

Influence of timbre on emotions and recognition memory for music

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Abstract

A basic issue about music as an emotive language concerns whether music produces emotional changes in listeners, (the "emotivist" position) or simply expresses emotions that listeners recognize in the music: the "cognitivist" position. Several studies have evidenced that timbre dimension, or source cuing (Radvansky and Potter 2000) is an important element in the perceptual processing and we suppose that listeners' memory performances may be influenced by timbre characteristics (Padova, D'Ausilio, Jeric and Olivetti 2003, Radvansky et al. 1995; Radvansky and Potter 2000). The aim of this study is to investigate how timbre changes influence listeners' emotional responses and the recognition memory performance. We used 24 musical stimuli organized into 2 categories according to the presence/absence of tonality or salience intending salience as the redundancy of a single parameter using temporal or pitch patterns easily perceived. Each stimulus was presented in three instrumental versions were presented: piano, flute and an hybrid timbre. The hybrid timbre was created crossing attack phase of a piano with the phase pattern of the flute. Subjects were asked to identify which of 2 melodies, a target and a distractor, was heard previously. On one half of the trials, the target and the original melodies were in the same timbre and the distractor was in a different timbre. For the other half of the trials, the distractor melody was in the same timbre as the original one and the target melody was in a different timbre. An emotional evaluation of stimuli was also asked: subjects were asked to select one or more of the emotions suggested in Russell' model (1987) and for each emotions they chose to identify the intensity (Likert scale 1-3). 160 university students (musicians and no musicians) participated in the experiment. Results suggest that timbre influences recognition memory and emotional responses. Musical training, genre, and presence/absence of tonality/salience also influence subject's performance. In particular we observed that timbre changes influence subject's performances with NS-T and do not with NT-S stimuli, subjects performances are worse when hybrid sound is presented and that hybrid and piano's sound, more than flute's one, arouse emotions that we can define as "negative". In general results suggest that subjects considered the sound's attack phase relevant in memory task but do not in emotional evaluation. Thanks to the "new music" or electroacoustic music, the possibilities of creation and control of sound are increased, helping the comprehension of processes of music perception so as the possibilities of manipulating timbre feature. This study could help contemporary musicians in the compositional phase by suggesting the proper timbre according to the message they want to convey. The comprehension of timbre perception could be also useful to other figures than musicians or psychologists, while the comprehension of the cognitive features of that process could be implemented in several domains, such as rehabilitation programs for disabled people and composing education.

Introduction

We can say that musical timbre is an attribute of sound that allows us to distinguish musical instruments when pitch, loudness and duration remain identical. Helmholtz called "timbre" of the sound what makes for us a sound the same sound even at different intensities or pitches. Musical timbre does not depend upon a single physical dimension. Several studies provide support for the notion of multidimensionality of timbre. Different attributes, such as amplitude, phase patterns, decay and attack time, temporal characteristics of a tone may influence the perception of this psychological attribute as well.

Contemporary composers, music theorists but also psychologists, have shown an increased interest in understanding how timbre is processed and how it may be used compositionally (Krumhansl & Iverson, 1992).

In the contemporary music, the electro-acoustic music, that has, in last years, an increased diffusion and appreciation by a larger audience, timbre is the target of composing. and tonality and acoustic instruments are no more the base of music language.

Even in the Electro-acoustic music, in which tonality and acoustic instruments are no more the base of music language, the composer still needs to communicate with the audience (Milecevic 1998; Whalley 2000).

The composer communicate with the audience using computer-synthesized or computer-processed sound instead of classic instruments, permit the "composer-performer" to manipulate the single components of sound: "The timbre is no more an indivisible structure [...] unpublished timbres are proposed [...]" (Lupone 2000). Listener's attention is no more directed to the melody but to the timbre's evolutions and transformations, (Milecevic 1998; Whalley 2000).

Huron's theory (2002) suggests that decoding timbre information would resolve problems relative to "state cues", that give us information about the producer of sound, its intention and, sometimes, its emotional state, and problems relative to the "Identity cues", or sound's identity.

Warrier and Zatorre (2002) examined spectral timbre's effect on pitch perception in varying contexts. In two experiments, subjects detected pitch deviations of tones differing in brightness in an isolated context in which they compared two tones in a tone-series context and in a melodic context. Results suggest that timbre influenced pitch judgments in all the conditions, but increasing tonal context allowed the subjects to extract pitch information more accurately. Authors concluded that melodies' tonal structure gives more cues that facilitate pitch extraction even in the face of conflicting spectral information.

According to Radvansky et al. (1995) timbre was used as source information to help retrieve the memory trace: timbre carries information that easily identifies the source from which the melody originated.

In this study authors report two experiments that test Wolpert's (1990) results that suggest no musicians memory performance reflects a greater use of the timbre dimension to make recognition decisions. In Radvansky et al. (1995) study listeners were asked to identify which of two melodies, a target and a distractor, was heard previously independent to timbre variations. Results show that subjects are less able to identify a melody as having been heard before when the instrument on which that melody is played is different from the original. but timbre changes affected not differentially no musicians and musicians. In particular musicians performed much better at the identification task than did the no musicians but musicians showed a pattern of errors that was comparable to that of the no musicians: for both groups more errors were made in presence of timbre changes (Radvansky et al. 1995).

In the Radvansky and Potter (2000) study, a modification of the design used by Radvansky et al. (1995), alternatives on the recognition test always differed on one or two critical dimension: timbre and pitch. That is, one recognition choice was in the same timbre and pitch as the original, and the other choice was in a different timbre or pitch. The authors used melodies selected because they were less well known and for their simple structure. It was found that a feature such as melody's timbre can serve effectively as a source cue and that subjects use this information in retrieval. In the melody recognition paradigm Radvansky and Potter (2000) assumed that timbre is a relatively clear indicator of source information. This is because different timbre are associated with different musical instruments; so timbre is referred as high-source cues in memory tasks. On the contrary shifts in pitch can really come from the same entity; pitch is referred to as low-source cues

This idea is not in accordance with Riccio, Raibinowitz and Axelrod's hypothesis (1994) that propose an other potential explanation: there is a forgetting of stimulus attributes in which the poorer memory performance was due not necessarily to features related to source.

One way to view this results are in accordance to the idea of encoding specificity (Tulving & Thompson, 1973): memory performance is better when the context is the same at the retrieval as at encoding. The results of Radvansky and Potter (2000) suggest that some contexts or features (timbre) are more effective in aiding memory retrieval than others. results of Warrier and Zatorre suggest that melodic context may decreasing timbre's changing effect.

In a pilot study Padova et al. (2003) investigate how timbre influences the recognition memory performance using 48 stimuli organized into 4 categories according to the presence/absence of tonality and salience. Results demonstrated, as timbre is an important feature in memory task according to the study that illustrates that source information is important for memory and timbre is a fundamental source cue.

The stimuli used were yet analysed in several studies (Olivetti, 2000; Olivetti Belardinelli, Rossi Arnaud, Pitti, Vecchio 2000; Olivetti Belardinelli, Rossi Arnaud 1999). They adopted Tulving's paradigm, distinguishing among "Know" and "Remember" responses, to investigate what could help memory while listening to music and the relative pre-eminence of perceived characteristics that allow recognition memory. They intended to verify if tonality or salience is a pre-eminent cues in retrieval task.

They tested samples of children and adults with and without musical training. The results demonstrate, not in according with Lerdhall and Jackendoff's hypothesis (1983), that salience more than tonality enhances musical recognition and that recollection and familiarity are two independent states of awareness in processing musical stimuli.

Aim of this study is to investigate how timbre influences the recognition memory performance using nontonal or nonsalience stimuli.

For this purpose we adopted Radvansky and Potter (2000) paradigm and we used musical stimuli organized into 2 categories according to the presence/absence of tonality or salience (Olivetti, 2000; Olivetti Belardinelli, Rossi Arnaud, Pitti, Vecchio 2000; Olivetti Belardinelli, Rossi Arnaud 1999).

We expect:

- Different performances due to timbre variation. In particular we suppose worse subjects' memory performance in presence of timbre changing We also suppose to observe different performances due to the timbre variations type (hybrid-sound vs instrumental-sound)
- Different performances due to the stimuli type, in terms of salience and tonality, In particular salience is, more than tonality enhances musical recognition
- Different performances according to listeners' musical training
- Different timbre correspond to different emotional response

Method

Subjects

160 university students (french and italian) participated in this experiment. Their mean age was 24 (range: 21-27). 80 subjects were musicians and 80 had no musical training.

Stimuli

Stimuli, composed by Fabio Cifariello Ciardi, were 24 short musical themes. 12 salient and non tonal, 12 non salient and tonal.

Three different synthesized instrumental versions were used: piano, flute hybrid sound

Our aim was to change some timbre aspects of a piano sound, merging perceptively it with the timbre of another known instrument; we used for that a flute sound. With convolution of a piano sound by a flute pulse sample, we obtained a new timbre, with only the flute partials but with the amplitude envelope of the piano partials (obviously only for the coincident partials). Perceptual timbre sensation was of a hybrid instrument with some peculiarities of both the starting instruments.

Procedure

At the beginning of each session, subjects filled out a questionnaire about their prior experience in musical performance or theory.

The original melody was presented. After each melody was presented subjects engaged in a distractor task (max 5 minutes) (Group Embedded Figures Test). This distractor task aimed to forgetting of the original melody. Then listeners were presented 2 melodies: the target melody and then the distractor melody. So 6 trials were presented.

On one half of the trials, the target and the original melodies were in the same timbre and the distractor was in a different timbre. For the other half of the trials, the distractor melody was in the same timbre as the original and the target melody was in a different timbre. Three different synthesized instrumental versions were used: piano, flute and hybrid sound.

So 2 conditions were created: match condition when target and original stimuli were played in the same timbre; mismatch condition when target and original stimuli were played in different timbre as shown in Table 1.

Trial 1 Match condition			OR	Trial 1 Match condition		
Original	themeA/	Timbre1		Original	themeA/	Timbre1
GEFT			GEFT			
Target	themeA/	Timbre1	Distractor	themeB/	Timbre2	
Distractor	themeB/	Timbre2	Target	themeA/	Timbre1	
Trial 2 Match condition			OR	Trial 2 Match condition		
Original	themeA/	Timbre1		Original	themeA/	Timbre1
GEFT			GEFT			
Target	themeA/	Timbre1	Distractor	themeB/	Timbre2	
Distractor	themeB/	Timbre2	Target	themeA/	Timbre1	

Table 1.

Listeners' were asked to identify which of two test melodies was heard previously independent to timbre changing.

The presentation order of target and distractor melodies was balanced as the type of timbre variations. While the presentation order of the different pairs was random.

An emotional evaluation of stimuli was also requested: subjects were asked to select one or more of the emotions suggested in Russell's model (1987) and for each emotion they chose to identify the intensity (Likert scale 1-3) (Fig. 1).

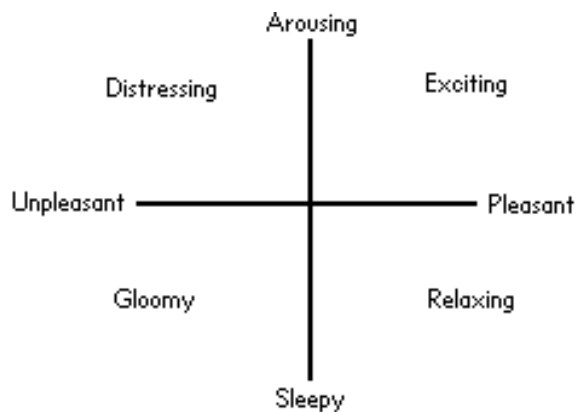


Figure 1. Russell's Circumplex Model 1980

Results

Within ANOVAs were calculated.

Independent variables were:

Between subjects

- musical training (2 levels; musicians and no musicians),
- musical stimuli (2 levels; NT-S, NS-T)
- gender

Within subjects

- condition (2 levels: match/mismatch)
- timbre variation (3level; piano, flute, hybrid)

Dependent variables were:

- number of correct subjects' responses (from 0 to 6).

Memory performance

We observe a significant effect of the variable "musical training" ($F(1, 152)=7,999$; $p<.05$). Musicians' performance is better ($M=2,78$) than no musicians' one ($M=2,47$) (Fig. 2).

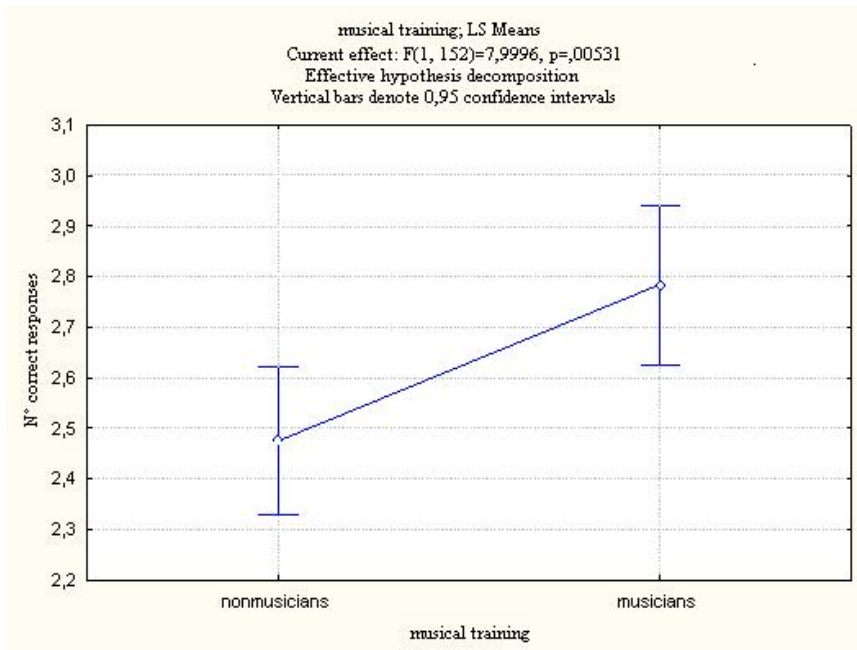


Figure 2. The Y-axes represents the number of correct responses

We observed a significant effect of the variable "condition": subjects' performance is better in match condition than in mismatch condition ($F(1,152)=10,30$ $p<.05$). However this difference is better explained by the significant effect of the interaction "condition*stimuli type".

We observed that the difference is related to the absence of salience. The same results are not observed using NT-S stimuli ($F(1,152)=6,23$; $p<.05$) (Fig3)

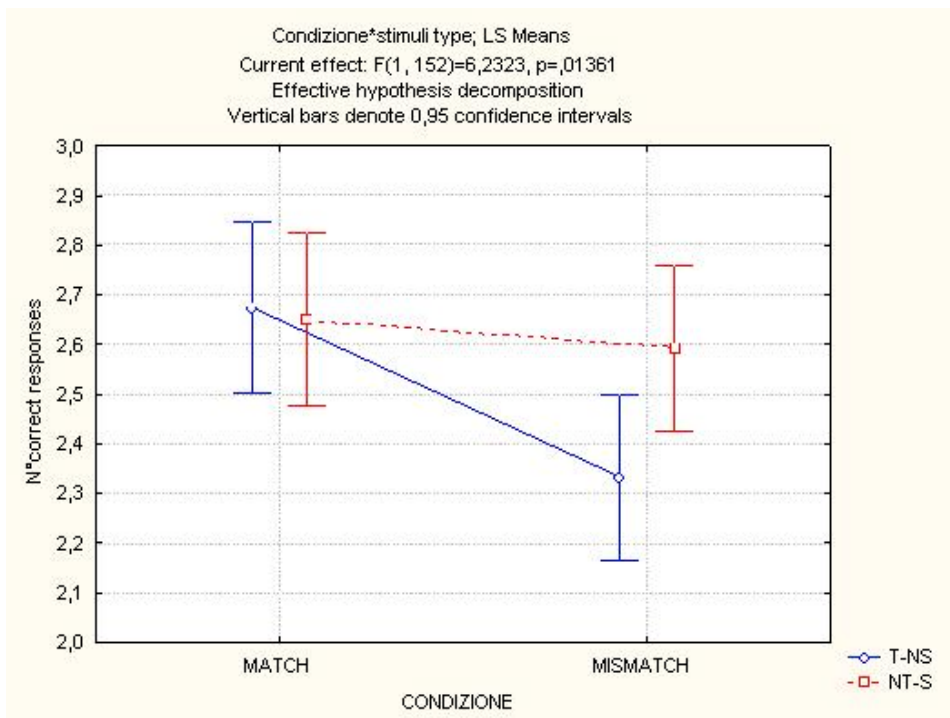


Figure 3. The Y-axes represents the number of correct responses

We observe a significant effect of the variable "gender" ($F(1, 152)=5,85$; $p<.05$)

Women performs better ($M=2,69$) than men ($M=2,46$). However is important to remember that subjects are not perfectly balanced for the variable "gender". This data may influence results.

We observed a significant interaction "Condition*Gender*Musical training" ($F(1, 152)=6,71$; $p<.05$). The most interesting data are:

- Men no musicians make more errors in MisMatch condition ($M=2.05$) than in Match condition (2.04)
- Men's performance in MisMatch condition is better for musicians (2.57) than for no musicians ($M=2.05$)
- No musicians performance in MisMatch condition is better for women (2.72) than for men ($M=2.05$).

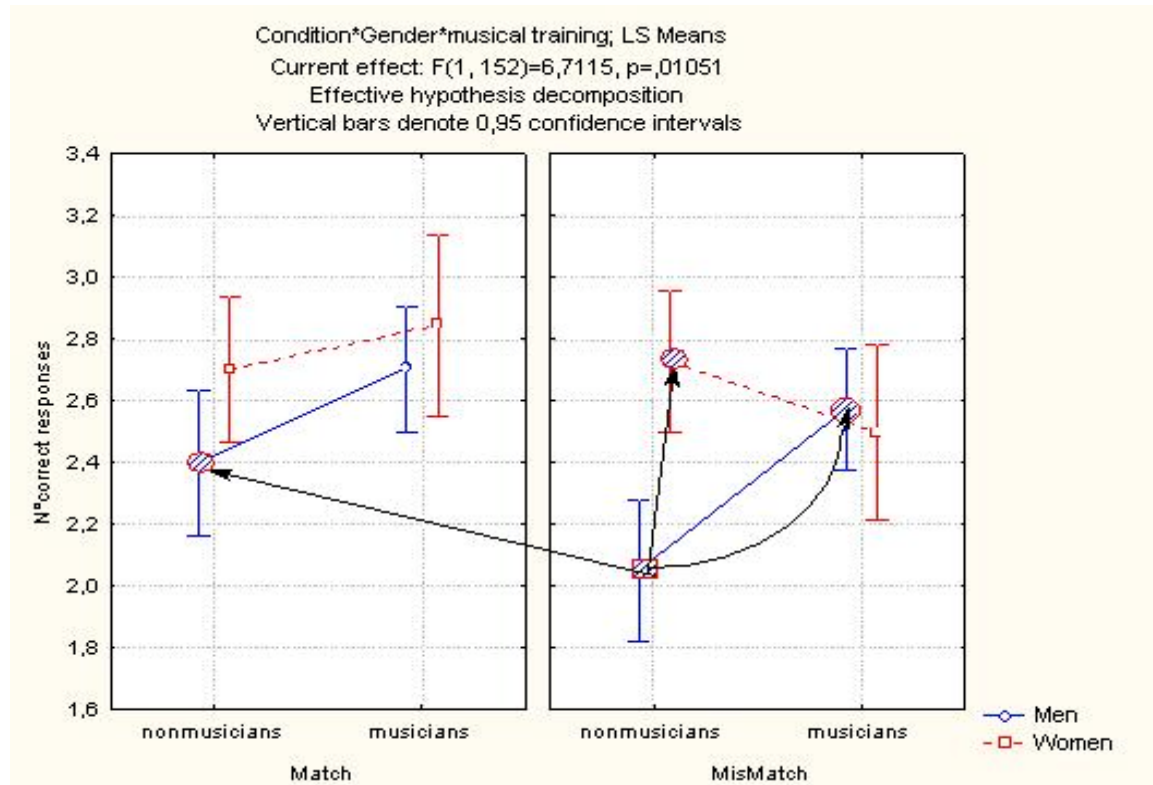


Figure 4. The Y-axis represents the number of correct responses

We observe a significant effect of the variable "timbre variation type" ($F(2, 152)=6,45$; $p<.05$). In particular when hybrid sound is presented subjects' performance decreases.

Emotional evaluation

We observed a significant difference in emotional evaluation related to the three different sound (flute, piano and hybrid) ($F(2, 152)=6,51$; $p<.05$).; in particular:

- hybrid and piano sound are evaluated more emotionally negative than flute's one (the 1st and 3rd field); ($F(2,168)=7.59$; $p<.001$)
- Flute's sound evaluations are located mostly in the 4th field

Discussion

Different results were observed using nontonal or nonsalience stimuli: timbre variations influence subject's performances when salience is absent (NS-T) and not with NT-S stimuli.

With NS-T stimuli subjects made more errors in mismatch condition than in match conditions. The same pattern is observed with NT-S stimuli but difference between match and mismatch conditions is not significant.

We also observed a significant difference in subjects' performance due to musical training. In general musicians' performances are better than non-musicians. Anyway musicians as non-musicians are influenced by timbre variation.

A significant difference between women and men was observed: overall women are more careful than men in both conditions (match and mismatch). Anyway the general pattern in these two groups is the same and it shows subjects' performances (both men and women) decreasing in the mismatch condition.

We also observed a significant difference in subjects' performance due to the nature of timbre variation. In particular, when hybrid sound is presented subjects' performance is worse than with piano and flute sound. This timbre variation seems to create more confusion in subjects' timbre perception.

Moreover we observed that different timbres are associated to different emotions: piano and hybrid sounds arouse emotions that we can define as "negative" and a different pattern is observed with the flute sound. These results seem to suggest that the attack-phase is not considered in emotional evaluation.

Conclusion

In the present study we investigated differences in memory task performance according to differences in musical timbre using three different versions of stimuli changing instrument adopting Radvansky and Potter's (2000) paradigm and using musical stimuli organized into 2 categories according to the presence/absence of tonality or salience (Olivetti, 2000; Olivetti Belardinelli, Rossi Arnaud, Pitti, Vecchio 2000; Olivetti Belardinelli, Rossi Arnaud 1999).

Our hypothesis were partly confirmed.

Timbre changing influences subjects' performances in recognition tasks. In particular we observed this effect only with non-salient stimuli. With nontonal-salient themes subjects in mismatch condition more than in match condition tend to recognize worse stimuli but this difference is not significant. Different results were obtained using nonsalient-tonal themes. In this case we observed a significant difference between match and mismatch condition: more errors were made when the timbre of the target and the original melodies were mismatched than when they were matched. This pattern in the different timbre distractor condition replicates Radvansky et al. (1995), Wolpert (1990) and Radvansky and Potter (2000). This data confirm previous studies' results (Padova, Olivetti Belardinelli 2004).

It is interesting the fact that these results confirm the previous studies on salience and tonality (Olivetti, 2000; Olivetti Belardinelli, Rossi Arnaud, Pitti, Vecchio 2000; Olivetti Belardinelli, Rossi Arnaud 1999). It seems that salience more than tonality enhances musical recognition, and subjects had more difficulty to discriminate stimuli when salience is absent. We hypothesize that in absence of salience (NS-T stimuli) timbre is used to aid recognition decisions.

The performance of musicians and non-musicians was directly compared. As we hypothesized musicians performed better than did the non-musicians. However it is important to observe that, despite their overall superior performance, the musicians showed the same pattern of error as non-musicians. For both groups more errors were made on mismatch condition than in match one. In accordance with Radvansky et al. (1995) "this suggests that whatever the source of the difference between musicians and non-musicians memory for melodies, it may not be a difference in the influence of surface features, such as timbre" (Radvansky et al. 1995).

These results are not perfectly in accordance with Wolpert's study (1990): author found that only non-musicians were affected by timbre changes. We found instead that timbre changing affects differentially musicians and non-musicians.

In general the present study demonstrates, one time more, as timbre is an important feature in memory task according to the study that illustrates that source information is important for memory and timbre is a fundamental source cue. However this effect is correlated to the characteristics of the musical stimuli.

The role of different temporal phases of sound in memory performance was also analysed. Results suggest the idea that attack-phase and the envelope-phase have different role in memory tasks and emotional evaluation. Attack-phase characteristics seems to be irrelevant in emotional evaluation but changing this sound's component memory performance decreases.

Further analysis could be interesting aimed to understanding how subjects considered the single acoustical sound's components in different cognitive processing.

References

- Chalfonte, B.L. & Johnson, M.K. (1996). Feature memory and binding in young and older adults. *Memory and Cognition*, 24, 403-416
- Grey, J.M. (1977). Multidimensional perceptual scaling of musical timbres. *Journal of the Acoustical Society of America*, 61, pp. 1270-1277.
- Huron, D. (2002) Towards a Theory of Timbre. Dissertation, Stanford University.
- Johnson, M.K., Hashtroudi, S. & Lindsay, D.S. (1993). Source monitoring. *Psychological Bulletin*, 114, 3-28.
- Krumhansl, C. L., & Iverson, P. (1992). Perceptual interactions between musical pitch and timbre. *Journal of Experimental Psychology: Human Perception and Performance*, 18(3), 739-751.
- Lerdhall, F. & Jackendoff, R. (1983). A generative theory of tonal music. MT press, Cambridge.
- Olivetti Belardinelli, M. and Rossi Arnaud, C. (1999), Recollection and familiarità in recognition memory for musical themes. In Vandierrendock A., Brysbaert M., Van Der Goten K. (Eds), XI Conference of European Society for Cognitive Psychology, Academia Press.
- Olivetti Belardinelli, M. (2000), Structuring factors in musical processing. Proceedings of the 6th International Conference on Music Perception, Keele University.
- Olivetti Belardinelli, M. and Rossi Arnaud, C., Pitti, G. and Vecchio, S. (2000). Looking for the anchor points for musical memory. Proceedings of the 6th International Conference on Music Perception, Keele University.
- Padova, A., D'Ausilio, A., Jeric, D. and Olivetti Belardinelli, M. (2003) Pilot study about the influence of timbre on recognition memory for music. Proceedings 2003 Creating and Understanding Music, Caserta, Italy
- Padova, A, Olivetti Belardinelli M.(2004) Timbre Variations and Recognition Memory. Proceedings 2004 Creating and Understanding Music, Caserta, Italy
- Pierce J.R. (1988), *La scienza del suono*, Zanichelli Editore
- Radvansky, G.A., Fleming, K.J. & Simmons, J.A. (1995). Timbre reliance in nonmusicians' and musicians' memory for melodies. *Music Perception*, 13, 127-140.
- Radvansky, G.A. & Potter, J.K. (2000). Source cuing: Memory for melodies. *Memory and Cognition*, 28 (5), 693-699.
- Riccio, D.C., Rabinowitz, V.C. & Axelrod, S. (1994). Memory: When less is more. *American Psychologist*, 49, 917-926.
- Samson, S., Zatorre, R., & Ramsay, J. O. (1997). Multidimensional Scaling of Synthetic Musical Timbre: Perception of spectral and temporal characteristics. *Canadian Journal of Experimental Psychology*, 51(4), 307-315.
- Tulving E., & Thompson, D.M. (19973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review*, 80, 352-373.
- Warrier, C.M. & Zatorre, R. (2002). Influence of tonal context and timbral variation on perception of pitch. *Perception and Psychophysics* 64(2), 198-207.