Al crocevia tra tempo scolastico e tempo libero: musica di sottofondo come innesco cognitivo in una generazione multitasking
School time- Free time crossroads: Background music as a cognitive enhancer in a multitasking generation

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ABSTRACT
This study aimed at searching for crossroads between teenagers' enjoyment and learning, breaking the ancient taboo of bringing chart music in the classroom during classwork simulation. To do this, I decided to investigate the effects of background pop music listening on logical and mathematical performance. Participants included a group of 50 Italian students with a mean age of 16,29 years old. These teenagers from a scientific high school of Rome (Italy) were exposed to 3 different conditions, being Silence-No music, happy-Major mode music and sad-Minor mode music, while completing a battery of tests that included a series of logical-mathematical and spatial tasks. The results showed important differences in performance among the different tests and background conditions. In particular, a sad attitude towards mathematics seems to be predictive of a better mathematics performance during Minor mode music listening.
The study offers support to previous research about mood-dependent memory and cognitive-emotional induction, indicating that previously acquired mathematical notions and totally new logical solutions can be triggered or inhibited by different music listening choices through acoustic stimulation, with consequent effects on academic areas, and thus possible applications in the emerging field of neurocognitive pedagogy.

Lo studio mira a cercare punti d'incrocio tra gradimento e apprendimento nei giovani, rompendo l'antico tabù di portare la musica da classifica in classe durante la simulazione di un compito in classe. Per farlo, ho deciso di indagare gli effetti dell'ascolto di musica pop in sottofondo sulla performance logico-matematica. I partecipanti includevano un gruppo di 50 studenti italiani con un'età media di 16,29 anni. Questi ragazzi di un Liceo scientifico di Roma (Italia) sono stati esposti a 3 diverse condizioni, ossia Silenzio-Assenza di musica, Musica allegra-in modo maggiore e musica triste-in modo minore, durante il completamento di una batteria di test che includeva una serie di compiti logico-matematici e spaziali. I risultati hanno mostrato importanti differenze di performance tra i diversi test e le condizioni di sottofondo. In particolare, un'attitudine triste verso la matematica sembra predittiva di una migliore performance matematica durante l'ascolto di musica in modo minore.
Lo studio offre sostegno a ricerche precedenti sulla memoria umore-dipendente e sull'induzione cognitivo-emotiva, indicando che nozioni matematiche precedentemente acquisite e soluzioni logiche totalmente nuove possono essere innescate o inibite da differenti scelte di ascolto musicale attraverso la stimolazione acustica, con effetti conseguenti sulle aree accademiche, e quindi possibili applicazioni nel settore emergente della pedagogia neurocognitiva.

KEYWORDS
Neurocognitive pedagogy, Background music, Logical-mathematical thinking, Mood-dependent memory, Cognitive-emotional induction.
Pedagogia neurocognitiva, Musica di sottofondo, Pensiero logico-matematico, Memoria umore-dipendente, Induzione cognitivo-emotiva.

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Introduction

Background music can be defined, following Radocy & Boyle (2003), as any music played while the listener's attention is focused primarily on a task or activity – studying, working or other academic preparations – other than listening to music.

In particular, Boal-Palheiros & Hargreaves (2001) state that home music listening is linked to mood, enjoyment, and social relationships, while school music listening, typically centred on classical and scholarly repertoire and mostly disliked by students, is more often associated to motivation, achievement, and learning.

In an interview with the Washington Post, Jay Giedd, a practicing youth psychiatrist and chief of brain imaging at the National Institute of Mental Health in Bethesda (USA), points out that "if a teen is doing music, sports, and academics, those are the cells and connections that will be hardwired" (Are Teens Just Wired That Way?, 2001, p. A01).

Indeed, some researchers have explored the possible transfer of cognitive abilities to other curricular areas by theorizing that exposure to music, through informal participation and/or formal instruction, can facilitate nonmusical learning (for an overview, see, e.g., Cockerton, Moore & Norman, 1997; Madsen & Forsythe, 1973; Manthei & Kelly, 1999; Schellenberg, Nakata, Hunter & Tamoto, S., 2007; Wolfe, 1983).

Even so, a solid research base for these claims seems to be lacking.

1. Theoretical Background

1.1 *Media literacy education*

Following the footsteps of Umberto Margiotta (1997, 2006), media education can be considered as the ongoing process that allows students to become multi-alphabetical citizens, and achieve media literacy, an exceptionally versatile educational tool to enhance programs of experimental didactics and pedagogy.

Jolls & Thoman (2004, p. 22) of the Center for Media Literacy (CML) state that "Media literacy is the 21st century approach to education [...] provides a framework to access, analyse, evaluate, create and participate using messages in a variety of forms [...] builds an understanding of the role of media in society, as well as essential skills of inquiry and self-expression necessary for citizens of a democracy".

Pioneering Canadian media educator Chris Worsnop (1999, p. x) chooses the term "media education as a broad description of all that takes place in a media-oriented classroom, whether the subject matter is English, history, geography or science", while "media literacy is the expected outcome from work in either media education or media study. The more you learn about or through the media, the more media literacy you have (...)".

It is possible to exploit music as a target medium to help students become mathematically literate, in line with my previous studies about media literacy and music (Barone & Olivieri, 2005a, 2005b, 2006, 2007; Olivieri & Barone, 2007). After all, the existence of a relationship between music and spatial reasoning – a skill that mathematics can use effectively – has already been firmly established (see, e.g., Hetland, 2000; Rauscher, Shaw & Ky, 1993; Rauscher, 2002; Scripp, 2002).

1.2 *Mathematical literacy*

Maths literacy and numeracy refer to the ability to identify and understand the role that mathematics plays in the world.

Students with high levels of mathematical literacy may have better opportunities for post-secondary education, jobs, and lifelong learning, particularly for careers in science and technology, which ultimately enhance the capacity of the Italian economy for innovation.

A limit of Italian secondary school is apparently to privilege algorithmic-procedural learning over strategic one, intended as the habit to solve problems, searching for the most efficient strategy.

In Italian high secondary school, the central contents of mathematics are: number, geometry, measure, data, predictions, and an introduction to rational thinking, all key elements of the disciplinary structure at the epistemological level.

1.3 *PISA Programme for International Student Assessment*

PISA evaluation of the scholastic system is an OECD (Organisation for Economic Co-operation and Development) cyclic, decentralized project of comparative data.

Like every other domain, the PISA framework for the assessment of mathematics – comprising the four overarching ideas of space and shape, change and relationships, quantity, and uncertainty – defines the content that students need to acquire, the processes that need to be performed, and the contexts in which knowledge and skills can be applied[1].

If we take a look at PISA 2006, 15-year-old Italian students achieved an estimated average combined maths score of 462, performing at roughly the same level as in 2003 (466).

Since the middle range of PISA scale score for 15-year-old students among the 57 countries participating in the OECD PISA assessment was 484, Italian score only falls into the low range of PISA scale, locating Italy as the G-7 country[2] with the lowest average maths score (see Figure 1). It also compares unfavourably with scores internationally.

A key policy challenge, for G-7 countries, is to improve the performance of education and health systems, while containing their cost. It makes the national picture for Italy even more desolating.

1 In PISA 2003, students' performance in mathematics was reported separately for each of the four content areas, as well as the combined mathematics scale. In PISA 2006, however, because mathematics was a minor focus and had a smaller proportion of the testing time, results have only been reported on a single combined scale. In spite of this, the 2003 and 2006 mean scores for each country show very similar trends, and thus they are comparable.

2 The G-7 countries – France, Germany, the United Kingdom, the United States, Canada, Italy, and Japan – are the seven leading and most industrialized countries.

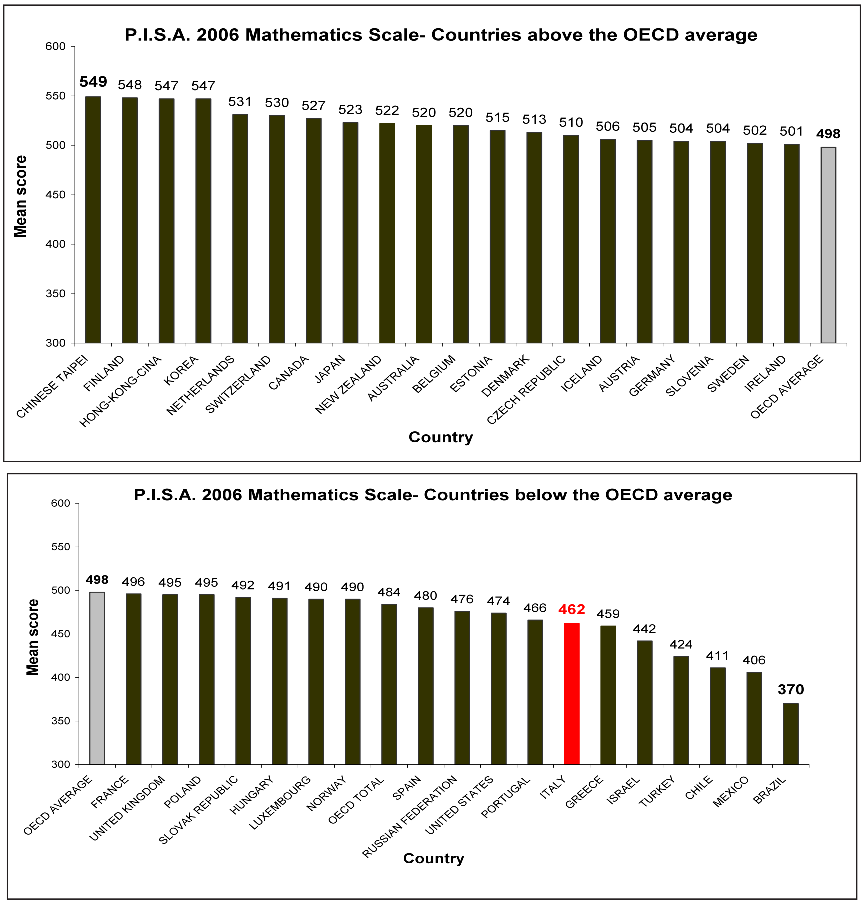

Figure 1 - PISA 2006 mathematics scale: Countries above the OECD average (upper graphic) and countries below the OECD average (lower graphic).

2. Research objectives

The influence of music exposure has been well documented, and students of all ages often claim that they can study and learn more effectively while listening to music. That being so, I decided to explore the effects of two conditions of background music listening (sad-Minor versus happy-Major music mode), and a control condition (Silence-No music) during maths class, on a complex cognitive performance.

The two background music conditions mimic homework settings, since students indicated, through a specific questionnaire, to devote themselves to massive multitasking[3] while studying. The control condition mimics a normal classwork setting.

3 The term "multitasking" refers here to the student habit of constantly switching among multiple activities, such as listening to music, instant-messaging, checking emails, sending and receiving SMSs and MMSs while studying.

Students' grades in mathematics and the three acoustic background conditions were the independent variables for this research, while the dependent variables were students' cognitive test scores, obtained under the three above mentioned conditions.

Our group of scientific high school students from a public school of Rome, Italy (N = 50, mean age = 16,29, std.dev. = 0,69) represented a cross-section of the high school community, and could be described as substantially homogeneous in terms of age, social class (middle), gender distribution, educational level, and maths grades.

Though all the students had previous musical background exposure, none of them serving as subjects were music majors.

3. Apparatus and materials

3.1 *Music selection*

Since the terms "Major" and "Minor" mode may cover a wide range of stylistic variability, this study used specific musical examples, taken from the international pop scene of bands, singers, and performers explicitly indicated as liked (i.e., habitually downloaded and listened) by the study participants.

The two music selections had the following criteria of choice: a) Ionic-Major mode, fast staccato, happy-positive sounding intervals (e.g., perfect fifth C-G or D-A interval) as in Fool's Garden's *Lemon Tree*, Linkin Park's *Shadow of the Day*, or Oasis' *Whatever*; b) Phrygian-Minor mode, slow/fast legato, sad/angry sounding intervals (e.g., minor second E-F or C-Db, diminished fifth-"tritone", and flat seventh) as in Tokio Hotel's *On the Edge*, My Chemical Romance's *Sleep*, or Nirvana's *Heart Shaped Box*. Ionic and Phrygian modes were specifically chosen in order to maintain equal distance on the chromatic line that goes from a maximum of lightness to a maximum of darkness, respectively (see a graphic illustration of chromatic effects in Figure 2).

While Phrygian or natural Minor mode – also known as the Spanish gipsy scale, more linked to structural surprise and dissonance – is universally associated with sadness, fear, and failure, Ionic mode – also known as Major mode, structured upon the traditional style of consonant Baroque intervals – is naturally associated with happiness, success, and achievement.

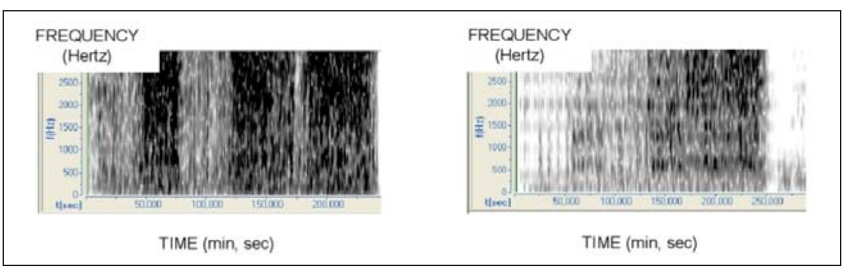

Figure 2 - Spectrograms of two selected songs. On the left: Phrygian mode song On the Edge by Tokio Hotel. On the right: Ionic mode song Shadow of the Day by Linkin Park[4]. As we can see, the image on the right side is much clearer and more brilliant than the left one.

4 A spectrogram or "sonogram" is a psychoacoustic tool that transforms sounds into images to represent graphically the frequencies of a sound signal that vary with time.

Nowadays, we also know that Phrygian music is heavily proposed by the music industry, and almost universally liked by youngsters and teenagers all over the world.

The acoustic level of listening was fixed at comfortable 70 decibels of sound pressure for the two background music conditions, while in the control condition of Silence-No music, there were 40 decibels of natural sound pressure.

3.2 *Maths & Music Attitude Questionnaire*

Cognitive and emotional attitudes of teenagers towards music and mathematics were investigated through a self-rating questionnaire, compiled by the author and checked by professionals. The Maths & Music Attitude Questionnaire asked students to assess their personal approach to music and mathematics (e.g., music listening style, preferred songs, favoured music styles/genres, mathematics adjective checklist, etc.), and to indicate their actual grade in high school mathematics.

3.3 *Battery of cognitive tests*

The cognitive battery of four paper and pencil tests selected for this research included:

- The AC.MT (Calculus Ability, Memory & learning Transfer) protocol comprising 7 exercises for each test booklet, analogue to OECD PISA 2006 for the assessment of mathematical literacy (Cornoldi & Cazzola, 2003; OECD, 2006, 2009).
- The GEFT-Group Embedded Figures Test (Witkin, Oltman, Raskin & Karp, 1971) comprising 6 items for each test booklet, a spatial reasoning test about flexibility of closure, based on mental rotation and disembedding of fractal shapes.
- The SPM-Standard Progressive Matrices (Raven, Court & Raven, 1996) comprising 20 items for each protocol, a logic nonverbal culture-fair test about reasoning skills.
- A set of 20 series of figures taken from the "Hunting Error" Test (Boncori, 1989), a graphic-symbolic test about critical thinking.

The first part of the battery of tests requires to access long term memory, and to apply algorithm rehearsal strategies, while the other three components imply multidimensional constructs of problem solving strategies, and spatial ability.

The total score gives a report of reasoning proficiency, while the first component alone of the battery (i.e., the AC.MT Test) gives a specific score of strictly mathematical ability.

4. Procedure summary

In a first phase, the students completed a self-rating questionnaire about the following areas: school level in mathematics (from A-Excellent to F-Failure), multitasking tendency, music listening habits, preferred songs, and favoured music styles/genres. The students were also asked to choose one or more adjectives from a list of 12 possible choices to describe their personal attitude towards maths discipline. Examining questionnaire responses as a whole, it emerged that all students admitted to listening to music at home while studying, and in their free time too.

In a second phase, the students were exposed to three different background acoustic situations – Major mode music, Minor mode music, and Absence of music – over an established period of time, while completing three parallel forms of a measure of cognitive level and maths placement during class time. All tests – a total of 53 verbal and nonverbal items – were set in Italian. The three parallel versions of the battery of tests showed significant correlations, ranging from r = 0,69 to r = 0,67 (= 0,01).

The students were told the following: "You will be played a series of music files that you told us you like very much. At the same time, you will be asked to complete a series of graphical and pencil exercises, similar to the ones you would find in a test for university orientation and/or admission".

Examinees were invited to take all the time they needed to complete all tests (indicatively 5 minutes for questions/explanations and 45 minutes to take the tests).

They were also asked to do the tasks the best they could, although their performance would not be graded for school in any way. Any verbal comment was recorded.

Before the real experiment began, subjects were presented with training trials to familiarize with the task and the quasi-experimental setting. The researcher then distributed the booklet of tests.

In the first class session, Phrygian-Minor mode music played throughout the entire battery of test administration. During the next class session, the researcher followed the same procedure for the battery of tests-form two, except that, this time, Ionic-Major mode music recordings provided the background music. Again, the selected music played during the whole test session. For the third test form, the research design did not include any music at all.

The students were then classified according to a median split on each test.

Finally, the last phase of the classroom intervention was dedicated to a conclusive joint discussion. The students were also given some technical explanations about the principles that guided music selection, as the proposed media literacy approach dictates.

5. Results

5.1 *Questionnaire responses*

46% of subjects indicated to study while multitasking as their first choice (see Figure 3), and 42% as their second choice.

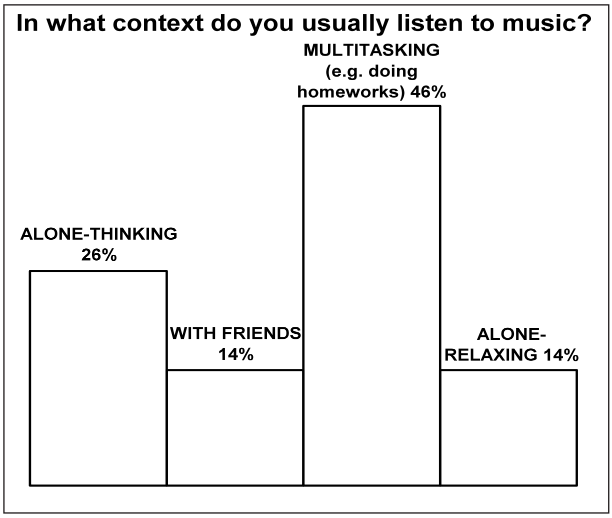

Figure 3 - Questionnaire results: % answers to the question about music listening style in our sample of students (N = 50).

It really seems that we are asked to face a "multitasking generation".

Participants also reported a worrying 43% failure rate in mathematics (see Figure 4), with high ratings of a negative attitude towards this discipline, compared with all other major school subjects (see Figure 5).

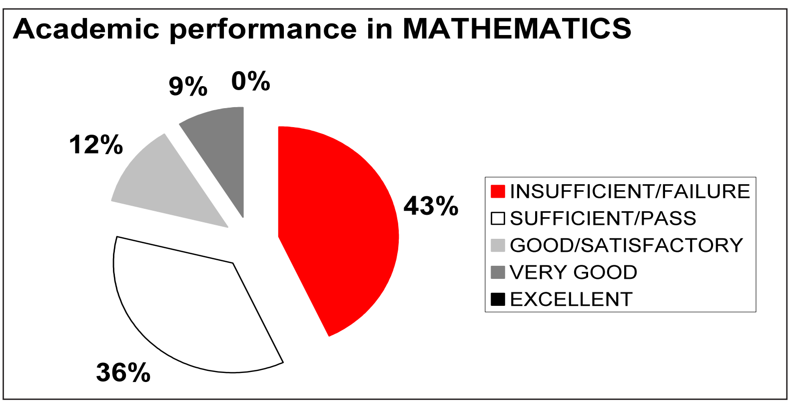

Figure 4 - Questionnaire results: Rates of academic performance in mathematics in our sample of students (N = 50).

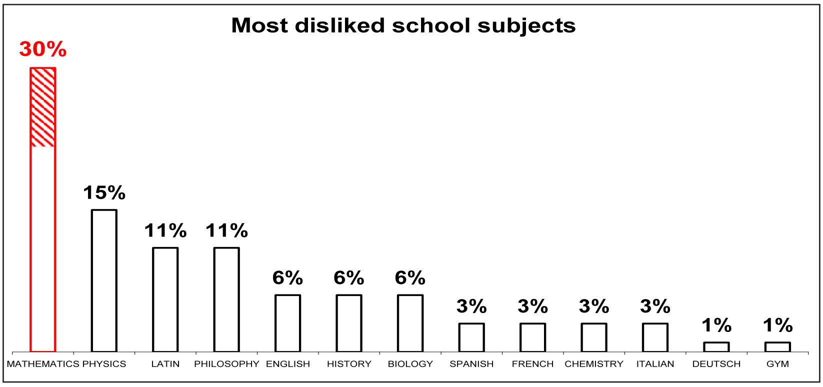

Figure 5 - Questionnaire results: % answers to the question about the most disliked (upper graphic) and the most liked (lower graphic) school subjects in our sample of students (N = 50).

As we can see in Figure 6, adjectives that better described personal attitude towards mathematics in our sample of students were:

"Complicated" (20%).

Almost equally "Boring" (18%) and "Annoying" (17%).

"Sad" (14%), "Constructive" (11%), and "Fundamental" (6%).

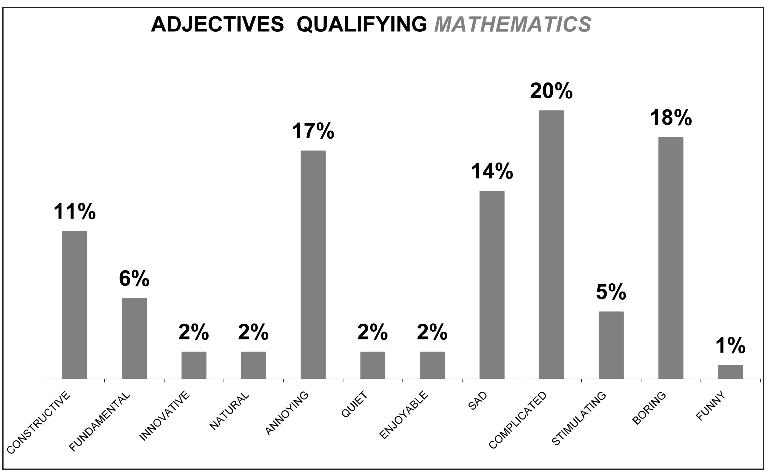

Figure 6 - Questionnaire results: % of adjectives qualifying mathematics, checked from a list by our sample of students (N = 50).

5.2 *Correlations*

Correlations were calculated to see if there was any relation among cognitive-emotional tendencies towards mathematics, maths grades, and multitasking habit.

In Table I, only significant correlations were reported. In particular, a significant negative relation emerged between multitasking and considering mathematics a "Fundamental" subject, which needs total concentration.

Independent Variables Correlations – Pearson's Correlations								
	Boring	Sad	Annoying	Fundamental	Constructive	Complicated	Maths Grades	Multitasking
Boring	-	.449**	.730**	-.306*	-.317*	-	.403**	-
Sad	.449**	-	.615**	-	-	-	-	-
Annoying	.730**	.615**	-	-	-	.354*	-.329*	-
Fundamental	-.306*	-	-	-	-	-	-	-.374**
Constructive	-.317*	-	-	-	-	-	-	-
Complicated	-	-	.354*	-	-	-	-	-
Maths Grades	.403**	-	-.329*	-	-	-	-	-
Multitasking	-	-	-	-.374**	-	-	-	-
N	50							

* Correlation is significant at the 0.05 level (2-tailed)
** Correlation is significant at the 0.01 level (2-tailed)

Table I - Product-moment correlations for adjectives qualifying mathematics

5.3 *Analysis of Variance*

ANOVA technique was used to analyse the differences among test scores for the three background acoustic conditions.

All maths grades obtained better results in the Major mode listening condition, a similar average performance for the SPM component in both the control (Silence-No music) and Minor mode listening conditions, and worse results in the Minor mode listening condition for both the GEFT and "Hunting Error" components of the cognitive battery of tests.

Overall, one-way repeated measures ANOVA revealed statistically significant differences among the three testing conditions.

There emerged remarkable better scores in the Major mode condition ("Major mode" mean score = 0,66) than in the other two conditions ("Silence-No music" mean score = 0,57; "Minor mode" mean score = 0,56), confirming the differential effect of background music stimulations on general cognitive performance (see Table II and Figure 7).

Mean number of the Total Cognitive Battery items answered correctly						
Listening condition	N	M	SD	F-value	df	p-value
Major mode	50	0,66	0,14	33,49	2, 44	<,0001
Minor mode	46	0,56	0,14			
Silence-No music (Control)	50	0,57	0,16			

Table II - Descriptive statistics of the Total Cognitive Battery Scores for the three background acoustic conditions

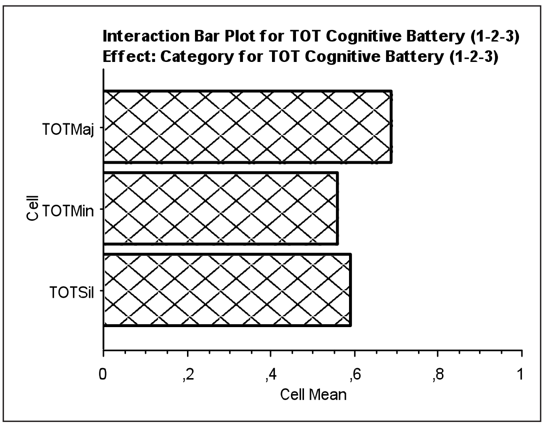

Figure 7 - Histogram about cognitive performance for repeated measures on the battery of tests: Total mean scores on the three background conditions (Major mode, Minor mode, and Silence-No music).

In particular, our students performed constantly better in the Major mode condition for all the three graphic components about spatial intelligence and critical thinking.

In both Silence-No music and Minor mode administrations, scores were relatively low, with no statistically significant differences for all four school levels (i.e., B-Very good, C-Good, E-Sufficient, and F-Failure).

Compared with both Minor mode and Silence-No music condition, in the Major mode condition students appeared more skilled in choosing the right matches in all spatial and critical exercises, without big hesitation.

Quasi-experimental data for each component of the cognitive battery of tests were then separately analyzed.

While all the other components (i.e., the creative ones, linked to problem solving) reconfirmed the overall tendency, the AC.MT maths & memory component, linked to algorithmic learning, showed a very different trend, with a significantly better performance in the Minor mode music listening condition (F = 5,67; p-value = 0,02). The ANOVA table for each component of the cognitive battery shows this particular trend (see Table III).

ANOVA for the three listening conditions (Major mode, Minor mode, Silence-No Music)				
	count	F-value	df	p-value
AC.MT	45	2,45	2, 44	,02 (n.s.)
SPM	44	87,68	2, 43	< ,0001
GEFT	45	20,94	2, 44	< ,0001
"Hunting Error"	44	26,88	2, 43	< ,0001

Table III - ANOVA for the three background acoustic conditions: single tests (AC.MT, SPM, GEFT & "Hunting Error")

The apparent absence of significance for the maths component is explained by a further observation.

If we look at Table IV and Figure 8, we can see that in both the Control (Silence-No music) and Major mode conditions, the students obtained very similar results on the AC.MT maths test.

Mean number of the items of the four components of the Cognitive Battery answered correctly									
	Major mode			Minor mode			Silence-No music (Control)		
	N	*M*	*SD*	N	*M*	*SD*	N	*M*	*SD*
AC.MT	50	0,58	0,20	46	0,66	0,19	50	0,59	0,23
SPM	49	0,86	0,09	45	0,67	0,12	49	0,64	0,18
GEFT	50	0,73	0,22	46	0,57	0,18	50	0,59	0,21
"Hunting Error"	50	0,61	0,20	46	0,41	0,25	50	0,53	0,22

Table IV - Descriptive statistics of the single tests' scores of the cognitive battery for the three background acoustic conditions

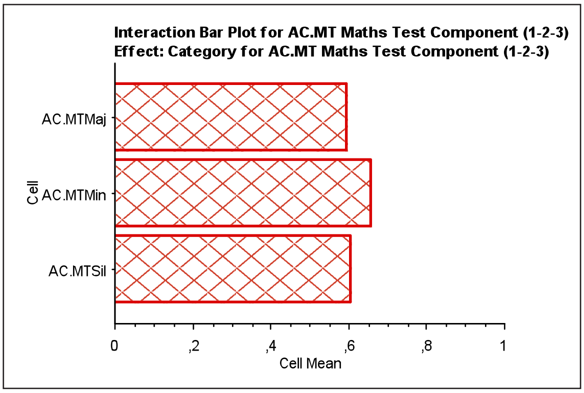

Figure 8 - Histogram about cognitive performance for repeated measures on the maths component of the battery of tests: Mean scores on the three background conditions (Major mode, Minor mode, and Silence-No music)

Furthermore, in the Control condition a statistically significant correlation emerged between considering maths "complicated" and not doing multitasking while studying (t = 2,23; p-value = 0,03) for the students who obtained higher scores on the cognitive battery of tests.

Finally, in the Minor mode condition, for the Hunting Error component of the battery, emerges a sort of transposition of the annoying effect of Phrygian music for high level students.

Overall, these data indicate that students who perform well in mathematical literacy perform better than students with poor marks in mathematics not only in a normal school setting, but also in both the proposed background music listening conditions.

5.4 *Multiple Linear Regression*

Further analyses were conducted to explore the origin of the emerged patterns of interactions.

Searching for explanatory variables, total scores were regressed on maths attitude tendencies, maths grades, and multitasking habits.

Regression analysis applied to these data showed that music had a significant impact on cognitive scores, also confirmed by post-hoc analyses. Independent F-tests were done to examine where to locate the main effects of the two background music conditions.

A statistically significant effect on AC.MT maths scores emerged for Minor mode music. The multiple regression model for the Minor mode listening condition for the total battery returned F = 3,76 with a p-value of 0,005, and a beta-coefficient of 0,48 (t = 2,80; p-value = 0,008) for the "Maths is Sad" variable.

The same proposed model also returned a significant F = 3,01 and a p-value of 0,02 in the AC.MT maths component of the battery, with the "Maths is Sad" variable explaining by itself 34% of data variability (model fitting $R^2 = 0,34$), for a high beta standardized coefficient of 0,59 (t = 3,31; p-value = 0,002).

Relatively low VIF-Variance Inflation Factor indexes confirmed a lacking of multicollinearity among the independent variables.

The same multiple linear regression model didn't show to contribute substantially to the data set variability in both Control (TOT "Silence-No music": F = 2,20; p-value = 0,06; R^2 = 0,25) and Major mode conditions (TOT "Major mode": F = 1,11; p-value = 0,37; R^2 = 0,14).

In the Control condition, in particular, a strict correlation emerged between scores and the following:

Not doing multitasking (t = -2,228; p-value = 0,03).
Considering mathematics as "complicated".

The conditions "Major mode pop music listening during cognitive test" and "Minor mode pop music listening during the cognitive test" were then regressed on MS ("Maths is Sad") and MNS ("Maths is Not Sad") respectively, controlling for the Silence-No music condition.

Regression analysis confirmed a statistically significant better effect on the Minor mode condition for the "Sad" subgroup (F = 16,84; p-value = 0,0003: see Table V) and no significance for the "Not Sad" subgroup of students (see Table VI).

Independent variable: "Maths is Sad"

	Major mode	Minor mode	Silence-No music (Control)	F-value	p-value
count	28	28	28	16,84	0,0003
df	2, 27	2, 27	2, 27		
mean	0,59	0,69	0,63		
std. dev.	0,19	0,17	0,22		

Table V - Descriptive statistics and ANOVA for the "Maths is Sad" variable

Independent variable: "Maths is Not Sad"

	Major mode	Minor mode	Silence-No music (Control)	F-value	p-value
count	22	22	22	0,05	0,95 (n.s.)
df	2, 21	2, 21	2, 21		
mean	0,58	0,57	0,58		
std. dev.	0,21	0,20	0,25		

Table VI - Descriptive statistics and ANOVA for the "Maths is Not Sad" variable

At this point, the variables "Maths is Sad" (MS) and "Maths is Not Sad" (MNS) were coded 1 and 0 respectively, in order to allow post-hoc procedures.

Using post-hoc Bonferroni method for the "Sad" and "Not Sad" variables to control and reduce global familywise error Type 1, the results were fully reconfirmed significant at the p <.05 level (mean difference = 0,06; critical diff. = 0,05; p-value = 0,02).

Post-hoc analyses also showed a constant significant difference between B-Very good and F-Failure maths levels in all four tests of the cognitive battery.

The proposed regression model appears good for the Minor mode listening condition, showing an amazing positive impact of this background music on maths test scores for the students who consider mathematics a "sad subject", being "Sad" the variable that mostly explained the data variance.

In the next paragraph, we will examine a range of possible explanations for the reported higher maths scores in students with a "sad" attitude towards mathematics, during Minor mode music listening.

6. Discussion

Emotion induction seems to be strongly implied in cognitive performance. Kandel, Schwartz & Jessell (1995, p. 607) remark that "cognition and emotion affect each other reciprocally", so that thoughts cause emotion elicitation, and emotion affects thinking processes.

The proposed regression model may indicate a fundamental priming of negative emotional states through Minor mode-*Phrygian* pop music listening, with established effects on cognitive performance.

The mind of our group of teenagers seemed more prone to wander in negative emotional states during this listening condition, and we all tend to indulge in bad moods when we are sad, disappointed or frustrated.

It may be that music enhanced cognition through emotional consonance, so Minor mode music primed negative emotions, influencing in particular students who considered mathematics as a sad subject. The students were tuned to the negative emotion produced by Minor mode music, with its components of sadness and failure.

In other words, music seems to have enhanced cognition, and thus academic proficiency, through emotional arousal.

In the Major mode pop music listening condition, a cognitive dissonance between conflicting emotions brought to worse scores in the strictly mathematical component of the cognitive battery of tests proposed to the sample of students.

By contrast, in the Minor mode pop music fruition, sad mood matched with the emotional valence of this kind of music. Not only declared sadness, but also the undeclared anxiety elicited by this music probably contributed to a better maths proficiency (see Yerkes & Dodson, 1908).

The behavioural index of increased anxiety was represented by the students' faster rate of completion of the battery of tests (in terms of the average time required to complete the task) during the sad-anxious music listening session, compared with the happy-heartening music listening session.

Modern Phrygian music, massively offered by the music market to adolescents, due to the hybrid nature of its structural cues, produced a state of arousal and remarkable sadness at the same time. This music mode, mathematically irregular and hardly decipherable, allows the listener to experience a combination of sadness and anxiety in the same music excerpt.

Because psychomotor acceleration is a salient index of arousal, whether naturally occurring or experimentally induced, it seems reasonable to suppose that the students were also activated by the selected music.

An intriguing explanation for these results is based on the principle of communicating vases, which not only applies to physics, but also to psychosocial and educational matters.

Finally, during the Silence-No music condition, attention was focused on exercise complexity and cognitive demand, as referred by students in their verbal comments.

These results suggest that a possible reason for the main effect of emotional tendencies towards mathematics over cognitive performance – that is, the fact that the “Maths is Sad” and “Maths is Not Sad” groups showed an overall performance remarkably different in this quasi-experimental design – was due to the presence of different background acoustic conditions.

Sad-sounding music seems to “trigger” cognitive performance in mathematical testing, through emotional consonance. In fact, the students appeared “tuned” on the negative emotion produced by the Minor mode pop music.

Conclusions

Music is worldwide identified as the subject students probably love as much as they hate mathematics. Emotion and cognition are two faces of the same coin, and new didactic models should take advantage of this relationship, drawing on the ultimate findings of neuroeducation and psychological research.

To sum up, we can draw some in-depth observations that may help expanding the meaning and applications of what has emerged from this study:

– It is important to favour personal implication in the construction of knowledge and competence: As Guy Brousseau (1998) proposes, the most effective learning situations are a-didactic ones, usually considered ecologically valid by students themselves. Media (literacy) education, in particular, can reach teenagers’ needs, by speaking “their language”.
  Outcomes like the ones presented in this study are the best measures about the effectiveness of a curriculum based on Media (literacy) education, starting, e.g., from Cultural Studies to bridge the gap between school and out-school life.
  Moving in the same direction, Meinert Meyer proposes to make the learner’s habit formation (e.g., the apparently widespread multitasking tendency emerged in my study) a part of didactics. Being these habits structurally fundamental in the formation of people’s behaviour, he also states that “teachers should create *learning environments*, ensuring that the students’ personal experience becomes the focus of all learning endeavours” (Meyer, 2007, p. 162).
– Listening to music seems to play an important role among higher brain functions. Since the early nineties, Hellmuth Petsche and his collaborators at the University of Vienna, have started to determine the coherence of sonic waves on many sites of the cerebral cortex, and to locate various systematic patterns of cerebral functioning for different listening strategies (e.g., Bhattacharya & Petsche, 2001; Petsche & Bhattacharya, 2002; Petsche et al., 1993). Other studies have further suggested the different effects of various types of music and different musical preferences on the EEG (see Birbaumer et al., 1996; Jeong, Joung & Kim, 1998). For instance, a subject will concentrate on sound patterns, without paying attention to their structure when he/she listens to Schoenberg (i.e., dodecaphonic music, analogue to ancient Phrygian mode), while he/she will pay attention to both pattern and structure when he/she listens to Mozart (i.e., Baroque music, analogue to ancient Ionic mode). Thus, his/her brainwaves will show differences in their patterns of cooperation. Influence of music exposure in the absence of explicit memory has also been well documented (see, e.g., Peretz, Gaudreau & Bonnel, 1998).

– If we listen to music while studying and trying to learn something, information may become more specialized and difficult to recall and codify for further use.

With regard to this view, information stored in the hippocampus allows to change the original context of acquisition, while information stored in the striatum is tied to the context of acquisition (McDonald & White, 1993): if the emotional background is the same, the work will be easier to accomplish.

This probably means that our multitasking students had stored maths information not only in the striatum, but also in a context of bad mood and discontent. It surely doesn't mean that every student in the world will consider maths a "sad subject", fortunately…

Specifically, we know that a negative encoding context will trigger activity in the right amygdala, an area frequently associated with negative emotions.

Results showing involvement of amygdala in recall of emotionally charged information provide some support for this idea by illustrating a functional role for this structure in retrieval (Baxter & Murray, 2002; Erk et al., 2003; Lewis & Critchley, 2003; Schneider et al., 1997).

It means that emotions act not only as cues, but can fundamentally alter the way that subjects deal with cognitive information.

– Mathematics contents are, in themselves, emotionally neutral, but they have repeatedly shown to acquire a (negative) emotional valence, thus requiring an involvement of the emotional neural system for their retrieval. Accordingly, this pilot study can be explained as an interesting and clear example of long-term mood-dependent effect on memory, applied to a specific school subject and consequently, to academic proficiency.

Mood-dependent memory occurs when the congruence of current mood with the mood at the time of memory storage helps recall of that memory (see, e.g., Blaney, 1986).

As noted by Eich & Macaulay (2006), the existence of mood dependence is predicted or implied by many influential memory theories, and today research has shown the possibility of obtaining consistent evidence of mood dependence, provided that certain conditions are met.

In particular, mood-dependent memory effects on cognition are extremely evident when moods vary on both pleasure and arousal than when they vary on pleasure alone. It means that they are consistently significant in anxious-sad combinations. Moreover, moods seem to preferentially affect the storage and retrieval of complex information.

A natural corollary to all this, is that attempts to recollect information when experiencing a mood unlike that experienced during the original learning event, may be harder and less successful than attempts made during a similar mood.

Finally, we can say that this study replicates and demonstrates mood dependent memory on complex information, that is mathematical strategies' rehearsal. In fact, past research has only demonstrated mood-dependent memory on literacy contents' rehearsal, such as target words, passages, and texts (e.g., Eich & Metcalfe, 1989; Schare, Lisman & Spear, 1984).

– The impact of environmental conditions on learning and performance may reveal interesting keys to the inner working of human thought processes.

The concept of "environment", applied to memory, shows a particular theoretical richness. At the same time, the concept of mood as a contextual cue for retrieval and remembering has won new support.

As Kirsti Klette points out, the understanding of context was recognized as a new research objective of educational interest about thirty years ago, through a renewed attention to the active role played by learners in their learning situations (Klette, 2007). Since a man's behavior is largely a reflection of his environment, Yves Chevallard (2007) makes another interesting observation, that is: "the maze explains the behavior of the mouse much better than does its cognitive structure or its exposure to other factors – for example, to classical music versus 'hard rock' music. In the case of mathematics teaching and learning, this conclusion led to another question – about what the pupil's environment was made of" (Chevallard, 2007, p. 131).

From this point of view, my study has shown that music listening choices can really become a "mental maze", in which adolescents constrain themselves. Moreover, mathematical knowledge was probably imparted in a climate of mutual tension and discontent.

– Research in the area of emotion and cognition indicates that experimental manipulations of mood exert powerful effects on the performance of some types of tasks, but often pose some ethical concerns, especially when dealing with young subjects.

Mood manipulation induced via the *continuous music technique*[5] (see Eich & Metcalfe, 1989), produces both substantial and stable modifications of mood by playing music throughout the entirety of the retrieval session, and may affect the level of arousal too, as suggested by several studies (see Clark, 1982; Revelle & Loftus, 1992). It also avoids ethical concerns, because the stimuli used (i.e., the music excerpts) are normally enjoyed by adolescents worldwide.

In this light, we can assume that, to allow a re-encoding of emotionally charged mathematical facts, algorithms, and strategies, they should be first "de-affectivized" from their negative valence. Once neutralized, they should be strategically implemented again.

The question is: Why are mathematical contents prone to absorb such a powerful emotional valence? According to Bower (1992), moods are represented as nodes in the associative network of knowledge. Mood-dependence allows for the creation of new connections between a mood node and previously non-associated concepts through co-occurrence during the learning phase (Lewis & Critchley, 2003).

– Italian High School education is partially failing to meet its needs and to reach good standards. Apart from making amends for this, this general concern should be overcome by encouraging educational institutions to look beyond the classroom walls and investigate students' free time habits to meet their needs.

Instead of trying to modify personal attitudes towards mathematics, it seems reasonable to profit from teenagers' undeniable passion for music to reach their mathematical skills.

Future research in this field should stem from a fruitful germ: If the didactic way to approach a scholastic subject changes, students' personal conceptions and beliefs about that subject will change as well.

– These outcomes also lend particular support to previous research about the

5 Eric Eich & colleagues have developed a mood manipulation technique of continuous background music listening, dubbed *LIRIC*, an acronym which means a *R*eflective, *I*deographically-based, and Criterion-based *LI*stening.

effects of background music on performance in other academic areas (see, e.g., Cockerton, Moore & Norman, 1997; Madsen & Forsythe, 1973, Manthei & Kelly, 1999; Schellenberg, Nakata, Hunter & Tamoto, 2007; Wolfe, 1983).

We may argue that distracted listening – or *Tafelmusik* in Kant's terms (1798) – can be a preferential gateway to access students' unspoken or tacit conception about the perceived difficulty of different school subjects, turning criticized pop music into functional-applied music or *Gebrauchmusik*.

It emerged that listening to affectively charged music looks promising for reliably inducing mood states (Eich & Metcalfe, 1989; Pignatiello, Camp & Rasar, 1986). In this regard, there seems to be a standardized canon of works for inducing happy and sad moods. The problem is to avoid personal choices, in favour of a more technical stimuli selection.

This study has tried to overcome the limits of intuitive music selection, blamed on Canadian psychologist Eric Eich and collaborators as their own procedural limit (1989, 1994). The investigation of the subjects' music tastes before selecting the stimuli to listen to (see Carter, Wilson, Lawson & Bulik, 1995; Sutherland, Newman & Rachman, 1982), and the use of a more conceptually principled approach to music selection has ensured that particular styles and ensembles would complement one another. Each style, in fact, communicates emotion through unique sets of compositional techniques. Keeping styles and genres consistent enhances naturally a more systematic review of the musical categories that are best suited for mood induction.

– The implication of music choices and mood-dependent memory for mathematical facts – to my knowledge – remains still untested in European countries other than Italy. Thus, it would be extremely valuable to repeat the same study considering the four worst and the four best performing European countries in the PISA 2006 maths evaluation.

At a first glance, it emerges a strong cultural bias and striking polarization of what we may define as "endogenously Phrygian countries"[6] at the extreme right of the below average graphic of PISA 2006 (see lower graphic of Figure 1).

In short, the European countries that obtained the worst scores in mathematics are all culturally and musically Phrygian; their musical structure is based on the afore-quoted Spanish gipsy scale, characterized by irregular, hardly computable numerical relationships. This "Phrygian pole" – formed by Turkey (43rd/57th position), Greece (39th/57th position), Portugal (37th/57th position) and Spain (32nd/57th position) – transposed into music, is highly congruent with perceived sadness, anxiety, and sense of failure. Italy is partially Phrygian in cultural terms: a noticeable example is the Neapolitan 6th chord, that originates in the Minor mode and resembles the Phrygian cadence. Nowadays, Italian pop music scene is living, just like many other countries all over the world (first in line, the United States), a superimposition of Phrygian music through the music market proposals and media broadcasting directed to young audiences.

In this light, one would logically expect to find an opposed "Ionic pole", too. Countries universally recognized as "culturally Ionic" in musical terms, such

6 For a definition of "Phrygian culture" related to music, the best reference is a collection of essays – *Songs of the Minotaur: Hybridity and Popular Music in the Era of globalization. A comparative analysis of Rebetika, Tango, Rai, Flamenco, Sardana, and English urban folk* – edited by Gerhard Steingress in 2002, and published by LIT Verlag edition.

as Germany and Austria[7], have obtained significant better results in maths than "culturally and musically Phrygian" countries (see upper graphic of Figure 1). The four European countries that obtained the highest scores in PISA 2006 maths evaluation are Finland ($2^{nd}/57^{th}$ position), the Netherlands ($5^{th}/57^{th}$ position), Switzerland ($6^{th}/57^{th}$ position), and Liechtenstein ($9^{th}/57^{th}$ position).

Let's examine their musical tendencies: Finnish music has been traditionally influenced by Ionic German music, and the same applies to Liechtenstein, a micro-state bordered by Switzerland and Austria. Even if we know little about Swiss musical culture, one of the oldest varieties of folk music is the agricultural Alpine song *Kühreihen*, in the Lydian mode (i.e., the lighter musical mode on the chromatic scale, even more positively charged than the Ionic mode). Finally, traditional Dutch songs known as *levenslied* (i.e., "songs about the real life"), made of simple rhythms, melodies, and refrains in Ionic mode, are typically catchy and sentimental.

New comparative educational studies in search of possible school time – free time crossroads would surely benefit from more attention to cultural differences in terms of musical preferences. These differences may, in turn, be tied to amazing cultural biases in terms of emotional experience and cognitive expression.

At present, the best way to accomplish this task is by using the technique based on continuous background music listening to investigate academic questions.

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References

Are Teens Just Wired That Way?. (2001, June 3). *The Washington Post*, A01.

Barone, E., & Olivieri, D. (2005a). La Media literacy nella scuola: parte ottava. Linguaggi televisivi ed Educazione musicale (indagine pilota). *Psicologia e Scuola,* XXVI (128), 51-64.

Barone, E., & Olivieri, D. (2005b). La Media literacy nella scuola: parte settima. Media literacy e Educazione musicale. *Psicologia e Scuola,* XXVI (127), 57-64.

Barone, E., & Olivieri, D. (2006). Music education and critical thinking in early adolescence: A synectic literacy intervention. In M. Baroni, A. R. Addessi, R. Caterina & M. Costa (Eds.), *Proceedings of the 9th International Conference on Music Perception and Cognition* (Bologna, Italy, 22-28 August 2006) (pp. 1786-1793). Bologna: Bononia Press.

Barone, E., & Olivieri, D. (2007). Cognitive styles, theme songs, and TV zapping in preadolescence: An explorative study. In Proceedings of the *International Workshop on the Biology and Genetics of Music* (Bologna, Italy, 20-22 May 2007) (p. 26).

Baxter, M. G., & Murray, E. A. (2002). The amygdala and reward. *Nature Reviews Neuroscience,* 3 (7), 563-573.

Bhattacharya, J., & Petsche, H. (2001). Universality in the brain while listening to music. *Proceedings of the Royal Society B: Biological Sciences,* 268 (1484), 2423-2433.

Birbaumer, N., Lutzenberger, W., Rau, H., Braun, C., & Mayer-Kress, G. (1996). Perception of

7 Many of the best classical musicians such as Mozart, Bach, and Brahms were ethnically German. Their music makes a preferential use of the so-called "Ionic mode", structurally regular and affectively charged with a sense of happiness, success, and joy of life.

music and dimensional complexity if brain activity. *International Journal of Bifurcations and Chaos*, 6 (2), 267-278.
Blaney, P. (1986). Affect and memory: A review. *Psychological Bulletin*, 99 (2), 229-246.
Boal-Palheiros, G. M., & Hargreaves, D. J. (2001). Listening to music at home and at school. *British Journal of Music Education*, 18 (2), 103-118.
Boncori, G. (1989). *Test del Pensiero Critico "Caccia all'errore 12"*. Roma: Kappa.
Bower, G. H. (1992). How might emotions affect learning?. In S. A. Christianson (Ed.), *The Handbook of emotion and memory: Research and theory* (pp. 3-31). Hillsdale, NJ: Erlbaum.
Brousseau, G. (1998) *Théorie des situations didactiques*. Grenoble: La Pensée Sauvage.
Carter, F. A., Wilson, J. S., Lawson, R. H., & Bulik, C. M. (1995). Mood induction procedure: importance of individualizing music. *Behaviour Change*, 12, 159-161.
Chevallard, Y. (2007). Readjusting Didactics to a Changing Epistemology. *European Educational Research Journal*, 6 (2), 131-134.
Clark, M.S. (1982). A role for arousal in the link between feeling states, judgments, and behaviors. In M. S. Clark & S. T. Fiske (Eds.), *Affect and cognition: The 17th Annual Carnegie Symposium on Cognition* (pp. 263-289). Hillsdale, NJ: Erlbaum.
Cockerton, T., Moore, S., & Norman, D. (1997). Cognitive test performance and background music. *Perceptual and Motor Skills*, 85 (3), 1435-1438.
Cornoldi, C., & Cazzola, C. (2003). *AC.MT-Test di Valutazione delle Abilità di Calcolo e Problem Solving dagli 11 ai 14 anni*. Trento: Erickson.
Eich, E., & Macaulay, D. (2006). Cognitive and clinical perspectives on mood dependent memory. In J. P. Forgas (Ed.), *Affect in social thinking and behavior* (pp.105-121). New York, NY: Psychology Press.
Eich, E., & Metcalfe, J. (1989). Mood dependent memory for internal versus external events. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 15 (3), 443-455.
Eich, E., Macaulay, D., & Ryan, L. (1994). Mood dependent memory for events of the personal past. *Journal of Experimental Psychology: General*, 123 (2), 201-215.
Erk, S., Kiefer, M., Grothe, J., Wunderlich, A. P., Spitzer, M. & Walter, H. (2003). Emotional context modulates subsequent memory effect. *NeuroImage*, 18 (2), 439-447.
Hetland, L. (2000). Listening to music enhances spatial-temporal reasoning. *Journal of Aesthetic Education*, 34 (304), 179-238.
Jeong, J., Joung, M. K., & Kim, S. Y. (1998). Quantification of emotion by nonlinear analysis of the chaotic dynamics of electroencephalograms during perception of 1/f music. *Biological Cybernetics*, 78 (3), 217-225.
Jolls, T., & Thoman, E. (2004). Media literacy: A national priority for a changing world. *American Behavioral Scientist*, 48 (1), 18-29.
Kandel, E. R., Schwartz, J. H., & Jessel, T. M. (1995) *Essentials of neural science*. Norwalk, CT: Appleton & Lange.
Kant, I. (2006). *Anthropology from a Pragmatic point of view.* (R. B. Louden, Trans.). New York, NY: Cambridge University Press. (Original work published 1978).
Klette, K. (2007). Trends in Research on Teaching and Learning in Schools: didactics meets classroom studies. *European Educational Research Journal*, 6 (2), 147-160.
Lewis, P. A., & Critchley, H. D. (2003). Mood-dependent memory. *Trends in Cognitive Sciences*, 7 (10), 431-433.
Madsen, C. K. & Forsythe, J. L. (1973). The effect of contingent music listening on increases of mathematical responses. *Journal of Research in Music Education*, 21 (2), 176-181.
Manthei, M., & Kelly, S. (1999). Effects of popular and classic background music on undergraduate math test scores. *Research Perspectives in Music Education*, 1, 38-42.
Margiotta, U. (A cura di) (1997). *Pensare in rete. La formazione multialfabetica*. Bologna: CLUEB.
Margiotta, U. (A cura di) (2006). *Pensare la formazione*. Milano: Mondadori.
McDonald, R. J., & White, N. M. (1993). A triple dissociation of memory systems: hippocampus, amygdala and dorsal striatum. *Behavioral Neuroscience*, 107 (1), 3-22.
Meyer, M. A. (2007). Didactics, Sense Making, and Educational Experience. *European Educational Research Journal*, 6 (2), 161-173.
OECD. (2006). *Assessing Scientific, Reading and Mathematical Literacy: A framework for*

PISA 2006. Paris: OECD. Disponibile in: http://edu.au.dk/fileadmin/www.dpu.dk/viden/temaeraaa/internationaleundersoegelser/om-dpu_institutter_paedagogisk-psykologi_pisa_20071109154105_framework2006.pdf [21 aprile 2011].

OECD. (2009). *PISA 2006 Technical Report*. Paris: OECD. Disponibile in: http://www.oecd.org/pisa/pisaproducts/42025182.pdf [21 aprile 2011].

Olivieri, D., & Barone, E. (2007). The "Analytic Mind": Youth involvement in music jingles and TV choices. In Proceedings of the *International Workshop on the Biology and Genetics of Music* (Bologna, Italy, 20-22 May 2007) (p. 37).

Peretz, I., Gaudreau, D., & Bonnel, A.M. (1998). Exposure effects on music preferences and recognition. *Memory and Cognition*, 26 (5), 884-902.

Petsche, H., & Bhattacharya, J. (2002). Musical thought and intelligentsia. *Österreichische Musikzeitschrift*, 57, 6-12.

Petsche, H., Richter, P., von Stein, A., Etilnger, S., & Fitz, O. (1993). EEG coherence and musical thinking. *Music Perception*, 11 (2), 117-151.

Pignatiello, M., Camp, C., & Rasar, L. (1986). Musical mood induction: An alternative to the Velten technique. *Journal of Abnormal Psychology*, 95 (3), 295-297.

Radocy, R. E., & Boyle, J. D. (2003). *Psychological Foundations of Musical Behavior*. Springfield, IL: Charles C. Thomas.

Rauscher, F. H. (2002). Mozart and the mind: Factual and fictional effects of musical enrichment. In J. Aronson (Ed.) *Improving academic achievement: Impact of psychological factors on education*. New York, NY: Academic Press.

Rauscher, F. H., Shaw, G. L., & Ky, K. N. (1993). Music and spatial task performance. *Nature*, 365 (6447), 611.

Raven, J. C., Court, J. H., & Raven, J. (1996). *Manual for Raven's Standard Progressive Matrices*. Oxford, UK: Psychologists Press.

Revelle, W., & Loftus, D. A. (1992). The implications of arousal effects for the study of affect and memory. In S.-Å. Christianson (Ed.), *Handbook of emotion and memory*. Hillsdale, NJ: Erlbaum.

Schare, M. L., Lisman, S. A., & Spear, N. E. (1984). The effects of mood variation of state-dependent retention. *Cognitive Therapy and Research*, 8 (4), 387-408.

Schellenberg, E. G., Nakata, T., Hunter, P. G., & Tamoto, S. (2007). Exposure to music and cognitive performance: Tests of children and adults, *Psychology of Music*, 35 (1), 5-19.

Schneider, F., Grodd, W., Weiss U., Klose, U., Mayer, K. R., Nagele, T., & Gur, R. C. (1997). Functional MRI studies reveals left amygdala activation during emotion. *Psychiatry Research*, 76 (2), 75-82.

Scripp, L. (2002). An overview of research on music and learning. In R. Deasy (Ed.), *Critical links: Learning in the arts and student academic and social development* (pp. 143-147). Washington, DC: Arts Education Partnership.

Sutherland, G., Newman, B., & Rachman, S. (1982). Experimental investigations of the relations between mood and intrusive unwanted cognitions. *British Journal of Medical Psychology*, 55 (2), 127-138.

Witkin, H. A., Oltman, P. K., Raskin, E., & Karp, S. E. (1971). *A manual for the Embedded Figures Test*. Palo Alto, CA: Consulting Psychologist Press.

Wolfe, D. (1983). Effects of music loudness on task performance and self-report of college-aged students. *Journal of Research in Music Education*, 31 (3), 191-201.

Worsnop, C. (1999). *Screening Images: Ideas for Media Education* (2nd ed.). Mississauga, ON: Wright Communications.

Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology*, 18 (5), 459-482.