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Connections between human music and natural language*

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Abstract. There have has been a lot of discussions about the connection between natural language and music. From an evolutionary perspective, there is a dispute over the primacy of language or music. What is music? What is language? What do they have in common? Are there common areas in the brain for music and language? Leaving aside these questions, one certainty is that much of the musical creations are accompanied by lyrics and, on the other hand, poetry has usually musicality. However, the connection between music and language also occurs in other types of texts, both literary, political speeches, and in conversations. Repetitions, rhythm, discursive structures have many common elements in the two cases. This paper presents some results of research exploring the links between music and language from the perspective of artificial intelligence and polyphony. Connections between music, natural language and the brain are investigated.
Keywords: human language, music, discourse, coherence, creativity, natural language processing, polyphonic model of discourse

1 INTRODUCTION

This paper discusses the links between natural language and music in several ways, some of them obvious, such as in poetry, and other less obvious but not less important: the rhythm of texts outside the lyrical domain (Balint, Dascalu, and Trausan-Matu, 2016), the polyphonic model of any natural language discourse (Trausan-Matu, 2013c), and even the musical structure of some texts, for example, in the case of Plato's dialogues (Kennedy, 2011). Neurological correlates, psychological, anthropological, philosophical, and religion perspectives are also considered.

There are multiple essential links between human language and music. An important fact is that it seems that both are differentiating humans from other beings. If it is obvious that human language cannot be achieved even by non-human primates, the case of musicality is not so evident, because it might be attributed also to, for example, birds or animals. However, if some animals and birds seem to enjoy music and/or rhythm, a first distinction may be remarked between enjoying and producing

* This paper is an extended version of a previous publication (Trausan-Matu, 2017)

human-like music. Several features characterize music produced by humans, two important ones being complex rhythm and syntax.

If very simple rhythms may be considered that are produced also by animals, for example, cat purring or the croaking of frogs, even a few more complicated rhythms, such as the third-based of waltz dance, as Oliver Sacks mentions: "in this special sense of combining movement and sound— appears spontaneously in human children, but not in any other primate" (Sacks, 2007). In fact, is questionable if purring or croaking may be considered as music, they are a monotonous repetition and a major feature of human music is variation, dissonances followed by consonances, and, related to them, creativity.

On the other hand, a language with a syntax is present only in humans, complex structuring being also a main feature of the produced music by humans, similarly with language. Is there a connection between these two? One attempt to answer to this question might be the approach of Jackendoff and Lerdahl (2006), who proposed a link between music and natural language based on Chomsky's grammatical theory.

There is a consistent body of research that analyzed the relations between musical aptitudes and language, revealing, for example, that phonological awareness was associated with musical aptitude and reading; that pitch and rhythmic aptitude positively correlated with vocabulary and reading, and spelling (Schellenberg and Weiss, 2013). However, the same authors mention and cite several other researches that contrast with these results, therefore there are debates about this subject. Links between language and music were also revealed by brain research, examples being the successes in the therapy of some neurological problems in speech (aphasia) using music (Sacks, 2007, Wan and Schlaug, 2013).

From the Artificial Intelligence (AI) perspective, we assert that, starting from the link between music and language, and from the connection of music to the brain, we could develop computer applications that could perform better in analyzing discourse in natural language. Some steps in this direction has been done by implementing systems that analyze discourse from a musical polyphonic perspective (Trausan-Matu, Dascalu, and Rebedea, 2014; Dascalu, Trausan-Matu, McNamara, and Dessus, 2015). However, the link between polyphony and the brain should be further investigated. The musicality of the sonification of chats (Trausan-Matu, 2018) is another prove of the strong link between language and music.

For music, we will consider in our analysis its defining factors: rhythm, melody, the dissonance/consonance "game", and the most advanced form of music: polyphony, best exemplified by creations of Johann Sebastian Bach. All these are encountered also in the natural language, as we will discuss herein.

On the other hand, from the perspective of natural language, we believe that musicality may be intrinsic (for example, prosody, rhythm, polyphony) and extrinsic, targeted: syntactically (Dascălu-Jinga, 2001), pragmatically and discourse (rhythm in political speeches, in literature and paintings (Wiskus, 2008, 2013), in Plato's dialogues (Kennedy, 2011) and the polyphonic structure of conversations (Trausan-Matu, 2020; 2010)).

Regarding the “game” of dissonances and consonances, it is present not only in music and texts, it is a general human feature, which can be seen as a trend towards exploration, to creativity, to confrontation, to something new, "out of daily life", the eternal story of the "challenges of life", of conflicts, which, are finally solved with a happy-end. A dissonance solved by a consonance is also commonly encountered in the form of the question-answer adjacency pairs both in conversations and narration, but also (even with this terminology) in music. Moreover, we tend to achieve consonance, but it is more "pleasant" when it comes after a dissonance.

Discourse Analysis is one of the most difficult problems of linguistics (and especially computational linguistics). First of all, it should be mentioned that the sense of “discourse” considered in the paper is that of “a coherent structured group of sentences” (Jurafsky and Martin, 2009), specific to linguistics, not other senses, for example of a “political speech”.

Discourse is also a fundamental component in a piece of music, in a similar way to natural language. For linguists, the essential feature of a discourse is coherence (Jurafsky and Martin, 2009), but this concept is very hard to define in linguistics, to assure in a text, and practically impossible to measure in computational linguistics, a typical simplification being the consideration of cohesion. From the perspective of music, however, coherence is easier to measure and assure (and this fact, in our opinion, worths further analysis). In music are clear theories and methods to ensure, for example, harmony and structure of a musical piece. Therefore, considering the natural language discourse from the music perspective can give useful suggestions.

2 MUSIC AND ITS FEATURES

Before analyzing the connections between music and natural language, and their link to the brain, we include a brief analysis of what is meant by music. Based on a series of quotes (the first seven of them taken from http://www.quotegarden.com/music.html) we find a variety of definitions of music.

1. “Music is what feelings sound like.” (unknown author)
2. “Music is the mediator between the spiritual and the sensual life.” (Ludwig van Beethoven)
3. “Music is a moral law. It gives soul to the universe, wings to the mind, flight to the imagination, and charm and gaiety to life and to everything.” (Plato)
4. “A jazz musician is a juggler who uses harmonies instead of oranges.” (Benny Green)
5. “Music is the universal language of mankind.” (Henry Wadsworth Longfellow, Outre-Mer)
6. “Music is what life sounds like.” (Eric Olson)
7. “If a composer could say what he had to say in words he would not bother trying to say it in music.” (Gustav Mahler)
8. “Rise with the Poetry, stand with li, consummate with music.” (Confucius, 2003)

9. “Where the word fails, remains the music (…) Ideas are dead melodies” (Cioran, 2016)
10. "Music has nothing to do with sound. Sound is the vessel, the glass, the vehicle. So is rhythm, so is harmony, so is everything. The purpose of music is not to be beautiful. Music is not beautiful. Music is truth. Music is reality” Sergiu Celibidache, in an interview with John Rockwell (1989).

We can consider music, in a first approximation, as a phenomenon by which we perceive, for a certain time, sequences of sounds, overlapping or not, which that give us a feeling of pleasure. From the above definitions, we can conclude, however, that, excepting the first and the second ones, the music is viewed from a much larger scope, leading even to a characterization of life (6th definition).

Music is seen as a path to spiritual life (2nd definition), a moral law, an inspiration, it gives "wings to the mind, flight to the imagination" (http://www.quotegarden.com/music.html) and allows musicians to juggle with harmonies. But what is very important in our view, music is an universal language (5th definition), stronger than natural language, being able to express more than words. Cioran even said that "Ideas are dead melodies" (Cioran, 2016).

According to most theories, three key features characterize music: melody, rhythm, and harmony. I would also add the discursive structure and, as the highest feature, polyphony.

Music is intrinsically linked to melody, the latter seen as a tune, as stated by the composer, musicologist, and conductor Leonard Bernstein. He characterized the melody "as a tune, something you go out whistling, that's easy to remember, that ’sticks in your mind’", which is close to our voice capabilities (Bernstein 1991, p.7). He also expresses the connection between melody and rhythm: "melody is the singing side of music, just as rhythm is the dancing side" (Bernstein, 1991, p.8).

Rhythm is an essential dimension in music, and it is important also in natural language, as we shall see in a separate section dedicated to it. Harmony is, in my opinion related to coherence and discourse and they will be also considered below. Both features are connected to the brain: Sacks (2007) proved that rhythm is neurologically connected to language. Harmony (coherence) may be seen as an upper level manifestation of homeostasis.

3 RELATIONS BETWEEN NATURAL LANGUAGE, MUSIC, AND THE BRAIN

3.1 The relations between music and language

As discussed in the previous section, still it is not a consensus about what music is, how it is related with our existence, our thinking, and natural language. The relationship between music and natural language is seen from divergent positions:

1. **Music preceded language**, in the Darwin's evolutionist perspective, as cited by Levitin (2006). This can be interpreted as the evolution of the brain from the human musical capacity to natural language ability.
2. **Between music and language there is a similarity**: Bernstein (1976), and Jackendoff and Lerdahl (2006) propose an approach from a linguistic perspective on music - a syntactical approach using a Chomsky grammar style for music. Chomsky's perspective is based on the supposition that human brain has some innate capability to tackle with grammatical syntactic structures. It should be noted that this second position is not in conflict with the first one, the evolutionist one, but, however, it is not mandatory explained by it.
3. Pinker and others (Levitin, 2006) **minimize the role of music**. We mention that Pinker discusses in detail about the relation between language and brain (neurolinguistics) and, he criticizes Chomsky (see, http://www.floatinguniversity.com/pinker-transcript).
4. **Music is more complex than language**: "Where the word fails, remains the music […] Ideas are dead melodies" (Cioran, 2016)
5. To complete the range of ideas, it should be included also an alternative view that links music, language, and mind under a position that usually gives a minor role to the brain. Some composers and interprets share this view based on various religions, for example, Christian or Zen Buddhism. It is known that Sergiu Celibidache and John Cage (a famous 20th century music composer) shared a Zen perspective (Rockwell, 1989). A Christian position may be exemplified by the following quote: "By the power of the Holy Spirit He arranged in harmonious order this great world, yes, and the little world of man too, body and soul together; and on this many-voiced instrument of the universe He makes music to God, and sings to the human instrument" (Clement, 1919).

We see that there are various perspectives for analyzing the relationships and differences between music and natural language. Some of them are directly related to considering the brain (1-3 above), but there are also some (4 and 5) stating that there are also other (even religious/mystic) dimensions of music. In fact, in many philosophical systems and in the majority of religions natural language (the "Word") and music are fundamental, many mystical practices are using them, often combined. From another point of view, also in politics the combination of music and language is an important mean for various occasions. Anyway, of course that the brain has a major role both in music and natural language processing, in all the previous mentioned cases.

3.2 Music and language processing in the brain

From the neurological point of view, natural language has associated in the brain the Wernicke and Broca areas. In contrast, it seems that music is not concentrated in such areas, it is distributed throughout the brain (Sacks, 2007; Levitin, 2006; Ball, 2010).

Levitin (2006) indicates the various areas associated to music, from the perspectives of the listener, the performer or of the dancer:

- In the *motor cortex*: playing an instrument, dancing, movement, foot tapping.
- The *prefrontal cortex*: Creating expectations, their satisfaction or violation.
- In the *sensory cortex*: tactile feedback from dancing and playing an instrument.
- In the *auditory cortex*: The early stages of listening sounds, tonal perception and analysis.
- In the *visual cortex*: Reading music sheets, looking at music performers.
- The *cerebellum*: Emotional reactions to music, legs beating the rhythm, dancing or playing an instrument.
- The *corpus callosum*: links the two hemispheres of the brain.
- In the *hippocampus*: Memory related to music.
- The *nucleus accumbens*: Emotional reactions to music.
- The *amygdala*: Emotional reactions to music.

There are links between music and language proven by the recovery of spoken language through music - Oliver Sacks (2007) revealed that music and particularly rhythm can help the recovery of patients who have lost the faculty of speech (aphasia) after severe head injuries.

Several experiments were performed in recent years regarding the relations between music and the brain, many of them using state of the art imagining technologies. For example, there were analyzed, using fMRI, "the effects of intensive music-based treatments on speech-motor functions of chronic stroke patients with aphasia and of nonverbal children with autism" (Wan and Schlaug, 2013)

The effects of rhythm, consonance, and dissonance on performing a visuomotor detection task were investigated using fMRI. Evidence was found for the effects "induced by entrainment to the meter of natural music" demonstrating the presence of 'specific neural substrates for such effects in both subcortical (basal ganglia) and cortical (parietal networks)" (Trost et al., 2014). Moreover, the same experiments revealed that "the caudate nucleus is sensitive to the metrical structure of music, even without explicit orienting of attention to the music. In addition, a region in the right inferior precuneus was also found to be selectively sensitive to musical meter, but only during pleasant/consonant music." (Trost et al., 2014).

A correlation between learning a foreign language and increases in the volume of gray matter in language-related brain areas (Mårtensson et al., 2012). Researchers also conclude that the "plasticity of the hippocampus and the left STG might be important for learning a new language" (Mårtensson et al., 2012)

A similar phenomenon was identified also in connection to music. Levitin mentions that the Harvard neuroscientist Gottfried Schlaug has shown that musicians have a larger corpus callosum (Levitin, 2006, p.220).

Regarding the polyphonic music, Spada et al. (2012), made some experiments on using fMRI for analyzing aspects of the relations to the brain of melody and accompaniment of professional pianists. They have identified the role of several components of the brain in the processing of polyphonic melodic information: the posterior medial cortex, the precuneus, the posterior cingulate, and the lingual gyri (Spada et al., 2012).

4 THE MUSICALITY PERSPECTIVE OF THE NATURAL LANGUAGE DISCOURSE

Natural language is a means of communication closer to a discrete manner: every word has its meaning, unlike music, where the notes have no meaning individually, communication being closer to a holistic character. However, although linguistics, especially structuralist approaches, neglect holistic aspects, natural language holistic dimension should not be ignored. For example, coherence, essential in discourse analysis is a holistic notion in our opinion. The same, at a reduced scale, is characterizing metaphors (Trausan-Matu, 2000, 2006)[1]. Mikhail Bakhtin (1981, 1993) and Constantin Noica (1986) were among those who highlighted the holistic, non-reductionist dimension of natural language.

Musicality in texts can be explicit, perceptible, for example in poetry and spoken language, semi-explicit, through the rhythm of prose, or implicit in the form of the polyphonic structure of texts (Trausan-Matu, 2013c) or other structures, similarly to poetry. A remarkable case in this regard was musicality revealed by Kennedy in Plato's dialogues (Kennedy, 2011).

Related to the musicality of speech, I think it is obvious to everyone that we love to hear certain voices' inflections, while others are unbearable for us. Musicality of speech is usually studied in prosody and intonation (Dascălu-Jinga, 2001), subdomains of linguistics.

As in the case of natural language conversations, musical pieces are characterized by dialogism, which manifests in several ways: question-answer adjacency pairs in a similar way to conversations; inter-animation consonance-dissonance sequences (Trausan-Matu, 2020; 2010), which can be seen as the result of a pair of centripetal-centrifugal forces, phenomenon remarked in literature by Bakhtin (1981).

4.1 The coherence of natural language discourse seen from the musicality perspective

We consider discourse as a fundamental component in a piece of music, similarly to the natural language case. As mentioned before, an essential feature of discourse is coherence. However, a definition of coherence is difficult to give, especially in the case of computational linguistics, which relies heavily on the decompositional semantics paradigm and essentially on reductionism and the structuralism of deSaussure (1996). For example, a definition given in a well-known treatise on computational linguistics is "for a discourse to be coherent it must exhibit certain kinds of relationships with the entities it is about, introducing them and following them in a focused way" (Jurafsky and Martin, 2009). In this context, instead of coherence it is used the concept of cohesion in the analysis of discourse in texts. I personally believe, as I

[1] The ideas in these references were used in a system that considered the role of metaphors as facts of living in language learning. The system was developed under the EU funded project LarFLasT (Angelova and all, 2002).

wrote in above, that discourse should be viewed from a holistic approach, as those proposed by Bakhtin (1981,1993) and Noica (1986). I personally introduced the polyphonic discourse model, which is based on the example of music polyphonic discourse (Trausan-Matu, 2010; 2011; 2013b, 2013c; 2020) This model will be presented in a subsequent section.

Music and the fundamental principle of construction of a discourse is coherence, as Leonard Bernstein notes:

> "But the most important thing about a tune is that usually it is complete in itself — that is, it seems to have a beginning, middle and end, and leaves you feeling satisfied — in other words, it's a song, like Gershwin's Summertime, or Schubert's Serenade" (Bernstein, 1991, p. 8).

The same thing is said, in more detail, by Anton Webern, one of the greatest composers and music innovators of the last century:

> "The highest principle in all presentation of an idea is the law of comprehensibility […] something comprehensible is something of which I can get a complete view, whose outlines I can make out […] What, then, is differentiation? Broadly speaking, the introduction of divisions! What are divisions for? To keep things apart, to distinguish between what is principal and what is subsidiary. This is necessary, to make yourself intelligible, so it must also happen in music. […] So the whole thing must hang together, otherwise you are unintelligible. Here we have an element that plays a special role: 'hanging-together', unity, will be necessary to make an idea comprehensible." (Webern, 1960).

Coherence, as we see from the two previous quotes needs also a structure. For example, Bernstein stated that there must be a beginning, a middle and an end, which is significant for our study because this division is proper also to a story. But, of course, in this context it should be mentioned that this fact might be due to our experience of reading and listening to stories. Nevertheless, we can say that our predilection to read or listen to happy-ending stories is due to our need to listen music that ends harmoniously (in music theory, musical pieces generally end on specific, harmonious chords, after passing through others, even inharmonious ones).

4.2 Repetition in natural language, an element of musicality

Sacks (2007) says that music is based on repetition. Leonard Bernstein points out that repetition, accurate or slightly modified, but keeping the main theme plays a crucial role in determining the melody in our memory (Bernstein 1991, p.9).

Repetition is essential in natural language, especially in conversations (Tannen, 1989; Trausan-Matu, 2012, Trausan-Matu and Murarus, 2015), in this case inducing collaboration and even build new artifacts (Trausan-Matu, 2012). Repetition appears also in prose (Boychuk et al., 2005), an action that generates rhythm and musicality.

4.3 Rhythm in music and in natural language

As in the case of music, it is difficult to give a definition of rhythm (Giuleanu, 2013; Trăuşan-Matu, 2013b). In natural language, rhythm is evident in the case of poems, but it is much less noticeable in prose. In conversations, repetition and rhythm are essential, they ensure involvement (Tannen, 2010), being able to identify rhythms like "andante", "allegro" etc. (Ligorio & Ritella, 2010), similarly to the musical case.

Rhythm can be seen as a particular arrangement or sequencing of units in various arts (musical beats, phonemes, colors, etc.). In music, a definition would be that it "refers to the durations of a series of notes, and to the way that they group together into units" (Levitin, 2006, p.15). Also Levitin asserted: "Rhythm and meter are the engine driving virtually all music, and it is likely that they were the very first elements used by our ancestors to make protomusics, a tradition we still hear today in tribal drumming, and in rituals of various preindustrial cultures" (Levitin, 2006, p.53).

Rhythm is seen as an energy wave to a known composer and jazz performer:

> "What we call time in music, when referring to the narrow sense of the term (in English beat and German takt) is in fact an energy wave of an acoustico-psychological nature. It consists of a pulse, an energy peak corresponding to the beginning of the period which we consider a time. Other areas follow, with energies of different values, depending on the wave subdivisions we encounter until the beginning of a new time" (Tiberian, 2013).

4.4 Consonances and dissonances, attractiveness features of discourse in natural language and music

Ensuring coherence, repetition, and rhythm are not sufficient to ensure a discourse appreciated by humans. Both in natural language and in the musical discourses is needed another trait: unexpected element that ensures attractiveness:

> "Music is organized sound, but the organization has to involve some element of the unexpected or it is emotionally flat and robotic. Too much organization may technically still be music, but it would be music that no one wants to listen to. Scales, for example, are organized, but most parents get sick of hearing their children play them after five minutes." (Levitin, 2006, p.169)

Humans immediately perceive attractiveness in a piece of music (but considering the individual of every person: taste, musical training, etc.). One way to ensure this attractiveness, the unexpected, is the introduction of dissonances, which initially may surprise you, but after then, by solving them with consonances, a harmony is achieved that gives coherence to another level than the one before, inducing satisfaction similar to that after winning a battle.

Ensuring differences, that means dissonances, is essential also in natural language. We could say that any utterance (when it brings something new) may bring a dissonance, which contrasts, that means it is a difference with the status-quo existing and known / expressed in words previously:

> "Language can be viewed as a massive system of distinctions, or differánce. When someone makes an utterance—even a silent utterance of consciousness expressing self-awareness—that act relies for its meaning on the whole structure of this complex language. Derrida agrees with Heidegger's critique of the Cartesian view of Being as (physical, temporal) presence and concludes that the Being of beings is determined by formal systems of distinctions, e.g., the meaning of a particular utterance is determined by language as a system of differentiations" (Stahl, 2006, p. 412).

An interesting discourse, therefore, should be like a musical piece that appeals through a game of dissonances that are ultimately resolved by consonances: "Whatever the number of voices, the character of a polyphonic composition depends crucially on how it uses and resolves dissonances" (Pesic, 2017).

4.5 Polyphony, a musical model of the natural language discourse

Polyphony requires "at least two simultaneous melodic lines, with a different melodic-rhythmic structure" (Giuleanu, 2013). On another hand, several overlapping rhythms, that means polyrhythm dominates all polyphonic creation (Giuleanu, 2013). Polyphony is also closely linked to the dissonance/consonance game, taking it to a pinnacle.

> "We see different voices singing different on the same theme. They form the 'polyphony', revealing the variety of life and the complexity of human experiences. 'In life everything appears in counterpoint, that means in contrast' [...] everything in life is a dialogue, that means a controversy. Moreover, if we adopt the viewpoint of philosophical aesthetics, the counterpoint relationships in music are no mre, in fact, than a variety of what we call in the large sense dialogic relations" (Bakhtin, 1993).

It is perhaps easier to understand the idea that discourse in conversations may have a polyphonic structure similarly to music because there are more participants (voices), each with personality, with different views and goals. However, this phenomenon occurs also with threads of repeated words, becoming discussion topics, which may be seen as voices entering on dissonant (divergent) and consonant (convergent) interactions. For example, in Figure 1, "reply", "(re)presentation", and "topic" become voices that interact in convergent ("conv") and divergent ("div") manners.

Based on these ideas, a polyphonic model was introduced, both for conversations and for any text and communication, including non-verbal cases (Trausan-Matu, 2010; 2013a; 2013c; 2020; Trăuşan-Matu et. al., 2014). The encountering of polyphony in natural language can be seen as a proof of the supreme musicality of language and of human communication in general.

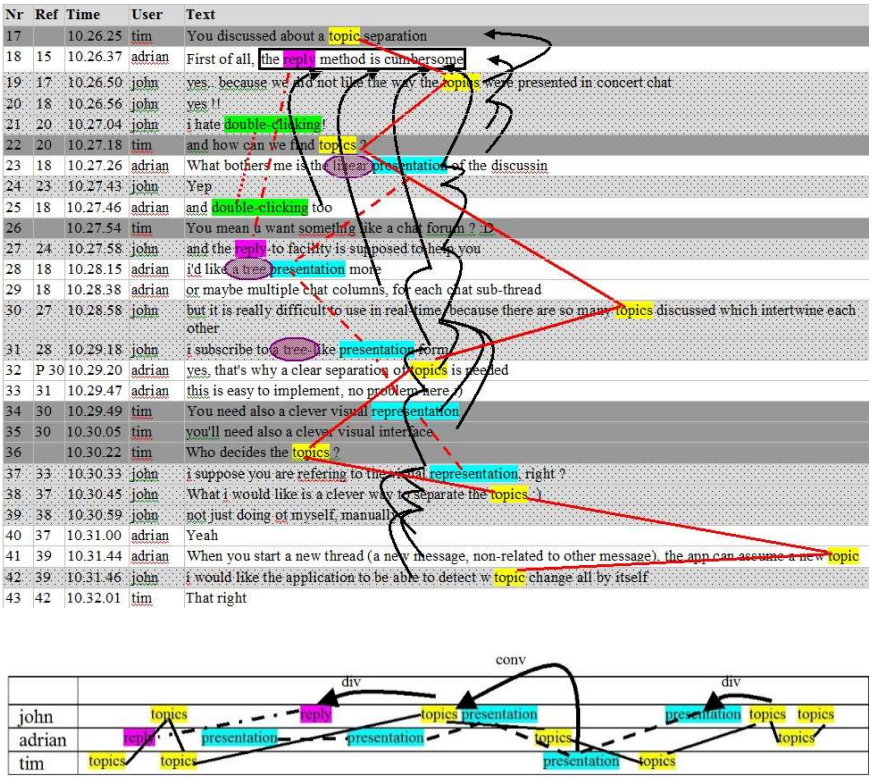

Fig. 1. Threads of repeated words (straight lines), of explicit references (curly lines) and convergent ("conv") and divergent ("div") interactions (Trausan-Matu & Stahl, 2007)

4.6 Artificial intelligence applications based on the musicality of natural language

Natural language musicality and the derived polyphonic model were the driving ideas for the design and development of a series of artificial intelligence applications:

- **Analyze of discourse in conversations and texts**. For example, in Figure 2 is presented a snapshot of the facilities of the PolyCAFe system (Trausan-Matu, Dascalu, and Rebedea, 2014), which is used for the visualization of discourse threads in Computer-Supported Collaborative Learning (CSCL) instance messenger (chats) and for computing various metrics, probably the most important being the collaboration degree.
- **Sonification of conversations**, that means generating music following the polyphonic structure of conversations (Trausan-Matu, 2018). The fact that the resulting musical pieces were very well received by musicians and even, after some orches-

tration details, interpreted at the Romanian Atheneum, proves that really there is a musicality of the discourse in conversations (listen https://www.youtube.com/watch?v=g6P7U9hrR5w).

- **Classification of texts starting from rhythmicity** (Balint et. al, 2016). A balanced text corpus of political speeches, essays, and newspaper articles was constructed. Using machine learning techniques, the genre of each text was determined (see Figure 3).
- **Analysis of the distribution of pauses** in CSCL chats and their role for analyzing learning (Denisleam & Trausan-Matu, 2015)
- **Generation of accompaniment to a poem** (Stere, Trausan-Matu, 2019)

5 CONCLUSIONS

The paper highlighted several elements that justify the claim that natural language has musicality, less (for example, in prose) or more (in poetry and in speech intonation). Anyway, it can be said that natural language has implicit musicality under the form of rhythm (which can be used for the classification of texts, as mentioned above) and the polyphonic structure of discourse. These facts lead us to the conclusion that musicality is a universal phenomenon specific to human beings.

Composing music with computers encounters similar problems with the composition of texts. Both activities require human creativity and imagination to achieve results that would not sound artificial, that are not monotonous. The success of sonification of chat conversations, in the sense that the generated musical pieces do no more sound mechanical, artificial, is another argument that natural language has musicality.

The paper also emphasized the experiments that shown the deep links between music, language, and the human brain. These facts may be used for further developing natural language processing systems for analyzing the discourse starting from the musical dimension, in general, and the polyphonic model, in particular.

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