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The taste of music

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Abstract. Zarlino, one of the most important music theorists of the XVI century, described the minor consonances as 'sweet' (dolci) and 'soft' (soavi) (Zarlino 1558/1983, in *On the Modes* New Haven, CT: Yale University Press, 1983). Hector Berlioz, in his *Treatise on Modern Instrumentation and Orchestration* (London: Novello, 1855), speaks about the 'small acid-sweet voice' of the oboe. In line with this tradition of describing musical concepts in terms of taste words, recent empirical studies have found reliable associations between taste perception and low-level sound and musical parameters, like pitch and phonetic features. Here we investigated whether taste words elicited consistent musical representations by asking trained musicians to improvise on the basis of the four canonical taste words: sweet, sour, bitter, and salty. Our results showed that, even in free improvisation, taste words elicited very reliable and consistent musical patterns: 'bitter' improvisations are low-pitched and legato (without interruption between notes), 'salty' improvisations are staccato (notes sharply detached from each other), 'sour' improvisations are high-pitched and dissonant, and 'sweet' improvisations are consonant, slow, and soft. Interestingly, projections of the improvisations of taste words to musical space (a vector space defined by relevant musical parameters) revealed that, in musical space, improvisations based on different taste words were nearly orthogonal or opposite. Decoding methods could classify binary choices of improvisations (ie identify the improvisation word from the melody) at performance of around 80%—well above chance. In a second experiment we investigated the mapping from perception of music to taste words. Fifty-seven non-musical experts listened to a fraction of the improvisations. We found that listeners classified with high performance the taste word which had elicited the improvisation. Our results, furthermore, show that associations of taste and music go beyond basic sensory attributes into the domain of semantics, and open a new venue of investigation to understand the origins of these consistent taste – musical patterns.

1 Introduction

Zarlino, one of the most important music theorists of the XVI century, described the minor consonances as 'sweet' (dolci) and 'soft' (soavi) (Zarlino 1558/1983, in *On the Modes* New Haven, CT: Yale University Press, 1983). Hector Berlioz, in his *Treatise on Modern Instrumentation and Orchestration* (London: Novello, 1855), speaks about the 'small acid-sweet voice' of the oboe. Different senses receive correlated information about the same external objects and this information is combined to conform multimodally determined percepts (Calvert et al 2004; Driver and Spence 2000). Cross-modal integration occurs in strong synergy between the senses of taste and smell in the construction of flavour (Auvray and Spence 2008; Djordjevic et al 2004; Small and Prescott 2005; Stevenson and Tomiczek 2007). While this association is quite evident, other cross-modal associations have been also shown for seemingly distant and unrelated sensations such as pitch and visual size (Evans and Treisman 2010; Parise and Spence 2008), brightness and frequency of vibrotactile stimuli (Martino and Marks 2000), colours and tastes (O'Mahony 1983), odour and colour (Demattè et al 2006), or sound and colour (Ramachandran and Hubbard 2003; Ward et al 2006).

Recent studies have also identified reliable associations between auditory and taste perception. These studies have focused mainly on low-level musical features, like pitch, and phonetic features, like voice discontinuity and formants. Crisinal and Spence found significant associations between pitch and foodstuff names (2009, 2010a) and also using real tastants and flavours instead of merely the names of such items (2010b). Simner et al (2010) showed that reliable taste–auditory associations extended to phonetic features, which map systematically to different tastants and concentrations.

It has been proposed that cross-modal associations are ubiquitously present in normal mental function (Hubbard and Ramachandran 2005; Cytowic and Eagleman 2009). Beyond this faculty, synaesthesic individuals report that stimulation in one sensory pathway elicits direct responses in a different sensory pathway. In particular, a single case of sound–taste synaesthesia has been described in detail, in the case of the musician ES who experienced different tastes in response to hearing different musical tone intervals (Beeli et al 2005; Hänggi et al 2008). For instance, when ES heard a minor second, she experienced a sour taste in her tongue.

A related line of research has been devoted to the semantic influence on music production and perception. Koelsch et al (2004) showed that both music and language can prime the meaning of a word and determine physiological indices of semantic processing. Bonini Baraldi et al (2006) performed an experiment in which musicians and non-musicians had to produce piano improvisations according to different expressive intentions. Listeners were able to recognise the majority of these intentions with very brief musical fragments.

In the present work we combined these ideas. We sought to investigate whether the basic taste names (sweet, salty, sour, and bitter) are reliably associated with specific musical parameters in musical productions induced by them. To investigate this high-level mapping between music and taste, we asked expert musicians to improvise in accordance with taste words. We mapped each improvisation to six relevant musical dimensions: (i) average pitch; (ii) average duration; (iii) articulation, which is a measure of the degree of continuity between successive notes. Articulation ranges from improvisations without breaks between notes, articulation ~ 0 (known in music as legato, see definition in section 2) to improvisations in which each note is sharply detached or separated from the others (staccato, articulation ~ 1); (iv) loudness, which is simply the average sound volume of the improvisation; (v–vi) these last two parameters determine the degree of dissonance. Dissonant sounds tend to be judged as unpleasant or unstable while consonant sounds are typically associated with psychoacoustical pleasantness (Fastl and Zwicker 2007). We use a dissonance measure for chords (simultaneous notes), referred to as harmonic dissonance, and a different measure for melodies (successive notes), named Euler's gradus suavitatis, henceforth called, for simplicity, gradus. Briefly, high values of these two parameters correspond to dissonant sounds and low values to consonant sounds. After mapping each improvisation to its corresponding parameters, we could examine whether each specific taste mapped reliably to dimensions in musical space.

In a second experiment we reversed the mapping, investigating whether the resulting improvisations elicited consistent responses of taste words in a population without specific musical training.

2 Methods

2.1 *Experiment 1. Production of musical improvisations by expert musicians*

2.1.1 *Participants.* All participants were professional musicians. A total of nine subjects (seven male and two female; mean age 37 ± 7 years) participated in the experiment. All had more than 10 years of musical activity, but they differed widely in their musical background, some having a classic or experimental music expertise and others specialising in popular music. All participants signed a written consent form.

2.1.2 *Experimental procedure.* Each participant performed a total of 24 improvisations. Before each improvisation, participants were shown a sheet describing the modality of the improvisation. Three different modalities were used: (i) melody (monophony, a single solo line); (ii) chords (a chord is a group of notes sounded simultaneously. In this modality musicians were asked to play a sequence of chords); (iii) free (no restrictions). The sheet also contained a target word. Participants were asked to freely associate a musical improvisation with the word. Before the experiment, participants were informed that some of these words would not be usual musical expressions. Target words were divided into two different groups: (i) taste names (salty, sweet, sour, and bitter), which were our main experimental target, and (ii) usual musical expression terms 'determined', 'sorrowful', 'ferocious', and 'delicate' (for these words we used the standard musical names, in Italian, 'deciso', 'dolente', 'feroce', and 'delicato', respectively) which served as control words, as they are thought to elicit predictable responses. For instance, we expected 'ferocious' and 'determined' to be associated with high loudness and short note duration, and 'sorrowful' and 'delicate' with low loudness and longer note duration. Once shown the modality and target words, participants were allowed to rehearse about 1 min and then improvised on a MIDI keyboard. Participants were asked to limit their improvisations to a maximum of 60 s. The average duration of all improvisations was 47.3 s.

Improvisations were produced with a Kurzweil K2500XS MIDI keyboard and recorded with the software Sonar 4. We used a piano timbre, library GrandP 2V-32 of the software Reason 3. The loudspeakers were Tannoy Active and we used a Motu Traveler audio interphase. Improvisations were recorded at the LIPM (Laboratorio de Investigación y Producción Musical del Centro Cultural Recoleta), Buenos Aires, Argentina. Improvisations were analysed with the MIDI toolbox: https://www.jyu.fi/hum/laitokset/musiikki/en/research/coe/materials/miditoolbox/.

2.2 *Experiment 2. Association of musical improvisations to taste words in a population without specific musical training*

2.2.1 *Participants.* A total of fifty-seven subjects (thirty-one female and twenty-six male, mean age 26 ± 7 years) with no musical training participated in the experiment. Participants signed a written consent form.

2.2.2 *Experimental procedure.* From the pool of 108 musical improvisations corresponding to taste words we chose randomly three melody improvisations corresponding to each taste word (sour, bitter, sweet, and salty).

The durations of the improvisations were all greater than 15 s. During the experiment, we played only the first 15 s of each improvisation. All improvisations were played to participants in random order. After listening to each improvisation participants had 10 s to respond, in a forced choice, which of the four taste words the improvisation had elicited.

2.2.3 *Quantification of the musical parameters:*
Pitch was measured using the MIDI note scale (the central C of the piano corresponds to MIDI note number 60. An ascending semitone interval corresponds to an increase of one unit of MIDI note number). The lowest note of each improvisation was highly correlated with the average and highest notes. For simplicity only the highest note value is reported here.

Duration was measured in seconds and averaged across all notes. For simplicity of analysis (mainly to deal with non-simultaneous but very close beginnings of notes in chords due to finger motion) durations were discretised in bins of 0.05 s.

Articulation is defined as $\max(1 - D/I, 0)$, where D is the note duration and I is the time interval between consecutive onsets.

Loudness was measured as the MIDI key-press velocity ranging from 0 (no sound) to 127 (maximum loudness).

Harmonic dissonance was only computed for free and chords improvisations with the algorithm implemented in the software OpenMusic developed at IRCAM: (http://recherche.ircam.fr/equipes/repmus/OpenMusic/). This measure is based on a weighted sum of interval density in a chord. Specifically, for each chord, the interval vector $I = (i_1, i_2, i_3, i_4, i_5, i_6)$ is determined and weighted by a dissonance weight vector $W = (90, 30, 15, 12, 9, 50)$ which reflects the potential dissonance of each interval class. Chord dissonance is computed as $IW = \sum_{j=1}^{6} i_j w_j$.

Gradus (Euler 1739/1968) was measured for all improvisations. In the case of melodies it is computed as follows:

(i) For each consecutive pair of notes, estimate the interval, ie the ratio of their frequencies. Important intervals are those measured by fractions of small numbers, such as 1 : 1 (unison or prime), 2 : 1 (octave), 3 : 2 (perfect fifth), 4 : 3 (perfect fourth), etc.

(ii) For the interval $n : d$, define $g = nd$.

(iii) Calculate the prime factorisation of $g = \prod_i p_i$. The quantity $s = 1 + \sum_i (p_i - 1)$ is computed (s is called the suavitatis of the interval).

(iv) The gradus is the average of s across all pairs of consecutive notes.

3 Results

3.1 *Experiment 1*

We first computed the musical parameters for each individual improvisation and then averaged them across all participants to measure musical attributes as a function of taste names and musical terms. Figure 1 shows the average values for pitch, duration, articulation, and loudness (parameters computed for improvisations of all modalities). Figure 2 shows the average values for the two measures of dissonance.

To examine whether taste words elicited coherent and reliable patterns of improvisation across participants we submitted the data to a 2×4 ANOVA analysis with word class (taste words or conventional music words) and word type as independent factors. We analysed the ANOVA without interaction since the four word types had no correspondence between both groups. An independent ANOVA analysis was performed for each musical parameter (table 1).

Table 1. 2×4 ANOVA analysis with word category (taste words or conventional music forms) and word type as independent factors.

Parameter	Word category		Word type	
	$F_{1,9}$	p	$F_{3,27}$	p
Articulation	0.88	0.35	12.65	<0.001
Loudness	1.38	0.24	21.67	<0.001
Duration	0.75	0.38	6.15	<0.001
Pitch	0.67	0.41	2.38	0.07
Gradus	3.9	0.05	3.4	<0.02
Dissonance	0.01	0.91	3.36	<0.02

ANOVA analysis revealed that—with the exception of pitch—word type had a significant effect on all musical parameters. For articulation, loudness, and duration, the effect of word type reached very high levels of significance.

For pitch there was a marginal effect, which did not reach significance. On the contrary, word category (taste words or control words) had almost no effect for all parameters, only reaching marginal significance for gradus.

To characterise the patterns elicited by different word types, we mapped each word to a vector conformed by the average values of the corresponding musical improvisations.

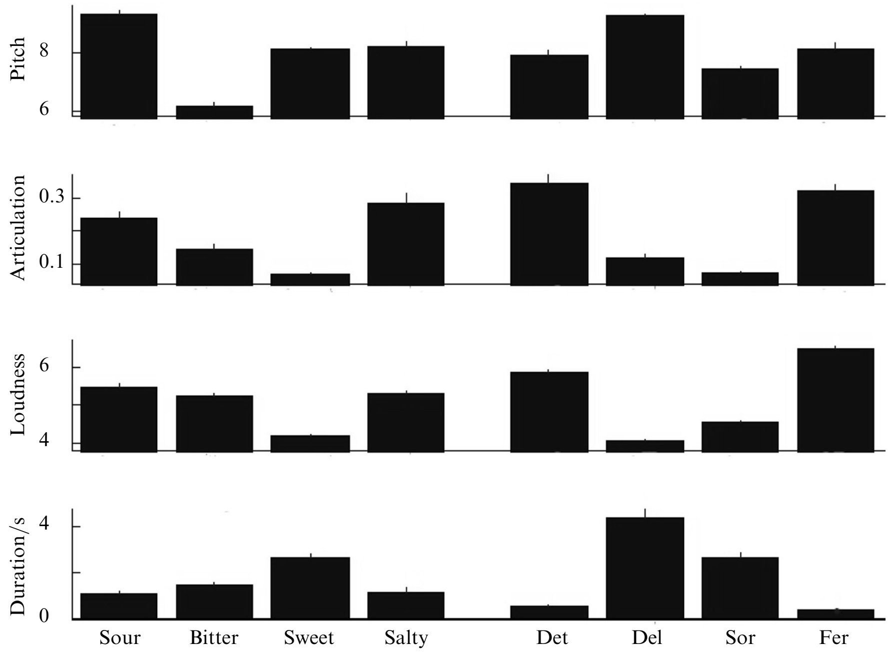

Figure 1. Musical parameters of improvisations (taste and expression words). Each row corresponds to a different parameter and each column to a word. Musical parameters were estimated from all improvisations (free, chords, and melody). Det stands for determined, Del to delicate, Sor for sorrowful, Fer for ferocious.

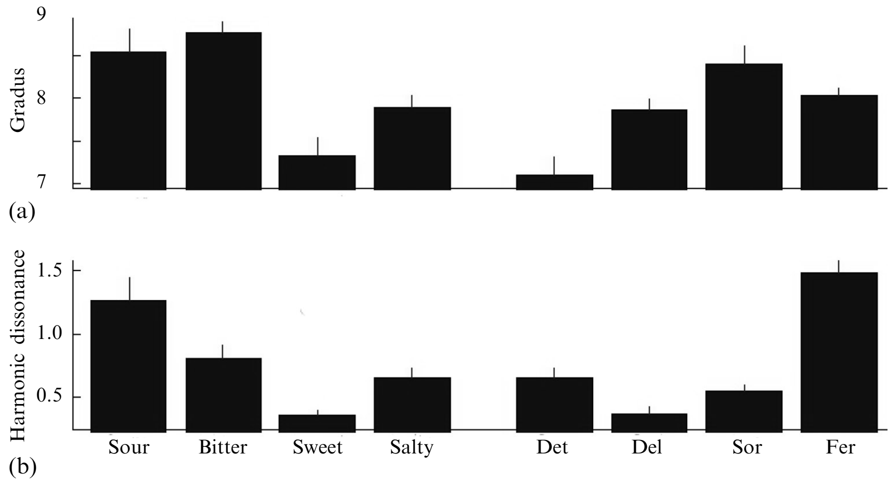

Figure 2. Dissonance parameters of improvisations. (a) Gradus (computed from melody improvisations) and (b) harmonic dissonance (computed from free and chords improvisations). Greater values of harmonic dissonance and gradus indicate more dissonance (Det is determined, Del is delicate, Sor is sorrowful, and Fer is ferocious).

Each dimension of the vector corresponds to a different musical parameter. For simplicity, we used only gradus for subsequent analysis.[(1)] Hence, each improvisation was mapped to a five-dimensional space indicating its degree of articulation, loudness, pitch, duration, and consonance.

[(1)] Gradus can be calculated not only for melody, but also for free and chords improvisations by taking at any given time the highest note present and computing the gradus of this highest voice, which is usually the one that carries the main melody.

First, we simply converted the numerical values from the continuum to a discrete vector (figure 3a) assigning a value of 1 (-1) to each word if the value for this word was greater (lesser) than two standard deviations from the mean (taken over the whole set of improvisations related to taste words). This threshold is arbitrary and used only to simplify the data on binary variables. We chose a relatively mild threshold to capture deviations from the mean which had a tendency towards significance. The same procedure was followed for the control words (determined, delicate, sorrowful, and ferocious).

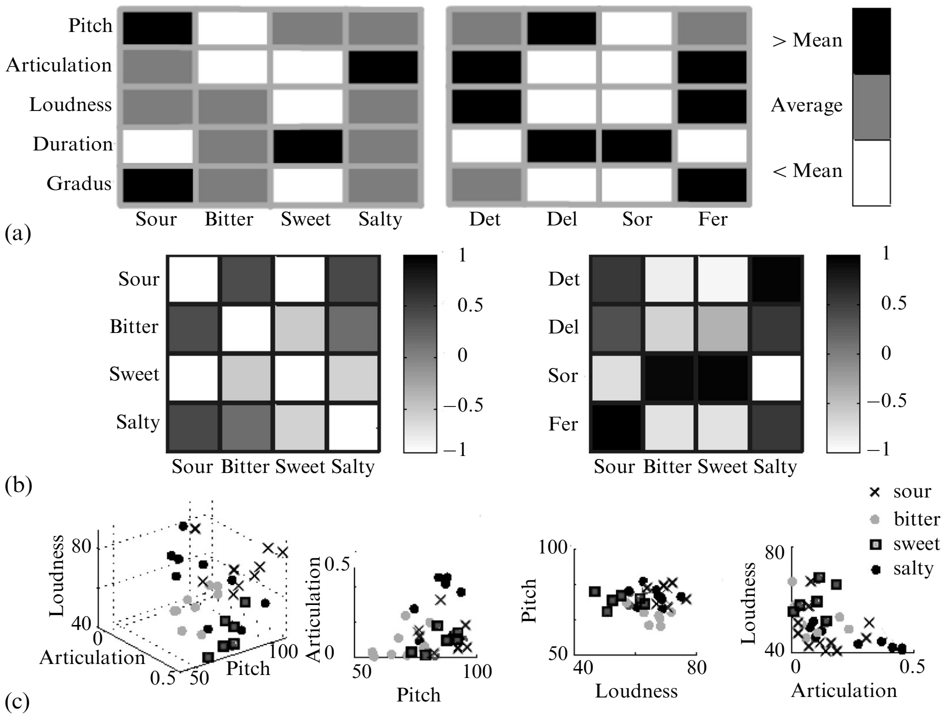

Figure 3. Clustering of target words in musical space. (a) For each musical parameter (pitch, articulation, loudness, duration, gradis), we assigned a grey scale to characterise each target word: black corresponds to values greater than two standard deviations from the mean and white to values lesser than two standard deviations. Grey indicates values close to the mean. Left panel corresponds to taste words and right panel to control words. (b) Correlations between the projections of different word types to musical space. (c) Projection of the distributions of melody improvisations in musical space for the most important parameters. We use Det for determined, Del for delicate, Sor for sorrowful, and Fer for ferocious.

Control words showed an expected pattern: 'determined' has short note duration, high loudness, and high articulation. 'Delicate' has low dissonance and loudness, long note duration, and high pitch. 'Ferocious' is represented as loud, dissonant, and highly articulated; 'sorrowful' is low-pitched, slow, soft, and has low articulation. These features were predictable since they reflect the musical contexts in which musicians use to encounter these words, and also because of their affective and sensorial connotations (see section 4). Taste words showed sparser projections indicating that dispersions from the mean were less frequent than in control words. Again, this was expected since, in contrast to control words, musical terminology does not provide a notion of how taste words ought to be converted into musical parameters (with the exception of 'sweet', which appears usually in scores in its Italian translation 'dolce', see section 4). This analysis permits assigning succinctly each taste word to a list of characteristic, qualitative ranges of values for the different musical parameters:

Sour: high pitch, long duration, high dissonance.
Bitter: low pitch, low articulation (legato).
Sweet: long duration, low dissonance, low articulation, and soft (low loudness).
Salty: short duration and high articulation (staccato).

Next we analysed the similarity between the improvisations elicited by each word. We measured the correlation between all pairs of vectors (figure 3b). Correlations between taste and control words [(b) right] were higher than correlations within taste words [(b) left]. Interestingly, in this last case, correlations are relatively close to zero. Since taste words span independently the space of tastes, finding that, in the majority of the cases, their mapping to musical space results in nearly orthogonal vectors provides a measure of a consistent (conform) mapping between these modalities. The case of sour and sweet is of particular interest, since it has been suggested that sourness may have co-evolved with sweetness in mammals (Breslin and Spector 2008). Coherently, both tastes map onto nearly opposite vectors in musical space [their correlation is close to -1, see figure 3b (left)]. The projection of taste words to canonical words revealed a reasonable pattern (see section 4 for possible origins of this correlation pattern): 'sweet' is sorrowful, but not ferocious. 'Bitter' is mainly sorrowful and 'sour' is ferocious. 'Salty' is primarily determined.

All previous measures were based on averages between all improvisations. The statistical comparisons revealed that for many dimensions (musical parameters) variability within the same dimension was considerably lower than across dimensions. To estimate the degree of clustering in musical space and provide a visual measure of within-factors and across-factors variability, we explicitly projected all melody improvisations in the five-dimensional musical space. We generated for visualisation purposes three- and two-dimensional projections for the most relevant parameters (figure 3c).

To quantify the degree of separability of these projections we trained a decoder, using the support vector machine (SVM) algorithm (Cristianini and Shawe-Taylor 2000). Each melody improvisation was projected to the melodic five-dimensional vector (pitch, articulation, duration, loudness, and gradus). Note that this projection maps each improvisation to a continuum for each musical parameter and thus is not dependent on the categorisation described in figure 3a. For each pair of words we then trained an SVM classifier with the improvisations based on these words. Two words were excluded; they were to be used for a subsequent test of the classifier. The performance of the classifier varied according to the chosen pair of words, much in accordance with the correlation structure (figure 3). Classification was considerably better for control words ($84.3 \pm 2.9\%$) than for taste words ($74.7 \pm 3.2\%$). For control words, several pairs exceeded 90% of classifications values, while the maximum decoding for pairs of taste words corresponded to the sweet–sour discrimination which was at 88%. Averaging across all pairs, performance was at $79.2 \pm 4\%$, well above chance.

3.2 *Experiment 2*

The previous results showed that trained musicians map reliably taste words to musical improvisations. Next, we investigated whether, conversely, these improvisations are mapped consistently to taste words by non-musical experts. We played back 12 of the improvisations, 3 corresponding to each taste word, to fifty-seven participants and asked them to determine, in a forced choice, to which of the taste words corresponded the improvisation (figure 4). Since this is a four-choice experiment, chance level is at 25%. We found that overall performance, when analysing all improvisations together, was significantly above chance, $68.8 \pm 5\%$ ($t = 9.5$, df $= 11$, $p < 10^{-6}$). Interestingly, this level of performance is worse than the decoder based on SVM discrimination. Performance was above chance for every single one of the twelve improvisations we investigated.

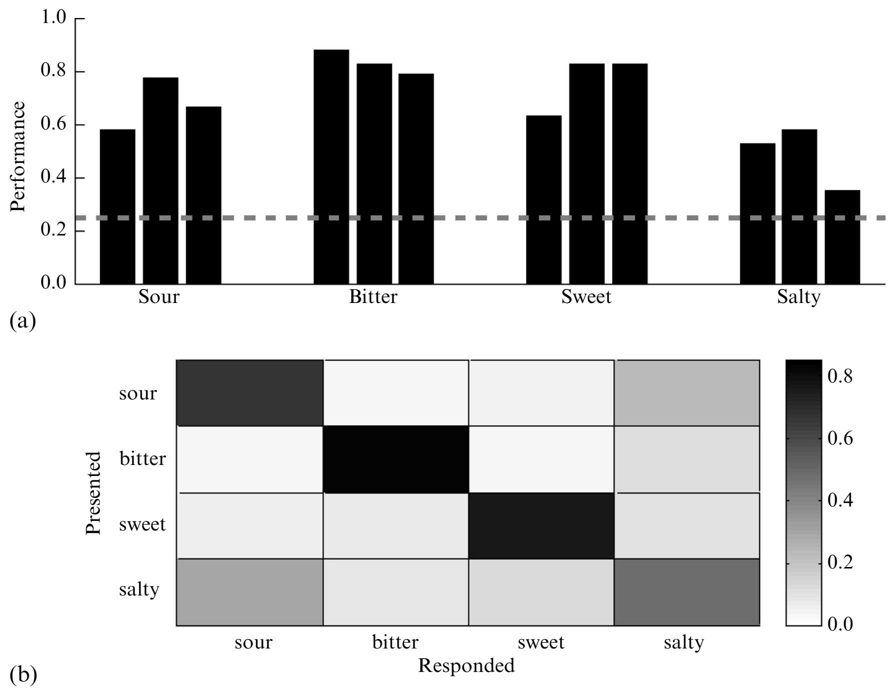

Figure 4. Mapping improvisations to taste words by non-musical experts. (a) Recognition performance for the 12 explored improvisations. The grey line indicates chance level at 25% since it is a forced-choice experiment with four alternatives. (b) Stimulus – response matrix. Each line indicates the taste word which triggered the improvisation and each column the average percentage of responses of non-musical experts. The diagonal elements correspond to the average of the bars in (a).

Average and standard error performances were $67.2 \pm 4.5\%$ for sour, $83.1 \pm 3.5\%$ for bitter, $76.0 \pm 3.7\%$ for sweet, and $48.5 \pm 0.4\%$ for salty improvisations.

We then compared responses for different taste words, performing comparisons across the matrix of presented improvisations and responded words (figure 4b), correcting for multiple comparisons using the Bonferroni criterion (ie testing each individual hypothesis at a statistical significance level of $1/n$ times what it would be if only one hypothesis were tested). Statistical comparison revealed that performance for bitter and sweet words was better than for salty improvisations ($p < 0.001$ after Bonferroni correction). The only significant difference in the error-matrix was found for salty improvisations which were recognised as sour more often than bitter or sweet ($p < 0.001$ after Bonferroni correction).

4 Discussion

In this work we sought to provide experimental grounds to the intuitive and historical descriptions of sounds and musical concepts in terms of taste words. We performed an empirical investigation relating taste words with musical production and perception. Our results show that taste words provide very coherent musical patterns which form distinct clusters in musical space. Moreover, non-trained musicians easily decode the taste words which triggered the improvisations, listening to their first 15 s. These results open new venues for future research aimed at understanding the origins of such coherent associations which, at this stage, remain merely speculative.

Two sources of the empirical emerging patterns stem from sensorial/affective and semantic associations. There is vast agreement that music and music playing makes reference to, or involves, emotional and physiological states (Zatorre 2005), which also are typically described with metaphoric language (Zbikowski 2002). Also, affective and sensorial spaces have been used to characterise musical performances (Canazza et al 2003). From a sensorial standpoint, for instance, the most pleasant taste—sweet (Moskowitz et al 1974)—may be thought to be related to high values of psychoacoustical pleasantness, which correspond to soft sound intensity and low roughness (Fastl and Zwicker 2007). Low roughness, in turn, is related to consonance (Plomp and Levelt 1965). The improvisations elicited by the word 'sweet' had these characteristics (see figures 1, 2, and 3). The word 'sour', on the other hand, elicited loud, dissonant, and high-pitched improvisations (figures 1, 3, and 4), which correspond to high values of sensory sharpness (Fastl and Zwicker 2007), a psychoacoustical magnitude that is inversely related to pleasantness.

If one examines a list of expressive indications appearing in musical scores, many of the most-frequently used terms are emotional, sensorial, or related to movement. Affective space can be modelled with a two-dimensional space of valence and activity (Russell 1980), and also sensorial and kinetic space may be represented in two dimensions, using kinetics and energy axes (Canazza et al 2003).

In our study we have employed the control words 'determined' ('deciso' in musical notation, often appearing related to positive affective valence and high activity, and also to high energy and kinetics), 'ferocious' ('feroce', connected with negative affective valence and appearing usually with music characterised by high activity, energy, and kinetics), 'sorrowful' ('dolente', of negative valence, low activity, energy, and kinetics) and 'delicate' ('delicato', positive or neutral valence, and often low activity and energy).

Leman (2008) gives the following relationships between amount of movement (kinetics), affective dimensions, and structural musical features: low (high) kinetics correspond to soft (high) loudness; positive (negative) affective valence corresponds to consonance (dissonance), and less pronouncedly to high (low) articulation; high (low) activity corresponds to high (low) loudness and high (low) dissonance, and less pronouncedly to high (low) articulation. These correspondences are in agreement with the results obtained for the control words (see figure 3a, right).

Another insight on the origin of such associations comes from semantics and is suggested by projecting the musical patterns induced by taste words to patterns associated with expression (control) words (figure 3b). Interestingly, sour and ferocious improvisations show high correlations. Likewise, sorrowful appears strongly correlated to sweet and bitter improvisations. Also, significant projections are found from delicate to sweet and from determined and ferocious to salty improvisations. Understanding these concordances will be an objective for future research. Here we merely discuss some possibilities based on preliminary data that we collected during the course of the experiment.

After each improvisation, the musicians were asked to write down the words that came to their minds while rehearsing or executing the performance. At this stage, these data are insufficient for proper statistical analysis; however, we note informally that some of the expression words appeared explicitly connected with taste words, seemingly in accordance with our observations: the word 'delicate' appeared with sweet performances; pain and sad were associated to bitter improvisations (connected to the control word 'sorrowful'). The emotional word joy and the sensorial words energising and movement appeared associated with salty, thus situating it close to 'determined' in affective–sensorial space. The word 'salty' also evoked the words unpleasantness and restlessness, which may relate it with the negative affective valence that one can reasonably associate with 'ferocious'. With 'sour' we obtained the words unpleasantness, fear, fast, cruel and power, combining with the emotional and sensorial characteristics attributable to 'ferocious'.

Unlike the other taste names, the word 'sweet' (Italian 'dolce') is a usual indication in music, at least since the nineteenth century. The fact that it is normally applied to soft and low-articulated musical contexts probably conditioned the low intensity and legato playing (figure 1). More speculatively, one could relate the musical productions evoked by sweet or salty to some paradigmatic food items for each taste. The viscosity and stickiness of honey may suggest the slow motion of sweet improvisations.[2] The word sticky was explicitly associated by one subject with a sweet performance. Also the granular structure of salt may be related to the high articulation that produces discrete, temporally separated musical events (we have the word grains appearing with salty in another subject's list of words).

It is important to note that we used words rather than gustatory stimuli (tastants) to explore correlations between taste and music. Even though the use of taste words has been shown to be a valid approach to elicit tastes (Crisinel and Spence 2010b), the relationship between words and actual sensorial stimuli remains unexplored in our experiment. In fact, it is known that responses to taste words may be altered by food experience. Interestingly, some food names appeared in the list of words written by the musicians after musical performances. In particular, after salty improvisations appeared food names like 'cheese and wine' or 'rice with banana', in which one element of each pair is clearly an outsider, showing the emergence of non-trivial connections between food names and tastes.

We also examined melodic motion in the case of melody improvisations. We obtained greater melodic leaps in the case of salty, so this taste word was also related to frequential separation of events. Some studies (see Juslin and Sloboda 2001) relate intervallic leaps with excitement (the words restlessness, concern, nervousness, agitation, and jumps were associated with salty improvisations in our experiment). Also the interval of minor second, prominent in the interval histogram for sour and bitter, is the most dissonant interval (which perhaps reflects the lesser sensorial pleasantness of these tastes) and has been connected with melancholy (Juslin and Sloboda 2001); this last observation agrees with the fact, already mentioned, that bitter and sour improvisations were annotated with words related to painful and negative emotions.

As previously mentioned, at this stage these associations remain merely anecdotal. However, we believe that the results obtained in this work serve to stimulate and guide future experiments.

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[2] This connection was already made by Plato in the *Cratylus* dialogue, where he advances a mimetic theory of language, explaining the similar phonetics of glischron (sticky) and glyky (sweet) by a stopping motion effect of the tongue.

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