

NAMING OF MUSICAL NOTES: A SELECTIVE DEFICIT IN ONE MUSICAL CLEF

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ABSTRACT

We investigated the ability to perform solfeggio, i.e. oral reading of musical notes in MP, a 65 year-old female professional musician, who, following a left temporoparietal ischemia, showed a complex pattern of amusia. The deficit on which we focused was her inability to read orally the bass (F) clef, often substituting it with the violin (G) clef. This problem could not be attributed to a lack of comprehension. The patient could in fact correctly perform on the piano the same sequences she erroneously read aloud; she was also able to correctly judge whether two strings, one in bass clef and the other in violin clef, represented the same sequence of notes. The problem seems to lie in the inability to retrieve note names keeping into account the clef-rule. It is hypothesized that, in the production of note names, this function requires the identification and application of syntactic-like information, in analogy with what is thought to happen in the retrieval of other words.

Key words: amusia, clefs, lesion, music, naming, reading

INTRODUCTION

The production and comprehension of music are supported by several subordinate abilities that have been investigated via both classic experimental psychology and neuropsychological approach (see, for reviews, Sloboda, 1985; Peretz and Morais, 1989; Howell, West and Cross, 1991; Bigand, 1993; Peretz, 1993, 1996; Carrol-Phelan and Hampson, 1996; Deliège and Sloboda, 1997; Basso, 1999). The results appear still very unsatisfying when compared with those obtained for language. This disproportion is mainly due to the scarcity of suitable patients, as complex musical functions can only be studied in professional musicians. Moreover, most of the available case descriptions of amusia, while sometimes admirably detailed, lack a theoretical frame. Basso (1999) is very sharp in underlying the fact that “the encounter between a neuropsychologist and a brain-damaged musician has generally caused the study of the patient’s musical ability, independently of the researcher’s interest for music.” Indeed Basso identifies two other kinds of studies: one motivated by the “interest of the researcher for amusia”, independently of the patients’ musical knowledge; the other concerned with auditory agnosia where “among other stimuli, musical ones have also been used”. The encounter between a musically competent neuropsychologist and a brain-damaged musician is very rare. Thus information about the neural organization of music in the brain is still very

fragmentary, and several basic abilities, such as music reading and writing, still remain to be investigated. The present study addresses, for the first time, the impaired ability of naming written notes in a music script (henceforth oral reading), a task, also called *solfeggio* or *solmization*, that represents a very basic component of formal education in western music¹.

The few neuropsychological studies on reading music were mostly concerned with the dissociation between reading the alphabetic code and reading musical notation (Gates and Bradshaw, 1977; Brust, 1980; Marin, 1982; Judd, Gardner and Geschwind, 1983; Stanzione, Grossi and Roberto, 1990; Horikoshi, Asari, Watanabe et al., 1997). While musicians with alexia for words but not for music have been described (Benton, 1977; Gates and Bradshaw, 1977; Assal and Buttet, 1983; Basso and Capitani, 1985; Signoret, Van Eeckhout, Poncet et al., 1987; Brust, 1980), the reverse pattern of disturbance (preserved language reading with troubled music reading) was only recently reported (Cappelletti, Waley-Cohen, Butterworth et al., 2000). Cappelletti et al.'s patient had a "selective impairment in reading and writing musical notes, without major disturbances in reading or writing letters, words or numbers, nor major difficulties in other musical abilities". Findings of this sort, together with those from studies more specifically concerned with music reading processing (see Fasanaro, Spitaleri and Valiani, 1990; Stanzione et al., 1990; Horikoshi et al., 1995), suggest the idea that musical reading abilities, though represented independently, are as fine grainly organized as linguistic abilities. This analogy will become even clearer in the light of the present investigation.

The case is reported here of a patient, MP, who, within a complex pattern of amusia, shows a specific impairment of the ability to name notes in F clef.

Reading Music: A Minimal Model

Every professional musician must be able to read music, especially "exact" music (this term refers to music that is executed as it was written by the composer, at least as far as pitch and rhythm are concerned).

While the psychological literature is mainly concerned with instrumental sight-reading, a fundamental ability of a professional musician (Wolf, 1976; Sloboda, 1976, 1985; Goolsby, 1994), the subject of the present investigation is oral sight-reading. Instrumental and oral sight-reading may indeed be viewed as two different transcoding operations. They only have in common the first step, i.e. the recognition of music notational code. Then they diverge. In instrumental reading, movements that are dictated (cfr. Sloboda, 1985) by positions on the instrument must be activated. In the expert musicians, they are likely stored in the so called "action output lexicon", i.e. the repertory of known and well practiced actions that

¹ The term *solfeggio* derives from Italian language. "Sol-fa" are respectively "g" and "f". At Italian Conservatory, a three-year course of *solfeggio* is compulsory. Main focus is put on the ability to name notes, respecting their duration. Later on, a version where notes are sung is also studied, but with much less intensity (unfortunately!). The sung version (*solfeggio cantato*) was not used in this study, since the patient complained she could no longer sing (that was true, even if see Appendix: Tune Recognition), and refused to perform the singing tasks. In this work, the two components of music, pitch and rhythm, have been studied separately. Thus the term *solfeggio* is used here only with reference to the pitch component in a naming task, unless differently specified.

would subserve gestural performance (Ochipa, Rothi and Heilman, 1989). In oral reading, the names of notes must be activated in the phonological output lexicon. A more abstract stage involving “semantic” understanding of the notes must be postulated, but it may or may not be activated in these processes. While necessary for certain purposes it seems rather unlikely to be relied upon in other. Fluent performance may inhibit full activation of the “semantic” component as well as contemporary activation of the two transcoding processes. Thus an expert musician playing a Beethoven Sonata, would not think of the names of notes (besides the fact that notes are simultaneous, they are also far too fast to be named *in tempo*). On the other side, beginners often learn how to play from a score before being able to name the notes they are playing. The transcoding process from the notational to the name system may thus occur in a direct “asemantic” way. There is, however, another piece of information that must be taken into account, that conveyed by the clef. Clefs are graphical signs that, at the beginning of the staves, determine the pitch of the notes on the same staves. They act as “syntactic” index, analogously to what occurs in reading a complex Arabic number, where “syntactic” information, provided by place order, guides the proper translation of each digit according to the powers of ten. In oral sight reading, the clef sign before a musical sequence indicates how to relate the notes on the staff to the names in the lexicon. Similarly, in instrumental reading, the clef dictates the proper space positions on the instrument. What is not known is whether the activation of “syntactic” information given by the clef is independent in the two processes of instrumental reading and oral reading. The patient we had the opportunity to study permits to answer this question.

CASE REPORT

MP, a 65-year-old female professional organist, suffered from a cerebral ischemic lesion, localized by MRI in the left parieto-temporal region. Initially she was a severe aphasic; at the time of the present investigation, her spontaneous speech had remarkably improved, auditory comprehension was good and only repetition was still poor.

MP held an organ Diploma at the Music Conservatory, followed by various specialist courses in ancient music. She was also a researcher in paleography, the study of the old prepolyphonic notational systems in Greek and Gregorian modality and in rare organ music from the Renaissance. Besides her activity as an organ soloist in the churches of her city, she taught music at secondary school and gave private lessons. MP was, therefore, a highly qualified professional whose premorbid performance on the tests administered in this study was likely to be flawless.

Neuropsychological Examination

Spontaneous language was fluent, but characterized by the presence of phonemic paraphasias, conduites d’approche often leading to recognizable neologisms and rare semantic paraphasias. One year after the stroke, the patient was submitted to the Italian version of the Aachener Aphasia Test (Luzzatti, Willmes and De Bleser, 1991), which yielded results consistent with the diagnosis of conduction aphasia (repetition 37%ile, Token Test 93%ile, written language 65%ile, naming 70%ile, and comprehension 93%ile).

Reading revealed a pattern of mild dyslexia, characterized by a marked length effect; errors (mainly phonemic substitutions and omissions) were 7.5% for regular words and around 25% both for irregular words and non-words. Digit span was 4, disyllabic word span 3 and spatial span (Corsi’s test) 4 (this last score is normal for MP’s age, Spinnler

and Tognoni, 1987). The patient did not show any sign of apraxia. Acalculia was detected, involving numerical and calculation abilities (see later for MP's performance in reading complex numbers). Her performance on Raven Progressive Coloured Matrices was within normal levels (33/36).

General Music Abilities

All experimental tests reported in this paper were also administered to three professional musicians (average age of 49), with more than 30 years of experience. They performed at ceiling (hence the lack of statistical comparison with MP's performance), which attests to the elementary nature of these tasks for professional musicians.

MP's music abilities were studied with an ad hoc battery of general music knowledge (see Table I for a summary of the results and Appendix for a more complete description of certain tasks). As the focus of the present paper was on reading music, only a brief discussion of the main findings on general music abilities is presented here.

A major rhythmic disturbance emerged across tasks (reading, writing, playing, discrimination, reproduction, sight-reading, improvisation, pacing or tracking), while melodic discrimination was quite well preserved. Cases of arhythmia have already been described in the literature (Mavlov, 1980; Brust, 1980), in line with the hypothesis of independence in the processing of rhythm and melody at the perceptual level (Palmer and Krumhansl, 1987; Peretz and Kolinsky, 1993). Some features of MP's temporal processing impairment are worth mentioning. First, rhythmic discrimination was performed better than reproduction (see Fries and Swihart, 1990, for reproduction task). This could be due to a deteriorated rhythm plan system (Carrol-Phelan and Hampson, 1996). Second, metric identification was unimpaired. Given that the patient's lesion was in the left hemisphere, this seems to confirm the hypothesis that metre is processed in the right hemisphere (Peretz, 1990). However, M.P. could not tap along with music precisely, though she improved when tapping along with a metronome. Moreover, as her musical lexicon (Peretz, 1993, 1997) seemed to be unimpaired, she could recognize familiar tunes and often hummed along with the recording (though not precisely). Nevertheless, the subject could not play anything by heart, possibly due to a difficulty in activating the musical representation. MP had no absolute pitch.

TABLE I
General Music Test: Percentages of Correct Responses

Test	Version	Single notes	Sequences	Norms
Oral reading	rhythmic		20%	100%
Copying	rhythmic		easy 89 diff 50	100%
Musical dictation	melodic	19%	36%	100%
	rhythmic		10%	100%
Symbol writing			86%	100%
Instrumental reading	rhythmic		20%	100%
Pacing			impaired	100%
Rhythmic repetition			54,5%	100%
Score reading			poor	correct
Playing by memory			absent	present
Improvisation			impaired	correct
Symbols reading			90%	100%
Harmonic identification			47%	100%
Metric identification			80%	100%
Recognition and identif. of well known tunes			recognized 97% identified 46%	100%
Discrimination	melodic		95%	100%
	rhythmic		70%	100%
	harmonic		62,5%	95%
Was this note present?			66,7% (4 notes)	85,9%

EXPERIMENTAL INVESTIGATION

Four ad hoc constructed “reading” tests were used: an oral reading test (solfeccio); a same-different task using two strings of notes in the two clefs used by keyboard players (silent reading); a sight-reading test at the piano (motor reading) and a naming test in which the subject had to name the notes played by the experimenter, on the subject’s full sight.

The first two tests were differentiated along the pitch/rhythm components and bass (F) / violin (G) clefs. These two clefs are used to write notes in the bass and high register, respectively. Usually the left hand “reads” in bass clef, while the right hand “reads” in treble clef. The tests were presented in two versions: one with single notes, and the other with sequences of four notes (four was the performance at digit span and Corsi test).

Sequences of notes can be differentiated into “musical” and “non musical” strings, a distinction in a way analogous² to that between words and non-words. Some musical patterns exist that may be defined typical of the tonal system. Scales and arpeggios, for example, are sequences of notes depending on coded rules that fix the number of semitones between a note and the next. Other common musical patterns, like cadences, progressions, grace notes and others, are also clearly recognizable, definable and interpretable as a unique structure. In a sense, these sequences may be viewed as “lexicalized” items, in opposition to those that do not occur in any systematic fashion. These patterns, or parts of them, were used to build the “musical” strings.

Nonmusical strings were built using the bounds of musical strings by default. Namely, they were strings not identifiable as scales, arpeggios, cadences, progressions or other musical forms or structures, and which could not be interpreted beyond the level of the single notes composing them.

This categorization was verified empirically by administering the set of strings to three expert musicians. Those that they did not easily classify as musical or non-musical were rejected³. The aim of this distinction was to assess whether lexicality played a role in the patient’s disturbance. A difference in performance between “lexical” sequences (likely to be recognized as a whole) and “non-lexical” sequences (likely to require a note by note reading procedure) would force the extension of the model to encompass both a lexical and a non lexical routine, and would permit to identify disturbances analogous to deep and surface dyslexia.

Writing tests comprised a copying task, an oral dictation and a musical dictation task. These tests too were differentiated with respect to the melody/rhythm components, F and G clefs, single notes and sequences, musical and nonmusical sequences. Whenever possible, the same items were used in the reading and writing tests.

² In music, virtually every single musical passage is potentially ambiguous and open to diverse interpretations. The reason is that, differently from language, music is not bound to meanings and functions (Clynes, 1982; Lerdhal and Jackendoff, 1983; Aiello and Sloboda, 1994).

³ The terminology used here for the two categories is preferred to the classification between “good” and “bad” strings (Halpern and Bower, 1982), since it puts more emphasis on grammatical than esthetical features. Halpern and Bower confirmed the well-known fact (Wolf, 1976; Sloboda, 1976; Sloboda, 1985) that musicians do not read note by note, but they use a chunking strategy, similar to that of chess players. This strategy is only adopted by experienced musicians, since it requires good musical knowledge.

MP's performance in reading and writing music, collected over several testing sessions, is reported on Table II.

TABLE II
Reading and Writing Music (Sequences Tasks): Percentages of Correct Responses

	F clef	G clef	general	Norms
Oral reading sequences	70,8%	90%		100%
Oral reading sequences (limited time)	37,5%	87%		100%
Playing sequences	95,5%	97,5%		100%
Same-different task			90%	100%
Naming played notes			93%	100%
Copying of delayed sequences	58,5%	76%		100%
Writing on verbal dictation	41,5%	100%		100%
Playing on verbal dictation			97%	100%

Music Reading and Related Tests

Oral Reading (solfeggio)

This task was meant to assess the ability to transcode a notational code into a spoken code. It requires retrieving the names of the notes from the lexicon keeping the clef information into account.

Material. The patient was asked to read 72 notes, 36 in F clef and 36 in G clef, and 60 sequences, 30 in F clef and 30 in G clef, for a total of 240 notes. Half of the items were musical patterns easily identified by professional musicians as a single chunk (Halpern and Bower, 1982). All items were displayed on single staves, where the clef symbol was clearly printed (Petrucci font of Finale 3.5) and the patient was constantly reminded to take notice of it. MP displayed good knowledge of clef symbols (see later naming and writing of ideograms) and used them spontaneously in writing music. She was also given the same task on a double staff (double clef) sheet. Her performance did not show any difference. Only the single staff task result is reported.

A temporally limited version of the same test with a 2 second item presentation was also administered to the subject with the aim to induce a chunking strategy in reading. Items were individually presented on a single staff. The subject was requested to read orally the name of the note/s. The F clef items were presented first. Musical/non-musical sequences were randomly distributed. The names of the notes that MP provided in answering, whether right or wrong, were recorded on an answer sheet.

Results. The patient performed the single note task with G clef items (97% correct), significantly better than with F clef ones (41.5% correct; McNemar, $\chi^2 = 18.0$, $p < 0.005$). Moreover, F clef items were named significantly slower than G clef items. It is important to remember that in all these tests, F clef and G clef items were identical (obviously transposed at the octave), but the order of items presentation within a clef was random. In the sequence task, the performance in G clef was 90% correct, while it was 70.8% in F clef (McNemar $\chi^2 = 21.0$, $p < 0.005$) with no difference between musical and nonmusical items in both clefs.

A qualitative analysis, note by note, showed that about 2/3 of F clef notes errors consisted in reading the notes as if written in G clef, the remaining errors being random. This cannot be due to perseveration, since F clef items were always given first.

In this as well as in other tasks, the patient persisted in her errors, despite repeated experimenter's correction, across several testing sessions during the whole period of observation (12 months).

In the temporally constrained version, the performance on F clef items hardly ever went up to the second note of the string. The subject said she could not remember the sequence. The difficulty in naming compared to that observed in the test without temporal limit was striking, and the test was not even completed (partial result: 37.5% correct). On the contrary, the performance on the G clef task (87%) did not differ from that obtained in the non-temporally limited version. Again, a musical vs nonmusical items difference did not appear.

Comment. The patient showed an impairment confined to oral reading in F clef.

Instrumental Sight Reading at the Keyboard

This task assesses the integrity of the transcoding process leading from the notational code to a motor performance. It requires the activation of the "action lexicon", taking into account clef information.

Material. The ability of the patient to sight-read musical notation at the piano was tested with the same single note and sequence items used in the oral reading tests.

Results. In both clefs, M.P. performed almost flawlessly: 100% correct in the single note task and 96.5% correct in the sequence task.

Comment. Both clefs were correctly used when playing, rather than naming, was required.

"Same-Different" Discrimination

This task investigates the ability to access to clef information by requiring the patient to make same-different judgments on items in both clefs.

Material. Two written "strings" of four notes, one in bass and the other in treble clef, representing the same or different sequences transposed at the octave, were presented on a sheet, one beside the other. The F string was always on the left side, the G string just beside. Forty pairs were used. The pairs could be musically identical (target «same»), graphically identical (note that the same position on the two staves, in F and G clefs, implies different pitches), structurally identical (in terms of contour and interval) but transposed, or totally different (see Figure 1).

Results. The patient was able to correctly judge 36/40 pairs. The four errors were two false positives and two false negatives.

Comment. The patient showed a basically good comprehension of both clefs.

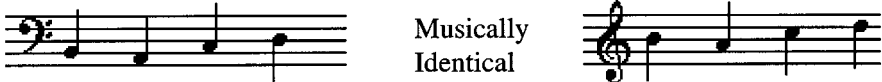
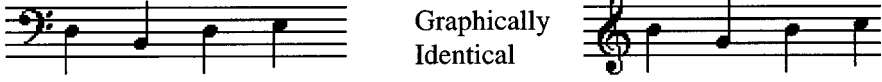
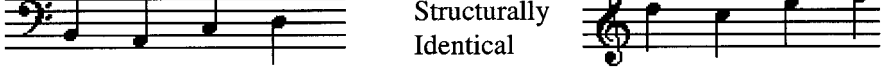
1	Musically Identical	
2	Graphically Identical	
3	Structurally Identical	

Fig. 1 – Examples of items from the same-different task.

Naming Played Notes

This task requires transcoding a visual spatial input into a spoken code (the possibility that the auditory input contributed to comprehension is unlikely, since the patient did not have absolute pitch). Its aim was to assess the integrity of the note lexicon.

Material. The experimenter sat at the piano, with the subject just besides, and played 16 single notes and 56 sequences. The latter could be musical or nonmusical. Both single notes and sequences were differentiated with respect to high and low registers. The subject had to look at the experimenter's hand and to name the played notes. Notes to the right of the middle C (C3) on the keyboard were played with the right hand, and the remainder with the left hand.

Results. The performance was at ceiling on the single note task and very good (95% correct) on the sequence task, without any difference between high and low registers. Note that each register corresponds in general to one hand and to one clef (low register to left hand and F clef). A slight difference appeared between musical and nonmusical items, with 2 errors on the former and 10 on the latter. Probably nonmusical items are harder to memorize compared to the musical ones that are “compressed” in a single chunk.

Comment. The patient did not show any problem in converting the keyboard representation of notes into a verbal one. Moreover, the good performance in this naming task confirmed that the patient's problem did not reside in the inability to recall the phonological form itself.

Music Writing and Related Tests

Musical writing was tested with a verbal dictation task and a delayed copying task. Musical dictation was also attempted, but the patient's performance was too poor to provide interpretable information.

Verbal Dictation

This task assesses transcoding from a verbal auditory code into musical notation taking into account the clef indicated on the staff.

Material. The subject was required to write to dictation 16 single notes and 30 sequences of 4 notes at a rate of about one note/second. An F or a G clef was indicated on the staff.

Results. In the single note task, the patient wrote only 6/16 notes correctly in F clef, showing a tendency to write them, as if they were in G clef. In the sequence task, F clef performance was 41.5% correct, with 40% of the notes erroneously written in G clef. On the contrary, in G clef she made 0/60 errors (McNemar $\chi^2 = 22.0$, $p < 0.005$).

Comment. The problem in the oral reading test was also present when the performance involved writing.

Playing on Verbal Dictation

This task represents transcoding from a verbal auditory code into a motor performance. No clef information is needed.

Material. The examiner named single notes and sequences of notes and the patient was required to play them on a keyboard. Items were selected from the previous test, 10 for the single note task and 16 for the sequence task. Neither rhythmical bounds were required to the subject, nor the contour of the sequence was specified, being irrelevant whether the subject interpreted “c”-“f” as an ascending fourth or as a descending fifth.

Results. The performance was perfect both with single notes and sequences, showing a good comprehension of the names of the notes.

Comment. When the task required playing the notes at the piano instead of writing them on the staff the performance was good, similarly to that found in the sight-reading at the piano test, though playing to verbal dictation did not imply the use of the two different clefs.

Delayed Copying Task

This task was administered in order to gather information about the way the patient held in memory musical notation. Being a musician, she was expected to perform the task not on the mere basis of visual-spatial abilities, but also of musical information. Thus lexicalized sequences should be easier to remember than non lexicalized sequences and trouble with one clef should prevent the subject from taking advantage of musical information.

Material. The same items of the oral reading test were presented for one second in the single note task and two seconds in the sequence task. The patient was allowed to start notation only when the presentation was over.

Results (1). With single notes the patient had a perfect performance in both clefs.

Comment. This was not surprising, since the task can be considered a spatial memory task for a single item (single note). In other words, it does not necessarily require musical knowledge.

Results (2). In copying sequences in G clef the patient showed a clear musical/nonmusical effect, copying correctly 93.5% of the musical items and only 58.5% of the nonmusical ones ($\chi^2 = 21.0$, $p < 0.005$). The performance in F clef was equally poor with musical and nonmusical sequences (58.5% correct). The comparison between the two clefs, yielded a significant difference (McNemar $\chi^2 = 19.0$, $p < 0.005$) only with respect to musical strings.

Comment. The musical/nonmusical effect showed that the patient was using a chunking strategy in G clef, but not in F clef. Again we found frequent clef substitution. The subject read F clef as if it were G clef (“g” became “e”), or read it correctly, but wrote it down as if it were in G clef (“g” became “b”).

Naming and Writing Ideograms, Chords and Key Signatures

This test was meant to specifically assess whether any difficulty with notational ideograms concurred to her deficit.

Material. The patient was requested to name and write, in two different sessions, 30 items involving clefs, rests, time signatures, dynamics, accidentals, slurs and similar.

Results. MP was able to name (20/22) and write (19/22) most of the ideograms presented. She easily recognized both the treble clef and the bass clef. However, she was not able to identify a tonality on the basis of the accidentals, to write the accidentals of a given tonality and to say whether a tonic triad was major, minor or diminished.

Comment. The knowledge of musical ideograms, such as clefs, was preserved.

Additional Nonmusical Tasks

All along reading and writing musical tasks, MP seemed unable to retrieve the names of the notes according to a rule as that expressed by the F clef. Further testing was carried out in order to establish whether this defect was not confined to musical domain and represented but an aspect of a more general impairment of the ability to keep into account a rule when retrieving a name.

Material. A modified version of Bock and Miller’s (1991) sentence completion task was administered. This task, which is used to induce agreement errors, requires the completion of sentences like “the journey to the islands...”, where the head of the sentence and the attractor differ in grammatical number. Even normal subjects make relatively frequent mistakes with these sentences, by agreeing with the latter name rather than with the subject (e.g. the journey to the islands *were** very pleasant). Twenty sentences, adapted from Vigliocco, Butterworth, Semenza et al. (1994) and Vigliocco, Butterworth and Semenza (1995) were used.

A second test required reading of complex numbers. It used 20 items of four digits whose correct reading depends on rightly interpreting the position of zero/s (e.g. 7700, 4040).

Results. MP was correct in 18/20 phrases and made one immediately self-corrected syntactic error (4400 instead of 4040), in reading complex numbers.

Comment. Despite her aphasia, MP was almost perfect in carrying out

linguistic production tasks heavily constrained by contextual, syntactic or syntactic-like information. Her failure in oral reading according to the F clef rule may thus be regarded as strictly domain-specific.

DISCUSSION

Within a composite pattern of amusia MP showed a dissociation between the impairment to name notes in F clef and the preserved ability to name notes in G clef. The patient persisted in her error (in oral reading as well as in verbal dictation and delayed copying tasks) even when it was pointed out and explained and she repeated it across several testing sessions, over the whole period of observation. Her difficulty could not be attributed to a comprehension deficit as she decoded correctly the graphical signs that, at the beginning of the staves, determine the pitch of the notes. This was shown by her good piano performance in both clefs of the same items failed in the oral reading test and by her same-different discrimination of two strings, one in bass clef and the other in treble clef. The latter task did not require a verbal or motor response, but demanded a good comprehension of the musical strings in both clefs. This was especially true in distinguishing “same” pairs from pairs that, although having the same contour and interval relations, were nevertheless musically different.

The patient’s problem was not one of recalling the phonological form itself, since she performed well in naming the notes played on the keyboard by the experimenter (in full sight of the patient). Moreover, the production problem was not modality specific, since it occurred with the same features in oral reading as well as in writing notes to dictation and in a delayed copying test. When playing instead of writing to dictation was tested, the performance was almost 100% correct.

The peculiar deficit of MP in the solfeggio task could be attributed to the use of a default strategy, as suggested by the finding that almost two thirds of the errors were substitutions of F clef with G clef (the remaining substitutions were random). In less musically expert patients, such strategy might have been determined by a familiarity effect. However, in a professional organist such as MP, for whom reading in both clefs has the same relevance, this hypothesis is very unlikely. Reading one clef hardly depends on reading the other, and there is no reason to suspect that one of the two clefs is more difficult than the other. In fact, all the scores for keyboard instruments make use of both G and F clefs, and this is the case since the very beginning of musical learning. Would any disparity exist, it would be in favour of F clef, which, in organ music, is used for the notes played by the left hand and for the notes of the pedals, while G clef is usually limited to the notes played by the right hand. Moreover, as the use of both clefs starts from the very beginning in keyboard instrument learning, reading in F clef cannot be considered a later acquired skill.

MP’s problem, therefore, seems to lie in retrieving, irrespective of modality (oral or written), the names of notes while keeping into account the clef-rule. It is noticeable how this defect selectively affects only the musical domain and only at the level of note name retrieval, while the retrieval of the corresponding motor acts (i.e. playing the notes on the keyboard) was flawless. On the

recognition sides the clef information is instead easily accessed as demonstrated by the ability to match different clefs.

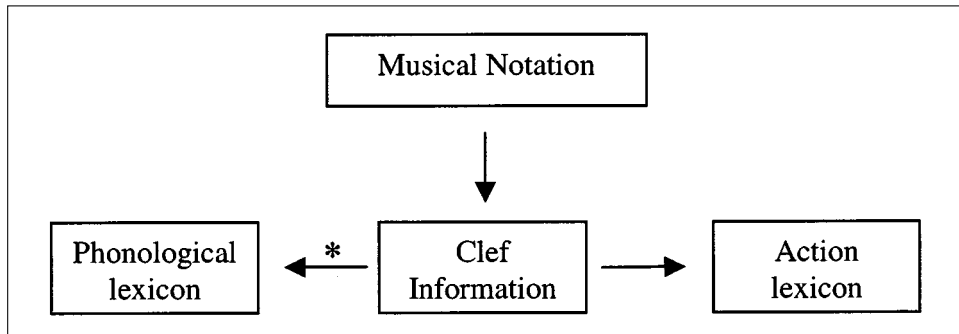


Fig. 2 – A minimal theoretical model of music reading. For the sake of simplicity the semantic system does not appear. The asterisk indicates the probable locus of MP's deficit.

These findings shed light on how the task of solfeggio is carried out. We hypothesize that the production of note names is organized in a way analogous to that of other words. The clef rule may be regarded as a parameter accompanying and constraining the information represented by the note on the staff. Indeed, in lexical retrieval, a function is conceived at work whereby success also depends on the identification and application of syntactic-like information (either in a special stage as in the “lemma” theory, Levelt 1989, or in parallel; see Semenza, 1999, for the neuropsychological aspects of the question). Ignoring this constraining information would lead, as most often was the case of MP, to the elicitation of a default form. This behaviour reminds that of patients who, being speakers of morphologically rich languages and having difficulties with morphological rules, tend to produce words in the masculine singular form, irrespective of the intended number and gender (Miceli and Caramazza, 1988). Likewise, it can be argued, MP's behaviour is analogous to that of patients who have difficulties in retrieving the names of complex numbers according to established syntactic rules (McCloskey, 1992). Yet our data show that the ability to retrieve words in accordance to specific rules is domain specific: MP indeed had no problems with sentence grammatical agreements and complex numbers reading. An interesting comparison, at this point, can be made with patient JL, a blind organist and composer, described by Signoret et al. (1987). As a result of a lesion involving the left temporal and inferior parietal lobes, this musician was still able to read music, but not letters and words (number performance was not clearly reported but also seemed to be deficient). In Braille, exactly the same signs are used for notes, numbers and letters: the only difference is a key-sign at the beginning of the line. The analogy with M.P.'s case is striking: in both cases, a particular type of name retrieval failed when it depended on an external rule. Further theoretical effort, coupled with experimental evidence, is necessary to fully appreciate the details of these particular examples of rule governed word retrieval.

In conclusion, a previously unreported, very specific deficit was isolated in a

case of complex amusia, which points out the role played by syntactic-like rules in reading and writing music, not differently from what has been reported with word and digit production.

In comparison with other deficits in musical knowledge, solfeggio impairment may be considered of minor relevance and also in M.P., it was not the prominent or most disruptive feature of her amusia. However, only careful and detailed descriptions of this sort can help improving our understanding of musical functions from a neuropsychological perspective. The theoretical gap still existing between the knowledge of music and that of other cognitive domains, such as language, will benefit from clarification of these issues.

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APPENDIX

Melodic Discrimination Task

Material. The ability to discriminate melodies was tested using a same-different task. Two sequences of four notes of the same duration (crotchet) were played one after the other, separated by an interval of 2 seconds. The “different pairs” were of four types: completely different, with inversion or retrograde inversion (Dowling, 1972), with interval variation and pairs where one sequence was a regularized version of the other. This regular/irregular distinction was made in analogy with that between regular and irregular words, made for language. It is here considered as “regularized” a non musical sequence transformed into a musical one, a sequence that is changed in a more frequent one and a sequence with a dissonant interval that is made consonant. The 60 items (30 same and 30 different) were played through a general MIDI (X-piano of a X5DR Korg) connected to a Macintosh and two speakers.

Results. The performance was 95% correct.

Comment. The contour and interval analysis systems (Dowling, 1978; Peretz, 1990; Carrol-Phelan and Hampson, 1996) seemed to be unimpaired.

Rhythmic Discrimination Task

Material. A same-different task with 54 items was administered to the subject using the same apparatus. The two 4/4 bars were separated by an interval of two seconds.

Results. MP’s performance was 70% correct, significantly different from chance (binomial test, $p < 0.005$).

Comment. Within certain limits, temporal analysis seemed still possible.

Tune Recognition and Identification Task

Material. 40 famous tunes of the period between the 40’s and the 60’s were played on a piano and recorded. To choose the tunes, a list of titles was read to five persons of the same age of MP. Only the titles recognized by everyone and considered “really famous” were recorded. Only the melody was recorded at the piano. A version with lyrics was also prepared in case the subject had difficulties in recognizing the tunes (Peretz, 1996); that was not the case. The subject was asked if the tune sounded familiar or not and possibly to name the title or say whatever the song reminded.

Results. 39/40 tunes were recognized as familiar, and 21/40 were correctly identified. MP sang very often along with the recording (though she often sang too quickly and with a very weak voice, “sottovoce”). She always gave some extra-musical information (genre, period, sung by, part of the lyrics) connected to the tunes, even when she could not properly identify the title.

Comment. The musical lexicon (Peretz, 1993, 1997) seemed to be unimpaired, if we consider that singing a song faster than its recording implies, to a certain extent, its preserved representation.

Rhythmic Reproduction Task

Material. This was a modified version of a Fries and Swihart (1990) test. Eleven basic rhythmical patterns were used three times for a total of 33 items, randomly presented. The subject had to reproduce, tapping with a hand, the pattern played by the experimenter. Single hand and both hand reproduction were tested.

Results. No difference between hands appeared. MP performed poorly, reproducing 18/33 correct patterns. All the 9/33 items that presented a dotted crotchet were wrongly reproduced.

Comment. The difficulty found in the rhythmic discrimination task was also apparent in reproduction and it was even worse, though the items were actually easier. This was probably due to a deteriorated rhythm plan system (Carrol-Phelan and Hampson, 1996) added to the limits already found in the temporal discrimination.