Dissociation between recognition and emotional judgements for melodies
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Dissociation Between Recognition and Emotional Judgements for Melodies

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Abstract

Current neuropsychological models of face perception admit three separate routes for processing information required in the recognition of a familiar face, in the matching of unfamiliar faces and in the analysis of facial expressions. The present study investigated these three classes of abilities for music processing in a music agnostic woman, IR, who sustained bilateral cerebral damage. The results show selective sparing of the processing of emotional tone of melodies in the presence of severe deficits in the discrimination and recognition of familiar and unfamiliar melodies. This dissociation supports the existence of two separate routes for the treatment of properties that subserve recognition and emotional evaluation of music.

Introduction

One striking finding that emerges from studies of processing impairments due to brain damage is the double dissociation observed between recognition of identity and of emotion in faces. It has consistently been reported that brain damage can produce selective deficits in the recognition of facial identity, while leaving intact the recognition of facial expressions. Inversely, selective deficits affecting the recognition of emotion from facial expressions without disturbing recognition of their identity have been reported (e.g. Etcoff, 1984; Parry et al., 1991; Young et al., 1993). These observations entail that certain aspects of face identity and facial expression are analysed separately.

Curiously, the possibility that similar dissociations may occur in the musical domain has never been addressed. The situation is odd because, like faces, melodies are highly structured, easily recognizable and conceived as an emotional medium. Just as for faces, brain damage can produce a selective loss of recognition abilities (Peretz, 1996). The deficit is selective in that it interferes with the identification of melodies while leaving intact recognition of speech and familiar environmental sounds (Peretz et al., 1994). This condition is referred to as music agnosia. Moreover, all three patients exhibiting music agnosia, whom we studied in detail (Peretz et al., 1994, 1997), claimed that they still enjoyed music. This claim suggesting spared emotional response has, however, not been assessed objectively.

The purpose of the present study was to document experimentally the possibility that music agnosic patients recognize the emotional tone of melodies, following the principles outlined in the visual domain for faces. As an initial step, we tested one patient (IR), the most severe case of amusia we have ever studied (Peretz et al., 1997). In addition to the assessment of the processing requirements involved in the recognition of familiar melodies and in the recognition of their emotional tone, we directly compared IR’s ability to discriminate familiar and unfamiliar melodies. Indeed, discrimination and recognition of familiar and unfamiliar stimuli have been shown to be dissociable in the visual domain. That is, some patients can no longer discriminate unfamiliar faces but can normally recognize familiar faces, and other patients show the opposite pattern (e.g. Malone et al., 1982; Parry et al., 1991; Young et al., 1993). Therefore, these three classes of abilities, discrimination and recognition of unfamiliar melodies, recognition of familiar melodies as well as recognition of their emotional tone, were assessed in IR in the present study.

Case summary

Neurology

IR is a right-handed woman in her early 40s who suffered from bilateral cerebral damage caused by the repair of
cerebral aneurysms at the age of 28. IR underwent a series of operations targeted at clipping mirror aneurysms located on the left and right middle cerebral arteries. At the time of testing, CT scans showed that in the left hemisphere, most of the superior temporal gyrus was damaged; only a small portion of the posterior superior temporal gyrus was spared. The hypodensity extended anteriorly into the posterior aspect of the frontal operculum, medially into most of the insula, inferiorly into the middle temporal gyrus, inferior temporal gyrus, and possibly the anterior parahippocampal gyrus, and posteriorly and superiority into the anterior inferior parietal lobule and postcentral gyrus. In the right hemisphere, the anterior one-third of the superior temporal gyrus was infarcted; all or most of the transverse gyrus appeared to be spared. There was extensive infarction of the right inferior and middle frontal gyri, precentral gyrus, and insula with extension into the lateral orbitofrontal gyri and putamen. Images of the scans are presented in Fig. 1.

Ten years after her brain surgeries, IR readily engages in conversation with a definite sense of humour. Her only obvious difficulties are a mild articulation problem and a left hemiplegic arm. She also complains of persisting difficulties with music. She can no longer recognize familiar melodies and can no longer sing a single note. IR did not receive a formal musical education, but was raised in a musical environment, since her grandmother and her brother are both professional musicians. IR received 10 years of school education. Before her brain accident, she worked as a restaurant manager.

**Neuropsychology**

A summary of IR’s cognitive and auditory functioning is presented in Table 1. IR’s latest assessment with the WAIS-R and WMS-R indicates normal intelligence for her level of education and normal memory functioning (with the exception of impairment of short-term memory for digits). There is no evidence of impairment of basic auditory functions, with normal audiometry. She also exhibits normal scores on language comprehension and discrimination tests (see Peretz et al., 1997, for detailed evaluation of language functioning). She has no difficulty in recognizing familiar environmental sounds as long as musical sounds are not involved. In contrast, her ability to recognize music is severely impaired. She cannot name any of the melodies which were highly familiar prior to her brain accident (see also Peretz et al., 1997, for detailed comparisons between text and music in songs). IR does show improvement in familiar melody recognition when written titles are provided as multiple choices. She does not, however, reach normal performance (see Table 1). Thus, IR presents an auditory agnosia which is limited to musical events.

With regard to emotional responding, IR appears to be normal, although her usual mood is somewhat upbeat; she does not easily get upset. On formal testing, she correctly classified most of the 110 black and white faces taken from Ekman and Friesen’s (1976) collection. As can be seen in Table 1, IR failed, however, to recognize the expression of fear while normal subjects (taken from Ekman and
**Discrimination and recognition of familiar and unfamiliar melodies**

IR’s hallmark symptom is a severe impairment in the recognition of familiar musical excerpts. In order to specify the source of IR’s agnosic disturbance, two test batteries were used. One battery of six subtests has been used systematically in our laboratory over the last 10 years, and is described in detail elsewhere (Peretz, 1990; Liégeois-Chauvel et al., 1998). This battery assesses the discrimination of various characteristics that are known to contribute to melody processing, while keeping the material as natural and identical as possible across conditions. The material is novel, but respects the rules of the Western tonal system. The second test battery is a new one. Its major difference lies in the use of highly familiar melodies as stimuli, while the previous battery uses unfamiliar melodies. Task demands and experimental conditions are otherwise identical in the two batteries. Comparison of the results obtained with the two batteries allows the assessment of the influence of familiarity on melody discrimination and recognition. In effect, discrimination and recognition of familiar melodies may in fact recruit different or additional processing components from those involved in the discrimination of unfamiliar melodies. As reported earlier, such a distinction in the discrimination of familiar and unfamiliar stimuli has been shown to have neuropsychological validity for processing faces.

**Equipment and procedures**

All stimuli were monophonic and computer-generated via a Yamaha TX-81Z synthesizer. The voice chosen was the approximation of a piano sound. The analogue output was recorded on a digital DAT SONY recorder which was also used to play the melodies back to the subjects.

The stimuli were organized into two versions of the same battery of tests. The unfamiliar version was constructed with the same pool of 30 novel musical sequences which were tonally structured. The sequences were four bars long, lasted ~4 s, and consisted of 8–19 tones (mean = 10.7). Half were written in a double metre, half in a triple metre. In the metric condition, the sequences involved two phrases instead of one, in order for subjects to build a stable metrical interpretation. The familiar version of the musical battery is constructed with a different pool of melodies. In this latter, 30 highly familiar melodic excerpts were taken from pre-existing vocal pieces. The excerpts were all judged to be highly familiar, with a mean rating of 4.8 (range: 4.4–5.0) on a 5-point scale, where 1 meant unfamiliar and 5 very familiar (Peretz et al., 1995). The familiar excerpts contained one to two phrases, with 6–17 notes, and lasted on average 5.7 s. Among these excerpts, only 20 were judged, in prior pilot testing, to have a stable meter. Hence, only 20 excerpts could serve as stimuli in the metric task. Half of these were written in a double meter and half in a triple meter.

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**Investigation**

The experimental situations in the first section were designed to characterize the nature and severity of IR’s melody recognition deficit. In the second section, IR’s ability to evaluate the emotional tone and familiarity for the same pool of melodies was compared. In the third section, IR’s ability to distinguish melodies according to their emotional tone was assessed in a ‘same-different’ classification task.
Table 1. IR's performance on tests of intelligence, memory, audition (language and music) and emotions compared to the performance of four matched controls on non-standardized tests

<table>
<thead>
<tr>
<th></th>
<th>IR</th>
<th>Normal controls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean (range)</td>
</tr>
<tr>
<td><strong>Intelligence</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WAIS-R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full scale IQ</td>
<td>94</td>
<td></td>
</tr>
<tr>
<td>Verbal IQ</td>
<td>98</td>
<td></td>
</tr>
<tr>
<td>Performance IQ</td>
<td>95</td>
<td></td>
</tr>
<tr>
<td><strong>Memory</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WMS-R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full scale MQ</td>
<td>99</td>
<td></td>
</tr>
<tr>
<td><strong>Audition</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Audiometry</td>
<td>Normal</td>
<td></td>
</tr>
<tr>
<td>Speech</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Token test</td>
<td>56/62</td>
<td></td>
</tr>
<tr>
<td>Auditory lexical decision</td>
<td>77/80</td>
<td></td>
</tr>
<tr>
<td>Word discrimination</td>
<td>36/36</td>
<td></td>
</tr>
<tr>
<td>Environmental sounds (naming response)</td>
<td>88.9%</td>
<td>82.0% (75.0-88.9)</td>
</tr>
<tr>
<td>Familiar music (naming response)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>(four written choices)</td>
<td>50%</td>
<td>88.8% (84.7-93.6)</td>
</tr>
<tr>
<td><strong>Emotions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ekman faces</td>
<td></td>
<td></td>
</tr>
<tr>
<td>happy</td>
<td>83.3%</td>
<td>98.6%</td>
</tr>
<tr>
<td>sad</td>
<td>82.4%</td>
<td>89.2%</td>
</tr>
<tr>
<td>fear</td>
<td>20%</td>
<td>87.7%</td>
</tr>
<tr>
<td>anger</td>
<td>100%</td>
<td>88.9%</td>
</tr>
<tr>
<td>surprise</td>
<td>100%</td>
<td>92.4%</td>
</tr>
<tr>
<td>disgust</td>
<td>86.7%</td>
<td>92.3%</td>
</tr>
<tr>
<td>Voices</td>
<td>84.7%</td>
<td>97.6% (94-100)</td>
</tr>
</tbody>
</table>

Each battery comprised the same six tests: three melodic, two temporal and one recognition memory tests, as follows.

**Melodic tests**
Each of three melodic tests was associated with the manipulation of a single feature on the pitch dimension. One manipulation consisted in creating a contour-violated alternate melody by modifying the pitch of one tone so that it changed the pitch direction of the surrounding intervals (see B in Fig. 2, for an example of these contour changes in the familiar melody Au Clair de la Lune; i.e. the interval directions surrounding the critical pitch were modified from +, − to −, +), while keeping with the original key. The serial position of this modified pitch varied across melodies; half fell in the beginning of the melody and half fell in the end. The first and last tone positions were avoided. The second manipulation consisted in the creation of a scale-violated alternate melody by modifying the same critical pitch so that it was out of scale (keeping the same average distance in semitones), the original contour being respected (see C in Fig. 2). This change is particularly salient because the changed pitch sounds out of tune. The third manipulation consisted in creating a contour-preserved or interval-violated alternate melody of these contour-violated and scale-violated melodies by modifying the same critical pitch within the same average distance (in semitones), while respecting the original contour and scale (see D in Fig. 2).

Average pitch interval changes were made equivalent across the three melodic tests. In the unfamiliar version, the changed pitch was, on average, 4.3, 4.3 and 4.2 semitones apart from the original pitch, in the contour-violated, scale-violated and interval-violated tests, respectively. In the familiar version, the changes were respectively, 3.4, 3.4 and 3.2 semitones apart.

Three melodic tests, each consisting of two practice trials and 30 experimental trials, were constructed with these manipulated melodies in each version of the battery. A trial consisted of a warning signal and a target melody followed, after a 2 s silent interval, by a comparison melody. Duration of the inter-trial interval was 5 s long. A first test, the contour-violated one, was constructed so that 15 trials were made of identical melodies and 15 trials of different melodies, consisting of the original melody paired with its contour-violated alternate (for example, A and B in Fig. 2). The second and third tests, prepared for the scale-violated and the interval-violated tests, respectively, were similar to the contour-violated test in that they kept the same target melodies; the only modification was that each different comparison melody was replaced by its scale-violated alternate (for example, A and C in Fig. 2) or by its interval-violated alternate (for example, A and D in Fig. 2). Trials were presented in a random order in each melodic test. These three tests will be referred to as the contour, scale and interval conditions in the unfamiliar and familiar version. Subjects were required to perform a 'same–different' classification task. They had to judge, on
Table 2. Percentages of correct responses obtained by IR, as well as the means of four normal controls on the same tests using familiar and unfamiliar melodies. The lowest and highest scores for control subjects are presented in parentheses.

<table>
<thead>
<tr>
<th>Melodic tests</th>
<th>IR</th>
<th>Normal controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Familiar melodies</td>
<td>47.7(a)</td>
<td>96.7 (96.7–96.7)</td>
</tr>
<tr>
<td>Unfamiliar melodies</td>
<td>50.0(a)</td>
<td>90.0 (73.3–100)</td>
</tr>
<tr>
<td>Contour</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Familiar melodies</td>
<td>63.3(a)</td>
<td>95.0 (90–100)</td>
</tr>
<tr>
<td>Unfamiliar melodies</td>
<td>50.0(a)</td>
<td>87.5 (80.0–96.7)</td>
</tr>
<tr>
<td>Interval</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Familiar melodies</td>
<td>33.3(a)</td>
<td>96.7 (93–100)</td>
</tr>
<tr>
<td>Unfamiliar melodies</td>
<td>50.0(a)</td>
<td>86.7 (76.7–93.3)</td>
</tr>
<tr>
<td>Temporal tests</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metre</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Familiar melodies</td>
<td>75.0(b)</td>
<td>81.3 (75–85)</td>
</tr>
<tr>
<td>Unfamiliar melodies</td>
<td>66.7(b)</td>
<td>83.3 (73.3–90.0)</td>
</tr>
<tr>
<td>Rhythm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Familiar melodies</td>
<td>56.7(b)</td>
<td>90.8 (76.7–100)</td>
</tr>
<tr>
<td>Unfamiliar melodies</td>
<td>50.0(b)</td>
<td>96.7 (93.3–100)</td>
</tr>
<tr>
<td>Memory recognition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Familiar melodies</td>
<td>63.3(a)</td>
<td>95.0 (93.3–100)</td>
</tr>
<tr>
<td>Unfamiliar melodies</td>
<td>50.0(a)</td>
<td>86.7 (76.7–96.7)</td>
</tr>
</tbody>
</table>

\(a\)At chance level (being 50%, by a binomial test).
\(b\)Above chance level.

Each trial, whether the target and the comparison sequence were the same or not.

**Temporal tests**

As mentioned previously, 30 two-phrase sequences served as unfamiliar stimuli and 20 familiar melodies did so for the metric tasks. Each sequence was recorded in a random order with an inter-trial interval of 5 s. These experimental trials were preceded by four practice trials. Subjects were informed that they would be hearing waltzes and marches, which they had to discriminate along that dimension. They were encouraged to tap along with what they perceived to be the underlying beat of each sequence.

For the rhythmic task, the target melodies were the ones used in the melodic tests. To create different comparison patterns, a change in the durational values of two adjacent tones was applied so that the metre and the total number of sounds remained identical (see E by comparison to A in Fig. 2). The serial positions of these changes varied across patterns. Thus, the only cue available for discrimination was the rhythmic pattern. A set of two practice and 30 experimental trials were constructed with these sequences following the principles adopted in the melodic tests. The task also required a ‘same–different’ classification.

**Memory recognition test**

From the initial pool of 30 melodies, 15 were selected for the recognition part of this study. Each of them was presented at least five times in the same format in prior trials. In addition to these ‘old’ melodies, a set of 15 recognition foils was prepared. In the unfamiliar version, the ‘new’ melodies were constructed along the same principles, but differed from the ‘old’ ones in their exact temporal and pitch pattern. In the familiar version, 15 familiar melodies which were not used as stimuli in the preceding tests were used as distractors; they had a mean familiarity rating of 4.6 (Peretz et al. 1995). In each version, the 15 ‘old’ and 15 ‘new’ melodies were recorded in a random order with a 5 s silent interval in between them. The task of the subjects was to respond ‘yes’ if they recognized the melody as having been presented earlier during the session and respond ‘no’ if otherwise. This last test came as an incidental memory test, since subjects were not informed in advance that they will be tested on their memory of the melodies.

Each subject was tested individually in two sessions 2 years apart, first on the unfamiliar version of the battery, then on the familiar version. There were as many pauses in between tests as requested by the subject, but the complete set of tests for each battery was presented in a 2\(\frac{1}{2}\) h single session. Subjects listened to the pre-recorded tapes via speakers placed in front of them; the intensity level was adjusted to be comfortable for each of them. The session began with the melodic tests, starting with the scale, then the contour and interval condition. It continued with the metric and rhythmic tests, and the session ended with the memory recognition test. No feedback on the accuracy of the responses was ever provided.

**Results and comments**

The results are summarized in Table 2. Compared to normal controls, IR is severely impaired, as she performs at chance level or far below controls in all tests involving familiar and unfamiliar melodies, with the exception of the
metric task. On the metric task, her performance lies in the low but normal range. Overall, IR exhibits a severe amusic disorder that affects most abilities involved in the discrimination and recognition of melodies.

The fact that IR achieves normal or near normal performance on the metric task while being impaired in all the ‘same–different’ discrimination tasks (i.e. all the melodic tests and the rhythm test) suggests that IR suffers from a short-term memory deficit. ‘Same–different’ classification tasks require subjects to hold a standard melody in memory for immediate comparison. In contrast, metric interpretation can be built on-line while the melody unfolds, thereby making less demand on short-term memory. In fact, IR suffers from a short-term memory deficit for both verbal and musical material (I. Peretz and S. Belleville, unpublished data). However, this short-term memory deficit cannot fully account for IR’s music processing impairments. First, delayed memory recognition (see Table 2) and familiarity decisions (Table 1) do not make heavy demands on short-term memory, but rather depend on long-term memory. IR performed poorly on both tests. Secondly, when the memory component of the task is set to a minimum, requiring IR to monitor melodies for error detection, IR also performs below normal controls (Peretz et al., 1997, 1998). Thus, IR appears to have a damaged perceptual analysis system as well as a disturbed memory system for musical information.

Of interest for the present study is the observation that IR is generally as impaired with the familiar melodies as with the unfamiliar melodies, although the familiar version seems generally easier for normal subjects. Thus, IR does not seem to access and/or use the stored representations of familiar melodies in order to discriminate and recognize these, as normal subjects would do. This memory access deficiency may be due to IR’s perceptual deficit. In other words, IR’s failure to build accurate representations of the musical input may account for her music agnosia, characterized by the inability to evoke memories associated with music.

Emotion and recognition

Although IR fails to show normal signs of recognition for familiar melodies and exhibits severe processing deficits for these melodies, she recurrently claims that she still enjoys music. In order to assess whether this subjective description of ‘emotion without recognition’ is related to the dissociation reported in the domain of face processing, we devised a test in which both recognition and emotional judgements can be compared.

We used a single set of 64 melodies, half of which are highly familiar and the other half unfamiliar. We selected the melodies so that half could evoke a ‘happy’ tone and the other half, a ‘sad’ one. The subjects’ task was to judge whether each melody was familiar or unfamiliar in a ‘familiarity judgement’ task, and to judge whether each melody was ‘happy’ or ‘sad’ in an ‘emotional judgement task’. The use of a binary classification response and a single stimulus set contributed in making the tests very similar in terms of task demands.

Equipment and procedure

Sixty-four musical excerpts, 40 of which were taken from popular songs and 24 from instrumental pieces, were used. The mean duration was 10.6 s per melody. Half of the melodies in each category were highly familiar (with a mean of 4.5; Peretz et al., 1995). Among the 20 familiar vocal melodies that were used as stimuli, 11 served as stimuli in the familiar musical test battery. The unfamiliar melodies were selected from the same repertoire (from Berthier, 1979, for the vocal material, and from the same composer for the instrumental material) and were considered to be unknown to the subjects because they are rarely played or sung. The melodies were selected so as to evoke either a ‘happy’ or a ‘sad’ tone. This emotional classification was essentially based on prior pilot testing: when ambiguous, the original tempo was slightly changed so that it became more congruent with the general tone of the excerpt. Half of the melodies in each category (i.e. familiar or unfamiliar) were considered as being ‘happy’, whilst the other half were considered as ‘sad’. The ‘happy’ and ‘sad’ melodies contrasted in their mean tempo which was 132 and 62 beats per minute, respectively ($t_{62} = 33.92$, $P < 0.001$). The mode of the melodies was less discriminant, since most of the familiar melodies were written in a major mode, which is generally associated to a ‘happy’ tone (see Crowder, 1984, for a recent review). Only 11 of the 32 ‘sad’ excerpts were written in a consistent minor mode.

All melodies were computer-generated on the same equipment used in the previous experiment. They were recorded on tapes with a 5 s inter-stimulus interval in two different and random orders. Subjects first classified the 64 melodies in terms of familiarity; they were requested to judge whether each excerpt was taken from a well-known musical piece or from an obscure one. Then, they performed the emotional judgement task on the same 64 melodies; they were instructed to judge whether each excerpt was ‘happy’ or ‘sad’. The session lasted about an hour.

Results and comments

Responses were scored as ‘hits’ if they corresponded correctly to a familiar melody in the familiarity judgement task and to an a priori happy melody in the emotional judgement task. False alarms corresponded to the same responses, that is ‘familiar’ and ‘happy’ responses, to unfamiliar and sad melodies respectively. The results are summarized in Table 3. IR’s scores again fell off the normal range in the familiarity judgements task with a lower hit rate ($\chi^2 = 18.35$ with 1 d.o.f., $P < 0.001$) and higher rate of false alarms than controls ($\chi^2 = 21.99$, $P < 0.001$). In the emotional judgement task, both the hit and false alarm
Table 3. Percentages of correct classifications as 'familiar' or 'happy' (hits) and percentages of false alarms (F.A.) in the familiarity judgements and the emotional judgements, respectively, for IR and her matched controls. The lowest and highest scores of the control subjects are displayed in parentheses.

<table>
<thead>
<tr>
<th></th>
<th>IR</th>
<th>Normal controls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hits</td>
<td>F.A.</td>
</tr>
<tr>
<td>Familiarity judgements</td>
<td>68.8</td>
<td>28.1</td>
</tr>
<tr>
<td>Emotional judgements</td>
<td>93.8</td>
<td>40.6</td>
</tr>
</tbody>
</table>

rates obtained by IR fell within normal variations ($\chi^2 = 1.17$ and 1.76 respectively, n.s.).

As can be seen in Table 3, there is, in general, a high level of false alarms in the emotional judgements indicating a bias to respond 'happy' instead of 'sad'; IR appears to exhibit this general bias. In order to identify the source of this bias, response consistency across subjects for each melody was examined. Response agreement across the five subjects (IR and her four controls) was found to be lower than expected: 34 out of the 64 melodies received a consistent classification by all subjects. On the remaining trials, IR did not diverge from the majority any more than control subjects did, with 17 and 18% of divergent responses respectively. A judgement that differed from all other four responses was considered divergent. Thus, there was some degree of disagreement in the emotional classification of the melodies presented. One source for this variability may lie in the mode in which the melodies were played. The mode was generally major, hence making emotional evaluation of the sad excerpts more ambiguous. This ambiguity could not be easily overcome, since it is inherent to the popular repertoire, which is mostly written in a major mode (Kastner and Crowder, 1990). For example, out of the 83 excerpts taken from the popular songs that were available for the present study (because they were normalized in a prior study by Peretz et al., 1995), 76 were written in a major mode.

Interestingly, 91% of the errors committed by IR in the familiarity and emotional judgements tasks do not occur on the same melodies. Thus, to her, the familiarity and emotional judgements appear to be independent. This observation is consistent with IR’s impaired recognition abilities and normal emotional interpretation. In her case, the limited access to stored representations of the melodies can no longer influence emotion evaluation of the stimuli. This may not be the case for normal controls, who can consult their stored knowledge of the familiar melodies in order to reach a proper emotional interpretation. For instance, knowing that the tune presented corresponds to the song *Happy Birthday* can bias the listener to respond ‘happy’, particularly in cases where the musical characteristics are not salient. Given that the control subjects performed almost perfectly in the familiarity decision task, a result that can argue for their easy access to their prior knowledge of the familiar melodies, memory consultation would predict that the emotional judgements would be both more accurate and more consistent for the familiar melodies than for the unfamiliar ones, particularly for the vocal excerpts which can evoke verbal associations more easily than instrumental pieces (Peretz et al., 1995). The results do not support this prediction. Control subjects obtained 80 and 90% correct in the emotional classification of the familiar and unfamiliar melodies respectively; each control subject showed this advantage for the familiar set. Moreover, prior knowledge of the melodies did not improve agreement across subjects: all four controls gave the same emotional classification for 56% of the familiar melodies, while they did so for 72% of the unfamiliar melodies. Finally, subjects did not perform better on the emotional interpretation of originally sung material (with 78% correct) than of instrumental melodies (92%). Thus, normal subjects as well as IR appear to perform the emotional and familiarity judgements independently.

**The role of emotion in discrimination**

In the previous section, IR was shown to be able to classify normally melodies as ‘happy’ and ‘sad’, while she failed to reach normal performance in classifying these same melodies as familiar and unfamiliar. The observed deficit in familiarity judgements is consistent with the results obtained with the ‘same different classification task’ used previously. In that initial investigation, IR did not exhibit an advantage for familiar over unfamiliar melodies in discrimination, as would be expected from a normal system. In contrast, IR’s ability to evaluate the emotional tone of melodies has not yet been assessed in a ‘same-different’ classification task. Therefore, unlike recognition abilities, it is difficult to evaluate how consistent are IR’s judgements across tasks in the emotional sphere. The goal of this last investigation was to provide such an opportunity (we thank an anonymous reviewer for suggesting this experiment). IR was presented with a ‘same-different’ discrimination task for melodies which, in half the cases, were distinguishable by their emotional tone. The prediction was that IR’s discrimination performance should improve when the emotional tone of the melodies is available as a discriminant cue.

**Method**

The least ambiguous melodies with respect to their emotional classification were selected from the pool used previously. Forty-eight melodies were so selected. Half were expected to evoke a ‘happy’ tone and the other half, a ‘sad’ tone. In each emotional category, half the melodies were familiar and half were unfamiliar. These melodies were paired so as to be as close as possible in length, familiarity and genre. Half of the pairs were identical in that they consisted of a melody paired with itself and the other half were made of different melodies. When different,
the two melodies either evoked the same emotional tone, such as *Happy Birthday* and *Pomme de Reinette* where both are considered as ‘happy’, or evoked a different emotional tone, as for *Happy Birthday* and *White Christmas*, the latter being considered ‘sad’. There were 48 ‘different’ pairs with similar emotional tone and 48 ‘different’ pairs with differing emotional tone, creating with the 96 ‘same’ pairs a full set of 192 trials. The material was generated and presented to the subjects with the same equipment as the ones used in the previous investigations.

Each trial started with a warning signal and consisted of a standard melody and a comparison melody. In between the standard and comparison melody was inserted a ‘distractor’ sequence. This distractor was generated by a random selection of 16 pitches used in the melodies that were presented in rapid succession (128 ms per tone). Insertion of such a distractor sequence aimed at making the melody comparison less obvious for control subjects. This procedure was not successful, though. Controls were performing at ceiling. The task of the subjects was to judge on each trial whether the melodies were same or different. They were invited to ignore the random pitch sequence inserted in between the melodies. No further information was provided to the subjects. They were tested in two sessions of 1 h each.

**Results and comments**

Overall, IR was 68.8% correct, with 50% of hits and 9% of false alarms (i.e. responding ‘different’ to ‘same’ melodies). As predicted, she made more hits when the different melodies were from different emotional categories than when the melodies were of the same category (with 62.5 versus 37.5% of hits respectively, $\chi^2 = 5.04$ with 1 d.o.f., $P < 0.05$, as computed on raw scores). Familiarity of the melodies did not have much influence; IR made slightly less errors in familiar melody comparisons (16.6%) than in unfamiliar melody comparisons (19.0%) but the difference was far from significant.

Given that control subjects performed at ceiling in this discrimination task, IR’s performance can hardly be considered as normal. IR is impaired when she has to discriminate two successive melodies, even when these differ by every single note as was the case here. This result is consistent with those obtained for discrimination and recognition of melodies, although, in those prior situations, the discrimination was more subtle, since the melodies to be compared only differed by one or two internal tones.

The interesting aspect in this context is to observe that IR shows an advantage for melodies with different emotional tones over those with similar emotional tones. This result suggests that IR improves her performance when her judgements can be mediated by emotional evaluation. Since the use of such a procedure was not explicit in the instructions, emotional evaluation of the melodies was probably performed without awareness or intention. IR’s comments were ambiguous, in this respect. She reported that the melodies were easier to discriminate when they were ‘of different style, like a lullaby followed by a song’, without mentioning that the two were evoking different emotional tones. Whether IR used emotional evaluation intentionally or not, the fact that she showed evidence of such a mediation in a ‘same-different’ classification task confirms her spared ability to access and exploit the emotional tone of melodies across task demands.

**General discussion**

We have observed, as postulated, dissociable impairments in the recognition of familiarity and of emotional tone of melodies in a patient with long-standing bilateral brain damage. The patient, IR, could normally classify melodies as ‘happy’ and ‘sad’ while she failed to reach normal performance in classifying these same melodies as familiar and unfamiliar. The two judgements were not only found to be separable by brain damage but were also found to be produced independently by the neurologically intact subjects. Normal subjects judged the emotional tone of the melodies without regard to their prior familiarity with them. This is, to our knowledge, the first empirical indication that music can be recognized and appreciated by separable processing components in the human brain. This finding extends to the auditory domain the striking dissociations observed in the recognition of identity and of expression in visual faces (e.g. Etcoff, 1984; Parry et al., 1991; Young et al., 1993).

However, unlike previous work done with faces, the present case does not exhibit evidence of differential treatment for familiar and unfamiliar items. IR experienced similar processing difficulties with familiar and unfamiliar melodies. This general deficiency is probably arising from a perceptual defect (Peretz et al., 1997). IR’s perceptual organization of the musical input is so severely disturbed that it may compromise access to long-term memory representations of familiar melodies. Thus, the present observation does not imply that familiar and unfamiliar melodies are treated by a single mechanism which would be damaged in IR. It only suggests that IR’s deficit is so severe and occurs so early in the perceptual organization of musical information that it interferes with most forms of recognition abilities.

The ensuing question is how IR derives successfully a proper emotional evaluation of melodies when her ability to recognize and discriminate them is so limited? Answering this question on the basis of the present results is not straightforward. The only musical ability that was shown to be spared to some extent is metric interpretation. However, it is difficult to conceive how metric information is relevant to emotional evaluation. In contrast, tempo, another close temporal characteristic, is directly relevant for emotional interpretation of music (e.g. Hevner, 1937). Fast tempi generally evoke happy tones while slow tempi evoke sad ones. Tempo interpretation was not assessed in
the music batteries used here, because it is orthogonal to the process of music recognition. Hence, tempo evaluation may be spared in IR and adequately used for emotional evaluation of the melodies. In other words, it is likely that IR abstracts the properties of the musical input that are emotionally relevant, while she fails to extract those features that are most determinant of recognition. Through this suggestion, we assume that the perceptual properties that are necessary for emotional and recognition responses are of a different nature. Testing this assumption was the goal of another set of studies (Peretz et al., 1998).

A cautionary note is, however, in order. As in any other neuropsychological single-case study, we observed here a simple dissociation. There are two different directions one may take in interpreting such data. One would be to argue that all musical stimuli are analysed with a common perceptual system whether the music is processed for emotional content or for non-emotional aspects. On this view, non-emotional processing would simply be more vulnerable to impairment of the perceptual system than emotional processing would be. The most likely reason is that non-emotional processing involves processing of structural features that are less perceptually distinct than the emotional aspects. This refers to a perceptual difficulty account. The alternative direction involves fractionation of this perceptual system along an emotionally relevant component and a recognition subsystem. We will call this the separate route account.

To determine which of these competing theoretical positions is the most likely will depend on future studies. If the same pattern of impairment across cases with different aetiologies is consistently revealed, then the perceptual difficulty account will be supported. Conversely, if evidence for double dissociation, i.e. differentially severe impairments of emotional and non-emotional processing emerges, then the separate route account will prevail. Anecdotal evidence tends to support the separate route account. Several brain-damaged patients whose recognition abilities seemed intact complained about having lost interest in music or that music sounded ‘flat’ or without emotion (Mazzuchi et al., 1982; Mazzoni et al., 1993). If the above claim is confirmed, it will provide the reverse situation to the one experienced by IR. Thus, what is needed at the present stage, is more experimental and systematic work on music and emotion in a neuropsychological setting.

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Dissociation between recognition and emotional judgements for melodies

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Abstract
Current neuropsychological models of face perception admit three separate routes for processing information required in the recognition of a familiar face, in the matching of unfamiliar faces and in the analysis of facial expressions. The present study investigated these three classes of abilities for music processing in a music agnostic woman, IR, who sustained bilateral cerebral damage. The results show selective sparing of the processing of emotional tone of melodies in the presence of severe deficits in the discrimination and recognition of familiar and unfamiliar melodies. This dissociation supports the existence of two separate routes for the treatment of properties that subserve recognition and emotional evaluation of music.

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Primary diagnosis of interest
Amusia

Author’s designation of the case
IR

Key theoretical issue
- Dissociation between emotion and recognition in audition

Key words: amusia; emotions; music; music agnosia; familiar melodies

Scan, EEG and related measures
CT scans

Standardized assessment
WAIS-R, Wechsler Memory Scale, audiometry, Token test, pictures of facial affect

Other assessment
Melody discrimination, memorization and identification, familiarity decisions for melodies, emotional classification of melodies

Lesion location
- Bilateral lesions in temporal and frontal lobes

Lesion type
Haemorrhages and surgical excision

Language
English