) ERP study, except that auditory and visual information in the current study were perfectly synchronized, congruent, and pleasant to be heard. Stimulus presentation, behavioral data acquisition, and EEG synchronization were managed by EEVOKE, ANT software

TABLE 1. *Musicians' biographical data, along with their lateral preference score (according to the Oldfield Edinburgh handedness inventory), their ocular dominance (assessed via practical tests), and their Age of acquisition (AoA) of musical ability (in years)*

Sex	Age	Conservatory Degree	Instrument	AoA	Practice x day (hours)	Lateral preference	Ocular dominance
F	21	Bachelor's Degree	clarinet	7	3	0.85	Right
F	22	Bachelor's Degree	violin	5	1/2	0.85	Right
M	23	Bachelor's Degree	violin	8	4	0.76	Right
F	25	Bachelor's Degree	clarinet	11	3	0.45	Right
F	26	Master's Degree	violin	8	3/4	0.71	Left
F	27	Bachelor's Degree	violin	11	6/8	0.52	Left
F	27	Master's Degree	violin	4	3	0.95	Right
M	27	Bachelor's Degree	clarinet	11	4/5	0.47	Left
F	28	Master's Degree	clarinet	12	4	0.47	Left
F	32	Master's Degree	violin	5	2/3	0.8	Right

(ANT Software, Enschede, The Netherlands). The stimulus set consisted of 180 video clips showing a clarinetist or a violinist playing one note (1 minim in 4/4 tempo; duration = 2 s) or two notes (2 semiminims; duration = 2 s). Half of the stimuli were played on the violin and half on the clarinet. Half of the stimuli consisted of one note tuning, the remaining in two notes. Single notes were never repeated and extended through the entire range of each instrument. Each two-note combination was novel and never repeated. Music was played non-legato, and slightly vibrato on the violin (metronome = 60 BPM) for 2 s of sound stimulation for each musical beat. Each clip lasted 3 s; during the first second the musician prepared to play, and the sound started. Stimuli were equiluminant across categories (violin = 15.75 cd/m^2; clarinet = 15.57 cd/m^2). The luminance was measured via a Minolta luminance meter. Audio sound values were normalized to -16 dB dB using the Sony Sound Forge 9.0 software. Stimuli were presented by using headphones. Stimulus size was 15 x 12 cm, corresponding to a visual angle of 7° 30' 6." Each video was presented for 3000 ms against a black background at the center of a PC screen. The interstimulus interval was 1500 ms. Participants were comfortably seated in an electrically and acoustically shielded cubicle in dimly lit conditions. They faced a PC screen placed outside the recording cabin at a distance of 114 cm. Participants were instructed to fixate on the center of the screen and avoid any eye or body movement during the recording session. They were instructed and trained to respond as accurately and quickly as possible by pressing a response key with the index or the middle finger corresponding to a 1-note or 2-note stimuli, respectively. The left and right hands were used alternately throughout the recording session, and the order of the hand and task conditions were counterbalanced across experimental subjects.

EEG RECORDINGS AND ANALYSIS

The EEG was recorded and analyzed using EEProbe recording software (ANT Software, Enschede, The Netherlands). EEG data were continuously recorded from 128 scalp sites according to the 10–5 International System (Oostenveld & Praamstra, 2001) at a sampling rate of 512 Hz. Horizontal and vertical eye movements were also recorded, and linked ears served as the reference lead. The EEG and electro-oculogram (EOG) were filtered with a half-amplitude band pass of 0.016–100 Hz. Electrode impedance was kept below 5 KOhm. EEG epochs were synchronized with the onset of sound stimulation. Computerized artifact rejection was performed prior to averaging to discard epochs in which eye movements, blinks, excessive muscle potentials, or amplifier blocking occurred. The artifact rejection criterion was a peak-to-peak amplitude exceeding 50 mV and resulted in a rejection rate of $\sim 5\%$. Evoked potentials from 100 ms before sound onset to 2000 ms after stimulus onset were averaged off-line. The large ERP deflection named "anterior negativity" was measured in between 900-1100 post-sound latency at F3, F4 sites where it reached its maximum amplitude. The anterior negativity response was measured within a temporal window comprising the end of the first note and the beginning of second note execution (from 900 to 1.100 ms) and including the peak of the evoked response for the 3 groups of listeners (which was about 930 ms for musicians-Own instrument, 1000 ms for musicians-Different instrument, and 1050 ms per controls, at Fz site).

A later central negativity (more task related) response was measured at C3, C3, FC3, FC4 sites in between 1100-1400 ms, where the stimuli reached its maximum amplitude, in order to detect the auditory processing of the second note. Electrophysiological data were subjected to multifactorial repeated-measures ANOVA with group (musicians Own, musicians Different, controls) as the between-groups variable and condition (1 vs. 2 notes), electrode (depending on the ERP component of interest), and hemisphere (left, right) as within-groups variables. Topographical voltage maps of the ERPs were generated by plotting color-coded isopotentials that were obtained by interpolating voltage values between scalp electrodes at peak of anterior negativity. Grand-average ERPs were obtained for each experimental group by considering ERPS recorded:

- In violinists for violin and in clarinetists for clarinet ($N = 8$: Own instrument)
- In violinists for clarinet and in clarinetists for violin ($N = 9$: Different instrument)
- In controls ($N = 7$ regardless of the instrument)

The ERPs recorded during presentation of violin and clarinet stimuli were averaged in the Own, Different, and Controls grand-means in order to neutralize the instrument-related specific effects, since the sound and the mechanics of violin and clarinet are so dramatically different. Indeed we wished to observe the effects of musical expertise for a specific instrument, regardless of the actual instrument played, i.e., clarinet or violin, by considering two exemplars belonging to the wind (aereophone) and string (chordophone) instrument class, respectively.

Response times exceeding the mean $\pm$ two standard deviations were excluded. Hit and miss percentages were also collected and arcsine transformed to allow for statistical analyses (the distribution of percentages is binomial and arcsine transformation of data makes the distribution normal, thus respecting homoscedasticity necessary for ANOVA treatment). Behavioral data (response speed) were subjected to multifactorial repeated-measures ANOVA with factors for group (musicians Own, musicians Different, Controls), condition (1 note, 2 notes), and response hand (left, right). Tukey's test was used for post hoc comparisons among means.

Results

BEHAVIORAL DATA

The analysis of response times did not reveal any statistically significant effect of group ($p = .19$) or condition ($p = .72$). Overall, error percentage was very limited (2.9%; musicians Own = 2.6%, $SD = 4.2$; musicians Different = 3.2%, $SD = 6.6$; Controls = 2.8%, $SE = 3.7$), therefore insufficient for allowing a category based analysis.

ELECTROPHYSIOLOGICAL DATA

Figure 1 shows grand-average ERPs recorded in the three groups as a function of stimulus type and note numerosity. The ANOVA performed on the mean area amplitude of anterior negativity showed the significance of condition factor, $F(1, 21) = 10.76$, $p < .004$, with larger amplitudes of the negative component in response to one note (-3.13 μV, $SE = 2.0$) than two-note stimuli (-2.25 μV, $SE = 1.66$). The significance of group factor, $F(2, 21) = 3.45$, $p < .05$, and relative post hoc comparisons among means, indicated a much greater amplitude of this negative deflection in controls (-4.76 μV, $SD = 3.26$) than in musicians Different (-2.00 μV, $SD = 2.55$, $p < .02$), and in the latter than in musicians Own (-1.32 μV, $SD = 2.64$, $p < .05$). See the topographic maps of Figure 2 for appreciating this group effect.

The analysis of variance performed on the late central negativity (in between 1100-1400 ms) showed the significant effect of condition factor, $F(1, 2) = 10.26$, $p < .004$, with larger negativities in response to one-note than two-note stimuli. However, the significant interaction of Condition x Group, $F(2, 21) = 3.94$, $p < .03$, and relative post hoc comparisons among means, indicated a lack of note numerosity effect in the Musician OWN group (see Figure 3 for mean amplitude values), and larger amplitudes of this component in response to one note than two-note stimuli in the other two groups (Musicians Different = $p < .02$; Controls = $p < .002$). Furthermore, post-hoc comparisons showed significant group differences (among each other) in response to one-note stimuli, and no differences between musicians Own and Different, in the response to two-note stimuli. Figure 4 displays the topographic distribution of late negativity over frontocentral sites in the three groups of participants.

Discussion

This study aimed at investigating whether musical expertise can be instrument specific, thus modifying the way the brain processes simple musical executions, as a function of musical expertise or lack of it. We expected to find a general musicianship advantage for musicians, as compared to controls, and a specific effect of the instrument played, due to the profound sensory/motor knowledge of its technicality and timbre, as compared to the unfamiliar instrument. Indeed, control subjects had a null experience with the violin and clarinet and never received specific musical education, while musicians had a mere visual and auditory familiarity with the other instrument (due to attending concerts, playing in

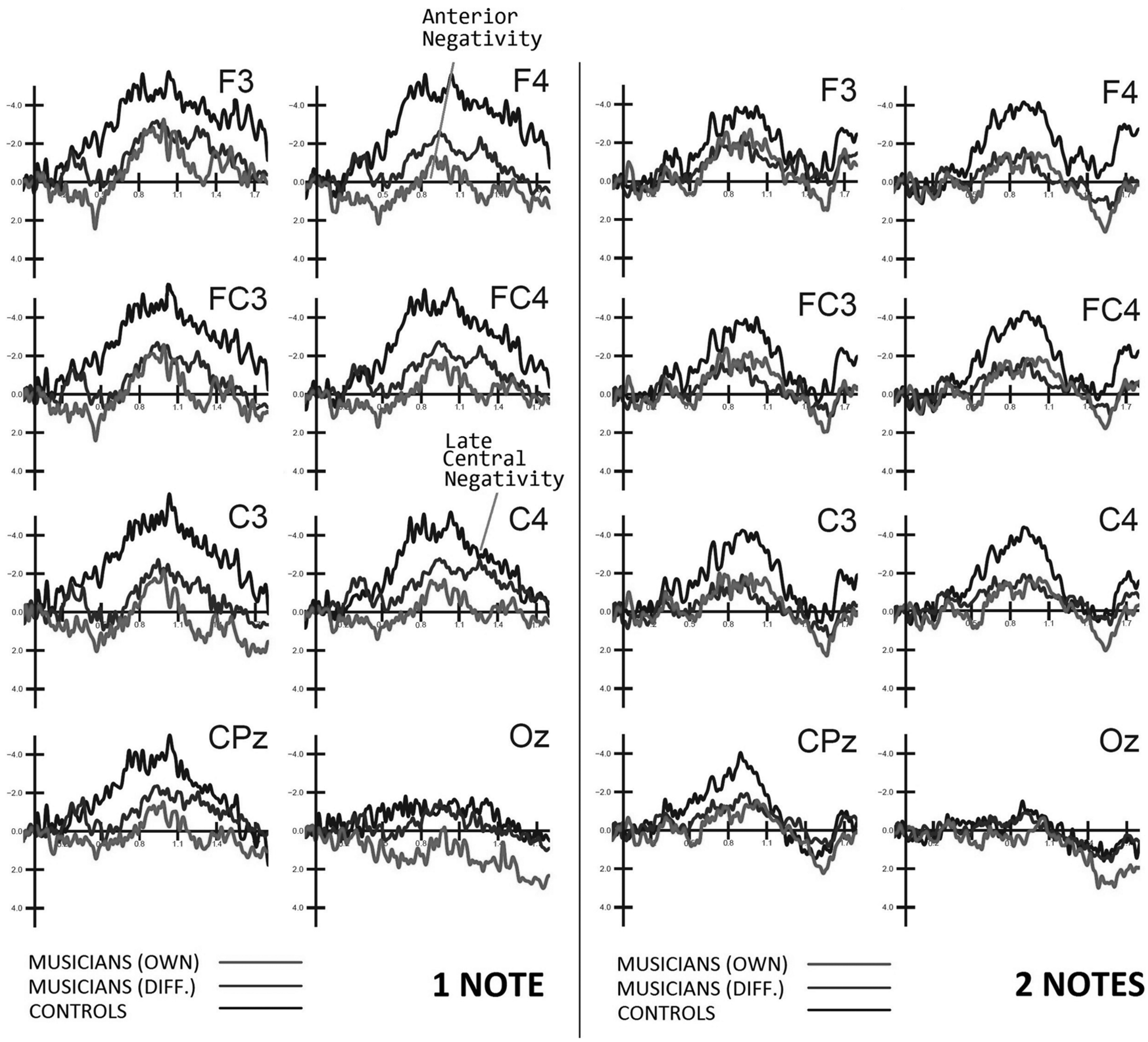

FIGURE 1. Grand-average ERP waveforms recorded at left and right frontal and central electrode sites, and at midline occipital sites, for the three groups of participants.

orchestras or ensembles, etc.), but a complete lack of knowledge about how to play it. Both behavioral and electrophysiological results evidenced the existence of a music training effect (which is well supported by previous literature; e.g., Chobert et al., 2011, 2014; Elmer et al., 2012, 2013; Gaab et al., 2005; Kraus & Chandrasekaran, 2010; Kühnis et al., 2013, 2014; Oechslin, Descloux et al., 2013; Oechslin, Van de Ville et al., 2013; Parbery-Clark et al., 2012; Schlaug, 2001; Strait & Kraus, 2011). Furthermore, the data hint at an unprecedented instrument-specific effect for visuomotor (mirror) processing, indicating that musical expertise is wired in specific visuomotor and audiomotor circuits (Lee & Noppeney, 2011; Paraskevopoulos et al., 2014; Proverbio et al., 2014). This finding fits well with previous literature providing evidence of auditory (due to timbre specificity; Pantev & Herolz, 2011; Pantev et al., 2001) and motor (e.g., due to instrument technicality; Bangert & Schlaug, 2006; Elbert et al., 1995; Halwani et al., 2011) instrument-specific effects of musical expertise.

The ANOVA performed on the mean area amplitude of anterior negativity revealed a larger amplitude of this component in controls than musicians Own ($p < .02$), and a significant difference with respect to musicians

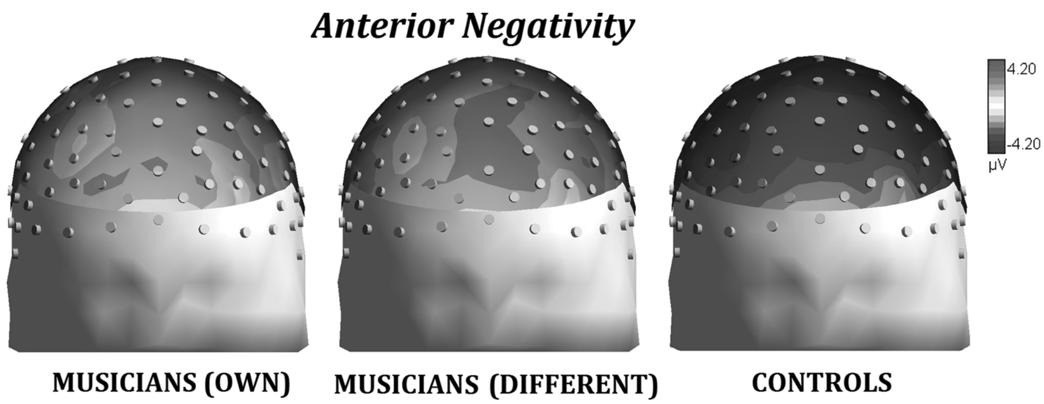

FIGURE 2. Isocolour topographical voltage maps of *anterior negativity's* distribution (front view) recorded in the three groups, regardless of condition, in between 800-1100 ms of latency.

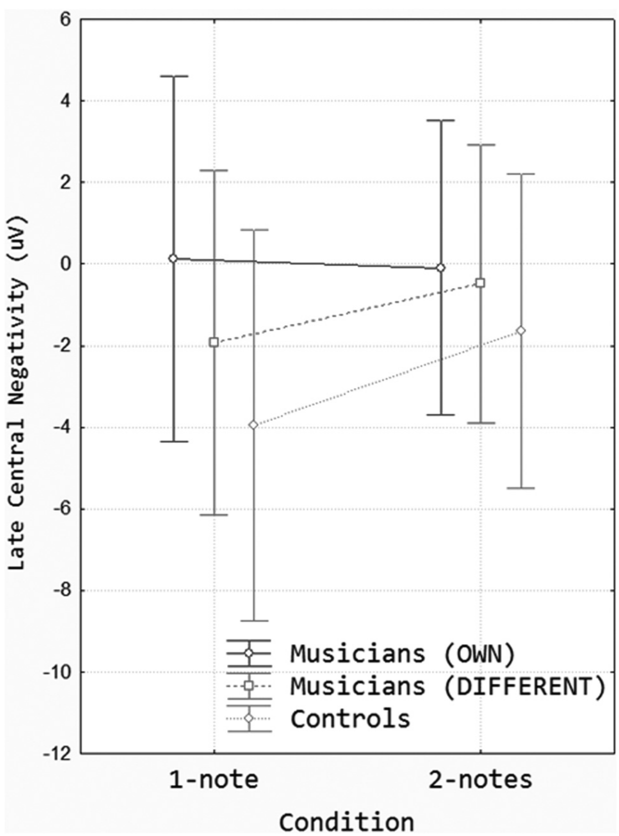

FIGURE 3. Mean amplitude of *late central negativity* recorded at frontocentral sites in the three groups of participants, as a function of condition (note numerosity).

Different ($p < .05$), over the prefrontal area (as visible in the topographic maps shown in Figure 4). This gradient suggests an effect of musical expertise on prefrontal coding of musical information that is instrument-specific, whereas the more general advantage of musicians vs. controls indicated a musicianship effect, due to visual and auditory familiarity with musical performances of whatever instrument.

The results of our study share some similarities with the recent ERP study by Elmer et al. (2014), who showed enlarged and sustained anterior negativities in controls compared to musicians during a categorization task consisting of assigning the presented auditory stimuli to the category of speech, music, or noise. It is possible that, also in that case, the increased anterior negativity in controls might depend on the scarce familiarity of this group for the music material (consisting in consonant chords played with a guitar).

Overall, our findings are strongly consistent with the neuroimaging literature on prefrontal encoding of unfamiliar information (Friese et al., 2012; Lee, Lee, Kim, & Jung, 2014; Tulving et al., 1994; Tulving, Markowitsch, Craik, Habib, & Houle, 1996), requiring stronger activity in naive vs. expert subjects, and the ERP literature on the FN400 effect (Yonelinas et al., 2005, 2010; Yu & Rugg, 2010). For example, Lee et al. (2014) showed an increased right frontal EEG theta activity during episodic novelty processing, while Kirchhoff, Wagner, Maril, and Stern (2000) provided fMRI evidence of the role of prefrontal cortex in episodic encoding. As for the specific effect of instrument familiarity on the amplitude of anterior negativity, our results might be explained in the light of FN400 literature, providing clear evidence that a lack in stimulus familiarity is associated with extra prefrontal cortex activity, reflected by an increased surface negativity in classical memory paradigms (Evans & Wilding, 2012).

In conclusion, the data provide solid evidence that, besides a general effect of musicianship, music training

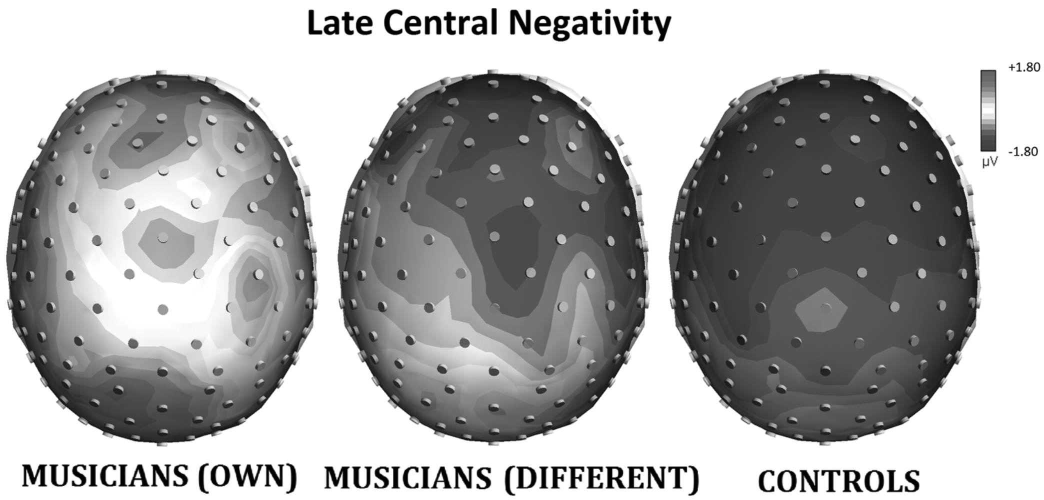

FIGURE 4. Isocolour topographical voltage maps of *late central negativity's* distribution (top view) recorded in the three groups, regardless of condition, in between 1100-1400 ms of latency.

is also instrument-specific, wired from specific sensorimotor abilities that permanently change the way the brain processes information relative to the particular musical instrument played (Proverbio et al., 2014).

The bioelectrical response data recorded after the second note execution (in between 1100-1400 ms: late central negativity) are very interesting because they show strong instrument specific effects in a very elementary task, such as counting one or two sounds. Given that this deflection was elicited after the delivery of the second sound and closer in time to response emission, it might reflect both task-dependent auditory processing and concomitant motor preparation processes (Schröter & Leuthold (2009). Indeed, while motor preparation is reflected by an increase negativity over central sites, many studies, since the first pioneeristic works by Näätänen and Picton (1987), have shown that the multiple intracranial generators of auditory potentials are best detected at surface over frontocentral electrode sites (see Wyss et al., 2014, for recent review). The results of the significant interaction of condition per group indicate that, while there was no effect of note numerosity on auditory processing in musicians (for their own instrument), note numerosity did affect this response in both controls and musicians for the other instrument, thus suggesting a very powerful effect of instrument-related expertise on timbre processing (Pantev & Herholz, 2011; Pantev et al., 2001), besides a more general effect of music training (musicians vs. controls) in the processing of musical information (Baumann et al., 2007; Chobert et al., 2011, 2014; Elmer et al., 2012, 2013; Gaab et al., 2005; Kraus & Chandrasekaran, 2010; Kühnis et al., 2013, 2014; Meyer et al., 2012; Parbery-Clark et al., 2012; Strait & Kraus, 2011).

As a general consideration, it should be mentioned that this is a cross-sectional study, and therefore the data presented might provide indices of music training effects, but cannot exclude effects of predisposition. However, while behavioral genetic analyses indicate that nontrivial proportions of individual differences (musicians vs. nonmusicians) in performance are associated with genetic factors (Hambrick & Tucker-Drob, 2014; Mosing, Madison, Pedersen, Kuja-Halkola, & Ullén, 2014; Vinkhuyzen, Van der Sluis, Posthuma, & Boomsma, 2009), the instrument-specific effects of musical expertise on audiovisual processing described in the present study hint at a crucial role of musical practice in shaping musical brain and behavior.

STUDY LIMITATIONS

It should be mentioned that the sample size: eight musicians (Own instrument), nine musicians (Different instrument), and seven controls — although sufficient to show main group differences — was not very large. In addition, it cannot be excluded that musicians and nonmusicians used a different strategy to perform the task. For example, it could be that nonmusicians only focused on the auditory channel whereas musicians focused on both the film and the auditory input. However, the presence of several instrument-specific effects within the groups of musicians (presumably using a similar strategy) rule out the possibility that the modulation of ERP components of interest reflected different processing strategies per se.

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