Representation of Silence in Soundscape Perception.

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Abstract — **Silence as the absolute absence or opposite of sound is unavailable in nature and it can exist only as an abstract concept. However, the presence of silence in our life as a perceptual experience is undeniable and in order to be perceived, it can only exist in the presence of sound. Silence can be considered in terms of a subjective contextual representation of environmental auditory stimuli which in acoustic ecology is studied as 'soundscape'. The purpose of this research is to study the perceptual-cognitive processes involved in the creation of the subjective mental representation of soundscapes which are perceived, categorised and evaluated as 'silence'. This has been done firstly through a review of researches and theories in the field of soundscape perception. Secondly, the information collected has been integrated with an analysis of twenty audio files collected by the *MoMA* museum in the project *Share your Silence* and sent by the participants as field recordings of environments subjectively considered as 'silence'. The interrelation between categorization of sound sources, emotional response and expectation has emerged as a primary determining factor in the representation of soundscape. In view of these aspects a possible ecological function of the perception of silence in the relationship between human being and environment has been discussed and the compatibility between our definition of silence and the *eco-field hypothesis* and the *general theory of resources* has been hypothesised. Silence arose as an optimal condition of the environment in which human activities aimed to satisfy personal needs can be accomplished with a low energy cost, as a result of the low difficulty to distinguish, organise and categorize sounds and a low level of ecological competition with other species, groups or individuals.**

I. Introduction

Physical silence is the state of absolute lack of sound, the absence of all vibratory existence. A first essential limitation of this acceptation of silence is that a similar state cannot be found in nature and it is hardly achievable artificially. A perfect vacuum is the only space where there is the absence of any propagating medium for sound. Attempts to study silence starting from this absolute view unavoidably rely on an approximation of this concept. Examples of this are experiments in anechoic chambers and studies focused on the reduction of noise based mainly on the attempt to achieve the best approximation of silence reducing the intensity of sounds in an environment.

On the other hand, from a psychoacoustic perspective and changing the point of view from the object to the listener we can talk about acoustic silence. Silence is what is not hearable. Sounds can be unhearable when they are below the threshold of human audibility or when they are not part of the listener's acoustic horizon because they are too distant or masked by other stimuli. This description of silence does not take into account one characteristic of human auditory perception. Indeed, human auditory sensibility is characterized by constant adaptation to the current stimulus. As we said, a complete absence of stimuli is practically impossible to experience and even in the most extreme situations, such as a very quiet area or a state of total deafness, human attention would gradually shift the threshold until it finds stimuli to focus on; barely audible distant voices, soft sounds produced by the body or even sounds perceived by vibrations through the sense of touch could be heard.

Physical and acoustical acceptations refer to silence in the negative, considering it as the opposite of sound. This logical-analytical view tends to define a discontinuity between sound and silence creating a binary relationship between them. Despite this perspective could be enough to explain specific aspects of verbal communication such as rhythm and phrasing, a binary interpretation represents an insuperable limit for the comprehension of the human experience of silence. Absolute silence is not part of human experience but it is undeniable that human beings perceive, imagines and memorises -essentially experiences- silence. Human perception as a collaboration between sensory perception which works with analog-continuous data and cognition through which raw data are elaborated and interpreted. For this reason, our research is an attempt to study silence as a perceptual phenomenon experienced as a positive auditory representation rather than the lack of stimuli. It has not meant as a metaphoric escape route from the limits of absolutely quantitative definitions but an attempt to make a subjective experience suitable for studies without renouncing to a scientific perspective.

In our research silence is going to be considered as a perceptual experience of a human subject in relation to the sonic environment. The sonic environment is perceived by the listener as a holistic auditory entity which in acoustic ecology

is studied as soundscape. We are going to investigate which perceptual-cognitive processes are responsible for the perception of the soundscape and in which way these are involved when a soundscape is perceived as 'silence'.

The results of this first section will be compared and integrated with an analysis of the components of soundscapes recorded for the *MoMa*'s project *Share your silence* (*MoMA* 2014). These field recordings were submitted by the participants as sonic environments subjectively considered as 'silence'.

The conclusions about the cognitive-perceptual nature of silence will be discussed in relation to the *eco-field* paradigm and the *general theory of resources* (Section II-C, V) in order to understand whether silence can have an ecological-adaptive role in the activity of configuration of the environment and localization of needed resources.

II. - Theoretical framework

Silence is a perceptual experience which arises from the listening of a sonic environment. For this reason, the first step of our research is an introduction to the theories related to the human perception of the sonic environment and its function in nature. This is the object of study of acoustic ecology in which the concept of soundscape has been introduced and a model related to its communicational function has been formulated by one of the founders of the field. In this first section we are going to describe the concept of soundscape and its role in the Barry Truax's *Acoustic Communication Model* (Section II-C). Ultimately we are going to introduce the *eco-field hypothesis*, a bioacoustic theory related to the ecological function of soundscape perception.

A. Acoustic ecology and soundscape studies

Acoustic ecology is the field which studies the relationship between the organisms of an environment and the composition of its sounds, which has been called *soundscape*. It studies the acoustic characteristics of an area not by themselves, but always in relation to the processes of influence between them and the components of the environments. As a general field, it covers different types of studies with different interests and approaches. However, the approach that we refer to in this research is the one defined by the "founders" of this discipline R. Murray Schafer and Barry Truax, who focused their interest mainly on human perception, interpretation of and interaction with the sonic environment.(Davies 2013)(Truax 1984) In other words, acoustic ecology studies "the overall acoustic environment with emphasis on the way it is perceived and understood by the individual, or by a society" (Truax 1999).

The aspects involved in this domain are uncountable and they necessary touch very different fields. Indeed, acoustic ecology is grounded on studies in single disciplines such as acoustics, psychoacoustics, cognitive psychology, physiology, neuroscience, linguistics, social science and sound art. More specifically, acoustic ecology relies on methods of research that we can divide into three types: quantitative, qualitative and artistic (Davies 2013). With the advancement of the discipline a holistic perspective has gradually been preferred and even though researches are often focused on one specific aspect of the domain, for this reason, acoustic ecology is essentially interdisciplinary. It is a "shared perspective from a range of disciplines"(Davies 2013) which attempts to collect and integrate quantitative, qualitative and artistic works.

B. The soundscape

The soundscape is composed of all the sounds of a landscape of which they are ecological properties. The acoustic characteristics of an area reflect the natural processes within the environment; presence and interaction between the components of landscapes produce a specific a unique acoustical pattern (Pijanowski 2001). Following this view soundscapes can be analysed making a distinction between their sonic components, according to the acoustic sources by which are produced. *Biophony* is the composition of sounds created by the organisms, *geophony* the non-biological ambient sounds produced by "geologic" elements such as wind, rain, thunders and *anthrophony* all the sounds produced by human activities (Pijanowski 2001). From coexistence and interactions between elements emerge systems. According to the soundscape ecology approach not only those systems can be observed and studied through their acoustic output, but going further it is stated that the interaction between the components itself occurs at the soundscape dimension. In other words, systems composed of natural and human elements emerge and their activities alter patterns and processes bidirectionally across different spatial-temporal scales (Pijanowski 2001). Those emergent systems and their functioning have been formalised by Barry Truax in his Acoustic Communication Model (Truax 1984).

C. Barry Truax's Acoustic Communication Model

The Acoustic Communication Model has a human perspective (Truax 1984). The individual and the environment live in a system of information exchange. Listening is the primary interface between the individual and the environment. Indeed, it is not just the auditory reaction to stimuli, it refers to how the individual perceives and understands the acoustic environment. The information perceived by the listener is not totally meaningful by itself but it is always dependent on the context in which it is heard. According to this model, the sonic environment is not just a flow of acoustic energy or a constant transfer of signals but a system of exchange of information. Three aspects are essential for the operation of the system and the comprehension of it: components, context and mediation. The components of the system are three: *sound*, *listener* and *environment*. These components of the system are not studied individually, what is studied is the information which is

transferred in the system. The sonic information is processed by the individual listener who is not just a passive receiver but an active part of a dynamic system of information exchange. The second fundamental aspect of the system is the context. The communicational significance of sounds is highly dependent on its environmental, social and cultural context. We can understand how a sound functions only analysing it within and through its context. The third aspect is the mediating nature of the relationship. The communicational system is not a linear chain in which a sonic information travels from the environment to the listener who sends it back to the environment again, like a signal. But a system of related elements operating at different hierarchic levels. The sound mediates the information sent from the environment to the listener.

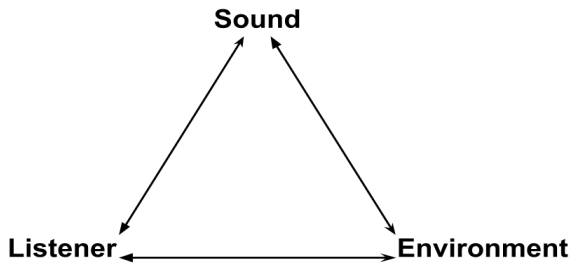

Figure 1 . In the Barry Truax's Acoustic Communication Model the sound mediates the information sent from the environment to the listener.

In a nutshell, the soundscape is a communication system which is functional for each component's presence in the environment, The characteristics of the soundscape are given by its perception which is always dependent on the listener, who decodes information according to the context and his own needs. This individually-based view is confirmed by the *eco-field hypothesis* (Farina 2005) which from a biosemiotic perspective defines the soundscape as the subject-specific configuration of the environment through which the listener is able to construct cognitive templates which relate particular space conformations with life functions (e.g. food, energy) (Farina 2005) (Farina 2012). The ecological function of the soundscape will be discussed more in details in the last section of the paper. For the moment it is enough to acknowledge that a specific evaluation of the environment, in our case as 'silence', does not depend only on the objective characteristics of it but mainly on the way in which it is perceived by the listener. According to this idea the cognitive processes which define the soundscape perception become the core of our investigation and this is going to be the topic of the following section.

III. - Perception and cognition

As reported in the previous section, the soundscape is not the collection of objective characteristics of the acoustic environment but its subjective perception by the listener in relation to the individual and contextual elements. From this perspective it becomes essential to understand how the human listener collects, elaborates and interprets environmental acoustic stimuli and according to which aspects the holistic perception and evaluation of the soundscape take place. Human beings conduct this complex set of functions through cognitive processes which allow the listener to integrate sensory data with information related to context. Over this section, we are going to analyse the main cognitive processes involved in soundscape perception in order to understand in which way their role is decisive in the perception of 'silence'. We subdivided these cognitive activities into attention and sensory organisation, categorization, expectation and emotional response.

A. Attention and states of listening

Attention is the first critical aspect which determines the evaluation of a soundscape. From a bio-acoustic point of view the way in which animal's attention works can be explained by the basic function of hearing environmental sounds. Sound is a warning signal for potential dangers, it is the first element to localise prey, it is the main tool for communicating and the one of the most important sources to create a mental image of the surrounding environment. It is reasonable to think that human no exception and that our attention developed according to these natural necessities. Among these functions, the most interesting for our research is related to the use of sound as a source to understand the environment.

Attention can be seen as a first mechanism of organization of the sound inputs that we perceive. The base of this mechanism consists of a gradual and dynamic process which forms auditory streams. This means that sounds are heard as coming from a source, a single source or multiple sources. The general rule is that the more interesting a sound is the longer attention will be and the more detailed the analysis of the sound will be. The interest related to a sound can be indicated with the concept of saliency (Botteldoorena 2009). The saliency of a sound is mainly determined by changes in time. intensity and spectro-temporal irregularities. The presence of contrasts on the frequency scale and intensity tends to increase the saliency of sounds. Attention is a combination of activation and inhibition-of-return and a winner-takes-all competition which produce different states of attention. (Botteldoorena 2009) These states are clearly summarised by Truax in levels of listening. Listening in search, listening in readiness, background listening (Truax 1984).

Listening in search is the most active attention state, it is a conscious search of the environment for cues. The focus is highly detailed and it allows the listener to select one sound excluding the others (cocktail party effect). *Listening in readiness* is the state in which the subject is ready to receive significant information but without a specific attention focus. The listener expects a certain auditory event while considering other sounds as familiar and as background. In this state of listening, even when a sound is unexpected the listener is ready to treat it as a new information and evaluate its potential significance. Moreover, when a minimum signal-to-noise allows separating a signal from any competing noise, the listener is able to detect patterns. During the attention state defined *background listening*, the sound usually remains in the background of the subject's attention, he/she is not listening for a particular event and its occurrence has no special or immediate significance to him/her. The listener is still aware of the sound and he/she able to memorise it for a medium period of time. It is not subliminal perception because it is not totally subconscious and it usually occurs dealing with expected and predictable sounds. During the state of background listening and with the presence of low-level constant sound signal it is possible to perceive and memorise a keynote, a constant tone of the sonic environment. The keynote becomes a characteristic element of the environment and it can be the ground on which all the other sounds are heard and it changes the perception of them.

In relation to our research, what is important about the modes of listening is the relation between attention, active functions and *eco-field* function (Farina 2014). In the state of listening in search, the active function of questing for cues activates contemporarily a sonic *eco-field* function. In states of listening in readiness or background listening, non-active functions could be coupled with sonic *eco-field* functions. Whatever the mode of listening is, the *eco-field* element is a constant in auditory perception. For instance, the activity of reading a book does not require an *eco-field* "connection" by itself, but environmental acoustic signals could be perceived independently of our will and suddenly attract the listener's attention. As it will be explained in the next passages, the relationship between sound signals and their influence on the level of attention is one of the most important factors which determine the evaluation of the whole soundscape, thus, also in the case of silence. In the following section, we will start to describe the processes which regulate the attentional state of the listener in relation to the organisation and analysis of environmental sounds.

B. Organisation of sensory perception

The conceptualization of acoustic experiences is a complex process which integrates physical descriptors of the acoustic phenomena and semantic values attributed to it, in order to elaborate a mental representation. The process seems to have as a main goal the source identification and it relies mainly on semantic evaluation (Dubois 2006). The stimuli are principally processed as part of a meaningful event while the physical parameters are treated as properties rather than an identifier of the source. It is important to remind that at this cognitive level important differences can be observed between expert and non-expert listener, the resolution of the categorization system is defined by the individual "training"(Dubois 2006).

The reference model related to the perceptual organisation of sounds is the Auditory Scene Analysis (ASA) (Bregman 2004). ASA consists in the process by which the auditory system separates the individual sounds in a natural-world environment. A natural sonic environment is usually a complex auditory scene composed by sounds which are usually interleaved and overlapped in different domains such as time, space and frequency. According to this model, the ear has access only to the single pressure wave that is the sum of the pressure waves coming from all the individual sound sources. The listener accomplishes a perceptual organisation of the scene decomposing the auditory stimuli and grouping them into *auditory streams* which are treated as individual auditory objects. This grouping activity relies mainly on the categorization of stimuli according to the sound source and it is accomplished through heuristic processes based on (bottom-up) analysis of acoustic aspects of sounds and on (top-down) knowledge-based activities. The most generic distinction between two cognitive categories of complex sound environments is between sound *events* and *amorphous* sounds. In the first case an individual sound can be distinguished then a specific event can be identified. We perceive an amorphous sound when individual sounds are not distinguishable within it then specific events can not be isolated. This class is often described as ambient or background noise.

Two different cognitive processes deal with these two categories of auditory stream (Dubois 2013) (Woodcock 2017). Both the categories can bring to a first qualitative evaluation of the noises. In case of sound events, because of their highly descriptive value, a first "guess" about the type of source can be done. Indeed, in combination with primitive (bottom-up) processes, a semantic evaluation based on experience, knowledge and context allows the listener to produce a mental representation materially delineated by an object-source and evaluated through its semantic value. In case of amorphous sounds instead, such a straightforward process is not possible because of the impossibility to detect and evaluate individual events. Instead, the judgment initially relies on primitive processes related to acoustic parameters such as low/high frequency or continuity/discontinuity of the signal.(Dubois 2013)(Woodcock 2017). This does not mean that the resulting mental representation will be a composition of physical elements. Indeed, even in this case, a semantic evaluation will still have the priority (Lafay 2015) (Dubois 2006). The acoustic parameters are evaluated according to contextual and individual factors. This means that the same physical parameter (i.e. intensity) can have a different value depending on the context. The auditory stimuli are processed as abstract sounds represented by physical characteristics whose meaning is given by contextual and individual aspects related to the listener.

It arises that already in the preliminary phase of organisation of sensory data a contextualization of the inputs is attempted. Even when physical characteristics of sounds are analysed, as in the case of amorphous sounds, this is done in function of an attempt of conceptualization of the sound sources. In summary from this last section we realized that the first phase of organisation-analysis of the components of the sonic environment seems to be guided mainly by top-down processes, which attempt to give a meaning to each sound. We have seen as different types of sound can be more easily conceptualised than others but it is still not clear in which way and according to which aspects the sounds become 'meaningful'. In the next section, we are going to describe the process of categorization and evaluation of the individual components of a complex auditory scene in order to understand in which way this affects the final evaluation of the whole soundscape.

C. Categorization

Different researches were conducted to investigate the categorization of inputs in complex auditory scenes and the soundscape as its holistic perception. Semantic methods (Woodcock 2017)(Dubois 2006) are used to connect linguistic, psychological and emotional aspects of auditory perception in order to study the soundscape as a cognitive-perceptual entity; semantic analysis distinguish three semantic levels: *sound sources*, referred to physical entities originated by single or multiple agents; *sound descriptors*, which are nouns, adjectives and phrases used to describe sounds; *soundscape descriptors*, concepts used to describe the emergent sound perceived as soundscape. It is not always well definable the semantic level of categorization but indicatively we are going to proceed from the categorization of sound sources toward the categorization of the overall soundscape.

Before going to describe the aspects according to which categories are formed we should say that a first attempt to form a mental model of sound components of the sonic environments occurs through similarity (Gygi 2007). Acoustic and event information of the current sounds can be perceived as similar to those related to sounds recalled from the long term auditory memory. The subject attempts to associate the current sound with previously categorised sounds. Woodcock (et al.) (Woodcock 2017) through a clustering analysis revealed a hierarchical structure with three top level categories. The first category is related to *human vocalizations* and it includes elements labeled as "intelligible voices", "sound by humans", "speech" or "human undistinguished voices". The second top level category is related to *background sounds* with a long temporal extent such as "background sounds", "harmonic sounds", "background noise" or "sound by alive creatures". The third category involves transient sounds, object labeled as "vehicle sounds", "movement speeding up", "traffic movement slowing down". These top-level clusters contain sub-clusters which are related to specifications of the top layer categories, such as harmonic or not harmonic continuous sounds, *transient sounds* that indicate actions, clear speech or non-salient transient sounds.

The research confirms the source identification as a primary cognitive tendency. But as said above the identification of the source depends on contextual and subjective variables. Whether it is an event or an amorphous sound the object is perceived as a meaningful entity (Dubois 2000). The first semantic form seems to be given by the movement or action that generates the noise. In order to realise the function of source, when it is possible movements and actions are associated with similar sources about which the listener has already experience. Movements and actions are conveyed by variations in different domains and interaction between elements from the same or different categories. Roma (et. al) (Roma 2010) gives three main examples of these: *temporal patterns,* which are complex events formed by repetitions of basic events, *compound events* described as the superposition of more than one type of basic event, and *hybrid events*, interaction between different materials. This is a more advanced reformulation of the traditional idea expressed by Vanderveer who asserted that interactions are perceived in the temporal domain, while objects determine the frequency domain. The semantic difference analysis in Kang (et. al) (Kang 2010) seems to confirm that the categorization of the contents in soundscapes is distributed according to three main domains that can be summarised in *function*, *space* and *time*. Specifically, the research identified four major factors that characterise the soundscape. The first factor is mainly associated with *relaxation*, including comfort-discomfort, quiet-noisy, pleasant-unpleasant, natural-artificial, like-dislike and gentle-harsh. The second factor is about *communication* and it refers to social-unsocial, meaningful-meaningless, calming-agitating or smooth-rough. The third factor is mainly associated with *spatiality* involving elements such as varied-simple, echoed-deadly and far-close- The fourth factor is mostly related to *dynamics*, including hard-soft and fast slow.

At this point, a general consideration can be done. The process of categorization and perception are strongly influenced by the semantic weight which characterises the sound, the presence of meaning related to it. It will be even clearer in the next section that the semantic weight of sounds is defined by the relevance of the events in relation to previous knowledge but also to social, contextual and subjective aspects. In some cases, specific sounds are able to act as *soundmarks* (Dubois 2000) (Lafay 2015) (Bruce 2009). This concept traditionally describes the most characteristics element of a soundscape but we would go further stressing evocative power related to it. The semantic weight associated to specific sounds can be so important to be not only easily associated to a certain categories but even to evoke more complex cognitive representation such as social contexts or emotional states.

D. Expectation and behavioural representation

Categorisation is an act which is usually associated with the highest level of cognitive functions, a process of an abstract nature. However. as we have shown a certain kind of categorisation is present not only from the beginning of the actual process of cognition but it actually influences the sensory perception, determining its organisation. The influence of previous knowledge and experience on soundscape perception takes the form of *expectation* (Bruce 2009). This notion is partially based on the concept of 'competence' defined by Chomsky in linguistics and re-interpreted by Truax in the study of soundscapes (Truax 1984). Truax describes the *soundscape competence* as the:

> *[...] tacit knowledge that people have about the structure of environmental sound, knowledge that manifests itself in behavior that interprets such sound and acts upon it [...]. Our lifelong exposure to environmental sound gives us a complex body of knowledge about how to recognize and interpret the structure of environmental sound in order to obtain information that we can use. Soundscape competence permits us to understand environmental sound as meaningful.*
> (Truax 1984)

This means that the evaluation of a sound environment is strongly dependent on the "meta-knowledge" about the context. From the perspective of Truax's communicational model (Truax 1984), this could be seen as the knowledge about the correct communication related to the current context. According to this idea, the way in which we perceive the soundscape structure, meant as the relationship between sound and its meaning, have been learnt and this learnt behaviour determines soundscape expectation. Expectation is a combination of interrelated factors which relate to the listener's experience of the space he/she is in. This experience is mainly constituted by cultural background and long-term environmental experience. Expectation derives from what the listener knows or deduces about the space intended as context, purpose, activities and users related to it but also about its acoustic structures. Indeed, the listener can experience two different situations: he/she can be in a space for the first time or he/she can be in a space in which he/she has been before. In the first case, in absence of direct information about the space, the expectation is determined by similarity (described above). The listener tries to match the soundscape he/she experiencing with similar soundscapes he/she experienced before in similar settings, applying the same criterion of judgment. In the second case, the judgment relies on "information" derived from direct experience. In both cases, the knowledge, whether obtained from direct experience or by similarity, constitutes the expectation of the listener which is going to define the first reaction to the sound.

The aspects involved in the expectation about the soundscape can be highly subjective and related to very personal dimensions such as emotive involvement of the listener and it has also be said that other sensory data about the space -especially visual elements- can be strongly determinant. It would not be very easy to make a list of all the possible individual aspects. However, Bruce (et. al) (Bruce 2009) identified an essential aspect of expectation with the behavioural component. Expectation takes the shape of a set of rules that the listener associates to a specific place. These rules are mainly related to activities, time of day, acceptable behaviour and users of the space. A good example is given by the Aarts's (et. al) research (Aarts 2003), which shows that an environment is able to automatically activate mental representations of normative behaviour influencing the reaction of individuals. Situational norms are not only individual rules but they are socially developed, they are accepted behaviour collectively valid. Thus it is clear that when the individual is in a place he/she has a specific representation of the appropriate behaviours in that situation, which are valid for himself/herself but they are also applied to the other users. The listener has constantly in mind a range of probable events that could happen in that situation, and this produces in a large part the expectation. Data collected through sound walks (Aarts 2003) shows that this aspect of expectation seems to be strictly related to the type of activity usually occurring, thus expected, in the space. At the same time, another aspect of expectation is indicated by Bruce (et. al) (Bruce 2009) as a constant, the 'expectation of controllability'. Perception seems to be influenced by the listener's feeling about how much control he/she has on the interaction with the soundscape, how much his/her presence/absence or action/inaction is able to influence the soundscape. In other words, this feeling can be seen as a representation of the hypothetical sonic effects of one's behaviour within the soundscape, for instance, the ability to remove a specific sound from the soundscape or the possibility to easily leave the current sonic environment. From the perspective of the Truax's Communication model, the potential or effective influence of the subject with the sonic environment is an essential aspect of the configuration of the soundscape. Truax states that the subject according to the quality of the feedback received after an acoustic interaction perceives the environment as *lo-fi* or *hi-fi* (Truax 1984). In a lo-fi environment, the listener finds difficult to detect individual signals and the subject's interaction has a weak effect on the overall soundscape. In this situation, the listener has the feeling to be cut-off from the sonic environment. On the other hand, in a hi-fi environment, all sounds can be heard clearly, with details and spatial orientation. The listener can easily hear the effect of his/her acoustic intervention, the interaction with the environment is effective and because of it, the subject could feel involved in the soundscape.

To sum up, acquired competence about spaces and social-contextual factors define a behavioural expectation related to users and components of the soundscape. Moreover, the expectation is also determined by how subjects can interact with the environment. Thus, the listener's perception and

reaction are defined by the conformity between current soundscape and expected events. Appraisal responses derived from expectation can be summarised in imagination, tension, prediction, reaction and appraisal. It arises that the two main aspects interdependent with expectation are attention, that we have already treated above, and emotional response.

E. Emotional response

The expectation has an important role in the evaluation of soundscape, especially it contributes determining the emotional response in the listener. Generally, we can say that a negative emotional response occurs when the soundscape is not conformed to the subject's perceived sense of normality or it contrasts with the current personal feelings. On the contrary, a positive response is caused by the harmony between soundscape and subject's representation of the location. Because of the predominance of high-level cognition in soundscape perception, emotional responses were mainly studied through semantic and linguistic analysis. Beyond a general distinction between positive or negative judgment about soundscapes, it is important to understand on which factors the listener's emotional reaction is based.

The emotive response is determined by the emotions evoked by the composition of the soundscape: informational properties related to the sound sources and their activity over space and time. Synthesising the Axelsson's (Axelsson 2010) and Davies's (Davies 2013) works we could say that the listener is mainly affected by two dimensions: how arousing the environment is and the perceived pleasantness of it. *Arousal* is determined by two factors, the levels of calmness and vibrancy. Calmness is related to how calming, comforting, intrusive an environment is. Vibrancy is defined by the eventfulness expressed by the environment, how rich of events it is and how variations are distributed. The relationship between events is perceived in relation to the level of dissonance/harmony and to the amounts of variation in different domains such as time or frequency. The Cacophony/hubbub of soundscapes and their perception as constant/temporal sonic environments stimulate to varying degrees the sensitive perception and it has a direct effect on the listener's attention, producing in the subject a first emotional response which is going to be integrated by the pleasantness/unpleasantness of the listening experience.

As we have said, besides arousal the other fundamental aspect of emotional response is *pleasantness* (Davies 2013). different combinations of the aspects related to arousal can produce a pleasant or unpleasant effect in the listener. Davies reports that cacophony is usually referred to a soundscape which is perceived as a negative mix of sounds and associated with a negative listening experience. On the other hand, Hubbub is perceived as a positive mix of sounds and associated with a negative listening experience The distinction between constant and temporal soundscapes has a less defined correspondence with pleasantness. A constant unchanging soundscape can be perceived negatively if it is mainly composed of a monotonous sound which masks everything else or positively if the main sound comes from a relaxing waterfall. In the same way, a temporal soundscape composed by frequent car horns will have a less positive affection rather than a bird concert at the park.

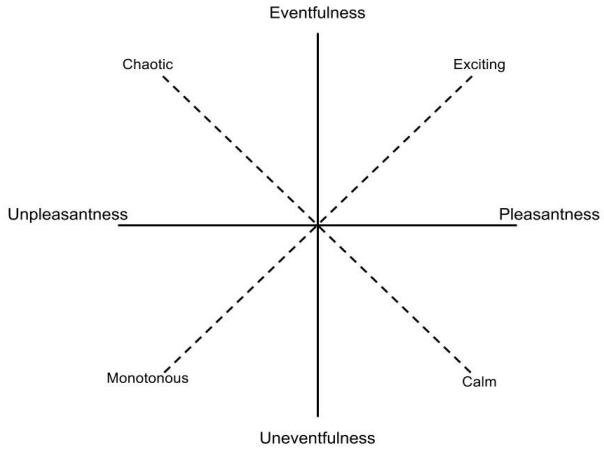

Figure 2 - Pleasantness and eventfulness aggregate the soundscape attribute in a circumplex pattern. An exciting soundscape is the combination of pleasant and eventful, a calm soundscape is the result of the combination of a pleasant and uneventful condition. A calm soundscape would be pleasant and uneventful, but a chaotic soundscape would be unpleasant and eventful, and a monotonous soundscape would be the result of unpleasant and uneventful. (Farina 2014)

From Axelsson (Axelsson 2010) and Davies (Davies 2013), we realise that a combination of aspects related to the order and dynamics of the components in different dimensions of the sonic environment have a direct effect on the listener's emotional response. We think that this model has not to be seen as a well defined and one-way relationship but only as an indication of general correlations between certain characteristics of the soundscape and emotional reactions. Indeed, we think that the correlation is also valid in the opposite direction, emotions can influence the perception of the dynamics and order in the soundscape composition. This aspect leads us to think that the emotional response related to a specific soundscape cannot be fully explained by the model that we just described. In order to have a complete idea about the way in which the listener is emotionally affected by a soundscape, we should describe how the correlations highlighted by the arousal/pleasantness model are actually strongly influenced by the categorization and evaluation of the sound sources described in the previous section.

As we mentioned above in acoustic ecology the components of the sonic environment are divided into three macro-categories according to the type of source: biophony, geophony and anthrophony. This categorization found confirmation (Axelsson 2010) in semantic analysis about soundscape perception which also reported a clear correlation between certain source-domains and pleasantness of the listening experience. Different studies (Axelsson 2010) indicate that people tend to perceive natural sounds as positive components. Natural sounds are considered those which are produced by

natural sources belonging to the biophony and geophony domains. Birds singing and moving water are common examples of it. On the other hand, technological sounds and in general sounds produced by human activity are more often perceived as negative components. A clear example of it is traffic noise. Despite this general tendency, different exceptions arose. Several soundscapes with dominant natural sounds but also containing low-level noise in the background were perceived as less pleasant. It was noticed (Axelsson 2010)that regardless the intensity of technological sounds compared to the rest of the components, the only perception of the character of technological sounds causes a negative appraisal about the soundscape. Anthrophony does not involve only technological sounds but also all the sounds produced directly from human beings such as speech. Human sounds increase significantly the perceived eventfulness of a sonic environment and are perceived as arousing components of soundscapes. The arousal related to human sound can produce pleasurable or unpleasurable emotional responses depending on the aspects which determine the pleasantness that we mentioned below. The correlation between human sounds and arousal seems to be related to one of the arguments in the section about expectation. The informational weight of human sounds have a strong effect on the perception of the sonic environment (Section III-B, III-C). Human sounds are an important mean by which the subject knows about the activities of the other human beings. Human activities are the elements with the highest probability of interaction with the subject's life and they have a high potential influence on the individual's behaviour. This could explain the strong affection and involvement of the listener in relation to human sounds compared to the other components of the soundscape.

IV. - Discussion

The object of our study is the experiential nature of silence. As we mentioned at the beginning of the paper physical and acoustical definitions of silence refer to it in the negative, as the absence of sound or the impossibility to perceive it. According to this view, silence is an abstract concept that can be thought, theoretically described but it cannot be directly studied because of the unavailability in nature. This means that the reduction of silence to one or more acoustic characteristics of sound or to a specific measurable acoustic output of a sound source is a dead-end street which collides with the evidence of human experience of silence. For this reason, in this paper, a different way is proposed. We consider silence as an auditory representation created by the listener in a specific space and time, it is the experiential result of the auditory perception of the environment in which the subjects is. The perception of the sonic environment is studied by acoustic ecology, a multidisciplinary field in which soundscape perception is studied for its ecological value.

The human being similarly to other species lives in a communicational system in which he acquires information about the environment collecting and interpreting sound outputs produced by its components (sections II-A, II-B, II-C). The totality of sounds and their interaction is perceived by humans as an individual emerging entity, the soundscape. From this view, the soundscape is the perceptual interface through which humans have a bidirectional communicational interaction with the environment. We consider the perception of soundscape an appropriate dimension to understand what does "perceiving silence" means. We think that experiencing silence can be seen as perceiving a soundscape as "silence". According to this view, It becomes essential to understand how human being perceives the soundscape: which cognitive processes are involved and in the presence of which characteristics a soundscape is perceived as silence.

A. Recordings

We are going to integrate our investigation with a set of field recordings collected by the *MoMA* museum in New York in the project *Share your silence* (*MoMA* 2014) (Appendix A). To celebrate the John Cage's famous work 4'33″ the museum invited people from all over the world to record their own silence - The call said: record the silence around you!-. The recordings were selected and collected in a global field recording map (*https://www.moma.org/share_your_silence*). We think that those examples of 'subjective silence' can be a useful reference to integrate into our discussion. We selected 20 recordings (Appendix B) according to the following method: it was our intention to distribute the choice of the audio files as much as possible equally over the global territory. However, the participation to the project involved almost exclusively the European and American continents. We randomly selected recordings with the following proportions: 3 from Southern Europe, 3 from Central Europe, 3 from Northern Europe, 1 from Great Britain, 7 from North America, 2 from South America and 1 from Oceania (i.e. Hawaii, formerly U.S.A.). We considered the field recordings as examples of soundscapes subjectively perceived as 'silence'. An analysis of the components was made through a form inspired by the information and methods reported in the first section of the paper about the categorization of complex auditory scenes.

The aim of the analysis is to observe which categories of sound sources can be recognised in the selected recordings and in which layer of listening they are. The matrix of analysis (Appendix B) is designed according to the description of the processes of organisation and classification of sounds mentioned in the first sections of the paper. The components are firstly classified according to the general distinction anthrophony/biophony/geophony (Section II-B) into three horizontal rows. Within these three categories, a more specific classification is done using the categorization of sound sources used in Woodcock's and Dubois's researches (Woodcock 2017) (Dubois 2006). The choice of which categories has to be

included as slots was done through a preliminary listening, in order to do not insert categories which never arise. However, a blank space was left in order to add eventual additional sounds which could arise during the proper analysis. Into two vertical columns, the two main levels of listening mentioned in section III-A and III-B, background-foreground are distinguished. A third column is reserved for soundmarks. We included in this space eventual clearly recognisable sounds which regardless the layer of listening in which they are, they can be considered highly distinctive and primary in the soundscape. This is clearly a subjective decision but it was made considering mainly sounds which were mentioned as potential soundmarks in Lafay's work (Lafay 2015).

B. Attention and saliency

Attention is the first crucial aspect in the perception and categorization of the soundscape. (Section III-A) We want to understand to what extent and in which terms attention can affect the perception of a soundscape as "silence". The state of attention determines the resolution of the auditory analysis of the listener, a high level of attention is characterised by high resolution and richness of details which requires an active psychophysical state of the subject. Using the mentioned Truax's distinction (Section III-A), *listening in search* and *listening in readiness* are the states of attention which require the higher level of activity and they are characterised by the presence of a target. In the first mode a target sound is well defined and the listener seeks it out filtering out other eventual inputs from the focus of the attention; in the latter mode the target sound is undefined and the level of focus dedicated to each input depends on the potential relevance of the sound (Section III-A – III-B). The common aspect in these two modes of listening is the mechanism of exclusion of irrelevant sounds, dividing the inputs into layers: background and foreground. In the absence of the target, all the components of the soundscape are heard as background sounds and they do not require an active "intervention" of the listener. The target sound becomes the 'figure' on the 'ground'. From the perspective of a communicational system, this is compatible with the conception of silence as the ground on which sound expressions take places, allowing the listener to differentiate meaningful from meaningless sounds (Miller 1993). The description of silence as the white canvas which allows all the other sounds to emerge is undoubtedly a first good indication about the nature of it. However, accepting entirely this view would lead to say that all the soundscapes in which the background layer is richer than the foreground layer generally perceived as silence, or even further silence is experienced when a soundscape presents only a background layer without additional sounds standing out from it. This would also mean that the third state of attention named by Truax as '*background listening* mode' is a general guarantee of experiencing silence. This would be a partial answer to our question and example recordings (Appendix A) (Appendix B) indicate that soundscapes entirely composed of background layers are rather rare and even the most silent environment presents foreground sounds without necessarily changing its overall perception.

To summarize, the low saliency of a soundscape seems to be an important factor in the perception of silence. The experience of silence is more likely in soundscapes which do not require a significant attentional activity for the listener and the background listening mode is certainly the state of attention which reflects this type of situation. However, foreground inputs are not a discriminating aspect per se, provided that those sounds do not produce a significant increase of the attentional state, or they involve the listener's attention in such a way that they allow or do not impede the perception of silence.

C. Semantic value and categorization

At this point, it is important to understand in which terms background and foreground sounds stimulate the attention and what the saliency of a soundscape depends on. In other words, in which terms the low saliency of a soundscape contributes to the perception of silence. In the researches reported in the previous sections of this paper(sections III-C, III-D) the semantic value associated with sounds arose as the essential aspect in the categorization and emotional response related to the soundscape. The 'extraction' of meaning from sounds is accomplished through a complex activity of categorisation which starts with the organization of the inputs which relies in the first place on the possibility to isolate 'sound events' or group inputs that can not be individually distinguished as 'amorphous sounds'. This distinction is actually a preliminary categorization of the inputs accomplished according to the potential semantic weight of the sounds. Indeed, 'amorphous' sounds tend to have less semantic content because of the difficulty to identify their sound source, for this reason they are often classified as background sounds and they generally do not increase the saliency of soundscapes On the other hand, 'events' are more easily associable with their sound sources and the listener is able to categorize them according to their meaning. Sound events can be at background or foreground level and the involvement that they produce depends in the first place on their semantic categorization. If a low level of attentional activation is not enough by itself to produce the experience of silence, other elements must be searched in the quality of the involvement of the subject, whose perceptual representation of the soundscape depends in the first place on the categorization of inputs.

We realised that the attention required by the soundscape is not the only element which contributes to perceive silence. Background/'amorphous' sounds but mainly sound 'events' produce a certain involvement of the listener according to their semantic value. We think that in addition to the low saliency the experience of silence depends in the first place on the categorization of the inputs and the consequent effects in the listener. We described those effects considering two interdependent factors, the emotional response related to the classification and evaluation of sound sources and the expectation developed by the subject in a certain environment.

In the following section, we are going to discuss in which way those two elements are directly related to the perception of silence.

D. Emotional response

We identified the attentional activation and the categorization of the components of the soundscape as two essential aspects in determining the experience of silence, which seems to be produced by what we generally defined as the 'effect in the listeners'. Most of these effects can be studied through the analysis of the emotional response of the listener, meant as the psychophysical reaction which determines the qualitative evaluation of the soundscape. The emotional response depends mainly on two elements that we are now going to describe in the following two sections:

- evaluation of the soundscape components based on semantic categorization of auditory inputs and their distribution and variation in the soundscape.
- Expectation

1) Emotional response and sources evaluation

The mental representation of the soundscape can be seen as the holistic categorization emerging from the categorization of the individual components. The categorization of the inputs seems to follow the organisation by layers instructed by the auditory attention but integrated by higher level cognitive activities. Indeed, we mentioned how the sounds of an environment are hierarchically distinguished by the character of the sound but also according to the nature of the sound sources. The three main categories are background sounds, human vocalizations and transient sounds (Section III-C). While the content of the 'human vocalization' category is self-explanatory, it must be said that the other two macro-categories depend mainly on the variation of the sounds in the time domain and in the prevalence of them in relation to the other components. Temporally extended and not very intense sounds are generally considered as background, brief and leading sounds are heard as transient sounds (sections III-B - III-C). It follows a deeper categorization mainly focused on the identification of the source. Researches showed that specific categories of sounds affect in different ways the two main dimensions of the emotional response: the arousal and the pleasantness associated to the soundscape. Clear correlations between certain source-categories and pleasantness of the listening experience. (Section III-E)

We would tend to say that a silent soundscape is generally not associated with an unpleasant experience. This is confirmed by the analysis of the recordings in which none of the soundscapes out of 20 have audible 'human activities' on the foreground layer. This means that according to our examples silence is not characterised by those elements such as 'technological sounds' or 'traffic noise' generally perceived as 'unpleasant-annoying'. The unpleasant effect of these 'negative' elements seems significantly reduced when their sounds are heard in the background. 7 out of 20 recordings have a low intensity 'traffic noise' in the background. and other 7 have a constant undefined amorphous sound in the distance. The distance of the source and the consequent reduction of the intensity seems to neutralise the negative effect of unpleasant components.

It is interesting to notice that the 5 out of the 7 recordings with audible 'traffic noise' in the background are characterized by the presence of distinguishable 'bird calls': 2 in the background (R3, R18), 1 in the foreground (R11), 2 in both background and foreground (R20, R8). Besides, the 2 out of 7 recording with 'traffic noise' and without 'bird calls' (R9, R19) can be considered soundscapes definitely poor of elements and with a low intensity background. This observation suggests that the positive effect of pleasant elements could be more influent than the unpleasant effect in the perception of silence. Indeed the researches mentioned in the first section tell us that natural sounds (biophony) tend to have a pleasant effect on the listener. Furthermore, some specific categories of sound can have the function of soundmarks. We used this term to describe the evocative power of certain components and 'bird call' is a good example of that. Indeed, 10 out of 20 recordings are characterised by the presence of 'birds call' and in 5 of them this sound can be considered the main component of the soundscape, R20 is an extreme example of that. It is clear that 'bird call' is a soundmark often associated with the experience of silence for its positive semantic (and symbolic) value.

Silence is not compatible with components of the soundscape which are perceived as unpleasant if their presence is heard in the foreground. On the other hand, the experience of silence is not impeded if the unpleasant sounds are only heard in the background. More important is the positive effect of pleasant components which are able to define the perception of the soundscape more than the unpleasant elements. We can say that silence can be associated with a pleasant perception and specific soundmarks are able to evoke semantically and emotionally the experience of silence.

Pleasantness associated to the components is only partially responsible for the evaluation of the soundscape which is also strongly influenced by another dimension of the emotional response, the arousal (Section III-E). A soundscape can be more or less arousing in respect of the number of sound events perceived by the listener, the dynamics of each event in different domains such as time and space, and the variation in those domains between different events. For instance, an eventful soundscape necessarily causes an increase of the mental activity required to process the high amount of information related to the sound sources. The arousal can increase even further if the variations of the sounds in time and space are frequent and inharmonic. A highly arousing soundscape is generally perceived as 'chaotic' if associated with unpleasant components and as 'exciting' if associated with pleasant components. We would exclude that those scenarios can be emotional effects of a silent soundscape.

Moreover, it must be said that the emotional arousal has necessarily direct consequences in terms of attention. As we mentioned before a high psychophysical involvement of the listener leads to an increase of the state of attention and this is usually not associable to the perception of silence. In case of not particularly arousing environments, the presence of pleasant or unpleasant components can cause in the listener a sense of calmness or monotony. This aspect depends mainly on subjective evaluation related to personal factors such as experience, age or taste. For instance, a teenager and an aged person could respectively perceive a quiet country environment as 'boring' and 'relaxing'. However, we think that there is no reason to necessarily associate silence with one of the two emotional scenarios, they can be both compatible with the perception of a soundscape as 'silence'.

Highly arousing soundscapes are perceived by the listener as chaotic or exciting (depending on the pleasantness) which are not emotional responses which can be associated with the experience of silence. On the contrary, silence is associated with soundscapes which do not cause a high level of arousal in the listener.

2) Expectation

As we described so far, the holistic evaluation of the soundscape is significantly determined by the emotional response which is described in terms of pleasantness and arousal and it can be considered as the effects of an evaluation of the components of the soundscape in terms of function, space and time (sections III-C, III-D). Relying on higher cognitive faculties the human listener is able to increase the ecological sense of this evaluation integrating it with contextual information based on knowledge and experience. We said before that the ecological value of the soundscape is lent by a bidirectional communicative interaction between the subject and the other components of the environment (sections II-B, II-C), this means that the mental representation of the environment involves not only the evaluation of the components but also a representation of their interaction with the subject. Indeed, through the information related to the typical components and activities of a certain environment, the subject creates a representation of the appropriate behaviour and interaction between the components in that specific space and time. This socio-behavioural representation takes the shape of expectation (Section III-D) and the concordance between it and the events perceived by the subject defines his reaction and the consequent evaluation of the soundscape. Therefore, we can say that certain elements, sources and events, communicate to the listener the characteristics of the context which requires a certain behaviour and interaction of the subject. This socio-behavioural template defines the sense of involvement of the listener which has effects in terms of attention and arousal.

For a human listener, the social dimension is essentially 'human' and most of the information related to the context are extracted from human sounds. From this perspective, anthrophony has certainly a critical relevance. This finds confirmation in the hierarchical organisation of sound reported above in which one layer is dedicated to 'human sounds' (human vocalization) (Section III-C, III-D). Moreover, we know that human sounds increase significantly the perceived eventfulness of a sonic environment and are perceived as arousing components of soundscape (Section III-C, III-E). In an environment rich with human sounds the sense of involvement of the subject is generally sustained, this requires a constant mental activity to process very communicative sounds and the attention is constantly stimulated by 'relevant' inputs. Those aspects lead us to hypothesise that a significant presence of human sounds could reduce the possibility to perceive a soundscape as 'silence'. This is confirmed by the field recordings: 0 out of 20 soundscapes submitted have 'human vocalization' among the components, neither in the background nor in the foreground, only 1 recording (R11) has a quick transient speech sound for few seconds. In the analysis, we also checked the presence of other types of human sounds indicating them as 'traffic noise' and 'human activities'. The latter includes any sound evidently produced by human beings ('technological sounds', 'construction sounds', etc.). As mentioned before, only 7 out of 20 recordings have some 'traffic noise' among the components and in all the 7 those sounds are in the background level. None of the 20 soundscapes has 'human activities' diverse from 'traffic noise' in the background and none in the foreground.

To sum up, researches consulted and analysis of the recordings suggest that sounds produced by humans, especially vocalizations, for their high communicative value tend to arouse the listener and stimulate the level of attention. Anthrophony is the portion of soundscape from which the subject extracts most of the information that uses to create a representation of the appropriate behaviour and the possible events in the environment.The high level of psychophysical 'involvement' required by an environment rich in human sounds seems to reduce the possibility to perceive a soundscape as 'silence'.

As we said, the listener develops an expectation about the environment consisting of a range of probable events in the current context and a range of normative behaviour. Every event or behaviour which is not in compliance with the expectation causes a reaction in the listener in terms of attention, and depending on the subjective evaluation it produces a different emotional response. The nature of the reaction is not easily verifiable and we

Despite this, we can conclude that unexpected events increase the level of attention, requires to update the evaluation about the soundscape determining an emotional reaction. Therefore, the occurrence of unexpected sounds decreases the perceived silence of the environment.

In the section related to expectation, we mentioned another behavioural aspect which contributes to the evaluation of the soundscape. The perception of the environment is influenced by the listener's feeling about how much control he/she has on the soundscape, how much his/her behaviour is able to influence the sonic environment. The auditory perception of the sounds produced by one's own behaviour is possible when they are not masked by the other components of the

soundscape and this is a typical characteristic of a hi-fi environment. It is reasonable to think that a silent place is likely perceived as a hi-fi environment. Thus, we can hypothesise that the presence of this element can lead the listener to consider an environment as 'silent'.

This hypothesis is confirmed by the listening of the field recordings. Indeed, in 12 of the 20 soundscapes was possible to hear the sounds ('1st person noise') produced presumably by the person who was making the recording (R3, R4, R6, R7, R9, R10, R11, R12, R13, R15, R17, R19). We can not say with certainty that the same sounds were perceived in the same way by the listener but this remains a good experiential indication in agreement with our hypothesis.

In summary, it is reasonable to think that a hi-fi environment and the fact that the listener is able to perceive the sounds produced by himself/herself in addition to other variables described so far can significantly contribute to perceive the environment as 'silence'.

V. Comment

A. - Ecological value of silence

In this last section, we want to summarise the information collected to this point attempting to propose an interpretation of silence according to its ecological value.

The relationship that the human being as a living organism has with the environment can be described as the constant activity to acquire resources (Farina 2012). The term 'resource' can be applied to every natural or man-made, material or immaterial element which after having been consumed regenerates itself by an independent mechanism. Resources can be in form of matter (e.g. proteins) energy (e.g. light), information (e.g.rules, behavioural conditions), meaning (sign processes) and culture (established knowledge). According to their importance in relation to the organism's life resources can be distinguished into: necessary, optional and unnecessary. Since resources are heterogeneously distributed in time and space every organism develops perceptual and cognitive mechanisms of individuation in order to reduce the energetic cost necessary for their localisation (Farina 2012). Resources are characterised by regular features. These regularities can be directly related to the resources (chemical, morphological) or expressed by other organisms (behavioural). In this way, it emerges a relationship between organisms and resources characterised by a reciprocal influence and exchange of information. Human beings are able to track the resources distributed in the environment by genetic and cultural mechanisms, extracting information related to their availability in the surrounding. The human being (animals) for each need produces-activates a cognitive template (Farina 2012) (Farina 2005) which consists in a spatial configuration of the surrounding through which the subject is able to interpret the environment in order to have access to the resources, the *eco-field*. From this point of view, the soundscape can be considered a sonic *eco-field* represented by sonic energy instead of physical objects distributed in the space. From a cognitive perspective the soundscape is the semiotic interface in which environmental sonic inputs become signs related to the distribution of resources or immaterial resources themselves.

We propose to see silence as a perceived configuration of the environment with a semiotic role in terms of tracking of the resources, with an ecological and adaptive function. Following this way we could explain why certain conditions of the soundscape prevent from perceiving silence. In the previous section, it arose how the experience of silence is not compatible with too active states of attention which is generally required because of the high semantic weight and complexity of the information or because of an emotional response characterised by unpleasantness and arousal. Arousing and unpleasant soundscapes are generally associated with noisy and chaotic environments. Disorder and noise can reduce the effectiveness of the resource tracking thus requiring a major psychophysical energy. In other words, we reported how different components of the soundscape require a different amount of mental activity according to the meaning associated with each category of sound source.

In a communicative relationship between organisms and resources an ecological competition between species, groups or individuals can arise (Farina 2005). The competition can arise in relation to resources which are considered 'important' for both the groups and especially when these resources are tracked using a similar mechanism of meaning. From this point of view, the high psychophysical activation caused by the presence of human sounds in the foreground (Section III-E), could lead us to think that the presence of other "active" human subjects around the listener could trigger an ecological competition for certain resources. We do not have elements for a more accurate description of them but it is reasonable to think that between human individuals the competition is rarely for necessary resources in terms of survival but more likely for immaterial resources related to personal well-being. The different relevance of background and foreground sounds can be seen as a confirmation of this view. Indeed human sounds in the background are less relevant and affect on a lesser scale the listener than foreground sounds, which instead are generally closer to the subject and then potentially more involved in the competition. Along the same line, the overlap between necessary-important resources for a human subject and another species is certainly less likely and sounds produced by animals (e.g. birds) do not often interfere with other signs of sources, do not making the humans resources-seeking activity more demanding. On the contrary, they can result as soundmarks of cognitive templates related to environments in which sources tracking is relatively easy, such as hi-fi or even silent environments.

From a similar perspective, Tim Mullet, in his research *Silence in Kenai's soundscape* (Mullet 2014) hypothesises that -Natural silence could also represent a time period when risks to wildlife are reduced. [...] It seems probable that the spectrum

of sound perceived by an organism as silence may provide acoustic information that says "All is calm: there is nothing to worry about."-. Mullet refers in particular to winter, a season characterised by low biological and animal activity, he recorded and analysed long time periods and areas that had no sound, not even wind - the complete absence of biophony, anthrophony, and geophony. In other words, silence. But not true silence; not the silence created in a sound chamber. It was the silence of nature.- In other situations, silence could communicate not only a low level of activity in the environment and ecological competition with a reduced energy cost in the source-tracking mechanisms but it could also be the sonic output of an environment poor of sources or signs of them. It is clear another time that the evaluation of a silent soundscape can assume a positive or negative value depending on individual and contextual aspects.

B. Conclusions

The aim of this paper is to propose a definition of 'silence' which involves perceptual-cognitive elements considered as common in the experience of silence and a possible ecological explanation of that.

In the first place, we investigated the perceptual conditions that a soundscape generally has when is experience as 'silence'. We argue (Section IV-B) that a silent soundscape does not require a highly active state of attention. A sustained level of the attention or the frequent activation of it tend to prevent the experience of silence. On the contrary, silence is associated with a soundscape which does not cause or require a significant psychophysical activation. The attentive state is modulated by the emotional response that the soundscape has on the subject. In this case too, we proceeded in the negative excluding those cases which are not associated with silence and prevent the experience of it. Silence is unlikely the perceptual result of highly arousing or eventful environments (Section IV-D), even if associated with a pleasant experience. Indeed, a positive response is compatible with the perception of silence but is not a necessary element. An environment can be perceived as silent even with a negative evaluation as in the case of a 'boring' soundscape. We conclude that a silent environment is usually associated with neutral or positive emotional responses with a low arousing affection. Low activeness of attention and low emotionally arousing affection give us the idea of a psychophysical state in which a limited use of mental and physical energy is required for the process of conscious/unconscious perceptual evaluation of the environment. Elements and events which provoke a stressful reaction or require an increase of the subject's psychophysical activation arise as incompatible with the experience of silence.

We have identified the semantic categorization of the soundscape and its components as the most important element which determines the subject's state just described (sections IV-C, IV-D). After showing the general semantic-emotional value of different categories of components and their influence according to the closeness to the listener and contextual variables we inferred that the categorization and assignment of meaning to sound sources and to the whole soundscape -and consequently the psychophysical-emotional reactions in the listener- are mainly driven by the evaluation of two aspects: the level of ecological competition associated with the components which are hearable in the environment and the ease of distinction, identification and localization of sound sources as potential resources. We interpreted these aspects as part of an ecological-adaptive function (Farina 2005) (Farina 2012) which consists in developing and activating cognitive mechanisms aimed to reduce as much as possible the energy cost needed for tracking and collecting resources. These mechanisms are described as cognitive templates (eco-fields) through which the listener interprets the environment in order to mentally represent a configuration of the space in which localisation of resources is facilitated.

In our view, 'silence' is an experience which arises from a correspondence between the perceived sonic environment and a learned cognitive template which has the function of resource tracking in the surrounding. This leads us to hypothesise that human beings have innate and learned cognitive templates of 'silence'. We think that these cognitive templates indicate optimal environmental conditions for the ecological-adaptive activity of resource-seeking. From this perspective 'silence' is the experience related to an optimal condition of the acoustic environment in which the activity of resource-tracking can be accomplished with a low energy cost as a result of the low difficulty to distinguish, organise and categorize sounds allowed by a hi-fi soundscape and a low level of ecological competition with other species, groups or individuals. Following this way, the subjective nature of silence mentioned at the beginning of the paper depends mainly on the diversity of individual needs which determines the variable importance assigned to different resources by each individual.

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Appendix

A. MoMA: Share Your Silence

Original project call:
"John Cage's 4'33" is a composition four minutes and thirty-three seconds in length, during which the performer—or performers—does not play a note. Often described as Cage's "silent" piece, 4'33" was in fact meant to shift attention away from the performer, to the audience itself, and to the richness and variety of ambient sound. Reflecting years later on the 1952 debut performance, Cage wrote: "What they thought was silence, because they didn't know how to listen, was full of accidental sounds."

Use your mobile device to record the "silence" around you. Visit this web site to submit your recordings to MoMA's SoundCloud dropbox. Indicate where you recorded it in the description field. Selected recordings will be added to this sound map."

Files have been considered not usable and excluded in the following cases:
Too low quality of the file.
File longer than 10 min.
Intentionally composed content.

Audio files: **https://mega.nz/#F!BzgOzSaI**
Password: **!0l9jSYD3jWbnLulRht1zDQ**

B. File analysis

File name	Original title	Location	Duration
R1	Wind	Portugal	2.17
R2	Any given morning at the La Palma [...]	Spain	1.43
R3	No hay Silencio en mi barrio [...]	Spain	1.13
R4	Me with the silence in your home [...]	Sweden	4.33
R5	Silence in Reykjavik	Islands	0.32
R6	Silence at Dalarna University [...]	Sweden	2.05
R7	Nouvel enregistrement4-33	France	4.33
R8	Fontenay Aux Roses	France	0.22
R9	Entrecom, Villa de Guelma [...]	France	1.00
R10	Librarysilence	UK	1.06
R11	4'33_ Jecca for John Cage [...]	USA	4.33
R12	Acreage Library Silence[...]	USA	6.10
R13	Calais, VT 8 a.m., February[...]	USA	2.02
R14	Daytime-Cedar-Bayou-Baytown-Texas-[...]	USA	1.00
R15	Mexico City, 10/02/2014	Mexico	2.22
R16	cdia de noche	Mexico	2.00
R17	Surroundings	Mexico	1.00
R18	Early Morning. Londrina, Brazil.	Brazil	1.05
R19	High school class: multiple choice	Hawaii	2.28
R20	Wild parrots during sunset [...]	Brazil	1.00

1

		FOREGROUND		BACKGROUNG		SOUNDMARKS
ANTHRO	n	1st person noise	n	Traffic noise	n	x
		Human activities	n	Undefined	n	
		Vocalizations	n	Vocalizations	n	
BIO	y	y				birds
GEO	y	Wind y		Wind		wind
				rain		

2

		FOREGROUND		BACKGROUNG		SOUNDMARKS
ANTHRO	n	1st person noise	n	Traffic noise	n	x
		Human activities	n	Undefined	n	
		Vocalizations	n	Vocalizations	n	
BIO	y	birds y		birds y dogs y		birds
GEO	y	Wind		Wind y		x
				undefined y		

3

		FOREGROUND		BACKGROUNG		SOUNDMARKS
ANTHRO	y	1st person noise	y	Traffic noise	y	x
		Human activities	n	Undefined	n	
		Vocalizations	n	Vocalizations	n	
BIO	y	n		birds y		x
GEO	n	Wind n		Wind n		x

4

		FOREGROUND		BACKGROUNG		SOUNDMARKS
ANTHRO	y	1st person noise	y	Traffic noise	n	x
		Human activities	n	Undefined	n	
		Vocalizations	n	Vocalizations	n	
BIO		n		n		x
GEO		Wind n		Wind n		x

5

		FOREGROUND		BACKGROUNG		SOUNDMARKS
ANTHRO	y	1st person noise	n	Traffic noise	n	bells
		Human activities	n	Undefined bells	y	
		Vocalizations	n	Vocalizations	n	
BIO	n	n		n		x
GEO	n	Wind n		Wind n		x

6

		FOREGROUND		BACKGROUNG		SOUNDMARKS
ANTHRO	y	1st person noise	y	Traffic noise	n	x
		Human activities	n	Undefined	y	
		Vocalizations	n	Vocalizations	n	
BIO	n	n		n		x
GEO	n	Wind n		Wind n		x

7

		FOREGROUND		BACKGROUNG		SOUNDMARKS
ANTHRO	y	1st person noise	y	Traffic noise	n	x
		Human activities	n	Undefined	y	
		Vocalizations	n	Vocalizations	n	
BIO	n	n		n		x
GEO	n	Wind n		Wind n		x

8

		FOREGROUND		BACKGROUNG		SOUNDMARKS
ANTHRO	y	1st person noise	n	Traffic noise	y	x
		Human activities	n	Undefined	n	
		Vocalizations	n	Vocalizations	y	
BIO	y	birds y		birds y		birds
GEO	n	Wind n		Wind n		x

9

		FOREGROUND		BACKGROUNG		SOUNDMARKS
ANTHRO	y	1st person noise	y	Traffic noise	y	x
		Human activities	n	Undefined	n	
		Vocalizations	n	Vocalizations	n	
BIO	n	n		n		x
GEO	n	Wind n		Wind n		x

10

		FOREGROUND		BACKGROUNG		SOUNDMARKS
ANTHRO	y	1st person noise	y	Traffic noise	n	x
		Human activities	n	Undefined	n	
		Vocalizations	n	Vocalizations	n	
BIO	n	n		n		x
GEO	n	Wind n		Wind n		x

11

		FOREGROUND		BACKGROUNG		SOUNDMARKS
ANTHRO	y	1st person noise	y	Traffic noise	y	x
		Human activities	n	Undefined	n	
		Vocalizations	n	Vocalizations	y	
BIO	y	birds y		n		x
GEO	n	Wind n		Wind n		Notes: Brief transient vocals

12

		FOREGROUND		BACKGROUNG		SOUNDMARKS
ANTHRO	y	1st person noise	y	Traffic noise	n	breath
		Human activities	n	Undefined	n	
		Vocalizations	n	Vocalizations	n	
BIO	n	n		n		x
GEO	n	Wind		Wind		x

13

		FOREGROUND		BACKGROUNG		SOUNDMARKS
ANTHRO	y	1st person noise	y	Traffic noise	n	x
		Human activities	n	Undefined	n	
		Vocalizations	n	Vocalizations	n	
BIO	y	n		birds y		x
GEO	n	Wind n		Wind n		x

14

		FOREGROUND		BACKGROUNG		SOUNDMARKS
ANTHRO	n	1st person noise	n	Traffic noise	n	x
		Human activities	n	Undefined	y	
		Vocalizations	n	Vocalizations	n	
BIO	y	n		birds y		birds
GEO	n	Wind n		Wind n		x

15

		FOREGROUND		BACKGROUNG		SOUNDMARKS
ANTHRO	y	1st person noise	y	Traffic noise	n	x
		Human activities	n	Undefined	y	
		Vocalizations	n	Vocalizations	y	
BIO	y	n		birds y		x
GEO	n	Wind n		Wind n		x

16

		FOREGROUND		BACKGROUNG		SOUNDMARKS
ANTHRO		1st person noise	n	Traffic noise	n	n
		Human activities	n	Undefined	y	
		Vocalizations	n	Vocalizations	n	
BIO	n	n		n		n
GEO	n	Wind n		Wind n		n

17

		FOREGROUND		BACKGROUNG		SOUNDMARKS
ANTHRO	y	1st person noise	y	Traffic noise	n	x
		Human activities	n	Undefined	n	
		Vocalizations	n	Vocalizations	y	
BIO	n	n		n		x
GEO	n	Wind n		Wind n		x

18

		FOREGROUND		BACKGROUNG		SOUNDMARKS
ANTHRO	y	1st person noise	n	Traffic noise	y	x
		Human activities	n	Undefined	n	
		Vocalizations	n	Vocalizations	n	
BIO	y	n		birds y		x
GEO	n	Wind n		Wind n		x

19

		FOREGROUND		BACKGROUNG		SOUNDMARKS
ANTHRO	y	1st person noise	y	Traffic noise	y	x
		Human activities	n	Undefined	y	
		Vocalizations	n	Vocalizations	n	
BIO	n	n		n		x
GEO	n	Wind n		Wind n		x

20

		FOREGROUND		BACKGROUNG		SOUNDMARKS
ANTHRO	y	1st person noise	n	Traffic noise	y	x
		Human activities	n	Undefined	n	
		Vocalizations	n	Vocalizations	n	
BIO	y	birds y		birds y		birds
GEO	n	Wind n		Wind n		x