Hemispheric Asymmetries in Setticlavio Reading

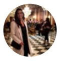
Article *in* Neuropsychology · February 2018

DOI: 10.1037/neu0000430

5 authors, including:


Anita D'Anselmo
Università degli Studi G. d'Annunzio Chieti e Pescara


Felice Giuliani
Università degli Studi G. d'Annunzio Chieti e Pescara


Federica Campopiano
Università degli Studi G. d'Annunzio Chieti e Pescara


Alfredo Brancucci
Università degli Studi "G. d'Annunzio" Chieti-Pescara

0894-4105/18/$12.00 http://dx.doi.org/10.1037/neu0000430

Hemispheric Asymmetries in *Setticlavio* Reading

AQ: au
AQ: 1

Anita D'Anselmo, Felice Giuliani, Federica Campopiano, Emanuele Carta, and Alfredo Brancucci
G. d'Annunzio University of Chieti and Pescara

Musical *setticlavio* (literally, seven clefs) reading refers to the ability to read (i.e., to say aloud, without to sing) the musical note labels in the 7 musical clefs. The present research report aims to investigate hemispheric asymmetries in such a basic musical ability, very poorly investigated in the domain of cognitive neurosciences. Sixty-three musicians underwent lateralized tachistoscopic presentation of musical notes on staves, 50% in the left and 50% in the right visual field, associated with each of the 7 musical clefs. The subjects' task was to pronounce as fast as possible the name of the presented note, taking into account the current clef symbol. Mixed directions of asymmetry with different involvements of the left and right hemisphere in each clef were observed. Whereas reading in the treble, bass, alto, tenor, and mezzosoprano clef showed no lateral asymmetries, a left hemisphere asymmetry was observed with the soprano clef and a right hemisphere asymmetry with the baritone clef. This effect was observed with accuracy but not with reaction time. These results suggest that there is not a univocal hemispheric balance in musical *setticlavio* reading, reflecting several possible underlying reading mechanisms. Moreover, inversely proportional results between performance (both accuracy and reaction time) and distance from the reference clef (treble) suggest that *setticlavio* reading is based on a spatial rather than verbal code.

General Scientific Summary
This study examines hemispheric asymmetries in musicians during the performance in *setticlavio* reading, that is the ability to read the musical note labels in the 7 musical clefs. Results showed asymmetries in mixed directions with a specific left asymmetry for the soprano clef and a right asymmetry for the baritone clef. Findings suggests that this task can involve different reading mechanism specific for each clef.

Keywords: hemispheric asymmetries, laterality, music perception, music performance, visual half-field stimulation

Music reading is a subskill of musical performance representing the ability to read and decipher musical notation symbols. Notation in music has often been compared to written language, but, although a certain parallelism, it has been shown that music reading differs from text reading in important aspects. Unlike text reading, the notation of a musical score contains information about duration, pitch, and interpretation of the musical material (Sloboda, 1984). The time value of a note is expressed through the shape of the given note and through the time signature indicated at the beginning of each line of the score. The pitch is expressed by the position of the note on the stave, according to the clef positioned at the beginning of each stave line (Bevan, Robinson, Butterworth, & Cipolotti, 2003). Musicians usually convert written music in an appropriate motor response by singing or by playing it on an instrument. They are also able to read musical notation orally or produce a phonological response during the reading of musical symbols.

Musical reading represents an important aspect for musical performance. Nevertheless, only limited research has paid attention to musical notation and reading, to how music reading is acquired and to the underlying cerebral organization. Most of the literature on music reading comes from case report studies of professional musicians with a brain damage who reported difficulties in some musical abilities. These studies have shed light on the question of whether processes involved in music sight reading are independent to those involved in reading words and numbers. Significant literature report principally clinical cases of association between musical (amusia) and words and/or numbers (aphasia) disturbances (Fasanaro, Spitaleri, Valiani, & Grossi, 1990; Horikoshi et al., 1997; Kawamura, Midorikawa, & Kezuka, 2000). Otherwise, an increasing number of researchers have found selective

Anita D'Anselmo, Department of Psychological Science, Health, and Territory, G. d'Annunzio University of Chieti and Pescara; Felice Giuliani, Department of Neuroscience, Imaging, and Clinical Sciences, G. d'Annunzio University of Chieti and Pescara; Federica Campopiano, Emanuele Carta, and Alfredo Brancucci, Department of Psychological Science, Health, and Territory, G. d'Annunzio University of Chieti and Pescara.

We thank the Conservatories of Music "Luisa D'Annunzio" of Pescara and "Santa Cecilia" of Rome, which provided us with facilities and resources to carry out the experiment.

Correspondence concerning this article should be addressed to Anita D'Anselmo, Department of Psychological Science, Health, and Territory, G. d'Annunzio University of Chieti and Pescara, BLOCCO A, Via dei Vestini 31, I-66013 Chieti, Italy. E-mail: a.danselmo@unich.it

deficits for language but not for music (Assal & Buttet, 1983; Basso & Capitani, 1985; Signoret, van Eeckhout, Poncet, & Castaigne, 1987; Brust, 1980) and vice versa (Cappelletti, Waley-Cohen, Butterworth, & Kopelman, 2000; Satoh, Furukawa, Takeda, & Kuzuhara, 2006). Likewise, in the more specific domain of music reading, there have been evidences of no dissociation between music and text reading abilities (Beversdorf & Heilman, 1998; Kawamura, Midorikawa, & Kezuka, 2000; Schön, Semenza, & Denes, 2001), and dissociations (Cappelletti, Waley-Cohen, Butterworth, & Kopelman, 2000; D'Anselmo, Giuliani, Marzoli, Tommasi, & Brancucci, 2015; Judd, Gardner, & Geschwind, 1983; Riva, Casarotti, Comi, Pessina, & Bello, 2016).

As stated above, key information that must be taken into account in music reading is the clef. Clefs are seven graphical signs written at the beginning of a stave line which determine, with specific
F1 rules, the pitch of the notes on the same stave (see Figure 1). In oral reading, a clef sign before a musical sequence indicates how to relate the notes on the stave to their names to be pronounced. Reading in the different musical clefs is referred to as musical
AQ: 2 *setticlavio* reading, and each instrument or singing voice uses typically one (or two, e.g., the piano) of the seven music clefs. In addition, classical music students undergo specific training in the first years of their courses to acquire the ability to read note names in all seven clefs. To our knowledge, no studies have been carried out to disclose the psychological and neural mechanisms underlying this ability. In our opinion instead, given the specific demands of the *setticlavio* task, analyzing this ability from a perspective of cognitive neuroscience could shed some light on the specific ability but also on the different ways our brain acquires information in reading-like situations.

As a first step, we undertook the present investigation focusing on the different contributions of the two hemispheres in *setticlavio* reading. Unlike the majority of the neurological and neuroimaging studies that have observed natural activity of the brain during music processing, we decided to use a lateralized tachistoscopic presentation approach. Other than being much less expensive, laterality studies look at brain function in a totally different manner. They force brain areas to perform the investigated task (e.g., the right hemisphere to read a text, in case of laterality studies of reading ability) and giving the researcher a totally different point of view compared with neuroimaging studies. The specific interest of this study in music lateralization processes arises from previous results on music perception that support the hypothesis of hemispheric asymmetry (Brancucci, Babiloni, Rossini, & Romani, 2005; Brancucci, D'Anselmo, Martello, & Tommasi, 2008; Salis, 1980; Segalowitz, Bebout, & Lederman, 1979). Furthermore, brain lateralization is an important aspect in relation to linguistic reading processes, and we want to extend this investigation in particular to the domain of music reading.

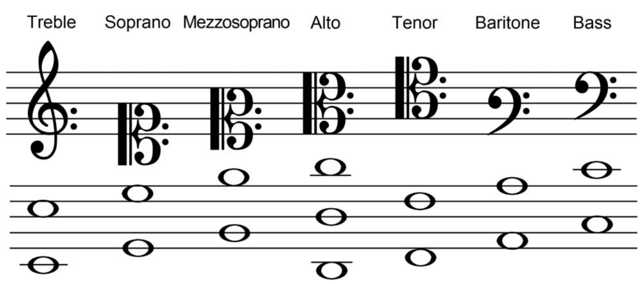


Figure 1. Top, The *setticlavio* (literally, seven clefs). Bottom, The positions, for each clef, corresponding to the note Do (or C). Notes with maximum one additional stave line are shown.

To this aim, we use tachistoscopic presentation of a note written on a stave, which can appear in the left (LVF) or in the right visual field (RVF) while a musical clef appears in the center of the screen (Figure 2). The subjects' task is to read (orally) the name of the F2
note, taking the clef information into account (i.e., *setticlavio* reading). Both accuracy and response times are measured. On the basis of previous works, which were, however, not specifically designed to answer our present question, the hypothesis hangs for an asymmetry in favor of the left hemisphere (LH), at least with regard to the bass clef. In particular, the results of our previous study (D'Anselmo, Giuliani, Marzoli, Tommasi, & Brancucci, 2015), in which we found a different lateralization for treble and bass clef, and from another study by Schön, Semenza, and Denes (2001) on a left hemispheric neurological patient with a specific deficit in reading in the bass but not in the treble clef suggest the possibility that there might be different brain asymmetries related to the different clefs. The present study envisages all clefs to possibly extrapolate one function that could link hemispheric specialization to a cognitive operation (e.g., that can be based on the spatial code used to read in a specific clef but not in another one).

Method

Participants

Sixty-three musicians, 37 males and 26 females, took part in this study (mean age = 22.17, SE = 1.08). All participants were either students or graduated musicians from Italian music conservatories, and they were musically active at the time of the experiment (practicing daily). They had a mean musical experience of 11.92 years (SE = 0.98) in piano, treble, flute, clarinet, song, classical guitar, saxophone, trumpet, double bass, oboe, organ, percussion, or cello as their main instrument. Thirty-five of them played more instruments other than the main one. They were all able to perform music oral reading (solfeggio) and *setticlavio* reading. Six of them had absolute pitch (self report).

Hand preference was assessed using the Edinburgh Handedness Inventory (Oldfield, 1971). The handedness scores ranged from −100 (totally left handed) to +100 (totally right handed) and were distributed as follows: Five subjects scored <–25, one subject scored ≥–25 and <25, seven subjects scored ≥–25 and <50, 24 subjects scored ≥50 and <75, and 26 subjects scored ≥75 and <100 (group mean ± SE = 58.61 ± 4.95).

Stimuli

Participants were tested with visual stimuli, 32 notes for each clef: treble, soprano, mezzosoprano, alto, tenor, baritone, and bass (see Figure 1) for a total of 224 notes. For every clef, 16 quarter note and 16 eighth note were presented, distributed in the interval between A3 and B5. Stimuli were presented at an equal distance from the central fixation point, subtending a visual angle of 4.5° (central part of the stimulus). Half of the stimuli were presented in

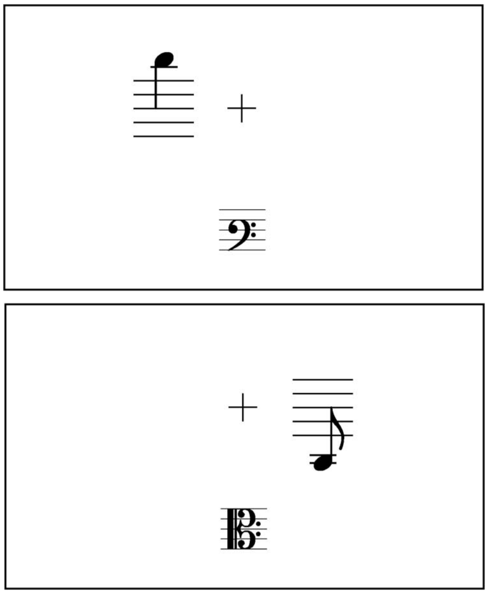


Figure 2. Examples of two stimuli. Top, The stimulus is presented in the LVF and has to be read in the baritone clef (correct response is here Fa, or F). Bottom, The stimulus is presented in the RVF and has to be read in the alto clef (correct response is here Si, or B).

the LVF and half in the RVF. All items were written on the musical five-line stave, and the clef symbol was presented centrally in the lower part of the screen (see Figure 2). Stimuli were generated using the notation software MuseScore (version 1.2; Schweer, 2012).

Procedure

The experiment was conducted in a quiet room. Subjects sat in front of the computer monitor and with the head at approximately 70 cm of distance. They were instructed to fixate the cross at the center of the screen and to not move their eyes during the experiment. Presentation of stimuli was completely automated using a software written in E-prime on a Windows computer with a 15.4-inch monitor. Each trial consisted of the presentation of a tachistoscopic visual stimulus in the left or right visual field (180 ms duration), followed by an interstimulus interval (4000 ms duration). Subjects were requested to say aloud the name of the note displayed on the computer monitor. Notes had to be read in the clef that appeared, blinking before each sequence of 32 notes, and that was stable during the sequence. The experiment started with a brief training session. The spoken notes were recorded using a microphone connected to the computer and then recorded digitally by using GoldWave (version 5.25; GoldWave Inc., St. John's, NL, Canada) software. AQ: 3

Subjects performed seven sessions, one for each clef; the order of sessions was counterbalanced across subjects. Each session was composed of 32 trials (notes) presented in a pseudorandom order. Sessions were separated by a 10-s interval. The total duration of the experiment was approximately 20 min including a break of a few minutes after the first four sessions.

Results

Performance was analyzed using accuracy (errors) and response times as dependent variables. These were computed using the software Goldwave on the basis of the recorded digital audio traces that contained (a) a trigger signal indicating the instant when the visual stimulus appeared on the computer monitor and (b) the audio trace recorded of subjects' oral response. Accuracy was calculated as the percentage of errors to stimuli presented in the LVF and in the RVF; RT was the difference between the onset of the vocal response and the trigger signal. Responses with reaction time (RT) values deviating more than 2 *SD* from the mean of each clef condition were excluded. Only RT of correct responses were considered. Responses of five subjects were excluded from the analysis because the quality of the recording did not allow an accurate visual analysis of the difference between the wave of the onset voice and the trigger signal.

Data were then analyzed using two 7×2 repeated-measure analyses of variance (ANOVA) at a significance level of $p = .05$ with clef (treble, soprano, mezzosoprano, alto, tenor, baritone, bass) and visual half-field (left, right) as independent variables. The first ANOVA was on accuracy and the second on response time. Preliminary statistical analyses showed that sex, handedness, age, music experience, and type of played instrument did not influence hemispheric asymmetries. These variables were therefore not included in the subsequent analyses. Table 1 reports descriptive data. T1

Table 1
Descriptive results

	Errors (%)		RT (s)	
Variable	LVF	RVF	LVF	RVF
Treble	7.341 (1.109)	6.845 (1.189)	.702 (.020)	.688 (.020)
Soprano	30.754 (2.991)	26.587 (2.970)	1.234 (.049)	1.207 (.046)
Mezzosoprano	33.532 (3.681)	34.722 (3.834)	1.479 (.054)	1.502 (.054)
Alto	20.933 (2.861)	21.925 (3.092)	1.009 (.033)	.980 (.035)
Tenor	22.421 (3.164)	20.734 (3.274)	1.029 (.038)	1.017 (.035)
Baritone	44.544 (3.954)	47.520 (3.872)	1.475 (.049)	1.529 (.060)
Bass	17.560 (2.894)	17.857 (2.922)	.960 (.039)	.985 (.046)

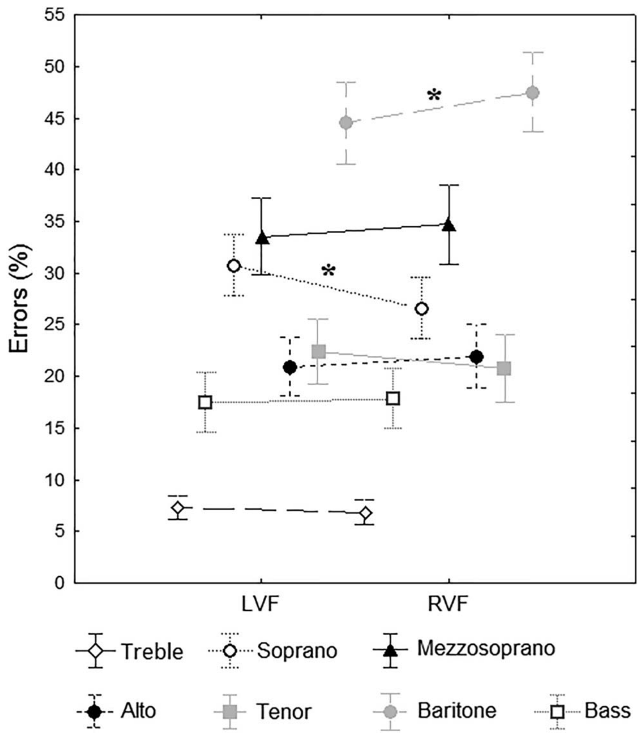
Note. LVF = left visual field; RVF = right visual field. Mean errors (percentages) and response times (RT; s) in the seven conditions (treble, soprano, mezzosoprano, alto, tenor, baritone, bass); *SE*s are in brackets. Data are reported separately for stimuli presented in the LVF and RVF.

Accuracy

Regarding the accuracy variable (percentage of errors), the ANOVA showed a significant main effect of clef ($F_{6,372} = 23.84$; $p < .001$, $\eta_p^2 = 0.28$) because of different performances in the different clef conditions. Duncan's post hoc tests indicated that the performance in the treble clef was significantly better than that in the other clefs (comparison with bass clef: $p = .003$; with soprano, mezzosoprano, alto, tenor, and baritone clef: $p < .001$). Performance in bass clef was significantly better compared with soprano ($p = .004$) and mezzosoprano and baritone clefs ($p < .001$). Performance in alto and tenor clefs was significantly better compared with mezzosoprano clef ($p < .001$). Performance in baritone clef was significantly worse compared with all other clefs ($p < .001$).

The two-way interaction of clef and visual half-field was also significant ($F_{6,372} = 2.79$; $p = .011$, $\eta_p^2 = 0.43$). Duncan's post
F3 hoc tests (asterisk in Figure 3) indicated that the performance in soprano clef was significantly better when stimuli were presented in the RVF ($p = .002$) and that the performance in baritone clef was significantly better when stimuli were presented in the LVF ($p = .030$). Regarding soprano and baritone clefs, the distribution of responses among participants was as follows: In soprano 44% of participants performed better in the RVF and 32% in the LVF; in baritone 41% of participants performed better in the LVF and 25% in the RVF.

Reliability for the accuracy-dependent variable showed a Cronbach's alpha of 0.58.



AQ: 6 *Figure 3.* Mean accuracy results (*, significant within-clef difference).

Response Time

Regarding response time data, the 7 × 2 ANOVA with clef and visual half-field as independent variables showed a significant main effect of type of clef ($F_{6,234} = 57.82$; $p < .001$, $\eta_p^2 = 0.60$). Duncan's post hoc tests indicated that response times in treble clef were significantly faster than those in the other clefs ($p < .001$). Response times in bass clef were significantly faster than those in soprano, mezzosoprano, and baritone ($p < .001$). Response times in soprano clef were significantly slower than in treble, bass, alto, and tenor clef ($p < .001$). Mezzosoprano and baritone had similar response times and were significantly slower than all the other clef ($p < .001$). No significant interaction effects were found (see
Figure 4). F4

Reliability for response time dependent variable showed a Cronbach's alpha of 0.06.

Discussion

This research reports faces the issue of hemispheric asymmetries in musical *setticlavio* reading, that is, in reading in the seven musical clefs. This skill is usually observable only in musicians who undertake classical training, being a typical subject of one of the first examinations of that type of studies, which among other things considers treble the reference clef and the first and principal clef to be learned. *Setticlavio* reading consists in pronouncing the name of a note translated on the basis of its clef, disregarding its pitch and octave. So, for instance, a note presented on the second line of the musical stave, usually labeled as *sol* (or *G*, treble clef), if preceded by the alto clef, should be read as *la* (or *A*). Of note, this skill is different from musical transposition, in which singers tune the voice pitch on the basis of the clef or of other indications (e.g., "sing this piece one third up") and that does not regard note labels.

The main results of the present analysis indicate the presence of a complex pattern of hemispheric asymmetries in *setticlavio* reading. Mixed directions of laterality with different involvements of the left and right hemisphere in each clef were observed. Whereas reading in treble, bass, alto, tenor, and mezzosoprano clefs showed no lateral asymmetries, the LH reached a better performance in reading in the soprano clef and the hemisphere (RH) a better performance in reading in the baritone clef. These results suggest firstly that there is not a univocal hemispheric balance in this ability and that multiple mechanisms possibly play a role.

In a task in which subjects had to read in the different clefs, the performance in the soprano clef was thus higher when stimuli were presented in the RVF, and the performance in the baritone clef was higher when stimuli were presented in the LVF. This dual pattern of lateralization can have different reasons. It can be explained considering the different strategies generally used by musicians in reading in the seven clefs. Because the more common musical trainings start with reading in the treble clef, the easiest assumption is that all musicians take the treble clef as a reference point and move different steps from it to identify notes in the other clefs. This strategy also includes the rule of step extent minimization, that is, the distance from the treble reference point should be minimal, allowing both upward and downward shifts. In this case, the soprano clef needs a two-step downward shift (do/C in soprano is mi/E in treble and vice versa) and the baritone clef a three-step downward shift (do/C in baritone is fa/F in treble, and vice versa).

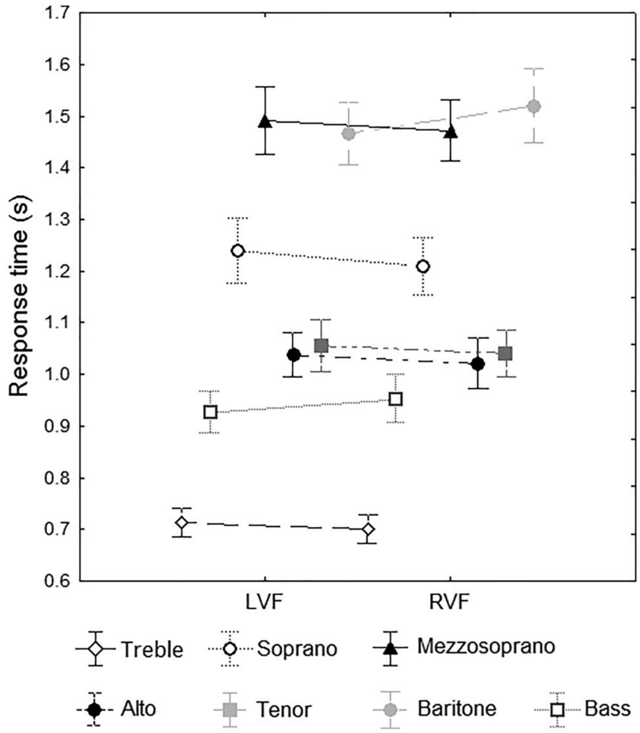


Figure 4. Mean response time results.

Under these assumptions, it can be speculated that (a) different shifts extents from the treble clef induce different directions of hemispheric asymmetries, or (b) different codes (spatial vs. verbal) are used while reading in the two clefs (based, e.g., on task demands). These explanations are thus disproven by the lack of asymmetry observed with the mezzosoprano clef. However, it should be taken into account that several students learn the baritone clef starting from the bass clef, which is usually the second clef to be learned after treble. In this case, taking the bass clef as a reference point, to read the baritone clef, it is necessary to perform, from the presented note, a two-step upward shift. Thus, under this assumption, to read in soprano and in baritone would need exactly the opposite mental operations, that is, a downward (soprano) and an upward (baritone) vertical shift starting from the respective reference note. In previous studies, some cues concerning spatial attention asymmetries in the vertical dimension were reported in addition to the more known asymmetries in the horizontal dimension.

From these studies, it emerges that the upper visual field (together with the left visual field) would enjoy an RH specialization (Bowers & Heilman, 1980; Jewell & McCourt, 2000; Thomas, Castine, Loetscher, & Nicholls, 2015). On these lines, the LVF advantage we found in reading in the baritone clef (mental operation: two steps shift toward up starting from bass clef) would be based on a special ability of the RH for attention toward up. On the contrary, the RVF advantage we observed in soprano clef reading (mental operation: two steps shift toward down) would be based on an opposite asymmetry, favoring the LH. This latter explanation is not supported by previous evidence, pointing to an RH superiority also in the low visual field (Cazzoli, Nyffeler, Hess, & Müri, 2011; Loughnane, Shanley, Lalor, & O'Connell, 2015; Nicholls, Mattingley, Berberovic, Smith, & Bradshaw, 2004; Pitzalis, Di Russo, Spinelli, & Zoccolotti, 2001; Verleger, Dittmer, & Śmigasiewicz, 2013). It can be, however, interpreted in the light of, in music neuropsychology, well-known notion that hemispheric balance in musicians is not the same as in the general population as shown first by Bever and Chiariello in 1974. Finally, of note, the opposite asymmetry observed with soprano and baritone clef excludes that asymmetry can be biased by performance level, lower in these two clefs compared with the others.

A further result of the present study concerns different performance levels in reading in the seven musical clefs. The best performance was observed in the treble clef, which is indubitably due to the fact that the majority of musicians begins studying music by learning the notes in this clef. The second clef in order of performance was the bass clef. This clef is generally learned as second, after treble. Treble and bass clefs were the most used ones by our participants in their musical studies and performances; in fact, most of them were pianists or had to learn piano as an instrument complementary to their principal one. A middle-level performance has been obtained in alto, tenor, and soprano, requiring, respectively, one step shift upward on the stave, one step shift downward, and two steps downward (see Figure 1). The worst performances were instead obtained with baritone and mezzosoprano clefs, requiring three steps shifts, respectively, downward and upward (with the mentioned possibility that reading in the baritone clef is done by some musicians with reference to the bass clef, needing in this case two-step upward shift).

One possible explanation for the main effect on performance is presumably the different level of expertise in reading each clef. Musicians, in fact, learn the seven clefs at different times during their musical education, and they have therefore longer periods of practice with earlier learned clefs (e.g., treble compared with mezzosoprano). However, it also must be noted that an increase in the difficulty level may be often offset by the use of specific strategies, such as transposing the notes from the most basic and earliest learned clefs (usually treble and bass). Thus, another possible explanation, which does not necessarily exclude the first one, refers to spatial mechanisms related to reading notes. Globally, as emerges from the graph in Figures 3 and 4, it can be noticed that the distance each clef requires to move from the reference clef (treble) is inversely proportional to performance. This outcome is not negligible because it sheds light on the mental mechanisms musicians may use to perform reading in the different clefs and suggests, for example, that the involved mechanisms are based on spatial rather than on linguistic codes, at least for single tone reading (Besson & Schön, 2001).

Finally in the present study, there were no gender effects on laterality results, differently from the literature of text reading in which male are more lateralized than female (Marcel, Katz, & Smith, 1974; Clements et al., 2006). This apparently odd result could have several explanations: (a) *setticlavio* reading and more broadly music reading do not rely on the same mechanisms of text reading, as suggested also by the present absence of a straight left hemispheric asymmetry as in language; (b) anatomical and functional brain asymmetries are strongly influenced by music learning; and (c) the provenance of subjects enrolled in the present study was from different instruments and music-training methods, which could have masked a possible effect of sex on laterality that, however, based on our knowledge, has never been reported for music.

The present results extend the findings of our previous study (D'Anselmo, Giuliani, Marzoli, Tommasi, & Brancucci, 2015), carried out on a sample of pianists required to perform a sight-reading task, that is, playing quickly on a keyboard notes presented visually in musical or verbal code. Observed asymmetries strongly depended on the motor output type, that is, whether two- or single (left or right) hand action were required and on stimulus coding (musical or verbal notation). Only when notes had to be played with the left hand, which reads in the bass clef, an LH advantage was observed. This suggested that asymmetry in music sight reading and playing depends from both the clef and the motor activity. The present results are instead relevant for the investigation of perceptual mechanisms in music reading and not for performance-related functions. It could be speculated that the main mechanisms that underlie playing an instrument reading *setticlavio* concern the perceptual side, with the addition of a prearranged motor schema that translates the read note in the output type requested by the played instrument. Nevertheless, it should be stated that whereas reading in different clefs is part of the education of each professional classical musician, reading and playing in different clefs is far more seldom and difficult, and just rare specific music courses envisage such an ability.

At odds with the present results is the outcome of a study by Schön, Semenza, and Denes (2001) on a neurological patient, a female musician with left temporoparietal ischemia. She showed a deficit in reading in the bass but not in the treble clef, although the ability to play notes on a piano in both clefs was preserved. This evidence would have suggested the presence of an LH specialization in reading in the bass clef, which was not observed in the present study. Such specialization has been suggested also by other studies on music reading (although not with *setticlavio,* i.e., in reading in different clefs). A selective deficit in music reading that does not interfere with other musical skills has been observed in a professional musician with a left posterior temporal lobe lesion (Cappelletti, Waley-Cohen, Butterworth, & Kopelman, 2000). In a previous study, Brust (1980) described the case of two musicians with LH lesions showing a deficit in both reading and writing music, although other musical abilities were intact. Finally, a recent study by Riva, Casarotti, Comi, Pessina, and Bello (2016) described a professional opera singer with a left temporal glioma. Using intraoperative stimulation mapping, they found that a specific site of the middle part of the superior temporal gyrus was associated with a selective impairment in musical score reading but not in language processing, pointing to a dissociation between processing of musical and linguistic material at a cortical level, which substantiates our suggestion of the existence of a spatial rather than verbal code in reading musical notes.

The differences in the results obtained with stimulus lateralization techniques (perceptual and experimental psychology) and neurological patients (neuropsychology) invoke the use, in future studies, of neuroimaging protocols in music reading in the different clefs. These experiments should aid to shed light on different aspects of mental operations: the specific neural mechanisms involved in musicians during *setticlavio* reading, the nature of the code they use to translate musical symbols, the neural correlates of attentional shifts in all directions, and, last but not least, the reason for which hemispheric asymmetries studied with different techniques do not always concord in their directions.

References

Assal, G., & Buttet, J. (1983). Agraphie et conservation de l'écriture musicale chez un professeur de piano bilingue. *Revue Neurologique, 139,* 569–574.

Basso, A., & Capitani, E. (1985). Spared musical abilities in a conductor with global aphasia and ideomotor apraxia. *Journal of Neurology, Neurosurgery, and Psychiatry, 48,* 407–412. http://dx.doi.org/10.1136/jnnp.48.5.407

Besson, M., & Schön, D. (2001). Comparison between language and music. *Annals of the New York Academy of Sciences, 930,* 232–258. http://dx.doi.org/10.1111/j.1749-6632.2001.tb05736.x

Bevan, A., Robinson, G., Butterworth, B., & Cipolotti, L. (2003). To play 'B' but not to say 'B': Selective loss of letter names. *Neurocase, 9,* 118–128. http://dx.doi.org/10.1076/neur.9.2.118.15074

Bever, T. G., & Chiarello, R. J. (1974). Cerebral dominance in musicians and nonmusicians. *Science, 185,* 537–539. http://dx.doi.org/10.1126/science.185.4150.537

Beversdorf, D. Q., & Heilman, K. M. (1998). Progressive ventral posterior cortical degeneration presenting as alexia for music and words. *Neurology, 50,* 657–659. http://dx.doi.org/10.1212/WNL.50.3.657

Bowers, D., & Heilman, K. M. (1980). Pseudoneglect: Effects of hemispace on a tactile line bisection task. *Neuropsychologia, 18,* 491–498. http://dx.doi.org/10.1016/0028-3932(80)90151-7

Brancucci, A., Babiloni, C., Rossini, P. M., & Romani, G. L. (2005). Right hemisphere specialization for intensity discrimination of musical and speech sounds. *Neuropsychologia, 43,* 1916–1923. http://dx.doi.org/10.1016/j.neuropsychologia.2005.03.005

Brancucci, A., D'Anselmo, A., Martello, F., & Tommasi, L. (2008). Left hemisphere specialization for duration discrimination of musical and speech sounds. *Neuropsychologia, 46,* 2013–2019. http://dx.doi.org/10.1016/j.neuropsychologia.2008.01.019 AQ: 4

Brancucci, A., & San Martini, P. (1999). Laterality in the perception of temporal cues of musical timbre. *Neuropsychologia, 37,* 1445–1451. http://dx.doi.org/10.1016/S0028-3932(99)00065-2

Brancucci, A., & San Martini, P. (2003). Hemispheric asymmetries in the perception of rapid (timbral) and slow (nontimbral) amplitude fluctuations of complex tones. *Neuropsychology, 17,* 451–457. http://dx.doi.org/10.1037/0894-4105.17.3.451 AQ: 5

Brust, J. C. (1980). Music and language: Musical alexia and agraphia. *Brain: A Journal of Neurology, 103,* 367–392. http://dx.doi.org/10.1093/brain/103.2.367

Cappelletti, M., Waley-Cohen, H., Butterworth, B., & Kopelman, M. (2000). A selective loss of the ability to read and to write music. *Neurocase, 6,* 321–332. http://dx.doi.org/10.1080/13554790008402780

Cazzoli, D., Nyffeler, T., Hess, C. W., & Müri, R. M. (2011). Vertical bias in neglect: A question of time? *Neuropsychologia, 49,* 2369–2374. http://dx.doi.org/10.1016/j.neuropsychologia.2011.04.010

Clements, A. M., Rimrodt, S. L., Abel, J. R., Blankner, J. G., Mostofsky, S. H., Pekar, J. J., . . . Cutting, L. E. (2006). Sex differences in cerebral laterality of language and visuospatial processing. *Brain and Language, 98,* 150–158. http://dx.doi.org/10.1016/j.bandl.2006.04.007

D'Anselmo, A., Giuliani, F., Marzoli, D., Tommasi, L., & Brancucci, A. (2015). Perceptual and motor laterality effects in pianists during music sight-reading. *Neuropsychologia, 71,* 119–125. http://dx.doi.org/10.1016/j.neuropsychologia.2015.03.026

Fasanaro, A. M., Spitaleri, D. L. A., Valiani, R., & Grossi, D. (1990). Dissociation in musical reading: A musician affected by alexia without agraphia. *Music Perception, 7,* 259–272. http://dx.doi.org/10.2307/40285464

Horikoshi, T., Asari, Y., Watanabe, A., Nagaseki, Y., Nukui, H., Sasaki, H., & Komiya, K. (1997). Music alexia in a patient with mild pure alexia: Disturbed visual perception of nonverbal meaningful figures. *Cortex, 33,* 187–194. http://dx.doi.org/10.1016/S0010-9452(97)80014-7

Jewell, G., & McCourt, M. E. (2000). Pseudoneglect: A review and meta-analysis of performance factors in line bisection tasks. *Neuropsychologia, 38,* 93–110. http://dx.doi.org/10.1016/S0028-3932(99)00045-7

Judd, T., Gardner, H., & Geschwind, N. (1983). Alexia without agraphia in a composer. *Brain: A Journal of Neurology, 106*(Part 2), 435–457. http://dx.doi.org/10.1093/brain/106.2.435

Kawamura, M., Midorikawa, A., & Kezuka, M. (2000). Cerebral localization of the center for reading and writing music. *Neuroreport, 11,* 3299–3303. http://dx.doi.org/10.1097/00001756-200009280-00050

Loughnane, G. M., Shanley, J. P., Lalor, E. C., & O'Connell, R. G. (2015). Behavioral and electrophysiological evidence of opposing lateral visuospatial asymmetries in the upper and lower visual fields. *Cortex, 63,* 220–231. http://dx.doi.org/10.1016/j.cortex.2014.09.003

Marcel, T., Katz, L., & Smith, M. (1974). Laterality and reading proficiency. *Neuropsychologia, 12,* 131–139. http://dx.doi.org/10.1016/0028-3932(74)90034-7

Nicholls, M. E., Mattingley, J. B., Berberovic, N., Smith, A., & Bradshaw, J. L. (2004). An investigation of the relationship between free-viewing perceptual asymmetries for vertical and horizontal stimuli. *Cognitive Brain Research, 19,* 289–301. http://dx.doi.org/10.1016/j.cogbrainres.2003.12.008

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia, 9,* 97–113. http://dx.doi.org/10.1016/0028-3932(71)90067-4

Pitzalis, S., Di Russo, F., Spinelli, D., & Zoccolotti, P. (2001). Influence of the radial and vertical dimensions on lateral neglect. *Experimental Brain Research, 136,* 281–294. http://dx.doi.org/10.1007/s002210000580

Riva, M., Casarotti, A., Comi, A., Pessina, F., & Bello, L. (2016). Brain and music: An intraoperative stimulation mapping study of a professional opera singer. *World Neurosurgery, 93,* 486.e13–486.e18. http://dx.doi.org/10.1016/j.wneu.2016.06.130

Salis, D. L. (1980). Laterality effects with visual perception of musical chords and dot patterns. *Attention, Perception & Psychophysics, 28,* 284–292. http://dx.doi.org/10.3758/BF03204387

Satoh, M., Furukawa, K., Takeda, K., & Kuzuhara, S. (2006). Left hemianomia of musical symbols caused by callosal infarction. *Journal of Neurology, Neurosurgery, and Psychiatry, 77,* 705–706. http://dx.doi.org/10.1136/jnnp.2005.068692

Schön, D., Semenza, C., & Denes, G. (2001). Naming of musical notes: A selective deficit in one musical clef. *Cortex, 37,* 407–421. http://dx.doi.org/10.1016/S0010-9452(08)70581-1

Schweer, W. (2012). *MuseScore* (version 1.2). Retrieved from http://musescore.org

Segalowitz, S. J., Bebout, L. J., & Lederman, S. J. (1979). Lateralization for reading musical chords: Disentangling symbolic, analytic, and phonological aspects of reading. *Brain and Language, 8,* 315–323. http://dx.doi.org/10.1016/0093-934X(79)90059-2

Signoret, J. L., van Eeckhout, P., Poncet, M., & Castaigne, P. (1987). Aphasie sans amusie chez un organiste aveugle. Alexie-agraphie verbale sans alexie-agraphie musicale en braille. *Revue Neurologique, 143,* 172–181.

Sloboda, J. A. (1984). Experimental studies of music reading: A review. *Music Perception, 2,* 222–236. http://dx.doi.org/10.2307/40285292

Thomas, N. A., Castine, B. R., Loetscher, T., & Nicholls, M. E. (2015). Upper visual field distractors preferentially bias attention to the left. *Cortex, 64,* 179–193. http://dx.doi.org/10.1016/j.cortex.2014.10.018

Verleger, R., Dittmer, M., & Śmigasiewicz, K. (2013). Cooperation or competition of the two hemispheres in processing characters presented at vertical midline. *PLoS ONE, 8,* e57421. http://dx.doi.org/10.1371/journal.pone.0057421

Received January 3, 2017
Revision received August 16, 2017
Accepted September 17, 2017 ■