UNIVERSITÀ CATTOLICA DEL SACRO CUORE
MILANO

Dottorato di ricerca in Psicologia
ciclo XXIV
S.S.D.: M-PSI/0

Listen to my breath:
Exploring expressive function of breathing sounds in imitation and emotional attunement

Coordinatore: Ch.mo Prof. Claudio Albino Bosio

Tesi di Dottorato di: Raffaella Pellegrini
Matricola: 3710340

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"Breath is the key to life,

movement and rhythm"

Hackney, P (1998)

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Introduction

Several psycho-physiological studies have provided evidences on the influence of psychological variables (such as cognitive processes, performance management and emotional experience) on respiration. Anyway, there is a lack of a comprehensive view on previous findings that allow an integrated outline of respiratory behaviour in relation to such variables (Davenport, 2010; Wientjes et al., 1998). Moreover, from a psychological point of view, we argue that some aspects have been so far neglected, like expressive role of *breathing sounds*.

Breathing is not only a physiological process but also something that can be *perceived* through different sensorial channels. For example actors breath in different way to express different *personality features* and *emotional experience of the characters* they interpret and call centre operators relies on them to make inferences about the emotional state of their callers. Could breathing sounds actually convey reliable information about the *identity* and the *emotional feelings* of an individual?

Previous studies that have addressed the relation between emotions and respirations provided evidences for quite distinct respiratory patterns associated to specific basic emotions (Bloch et al, 1991; Boiten et al, 1994; Boiten, 1998; Philippot et al, 2002) and, what's more, that *mimicking* such patterns induce correspondent emotional feeling state (Philippot et al, 2002). This technique is used in some counselling and therapeutic context (client-centred therapy, NLP and humanistic music-therapy) to reinforce rapport (Bandler et Grinder, 1975; Sutton, 2002; Scardovelli, 1999; Siegel, 1984) but it hasn't been rigorously tested. If "breathing together" could truly enhance emotional responding, that could provide significant cues to be used either in therapeutic setting, interpersonal relations and also in dealing with persons with highly compromised communicative skills. For example, Plotnik et al (2010) realized a "sniffing device" that uses breathing air pressure to enable paralyzed people to command a virtual keyboard and compound sentences, allowing them to communicate with the outside.

Finally, breathing sounds are effectively used to manage interaction synchrony in performances requiring high degree of synchronicity (like musicians, dancers and sportsman) but so far no studies have investigated how much respiration does actually serve interpersonal coordination.

Concluding, we believe that this research field could provide new, significant understanding to the field of both affective, communication and positive psychology. Moreover, it could produce effective knowledge and applications to be used in therapeutic settings and interpersonal relations management, to foster advances in facilitated communication and to help improving joint actions performance in different fields.

The first chapter of this Thesis illustrates previous findings on the relation between breathing and psychological variables (such as mental tasks, joint performance, emotional experience, etc) and carries on a reasoned discussion of what else could be considered in order to draw a more comprehensive picture of respiratory behaviour in relation to psychological processes.

Considering lack of previous studies, the first study aims to build a valuable and compound set of measurements that enable a reliable *respiratory and acoustic description of breathing sounds*, as well as to *relate partner's respiratory behaviour* during joint performances.

The second study investigates what could be inferred about a person's *identity*, *emotional state* and *activity* from the sound of his/her breathing. Moreover, it aims to verify whether imitation of breathing patterns could improve the identification of those features compared to pure listening.

Finally, the third study aims to provide a reliable description of the acoustic features of breathing in different emotional conditions and to investigate how "breathing together" influence the attunement process between participants, considering different dimensions: *emotional decoding, similarity of the emotional experiences*, *perspective taking, perceived physical activation*, and *interpersonal synchrony.*

1

State of the Art

From a merely physiological point of view, breathing is the process responsible for gas exchanges in and out the body, delivering the oxygen necessary for our organism vital functioning and removing metabolic by-products such as carbon dioxide. Its rate and depth change depending on the body's needs, such a huge amount of studies in the field of sport medicine and respiratory physiology have shown (Bachbache et Duffin, 1977; Rassler et Kohl, 2000; Steinacker et al, 1993). But respiration is also strictly related to processes that are inherently psychological: being our body directly and dynamically connected to our mind, breathing fluctuates considerably not only in relation to *physical activities* but also to *mental tasks* (Wientjes et al, 1998; Bernardi et al, 2000; Grossman e Wientjes, 2001; Vlemincx et al, 2011) and *emotional experiences* (Zajonc, 1985, 1994; Goldin & Gross, 2009; Homma, 2008; Osborne, 2008).

What's more, respiration is one of the few bodily function controlled through both the *central* and *autonomic* nervous systems. That means that respiration is not only an instinctive reflex but also a conscious process that could be managed to reach purposes different than life support. Regulation of breathing in speech or vocal training, for athletic activities and for many kind of meditation and yoga practices involves cortical and subcortical areas of the central nervous system different from those responsible for ventilation and basic homeostatic regulation. In this sense respiration could be considered not just a "*bodily function*" but more properly a complex "*psico-physiological behaviour*".

Thanks to the crucial connections that breathing interweaves between mind and body it is intimately connected to many aspects of our life (mental, physical and emotional) making it a crucial area of investigation in many different field: medical, psychological, sportive, etc etc. However, what's seems to lack is a comprehensive and integrate view of this subject: previous findings from a specific research disciplines were often poorly integrated with those from others (Davenport, 2010). As Wientjes and colleagues argued (1998), *"psycho-physiological research has, for a long time, (...) failed to adopt new respiratory assessment methods that are able to capture the most important aspects of* *respiratory behaviour"*. This statement shades light on two crucial and actually interrelated requirements that could help drawing a more comprehensive picture of the topic: first, the investigation of *key features* of breathing behaviour that have been so far neglected; second, the introduction of *new measurements* and assessment methods that could improve our comprehension of the topic. Both should then converge into an as much as possible *comprehensive* and *integrated analysis model.* Considering psychological studies, which aspects have been investigated so far?

As mentioned before, breathing is not only an automatic function ruled by physiological mechanisms but is also tightly controllable for specific purposes, primarily concerned with *performance* (physical and mental) and *emotional management*. Thus, Grossman et Wientjes (2001) argued that respiratory changes in relation to specific behavioural demands "*have evolved as functional integrative adaptations to best fit and coordinate metabolic activity, cognitive performance, emotional self regulation and perhaps even communicative signalling to conspecifics*".

Psycho-physiological studies have investigated the link between respiration and ***emotional experience*** (Zajonc, 1985, 1994; Philippot et al., 2002; Boiten et al, 1994; Boiten, 1998; Bloch et al, 1991) trying to find whether distinct respiration patterns could be related to specific emotions or to wider emotional dimensions (e.g.: valence, arousal, coping, etc). Recently huge attention has been also brought to the efficacy of breathing-based stress management techniques (like breath-focused mindful attention) proven them to be valuable (Goldin & Gross, 2009; Osborne, 2008). Also traditional oriental practices such as yoga and meditation have been exploring for centuries the potentiality of respiration in improving either of self-consciousness, stress management and emotional regulation; this field has recently caught the attention of scientific research (Brown et Gerbarg, 2005, 2009; Kjellengren et al, 2007) that is giving evidences of the efficacy of such practices. Yogis have been developing and applying breathing techniques also to influence cognitive processes, like attention and mental focus (Iyengar, 1989). To see a comprehensive review of the effective of yoga techniques in clinical settings see Brown and Gerbargs review (2005). Weymouth (2007) suggested a categorization of therapeutic breathing techniques in three kinds of intervention: 1. *Affect inductive breathing interventions*, to deepen emotional experience and awareness; 2. *Affect reductive breathing interventions*, to improve relaxation and reduce symptoms of anxiety; 3. *Awareness* *breathing interventions*, to help focusing on bodily and emotional experience in the present moment.

Breathing has been finally considered in studies on *vocal communication of emotions* (Ciceri & Anolli, 1999; Scherer, 1986, 2009; Laver, 1980, 1991), but so far it has been defined only by way of quite undetermined labels (such as “quick”, “deep”, etc). However, few studies investigated the **emotional expressive function** of *breathing itself* (Bloch et al, 1991; Boiten et al, 1994; Boiten, 1998; Philippot et al, 2002) and the existing ones dealt more properly with emotional *expression* and *induction* than on *identification* of emotional signals through breathing sounds of movements. Actually, actors and professional singers are specifically trained to use different breathing qualities to effectively convey emotional meaning to their audience. Help-line operators too rely on the breathing sound of the caller to make inferences about his/her emotional state. Moreover, in music-therapy setting, breathing is often an effective mean to get in touch with patients with highly compromised communicative abilities. Breathing has also recently been used as a mean to control electronic devices based on sniffing: inhaling and exhaling through the nose, numerous disabled people were enabled to navigate wheelchairs and communicate with their loved ones (Plotkin et al, 2010). But this application is based on the detection of air-pressure variations more than on breathing communicative valence. Breathing sounds are also an important cue for dancers and musicians in order to manage interaction synchrony. Although few studies carried on explorative acoustic measurements of breathing sounds (Ogata et al., 2008), these considerations rise new questions about what *breathing sounds* could express about the subject identity, activity and emotional experience. Plausibly, acoustic measurements could highlight significant features of breathing behaviour that couldn’t be inferred by physiological ones alone.

As performance is concerned, regulation of breathing has been studied in particular in relation to ***individual*** **activity**, (i.e.: sports, yoga, music). Those studies have shown that breathing is often entrained by simultaneous rhythmical movements and that it shows coordination-related changes in rhythm, both in animals (Holst, 1939) and humans (Wilke et al 1975; Siegmund et al 1999). Rassler et al. (Rassler et al, 1996; Rassler et al, 2000; Rassler, 2000) found also an association between movements precision and breathing phase-cycle. Although there is common agreement that training breathing may lead to a greater performance, there is actually poor scientific literature on the role of “skilled breath” in supporting “skilled practice”, such as in musical or sports activities. But what does actually support this popular belief? Physiologically, bringing automatic breathing to consciousness during a task prevents from lacks of oxygen that causes muscular stiffening; moreover, coordinating motions with respiration soften and relax the muscles. Besides, focusing on breathing stills the mind and implies greater body awareness, allowing the individual to become fully attentive to the task at hand.

Compared to the great amount of studies focusing on respiration and individual action, less have investigated whether breathing has a role also in managing ***joint performances***. Recently huge attention has been drawn to the investigation of the cognitive and interpersonal processes that underlies the ability to *coordinate actions with others*. An emerging issue is that, when we engage in joint actions, our body seemingly comes to help miming and synchronizing to some partner's behaviours, although unintentionally (Richardson et al. 2005; Shockley et al., 2003; Schmidt et al., 1990). *Temporal organization* of interactive behaviours, in particular, is claimed to be crucial in supporting joint action (Ciceri & Marini, 2004; Schutz, 1971; Siegman & Feldstein, 1979). There are evidences that synchronization improves the ability to manage joint activities, since it strengthens perceptual sensitivity to the motion of the other partner by increasing both attention and movement responding. This sensitivity enhances the ability to temporally organize movements in coordination tasks (Richardson, et al 2007; Sabenz et al, 2006; Schmidt & O'Brien, 1997; Valdesolo et al, 2010). Breathing is actually used, more or less unintentionally, to manage precise temporal coordination in joint actions requiring high degree of synchronicity. For example, musicians playing together use to breath together in key moment of the performance to keep timing (Pellegrini, 2010) as rowers do to coordinate their rowing movement. The Italian word "affiatamento", that expresses the sense of "being deeply in harmony, showing strong teamwork", literally means "breathing together" (as the originally meaning of "con-spire" express) stressing again this idea of a deep "physiological attunement". Therefore it could be interesting to investigate how much respiration does actually serves interpersonal coordination.

Temporal organization of interactive behaviours is crucial not only to joint actions (Ciceri et Marini, 2004; Schutz, 1971; Siegman et Feldstein, 1979), but also to ***communicative and emotional attunement*** (Stern, 1985; Murray et Trevarthen, 1985). A growing body of evidences is highlighting the role of synchronized actions in enhancing rapport, reciprocal liking, cooperation and prosocial behaviors (Bernieri, 1988; Miles et al, 2009; Wiltermuth & Heath, 2009) so that synchrony appears to enforce group cohesion.

But which is the linkage between joint action and attunement? In a joint action participants have to reciprocally adjust their behaviour in a flow of mutual adaptation and interactive co-ordination through a multitude of interactive actions (like mirroring, compensation, synchrony, etc) (Cappella, 1997). To manage those reciprocal adaptations through time, participants need to continuously share their reciprocal intentions and emotional state through a broad set of communicative signals, both verbal and non-verbal. In other words, the achievement of a joined intention requires the agent to arrange, maintain and coordinate a *communicative interaction* (Ciceri & Biassoni, 2006; Bratman, 1990). The partner's ability to "attune to" each other emotional feelings is called *emotional attunement*, while the process of mutual accommodation of their communicative behaviours is called *communicative attunement* (Cappella, 1994; Giles et al, 1991; Ciceri & Biassoni, 2006). Coming back to respiration, what is known about the association between breathing and attunement? Some studies on developmental psychology found a bidirectional relation between physiological and interaction rhythms. On one side, mother-infant interaction rhythms appear to resemble the temporal rhythms of sucking, heart beating and respiration (Stratton, 1982; Wolff, 1967). On the other, some studies have shown that interaction synchrony seems to entrain the physiological rhythms of the infant (Beebe et al., 1985; Sander, 1969) "*providing infant the only opportunity to match their own biological rhythms with those of another human being, co-creating not only a shared relational moment but a shared biology"* (Feldman, 2007i). Parental interactive behaviour would serve as an "external regulatory function" for the organization of the baby's neurobiological, sensory, emotional, physical and relational systems (Hofer, 1995; Hrdy, 1999). Levenson et Gottman (1983) coined the word "physiological linkage" to refer to patterned association between the physiology of social partners. This phenomenon has been observed first in spousal conflicts (Levenson & Gottman, 1983) then in empathic interactions (Marci, Ham, Moran, & Orr, 2007) making it important for socio-emotional processes. As clinical research is considered, the study of autonomic synchrony between patient and therapist was carried out in particular within two approaches: the psychoanalytic setting and the Rogersian client-centered therapy setting (Levenson et Ruef, 1997) but findings are controversial. NLP, music-therapy, shiatsu and some over counselling and interpersonal practices claim that synchronizing and matching client's breathing would help "to assume his physiology", leading to or reinforcing the attunement process. However this technique hasn't been rigorously tested. Thus, although some evidences suggest there's an association between communicative, emotional and physiological attunement, further investigation are needed. In particular it would be interesting to investigate whether breathing together reinforce emotional attunement or not.

Starting from this brief presentation of the principal interconnections between breathing and psychological functions that have been so far caught the attention of psycho-physiological research, in the following paragraph we will illustrate more in detail the major findings of these fields of investigation. Then, on the basis of what have been already investigated, we will focus on which aspects could be still considered in order to draw a more comprehensive picture of respiratory behaviour in relation to psychological processes.

1.1. Neuro-physiology of Respiration

Respiration is first of all an *action* under both volitional and unconscious control to serve various behavioural functions. Usually we distinguish between *autonomic/metabolic breathing* and *voluntary/behavioural breathing,* which are directed by different mechanism in nervous system. The former is automatically controlled by the autonomic nervous system by dedicated structures in the brainstem and varies in response to changes in the body metabolic needs. In contrast, the latter is influenced by internal and environmental changes and it is controlled by higher centres in the cerebral cortex (Guz, 1997). Beside these different control centres for metabolic and behavioural breathing, studies of Orem and Trotter (Orem, 1989; Orem & Trotter, 1994) shown that behavioural influences arising from higher centres could modify metabolic breathing patterns. Thereby, individuals are able, to some extent, to manage their breathing rate and depth to match changes in body demand.

Respiration management needs the integration of neural signals coming from four respiratory control centres. Two are located in the medulla allungata and they are responsible for inspiration (*Inspiratory center*) and expiration (*Expiratory center*). In particular the dorsal respiratory group controls execution and timing of inspiratory movements while the ventral respiratory group controls voluntary forced exhalation and operates to increase the force of inspiration. Two others are located in the pons region of brain. The so called *Apneustic centre* stimulates and prolongs inhalation while the *Pneumotaxic center* is involved in the fine tuning of respiration rate and is able to send inhibitory impulses to the inspiratory area.

Many receptors are involved in the regulation of the respiratory process: *Central chemoreceptors*, situated on the ventrolateral medullary surface, are sensitive the pH changes; *peripheral chemoreceptors* have a central role in detecting oxygen variation in the arterial blood; *mechanoreceptors*, located in the airways, are responsible for a variety of reflex responses. Other important afferent pathways came from the *limbic system* (carrying inputs concerning the emotional state of the subject) and from the *hypothalamus* (carrying inputs about temperature). Finally, PET studies indicates areas of the *motor cortex* and *cerebellum* that are implied in behavioural breathing (Colebatch et al, 1991; Fink et al, 1996; Ramsay et al, 1993). The neural basis for the integration of reflex and behavioural breathing is instead unclear (McKay et al, 2003). The respiratory system is strictly interrelated to all other physiological systems within the body; many different mechanisms and processes integrate respiratory function with the whole organism.

Not only breathing *is driven by* our autonomic nervous system but it could also *influence* in return cardio-respiratory and autonomic functions. Respiratory sinus arrhythmia (RSA) refers to natural variations in heart rate that are linked to breathing cycle, that is heart rate increases during inhalation and decreases during exhalation. During expiration the nucleus ambiguous, one of centers that control parasympathetic activity by the vaguus nerve, is activated, slowing down heart rate. In contrast, during inspiration, the vaguus nerve remains unstimulated and thereby the parasympathetic nervous system. Thus, breathing technique like meditation and relaxed breathing, can temporarily influence RSA and autonomic activity, inducing changes in our level of anxiety/relaxation and, as a consequence, on our performance. *Porges' Polyvagal Theory* (Porges et al, 1994, 1996), for example, states that in relaxing situation the vaguus nerve increases parasympathetic activity, slowing heart rate and facilitating attending to / engaging with the environment. In contrast, in activating situations, it leads to sympathetic dominance supporting increased metabolic demand to face the present challenge.

As the "mechanics" of respiration is concerned, normal inhalation is started and driven by the diaphragm and supported by external intercostals muscles: diaphragm descends, intercostals muscles contract and the rib cage volume increases, stretching the lungs and producing a fall of the intrapulmonary pressure that moves air moves the lungs. During strong (over 35 breaths/min) or forced inspiration also other muscles are recruited for support, like sternocleidomastoid and scalene muscles of the neck. Exhalation, instead, is generally a passive process: intercostals muscles relax, the diaphragm rises and the thorax descends. Thus, the intrapulmonary pressure rises pushing the air out of the lungs until the pressure in the thorax equals atmospheric pressure. If forcedly initiated, abdominal and internal intercostals muscles intervene to push air out of the lungs. This mechanism of pressure difference is responsible for the process of gas exchange between blood and external environment, which ensure oxygenation and removal of carbon dioxide and other gaseous metabolic wastes from circulation. Under physical and mental effort our body increases oxygen consumption requiring a more regular, steady supply of oxygen: an efficient breathing assures an adequate oxygenation of the *brain*, enabling also a more proficient control of physiological functions, and of our *muscles*, preventing soreness and fostering endurance. For example, weight trainers usually exhale during the effort and inhale when lowering the weight, supplying the adequate need of oxygen during the most difficult part of the exercise. Beside changes in metabolic demands, also emotional states have been proven to influence autonomic breathing. For that reason breathing technique are central in most sports performance, relaxation and meditation methods since it could influence physical performance, mental tasks and emotional states.

The air moving in and out the lungs during respiration produces *breath sound waves*, whose features depends on both airflow velocity and the anatomical features of the respiratory system. The respiratory system is conventionally divided in two tracts:

- *Upper respiratory tract or supraglottal airways*: nostrils, nasal cavity, paranasal sinuses, pharynx, larynx;
- *Lower respiratory tract or subglottal airways*: trachea, bronchi and lungs

Airflow velocity is determined by pulmonary ventilation and cross sectional airway area. Also the *state of health* could influence breathing sounds quality: for example mucus, lung diseases or deviated nasal septum could modify either air transmission, airflow velocity and sound resonances modifying the resulting sound. Respiratory sounds are generally identified trough *auscultation* of the chest with a *stethoscope*.

1.2. Respiration Measurements

The respiratory system is extremely complex and could be easily influenced by a variety of psychological variables (Lorig, 2007; Wientjes et al.1998). A huge range of respiratory parameters show significant changes under different behavioural conditions: respiratory rate and deepness, inspiration time, I/E ratio are some examples. It has been argued that this variability underlines the ability of the respiratory system to adapt to different physical, mental and emotional conditions in order to be as most efficient (Astrand and Rohdahl, 1986) or comfortable as possible (Chonan et al., 1990; Kikuchi et al., 1991). Respiratory patterns could vary in order to supply a range of psychological or *survival requirements*, such as preparation for fight/flight response, and appraisal patterns (Boiten et al., 1994). In addition, several ambulatory studies have assessed respiratory responses, including tidal volume, respiration rate, minute ventilation, and partial CO_2 at the end of normal expiration ($P_{et}CO_2$) to *mental workload and stress* (Harding, 1987; Bles et al, 1988; Brookings et al, 1996; Wientjes et al, 1996, 1997). Moreover, respiratory parameters have been found to show systematic variations in relation to *motivation and effort* (Wientjes, 1992; Wientjes et al, 1996, 1998; Brookings et al, 1996; Wientjes and Grossman, 2005).

Although there is common agreement that psychological variable could induce changes in physiological parameters, psycho-physiological literature has failed for long to provide consistent findings about such correlation (Wientjes et al. 1998). One problem concerns the relevance ascribed to respiration in influencing psychological variable. Commenting upon the literature on the influential role of respiration on psychological variables, Loring (2007) argued that their relation was sometimes overestimated; in particular he refers to some studies that suggested an existing connection between personality and respiratory parameters like I/E ratio (Feleky, 1916), breathing patterns (Nielsen and Roth, 1929) and respiratory curve (Sutherland et al, 1938). However, he stated that more often it has been ignored, being psycho-physiological research more focused on the heart, brain and electrodermal activity (Harver and Loring, 2000), perhaps because of respiration's susceptibility to conscious influences (Wientjes and Grossman, 1998). When respiration was recorded, it has been more often because it could interfere with other physiological functions, like heart rate (respiratory sinus arrhythmia- RSA) and electro-dermal reactivity (Rittweger, Lambertz, Langhorst, 1997; Lorig, 2007).

Another problem, is "the employment of inappropriate measurements techniques and rough estimation measures" (Wientjes et al 1998). Although there have been amazing progresses in data and analysis and methodological approaches related respiration in respiratory medicine, psycho-physiological research couldn't rely on these measurements: first, they have to answer totally different questions, secondly medical recording often rely on techniques that are to intrusive for psychological research settings: they often centre the patient's attention on the respiration process diverting it form the task (Han et al, 1997;

Lorig 2007) and could be physically invasive (for example, the use of a spirometer requires the subject to breath through a plastic tube placed into the mouth). Moreover, the need to relate psychological changes to respiration requires the use of continuous and non-invasive measurements leads psycho-physiologist to fall back on less precise measures and instruments like respiratory belts, temperature and pressure transducers. Ritz et al. (2002) provide a full list of measurements, techniques and experimental methods relevant for psycho-physiological research on respiration. Wientjes and Grossman (2005) identify two major respiratory assessments to be considered:

1) <u>measurement of the contribution of depth and frequency of breathing to ventilation</u>: they include tidal volume, respiratory rate, minute ventilation, inspiratory, expiratory and cycle duration, mean inspiratory flow rate and duty cycle time (see Wientjes, 1992)
2) <u>measurement of parameters associated with gas exchange</u>: they include the volume of oxygen consumed per time unit and the quantity of carbon dioxide produced.

Wientjes et al. (1998) suggested that new respiratory assessment methods, based on multiple respiratory measures, would be necessary to capture the correlation between behavioural demands and breathing changes.

Analysis of *breath sounds* is actually a significant part of the diagnosis of respiratory system diseases. This procedure is useful to identify adventitious (abnormal) sounds like wheezes, stridors, crackles and rhonchis caused by obstruction or secretion in the respiratory system (for a deeper illustration of the classification of abnormal breathing sounds see Pasterkamp et al, 1997). Patterns of normal breath sounds are generally described in function of their *duration, intensity, pitch* and *timing*. They could be described on the basis their location and classified into *tracheal*, *bronchial*, *bronchovesicular*, and *vesicular* sounds[1]:

- *Tracheal:*
  - <u>An I:E Ratio</u> : 1:1 with a pause in between inspiration & expiration
  - <u>Thoracic Geography</u>: over the trachea on the throat
  - <u>Sound Characteristics</u>: high pitched, harsh, tubular, hollow sound
- *Bronchial:*

[1] From: http://faculty.etsu.edu/arnall/www/public_html/heartlung/breathsounds/contents.html

    - An I:E Ratio: 1:1 or 1:1 1/4 with a pause in between inspiration & expiration
    - Thoracic Geography: over the large airways in the *anterior* chest, near the 2nd and 3rd intercostals space corresponding to the manubrium of the sternum
    - Sound Characteristics: high pitched, loud, tubular, hollow sound
- *Bronchovesicular:*
    - An I:E Ratio: 1:1 or 1:1 1/4 with a pause in between inspiration & expiration
    - Thoracic Geography: sounds could be heard in the *posterior* chest between the scapulae, and 1st and 2nd interspaces on the anterior chest of the *anterior chest*
    - Sound Characteristics: medium pitched, hollow, softer than bronchial ones but more tubular. Differences in pitch and intensity are often more easily detected during expiration.
- *Vesicular:*
    - An I:E Ratio: 1:0 or 1:1/4 with no pause in between inspiration & expiration
    - Thoracic Geography: everywhere on the thoracic wall
    - Sound Characteristics: low pitched, soft, blowing or rustling sound. Vesicular sounds are normally heard throughout inspiration and then fade away about one third of the way through expiration

Spectral characteristics of chest wall breath sounds have been carried out in order to provide physician with useful diagnostic classifications (Gavriely, 1981; Gavriely et al, 1995; Pasterkamp et al, 1997 Elphick et al, 2000) or automatic breath detection systems (Cohen, 1984; Cohen et Landsberg, 2007; Elphick et al, 2004; Mohammad et Zahra, 2004; Moussavi et Yadollahi, 2009).

Less studies and applications uses acoustic measurements of breath sounds *out of the lungs*, that is as perceived once out of mouth or the nose. Lorig (2007) reported the use of a small microphone placed at the nostrils to record different sounds for inhalation and exhalation, a method often used to record snoring. The primary disadvantage of is technique is its sensitiveness to ambient noise and vocal interference. To solve this problem Que et al (2002) suggested a new technique called *phonospirometery*: analyzing the sound related to the air flow in the lungs through a tracheal microphone they are able to reliably determine a range of respiratory parameters, including tidal volume. These measures appear to be consistent with more classical procedures and did not require the application of mouthpiece and nose clip. A part from breathing sound capture devices, there are few studies to that have dealt with *acoustic analysis* of breathing sounds, as perceived out the lungs. Major applications of non-verbal sounds analysis are in the field of speech analysis and professional voice recordings, in order to facilitate speech segmentation (Price et al, 1989; Wightman et Ostendorf, 1991) and also detection of badly pronounced or unwanted sounds (Ruinskiy et Lavner, 2007; Nakano et al, 2008). Between these studies, the one of Nakano et al. (2008) carried out the most detailed analysis of breath sounds, analyzing recorded audio-performance of professional singers. They collect a total number of 1448 breath events extracted from song samples by hand-marking. The total length of the final dataset was 128 minutes. Using a cepstrum model, spectral envelope was calculated and then a long term average spectrum (LTA-S) was obtained. They found that breath events have relatively stable spectral features. A common spectral peaks is located at about 1.6 kHz for male singers an 1.7 kHz for female singers, probably a constant could be due to breathing mechanisms independent from body size, voice range and singing context. Moreover, a secondary peak exists in the range of 850Hz-1.kHz in female voice.

We are not aware that any attempts have been made to deepen the study of breathing sounds in other context, like social interactions or emotional expression. Actually, breathing is a phenomenon that could be perceived through different sensorial channels: it's possible to *listen to* the breathing sound of a person who's close enough, as well as it is possible to *see* the chest moving up and down according to his/her respiration rate and depth, to *perceive* its warmth and pressure and also to *smell* its odour. Breathing sounds could provides important insights on people emotional feelings and physiological activation when we can't see them (for example during phone calls) or when they could not move and talk, like people in coma or people with unimpaired cognitive function who are completely paralyzed. Thus, more valuable and consistent measurements of acoustic breathing features could be highly useful in the research field of affective and communication psychology.

1.2.1 Most Common Respiratory Indexes

Indexes related to *temporal features* of respiration:

- **Respiration rate** (RR): number of cycle per minute. Average respiratory rate for an adult person under resting condition is generally between 12 - 15 breaths/min, with a time period of 2 seconds. Variation in RR may derive from alterations in either of Ti, Te and Pe.
- **Inspiration time** (Ti): time spent inhaling.
- **Expiration time** (Te): time spent exhaling.
- **Post-inspiratory pauses** (Pi): time between the onset of each Inspiration and the following Exspiration;
- **Post-expiratory pauses** (Pe): time between the onset of each Expiration and the following Inpiration.
- **Cycle duration** (Tt): total time for inspiration and expiration.
- **Inspiratory Duty cycle or Fractional inspiratory time** (Ti/Tt): the ratio of inspiratory time to total breath time. It may increase due to prolongation of Ti, shortening of Te, and/or reduction of pause after expiration.
- **I:E ratio** (Ti/Te): Adults have a I:E = 1:2, 1:1,5. Young children tend to have a I:E of 1:3. Generally a prolongation of expiration allows a more complete expulsion of CO_2 contained in the lung. The ratio will shift toward 1:1 during anxiety, grief, anger, or exercise. Some breathing exercises recommend for special purposes a 1:1 ratio; in those conditions, in order to avoid hyperventilation a healthy organism automatically reduces the volume of air breathed or the RR.

Indexes related to *lungs volume*:

- **Total lung capacity** (TLC): the amount of gas contained in the lung at the end of a maximal inhalation (approximately 5800 ml)
- **Tidal volume** (TV): it's the lung volume representing the normal volume of air inhaled after an exhalation when extra effort is not applied (about 500 ml). It depends on age, sex, height and weight. Variability in the waveform can be used to detect between some pulmonary diseases as well as acute anxiety.
- **Mean inspiratory flow rate**: TV/inspiratory time.

- **Peak inspiratory flow** (PifVt): it measures the respiratory drive. Rhe higher the value, the greater the respiratory drive in the presence of coordinated thoraco-abdominal or movements.
- **Peak/mean inspiratory** and **expiratory flow** measures the presence of upper airway flow limitations during inspiration and expiration.
- **Inspiratory reserve volume** (IRV=IC-TV): The volume of gas that can be forcefully inspired after a normal resting inspiration (between 2500 - 3500 ml).
- **Expiratory reserve volume** (ERV=VC-IC): The volume of gas that can be forcefully expired after a normal quiet expiration (approximately 1000 ml).
- **Closing volume** (CV) is the amount of air remaining in the lungs when the flow from the lower sections of the lungs severely reduced or halts during expiration.
- **Vital capacity (VC):** is the maximum amount of air that can be expired after a maximum inspiration. It depends upon size of the lungs, elasticity, integrity of the airways and other parameters (Lorig, 2000) (between 2000 – 7000 ml);
- **Closing capacity** (CC=CV+(TLC-VC)), with VC taken from the curve acquired from the nitrogen washout test. As a reference, it should be 70% to 130% of what is the average value in the population (which varies with geographic location).
- **Forced vital capacity (FVC)**:
- **Inspiratory capacity (IC)**: the volume of gas that can be hold into the lungs in a full inhalation, starting from the resting inspiratory position;
- **Minute ventilation (MV=RR*TV)** or **Respiratory minute volume**: is the volume of air which can be inhaled (inhaled minute volume) or exhaled (exhaled minute volume) from a person's lungs in one minute. A normal minute volume while resting is about 5–8 l/min. It is used to assess metabolic activity.
- **Residual volume (RV)**: The volume of air remaining in the lungs after a maximal expiratory effort. It depends upon the size of chest and lungs. (about 1400-1900 ml).
- **Functional Residual Capacity (FRC):** the amount of air remaining in the lungs at the end of normal quiet respiration. It is measured through tests such as nitrogen washout, helium diluition and body plethysmography.
- **Compliance:** a measure of the elasticity of the thoracic area and can be applied to the lungs, the chest wall or the thorax. It is determined by calculating the ratio of the volume change in the lungs or thorax to changes in external pressure.

The *tidal volume*, *vital capacity*, *inspiratory capacity* and *expiratory reserve volume* are the basic elements of a ventilatory *pulmonary function test.*

Indexes related to *gas exchange composition*:

- **End tidal CO_2:** CO_2 espirata; It is a measure of the amount of carbon dioxide at the end of the tidal volume. The higher the minute volume the more carbon dioxide (CO_2) the person is releasing. There is a device that is attached to a tube in the patient's trachea (ET tube), and it can be measured at the end of each breath. You can even graph the amount of CO_2 over time.
- **Volume of oxygen consumed per time unit** (VO_2),
- **Quantity of carbon dioxide** (VCO_2),
- **Partial CO_2 at the end of normal expiration** ($P_{et}CO_2$),

1.2.2 Most Common Respiratory Assessment Devices

- *Spirometer* is the most common of the pulmonary function tests to measure lung function, specifically the amount (volume) and/or speed (flow) of air that can be inhaled and exhaled.
- *Body plehysmography* is a very sensitive tool used to detect lung pathology. It measures the absolute volume of air within the lungs. It is made by a *top respiration band* that measures thoracic respiration and a *bottom respiration band* that measures abdominal respiration.
- *Inductive pletysmography* measures chest and abdominal wall movement rather than air flow or volume.
- *Nitrogen washout* (or *Fowler's method*) measures dead space in the lung during the respiratory cycle, and some parameters related to airways closure.
- *Ventilation/Perfusion Lung Scan*: Uses scintigraphy and medical isotopoes to evaluate the circulation of air and blood within patient's lungs, in order to determine the ventilation/perfusion ratio.

Tab. 1 resume the illustrated respiratory assessment indexes and devices.

Respiratory Assessment Aspect	Respiratory Assessment Devices	Respiratory Assessment Indexes
Depth and Frequency of Breathing, Gas Exchange	- Chronometer	Inspiratory time, expiratory time, cycle duration
	- Spirometer	Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 sec (FEV1), FEV1/FEV ratio, Forced Expiratory Flow (FEF), Peak Expiratory Flow (PEF), Tidal Volume (TV), Minute Volume (MV), Total Lung Capacity (TLC), Diffusion Capacity (DLCO), Maximum Voluntary Ventilarion (MVV), Static Lung Compliance (C_{st}), Forced Expiratory Time (FET), Forced Expiratory Time (FET), Maximal pressure (P_{max} and P_i), Mean transit time (MTT)
	- Body plethysmography	Functional Residual Capacity Residual Volume, thoracic gas volume (TGV), Alveolar Pressure (P_{alv}), airway resistance (*Raw*)
	- Inductive plethysmography	Respiratory rate, TV, minute ventilation (MV), Peak inspiratory flow (PifVt), Duty cycle (Ti/Tt), Work of breathing, Peak/mean inspiratory and expiratory flow, %RCi, Phase Angle – Phi, Apnea & hypopnea, qDEEL quantitative difference of end expiratory lung volume.
	- Peak flow meter	Peak Expiratory Flow (PEF)
	- Pressure transducer	Respiratory pressures, Respiratory pressure changes
	- Pneumotachograph, Pitot tubes	Rate of air flow (V'), air velocity
	- Forced Oscillation Technique (FOT)	Impedence (Z) of total respiratory system
	- Interrupter Technique	Resistance (R_{rs})

	- Respiratory inductive plethysmography - Respirometer	Volume of oxygen consumed per time unit (VO_2), quantity of carbon dioxide (VCO_2), partial CO_2 at the end of normal expiration ($P_{et}CO_2$), respiratory exchange ratio (RER),
	- Nitrogen Washout	Dead Space, functional residual capacity, Closing volume (CV), Closing Capacity (CC)
	- V/Q Lung Scan	ventilation/perfusion ratio.
Sound of Breath	- Stethoscope	Inspiration time, Expiration Time, Cycle duration, Respiratory rate, qualitative analysis of respiratory sounds.
	- Phonospirometery	Inspiration time, Expiration Time, Cycle duration, Respiratory rate, Tidal Volume, qualitative analysis of respiratory sounds.

Tab.1 – Assessment Indexes and Devices related to different respiratory aspects

1.3 Relation between breathing and physical performance

During physical effort, our cells increase their demand of oxygen and produce in return an higher rate of carbon dioxide. Specialized chemoreceptors detect this change and warning the inspiratory centre, which consecutively sends impulses to the breathing muscles to increase and deepen their activity. Other receptors are responsible for the detection of changes in the body to signal the inspiratory centre to modulate the breathing rate: receptors in the joints detect possible increase in movement rates, receptors in the circulatory system rise/drop in blood pressure, receptors in the skip are sensible to changes in body temperature.

Interaction between *performance* and *breathing* has been investigated in particular in sport science, although some attention has been directed also to specific activities, like yoga practices (Jerath et al, 2006) and musical performance (King, 2006, Kawase et al, 2007). In general, rhythmic simultaneous bodily actions often behave in phase-relation or even in synchronous. This phenomenon is named “entrainment” and was first systematically described by von Holst (1939) in fin movements of fish. Although entrainment has mostly been described in *active voluntary* movements, it seems to be based on unconscious nervous interaction and not on intentional factors. Such coordination occurs also between breathing and bodily rhythmic movements. Several studies have described coordination-related changes in the breathing rhythm and breathing entrainment to synchronous motor processes like *rhythmical eye movements* (Waurick 1973), *finger tapping* (Wilke et al. 1975), *rhythmical arm and leg movements* (Raßler et al. 1990) and *locomotor activities* such as walking and running (Bechbache & Duffin1977, Bramble and Carrier 1983; Hill et al. 1988; Loring et al. 1990; Bernasconi and Kohl 1993; Bernasconi et al. 1995; Raßler and Kohl 1996), cycling (Kohl et al. 1981; Jasinskas et al. 1980; Bernasconi and Kohl 1993) and rowing (Mahler et al. 1991; Maclennan et al. 1994). The degree of coordination between movement and breathing is affected by several factors such as *movement rate* (Bechbache and Duffin 1977; Jasinskas et al. 1980; Raßler et al. 1990; Bonsignore et al. 1998; Ebert et al. 2000) and *work rate* (Jasinskas et al. 1980; Bernasconi and Kohl 1993; Raßler and Kohl 1996): generally, the higher the rate the stronger the entrainment. Size of active muscle groups and mechanical interactions do not seems to necessarily affect the degree of co-ordination (Raßler and Kohl 2003). Although much weaker than the entrainment of breathing to a voluntary movement, also the reverse effect has been observed: respiration seems to influence both rhythms and precision of simultaneous actions (Rassler and Kohl 1996; Rassler 2000; Rassler and Kohl 2000). Coordination between breathing and rhythmical movements has often been described as an interesting phenomenon demonstrating that the respiratory rhythm is not only determined by the metabolic rate but also by the rhythm of a simultaneous movement (Waurick, 1973; Kohl et al, 1981; Loring et al, 1990; Bernasconi and Kohl, 1993).

1.4. Relation between breathing and joint action

Respiration is not only strictly inter-related to individual actions by it is also a sort of "regulator device" in activities that require high levels of *mutual coordination*, such as musical and sport joint performances. Much less studies have investigated the role of breathing in ***joint performances.*** Joint actions can be regarded as "*any form of social interaction whereby two or more individuals coordinate their action in space and time to bring about a change in the environment*" (Sebanz et al., 2006). What underpins it is the common intention to achieve a *shared goal*. From a cognitive point of view, several processes are involved in the management of joint action, such as (i) shared representation of the action, (ii) joint and divided attention, (iii) prediction of each other actions and their effect on the environment, (iv) choose of an appropriate complementary action, (v) adjusting movements to *maintain synchrony* through time (adaptive timing) (Sebanz et al, 2006; Keller, 2008). Adaptive timing and, more in general, temporal organization of interactive behaviours, appear to be crucial in joint actions effectiveness (Ciceri & Marini, 2004; Schutz, 1971; Siegman & Feldstein, 1979). Synchronization, generally conceived as a time relationship between two events that seem to be meaningfully related, plays an important role in joint actions. Feldman (2007ii) identified three prototypic definition of this phenomenon, arguing that it as “a timed relationship whether *concurrent, sequential or organized in an ongoing pattern format* between two or more events that cohere into a single process”. The first one refers to simultaneous behavioural or affective events in two partners; the second to the existence of a systematic sequential relation between the behaviour of one partner and the following one of the other; the third identify an ongoing lagged association between the partner’s stream of behaviours and it is measured by time series analysis.

Why is synchronization important? First, it improves perceptual sensitivity to the motion of the partner by increasing both attention and movement responding, resulting in a better interpersonal coordination (Richardson, et al 2007; Sabenz et al, 2006; Schmidt & O’Brien, 1997; Valdesolo et al, 2010). A part from effectiveness, a growing body of evidences is pointing out the role of synchronized actions in enhancing rapport, reciprocal liking, cooperation and prosocial behaviours (Bernieri, 1988; Miles et al, 2009; Wiltermuth & Heath, 2009). For long the idea that synchrony could enforce group cohesion has been only a speculation (Ehrenreich, 2006; Haidt, 2007; Haidt et al., in press; McNeill, 1995) but recent studies are providing consistent empirical evidences. Persons are more likely to increase emotional responding and altruistic behaviour to synchronous others compared to asynchronous ones (Valdesolo et al, in press); moreover, motor synchrony increases sense of interpersonal similarity (Valdesolo et al, 2010), joint identity and group affiliation without the need of positive emotions to be generated (Wiltermuth & Heath, 2009). In line with these findings, researchers from several disciplines hypothesize that cultural rituals implying synchronic movements (like marching, singing and dancing) may serve to foster social bonds among individuals and enhancing cooperation (Wiltermuth & Heath, 2009; Ehrenreich, 2006; Haidt et al. 2008; McNeill, 1995; Wilson et al, 2008).

Concluding, synchronized actions, by improving sense of similarity, seem to have two primary functions: increasing social cooperation (Haidt et al. 2008; McNeill, 1995; Wilson et al, 2008; Wiltermuth & Heath, 2009) and increasing the management of joint-action task (Valdesolo et al, 2010).

Which kind of non verbal cues participants use to coordinate each other through time, and what may help them to predict the timing of the other's actions? One of the mechanisms that might support precise temporal coordination of interpersonal behaviour is *breathing*. Breathing is actually used, more or less unintentionally, to manage precise temporal coordination in joint actions requiring high degree of synchronicity. Musicians playing together use to breath together in key moment of the performance to keep timing, dancers and rowers do to coordinate their movement. Anyway, as far as we know, no studies have dealt with this aspect.

1.6 Influence of cognitive activities on breathing

The effects of cognitive activities on breathing have been studied by several authors. In particular *focused attention*, *reaction time* and *arithmetic tasks* have been used as experimental conditions.

- ***Attention tasks:*** Focused attention has been investigated, often with reaction time tasks. Reaction time tasks tended to induce fast, shallow and regular breathing (Gautier, 1969; Rigg et al., 1977; Bechbache et al., 1979; Turner and Carroll, 1985; Allen et al., 1986; Carroll et al., 1986, 1987; Shea et al., 1987; Allen and Crowell, 1989; Mador and Tobin, 1991; Wientjes et al., 1998). Actually, evidences about *tidal volume* are not so consistent: some studies noticed slight decrease (Allen et al., 1986; Carroll et al., 1986; Allen and Crowell, 1989), others significant increase (Kagan and Rosman, 1964; Porges and Raskin, 1969; Porges, 1976; Boiten, 1998; Grossman et Wientjes, 2001). As *respiration rate* is concerned, a "Involvement hypothesis" has been suggested: the stronger the engagement in the task, the more respiration rate will increase (Carroll et al. 1986, Malmo, 1975). Anyway, it is not clear whether the component of sustained attention or the stress component elicits this rapid shallow breathing pattern (Boiten et al, 1994). Finally, attention seems to induce a reduction of respiratory variability (Kagan and Rosman, 1964; Porges and Raskin, 1969; Porges, 1976; Boiten, 1998; Vlemincx et al., 2011). Moreover, Vlemincx et al. (2011) reported an increase in sigh rates in the recovery phase. In previous studies increase in sighing has been associated to relief from negative affect and craving (McClernon, Westman,

& Rose, 2004), and from stress (Soltysik & Jelen, 2005; Vlemincx et al., 2009) thus it may be a coping strategy that could bring relief an psycho-physiological benefits, adopted to react to aversive states (Vlemincx et al., 2011).

- ***Arithmetic tasks:*** They were found to increase respiration rate (Grossman et Wientjes, 2001; Wientjes et al, 1998; Vlemincx et al., 2011) minute ventilation and mean inspiratory flow (Mador & Tobin, 1991). Results on tidal volume are quite controversial: some found increases (Grossman et Wientjes, 2001, Vlemincx et al., 2011), other decreases (Wientjes er al, 1998). Moreover, Grossman et Wientjes, (2001) found that tidal volume was much more responsive to subtle increases in task load and metabolic activity than respiration rate. They also found differences in breathing pattern while comparing mental tasks implying similar metabolic demands but different cognitive ability (silent preparation of a verbal speech VS computer generated mathematical problems): compared to baseline, math performance increased respiration rate and induce a small rise in duty cycle, while silent planning for speech induce moderate increases in respiration rate and thoracic breathing, a significant elevation in tidal volume and no change in duty cycle. Authors suggest that the differences could point out a different respiratory regulation in relation to mental task that internally organized VS externally paced. Vlemincx et al., (2011) recently made a distinction between *correlated* and *random* respiratory variability, the former representing "homeostatic capacity and respiratory stability" and the latter "enhancing respiratory sensitivity and adaptability". Total variability is the sum of the two. Investigating breathing in *arithmetic* tasks, they noticed more thoracic breathing, reduced correlated variability and increase of both random breathing and sigh rate. Also Mador et Tobin (1991) found that mental arithmetic had no effect on tidal volume variability.

- ***Noxious stimulation***, like Cold Pressor Tasks (immerge right hand with fingers spread in cold water) (Boiten, 1998; Cohen et al., 1975; Umezawa, 1992), generally induced fast, deep and irregular breathing, infrequently interrupted by inspiratory pauses (Boiten, 1998), with a significant reduction in expiratory pause duration (Boiten, 1998; Cohen et al., 1975; Umezawa, 1992). Breathing general variability increases (Lacey et al 1963; Mador & Tobin, 1991); Lacey et al (1963) suggested that this raise in autonomic activity could be related to the induction of a reduced transmission along sensorimotor pathways to diminish the influence of the external stimuli. However, this functional view has not been confirmed by further experimental research. Boiten (1998) associated the increased ventilatory activity to a state of excitement, where active coping is quite difficult as in threat, aversive stimulation or pain (Allen et al., 1986; Freeman et al., 1986; Suess et al., 1980; Boiten et al., 1994).

- ***Videogame tasks:*** Many studies investigated mental influence on breathing by measuring respiratory variables in subjects playing ***video games*** (Turner and Carroll, 1985; Miller and Ditto, 1988; Shea et al., 1993; Chin et al., 1996); anyway, their results are often highly contradictory, also in similar experimental design: some found *increasing* breathing frequency (Turner et al. 1983 and Turner; Carroll, 1985) others the *opposite* (Miller and Ditto 1988). Denot Ledunois et al (1998) suggested that different psycho-physiological components implied in cognitive tasks may influence breathing pattern in opposite ways: emotional response and arousal levels generally tend to increase breathing frequency (Grossman, 1983; Shea, 1996) while focused attention tends to slow down or inhibit ventilation (Stevenson and Ripley, 1952; Goldman-Eisler, 1955; Hare, 1973; Cohen et al., 1975). Also *coping ability* intervene in the process: Obrist et al. (1970) observed a decrease in breathing frequency in aversive conditioning situations and reaction time tasks with a warning stimulus. Thereby, Denot Ledunois et al (1998) suggested that breathing behaviour during mental tasks is likely to depend on the respective value of their attentional, emotional and arousal components

- ***Reading / Speaking:*** Bernardi et al. (2000) Compared spontaneous breathing with reading silently, reading aloud and free talking. Silent reading significantly rises mean respiratory frequency; conversely, it decreased during both conditions associated with speech (reading aloud and free talking). Compared with spontaneous breathing, reading silently also increased minute ventilation, whereas reading aloud decreased minute ventilation.

	Rapid / Slow	Deep / Shallow	Regular / Irregular	Sighs	Apnoeas
Reaction Tasks	+	-	R	+	//
Arithmetic Tasks	+	???	R	//	//
Noxious stimul.	+	+	I	//	+
Silent Reading	+	+	R	//	//

Concluding, effects of mental activities on respiration are a complex field of investigation and current findings are not always consistent and reliable. First, because cognitive influence on respiration cannot be easily distinguish from the one exerted by the emotional reaction to the task. Many aspects that are crucial in task performance are also involved in emotional experience: arousal, novelty, coping, etc etc. Secondly, it's difficult to separate the influence of discrete cognitive functions on respirations, since mental task involve many abilities at once.

1.6. Relation between breathing and emotional experiences

1.6.1. Emotions and related physiological response pattern

Emotion is commonly conceived as a multi-component process that implies "interrelated, synchronized changes in states of all or most of five organism subsystems in response to the evaluation of an external or internal stimulus event as relevant to major concerns of the organism." The five central components are: 1. the cognitive evaluation of the event; 2. the physiological response of the organism; 3. the motor expression component, responsible for communication of reaction and behavioural intention, 4. the subjective feeling states, 5. the motivational component, responsible for preparation and direction of action (Scherer, 2001). The physiological response of the organism is an important response component of the emotion complex (e.g. Gross, 1998; Lang, 1995; Scherer, 2001). Physiological changes in emotion are hypothesized to modify a context specific-physiological pattern (Lang, 1993; Leventhal, 1984; Scherer, 2001) in order to prepare the body for subsequent actions (Eckman, 1984; Levenson, 1994; Tooby et Cosmides, 1990). Thus, it is possible that specific emotions, basic ones in particular, could be linked to distinct psycho-physiological activation pattern. Every day observations actually seem to suggest that different visceral sensations underlie different emotions. These sensations could be so distinct and strong to suggest the assumption that emotions are differentiated peripherally as well as centrally. James (1884), in his *peripheral theory* *of emotion,* stated that discrete emotional experiences can be identified by distinctive patterns of bodily changes, and that the specific pattern of peripheral physiological changes *is* the actual emotional experience. In other words, he hypothesized that emotion specific somatovisceral patterns begins before and trigger the related, specific emotional experience. Cannon (1927) vigorously criticised this position providing evidences that autonomic events were too slow and undifferentiated to generate emotions; on the contrary, he suggested that information from peripheral activity were the not necessary to generate emotional experiences and rather originate from a "top-down" elaboration. In other words, body changes followed subjective feeling state. Schachter and Singer first (1962) shown how attribution processes initiated by the perception of undifferentiated arousal states can induce discrete feelings and influence emotional behaviour. Further studies on appraisal (Ellsworth, 1994) in emotion as well as emotional experience in spinal cord injured patients (Chwalisz et al, 1988) supported this hypothesis. We had to wait until '80 for the first studies aimed to find evidences for autonomic nervous system (ANS) differentiation of specific emotions (Ekman et al, 1983)

Although we have now built a significant body of research that focused on this hypothesis and some reliable autonomic differentiation has been actually pointed out across studies, the results seems far from definitive (for reviews: Cacioppo et al, 1997; Cacioppo et al, 2000; Zajonc & McIntosch, 1992). The same pattern of somatovisceral activity has been associated with highly different emotion, and the same emotion with quite different pattern of somatovisceral activity. A meta-analysis conducted by Cacioppo et al (1997) on whether emotion specific autonomic patterning do exist, indicated that discrete emotions cannot be fully differentiated by visceral activity *alone*, while a more reliable distinction could be found when positive and negative emotions are contrasted, since negative emotions are associated with stronger ANS responses than positive ones. Moreover, those studies have generally shown lack of consistency, being their results quite difficult to replicate and to allow reliable generalizations. Ekman et al. (1983) underlined some crucial methodological problems:

1. failure to verify that an emotional reaction has been actually aroused through *other kind of measurements* (self report, behavioural observations, etc);
2. failure to *equate the intensity* of the aroused emotion in different setting;
3. *mistiming of physiological recordings*, given the likely onset and offset of the emotion.

What is the present state of the art? Dealing with the association between emotions and body changes, Philippot et al. (2002) identified three main perspectives about the relation between emotions and physiological pattern. The **first,** drawn on Singer and Schachter model, state that different emotional feeling rely on an undifferentiated arousal pattern. This model assumes that the perceived emotional intensity is influenced by the arousal intensity (Schacther, 1964; Reisenzein, 1983).

The **second** regarded the cognitive appraisal models, stating that the pattern of body changes related to a specific emotional state is the sum of the changes induced by each appraisal component (Scherer, 1984; Smith & Kirby, 2000). The models pertaining to this perspective (like the neurobiological model of anxiety of Bernston, Sarter and Cacioppo, 1998) suggest that either of autonomic and central processes are involved in triggering, encoding and recalling emotional experiences although body changes have generally a more marginal role than cognitive evaluation. Cacioppo et al. (1992) model, the *Somatovisceral Afference Model of Emotion* (SAME) identify different kind of somatovisceral responses and cognitive processes that can lead to emotional feelings. Somatovisceral responses ranges from *distinct* somatovisceral patterns (Ekman et al, 1983; Levenson et al, 1990) to *general and undifferentiated* arousal state (Schachter et Singer, 1962; Mandler, 1975) while cognitive processes ranges from simple *recognition of discrete peripheral activation* to more complex *cognitive appraisal*. This model suggests also that quite different patterns could lead to the same emotional experience via different cognitive mechanisms and the same pattern, whether ambiguous and undifferentiated, can lead to different affective reactions.

A **third** perspective states that emotions are organized by innate neural structures (Eckman, 1999; Izard, 1979; Tomkins, 1980) or cognitive networks derived from individuals' experiences (Lang, 1979; Philippot & Schaffer, 2001) that link together different emotion components. This third view keeps together very different theories all sharing, anyway, three assumptions: 1. different emotion are related to different and specific pattern of body changes; 2. the activation of that specific pattern is able to elicit the related emotional feeling (peripheral feedback) 3. peripheral feedback occurs at an implicit level, without awareness (Cacioppo et al, 1992; Damasio, 1994; Teasdale, 1996). The "*facial feedback hypothesis*", that posits that facial expression manipulation could affect emotional feeling, follows this line (Laird, 1984; McIntosh, 1996). This phenomenon is well documented, with a significant although generally small effect size (13% of explained variance). Also *posture* (Stepper et Strack, 1993) and some *physiological variables* like heart rate or skin temperature (Hess et al, 1992; Levenson, 1992; Kappas, 1989) and *respiration* (Beck & Scott, 1988; Boiten et al, 1994; Bloch et al, 1991; Philippot et al, 2002) have been proven to affect mood. This result is of particular interest for our research focus: the amount of variance accounted for by breathing emotional induction pattern, in fact, was estimated about 40% (Philippot et al, 2022), highly greater than the 13% accounted for by facial feedback (Matsumoto, 1987). Among the studies that focus on the relation between facial expression and affective changes, also *Vascular Theory of Emotional Efference* (Zajonc, 1985; Zajonc et McIntosch, 1992; McIntosch, et al, 1991; McIntosch, et al, 1997) is of particular interest for our discussion, since it refers directly to respiration. In fact, this theory assumes that facial actions influence breathing patterns, altering the volume of air inhaled through the nose; this in turn influences brain temperature and, as a result, affective state. In fact, neurochemical brain processes are temperature sensitive: adequate cooling of the brain is associated with pleasure, the opposite with discomfort. Since normal nasal breathing is in part responsible for thermoregulation of the arterial blood entering the hypothalamus, changes in breathing could affect emotional state. Facial expression, finally, influence the volume of air inhaled through the nose: in subject posing facial expression similar to those displayed during negative affect, nasal breathing air volume decreased and forehead temperature increased; moreover, they subjectively reported more negative feelings than subject posing positive emotional expressions (Zajonc, 1989; McIntosh et al, 1997). Thus, it seems that facial expression effect on affective state could be more properly ascribed to breathing influence on emotional mood.

1.6.2. Emotions and related breathing pattern

Not much attention has been brought to the specific relation between emotions and respiration. Most of the studies were carried out at the beginning of last century (Rehwoldt, 1911; Benussi, 1914; Skaggs, 1926; Stevenson and Ripley, 1952) while it’s more difficult to find recent literature above this topic, being current studies more focused on the effect of rest, stressful task and paced breathing on cardiovascular and respiratory pattern than emotional states. This lack of studies is quite surprising, since respiration could be an effective mean to investigate the complex relation between emotions and physiological reactions (Philippot et al, 2002). First, being breathing under both voluntary and automatic control, it allows similar manipulation as with facial expressions. Thus, it could be an effective mean to test physiological emotion specificity. Secondly, respiration changes affect many other physiological responses, such as cardiovascular and skin conductance. Moreover, respiration seems to actually influence some emotional states, like anxiety (Beck et Scott, 1988). Boiten (1998) pointed out some of the major obstacles that discouraged further research on this topic:

1. Inducing real-life emotions in a laboratory setting;
2. Controlling the intensity of the induced emotions: the arousal level could significantly impact on respiratory pattern inducing similar features regardless of emotional valence (e.g., general excitement, as pointed out by Woodworth and Scholsberg, 1955) or, on the contrary, creating huge differences among the same emotional valence (Philippot et al, 2002).

Boiten, Frijda et Wientjes, (1994) carried out a review of the literature focused on the relation between emotion and respiration. They concluded that previous experimental works shown not consistency enough to allow firm conclusions on the relation between specific emotional state and induction of distinct respiratory patterns since they are often narrowed by *methodological shortcomings*, in particular:

- Small sample of participants;
- Deficient experimental control procedure;
- Inadequate baseline procedure (Boiten, 1998): if subjects are aware that their breathing is being recorded, they will be likely to allocate their attention on respiration and this may easily induce an alteration of spontaneous breathing. Thus, participants should be prevented from focusing attention on their breathing.
- Inadequate measurements techniques or statistical analysis;
- Limited number parameters (often respiration rate, amplitude, and volume).

The authors, in they review, identified two major positions on the relation between emotion and respiration; the first perspective, the “specificity model”, claims that specific respiratory patterns are associated to distinct *emotional state*; the second one, the “dimensional model”, instead argues that respiratory activity reflects not emotion as such but *emotional dimensions*, like:

- *Attention focus* (intake vs rejection): Lacey et Lacey (1970) observed that diverting attention toward the external environment or task induces deceleration of heart rate (perhaps useful to make people more sensitive to new information) while focusing attention on internal cues and rejecting external stimuli induces acceleration.
- *Coping* (active vs passive): Obrist (1981) observed that subjects perceiving to have control over aversive stimuli become more engaged in the task to actively coping with them; this resulted in an increase of autonomic activity;
- *Arousal* (calm vs excitement) and *affective valence* (positive vs negative) (Lang et al, 1990).

In particular they found a relation between breathing patterns and some general dimensions of emotional response: calm-excitement, relaxation-tenseness, affective valence and active versus passive coping. They then reported four types of breathing associated with similar (although far from being unique and specific) emotional states:

1. *Fast and deep breathing* was associated with excitement (such as in **anger**, fear, or sometimes even joy);
2. *Fast and shallow breathing* was associated with tense anticipation (including concentration, **fear**, and panic);
3. *Slow and deep breathing* was associated with **relaxed** resting state.
4. *Slow and shallow breathing* was associated with states of withdrawal and passiveness (such as **sadness**, depression or calm happiness)

In a further study (Boiten, 1998) the author investigated which of the two perspectives, the dimensional or the specificity model, provides the most appropriate explanation to the study of affect-related respiratory response. In particular he manipulated the *active vs passive coping* dimension, *intake vs rejection* and *arousal*. 27 participants took part to the experiment joining all the experimental conditions; respiratory signal was recorded with a pneumograph for a period of 2 min in three different tasks:

1. *7 emotional film scenes viewing*: they allow manipulation of set to test emotional specificity influence on respiratory patterns. Film were selected to induce a particular emotion and to induce strong emotional impact: neutral feelings, disgust, fear, amusement, sadness, suspense, tenderness. It was not possible to manipulate the coping dimension within this condition, whereas *arousal* and *hedonic valence* (pleasant vs unpleasant) could be controlled.

2. *A cold pressor test:* intake vs rejection. Subjects were asked to immerge their hand in cold water; they could control or not the duration of the aversive stimulation (*active – passive* dimension). This condition induces rejection of the external environment, representing the "*rejection*" condition.
3. *A reaction time test*: Subjects are involved in a reaction task and are led to believe that they have either control or not over the receipt of an aversive stimulus (*active – passive* dimension). This condition requires outer directed attention, representing the "*intake*" condition.

After each task participants had to fill in a questionnaire that concerns the quality and intensity of their subjective feelings. Mean, standard deviation and coefficient of variation of many respiratory parameters were calculated for each task-recording period (2min). In particular: Total breath duration (T_{tot}), tidal volume (V_t), minute ventilation (V_{min}), inspiratory time (T_i), Expiratory time (T_e), post inspiratory pauses (P_i), post expiratory pauses (P_e), inspiratory duty cycle time (T_i/T_{tot}), mean inspiratory flow rate (V_t/T_i) and the percentage of rib cage contribution to V_t (R_c/V_i).

Boiten concluded that specificity models could be more appropriate to phasic respiratory activity while other respiratory response better correspond to dimensional models. As specific emotions are considered, excluding extreme respiratory reactions (like laughter and cry events) and breath holding in disgust, it was not possible to associate distinct emotions with specific breathing. Prolongation of inspiratory pauses during vision of repugnant scenes suggests a relation between disgust and suppression on ventilation (breath holding) that could be explained as an instinctive response to exclude inhalation of smelly odours or to suppress nausea. Amusement / laughter, instead, induces a significant decrease in T_i and V_t and higher variability in V_t, V_{min} and V_t/T_i. Thus, since laughter is characterized by short and steep inspirations followed by prolonged, irregular expirations and sudden decreases in V_t. Finally, tenderness and sadness could not be distinguished from neutral pattern.

Besides, as dimensional aspect are considered, the analysis yielded to the following considerations:

- ***Arousal****:* a correlation was found between increase in arousal and more rapid breathing.
- ***Valence:*** *Positive affect* yielded *longer expiratory pauses* than negative ones, both in film vision and CP task. This result is consistent with previous findings (Cohen, 1975;

Umezawa, 1992). Negative affects enhance variability of breathing pattern, especially depth. Mild positive affect (relaxation) appears to decrease respiratory volume.

- ***Coping:*** *Fast, shallow and regular breathing were observed in RT task* and was explained by the influence of attention and task difficulty ("involvement hypothesis"). Increase in task difficulty inducing more arousal and active engagement has been previously associated with raise in respiratory rate (Caroll et al, 1986; Malmo, 1975). Previous literature has also reported that effortful attention to external input usually induces decrease in breathing depth and variability of breathing pattern (Kagan and Rosman, 1964; Porges and Raskin, 1969; Porges, 1976). Task involvement is actually linked to the coping dimension too, since the higher the subject feels involved in task, the higher the tendency to ***cope actively***; the less the involvement, the less the need to cope. Besides, CP task that force subject to a ***passive coping*** attitude, induces more deep and ireggular breathing patter, interrupted by inspiratory pause durations related to aversive stimulation/pain in CP task. Moreover, being an arousing tasl, also breathing rate augmented. These results are consistent with previous findings: noxious stimulation has been known to increase respiratory variability (Mador & Tobin, 1991) and autonomic variability in general (Lacey et al, 1963). Besides, pain has been observed to be associated with repeated breath holding (Tanii et al, 1973); this reaction could be functional in reducing the impact of aversive stimulation, since suppression of respiration produce relatively high vagal tone (Lin, 1974)

Finally, results underlined also a correlation between alert/ tense anticipation / expectancy and relatively fast and shallow breathing (Suter, 1912; Skaggs, 1930; Stevenson and Ripley, 1952)

Beside Boiten's work, there are few other studies that are worth of deep illustration. One of these, is the study of Bloch, Lemeignan & Aguilera (1991), the only one that investigate the possible *induction of differentiated emotional feeling states through breathing manipulations*. They proposed that each of six basic emotions (joy/laughter, sadness/crying, anger/agression, fear/anxiety, erotic love, and tenderness) was characterized by a specific respiratory-facial-postural action ("emotional effector pattern"). The respiratory components of the patterns were derived from qualitative analysis of respiratory movements and facial-postural expressions of either actors who were evoking strong emotional memories and normal subjects reliving intense emotional episode under deep hypnosis (Bloch & Santibáñez, 1972; Santibáñez & Bloch, 1986). Based on their findings, major elements of differentiation for anger, erotic love and tenderness were significant changes in amplitude, rate and duration of the 'expiratory pause', while for sadness, joy and fear were inspiratory over expiratory time ratios. As shown below, their results are somehow divergent from those from Boiten et al. (1994, 1998):

1. **Joy:** quick and deep nasal inspiration, followed by oral expiration with small jolts;
2. **Anger**: regular, quick and deep nasal breathing;
3. **Fear**: shallow and fast breathing;
4. **Sadness**: quick nasal inspiration with jolts followed by a quick expiration through mouth;

In their study they also demonstrated that actors trained to reproduce these patterns were *able to evoke the corresponding emotional experience*. However these findings could be narrowed by experiment's demand, since participants were both told the aim of the study and informed of which specific emotion each pattern was intended to induce. Moreover, being facial and postural feedback associated with respiration manipulation, it was impossible to isolate their effect (Philippot et al, 2002). Finally, laughter and cry, although being emotional expressive components of respectively joy and sadness, do not necessarily affect breathing patterns associated with these emotions (Philippot et al, 2002). Anyway, Boiten too (1998) chose to induce "amusement" rather than "joy" in his experimental procedure, registering and including in his analysis overt laughter events, which produce a decrease of inspiratory time on one hand and an increase of expiration duration on the other.

Another interesting study was the one carried on by Philippot, Chapelle and Blairy's (2002). They investigated the effect of respiration manipulation on emotional feeling state. First, they tested Bloch et al's results, replicating their study for 4 emotions (joy, anger, fear and sadness) and avoiding the underlined limitations. Anyway, they were able to confirm emotional induction only for *joy* and *anger* breathing conditions. Thus, they carried on two more studies aimed to: 1) describe the breathing pattern that fit characterize basic emotion of joy, anger, fear and sadness; 2) test whether reproduction of those breathing pattern would have been sufficient to induce correspondent emotional feeling state. In their <u>first study</u> they ask participants (N=23) to produce one of the previous emotions by modifying their respiration; they were told to maximise its intensity and to help themselves recalling personal memories or fantasies. After the task, they had fill in a questionnaire that investigated:

- the degree to which they felt *successful* in producing the required emotional breathing pattern;
- the intensity of the *emotional feelings* they had experiences during the trial through the Differential Emotion Scale (Philippot, 1993);
- several respiratory parameters referred to both inspiration and expiration: 1. breathing frequency, 2. breathing amplitude; 3. quantity of pauses; 4. did they breath through nose, mouth or both; 5. was respiration thoracic, diaphragmatic or both; 6. presence of sighs, tremors, tension in the thorax; 7. degree of breathing regularity.

Their major finding is that they were able to clearly identify different respiratory pattern for each basic emotion, with good consistency among participants and congruent with Boiten et al (1994) meta-analysis. Resulting patterns are summarized in Tab. 2

In their <u>second study</u> they used breathing instructions based on Study 1's results to test whether breathing manipulation could induce correspondent emotional feeling state. 22 naïve subjects, believing to participate to a health psychology experiment, took part to the study. Physiological measurements were taken, in particular: cycle duration, respiration amplitude, I/E ratio, number and length of pauses, number of hampers. Moreover, subjects rated 22 items, that includes 4 emotional scale related to emotional feeling states, from 0 to 100. Analysis shown that participants actually experienced different emotional feeling according to different breathing pattern; in particular *joy* and *anger* breathing conditions successfully induced the target emotions, while *fear* induced feeling of anger at a similar intensity level, and *sadness* of positive feelings.

Breathing component	Joy	Anger	Fear	Sadness
Frequency (Fast / Slow)	- Fast (Bloch et al, 1991) - Fast if excited, Slow if calm (Boiten el al, 1994; Boiten, 1998) - Slow (Philippot et al, 2002)	- Fast (Bloch et al, 1991) - Fast (Boiten el al, 1994) - Fast (Philippot et al, 2002)	- Fast (Bloch et al, 1991) - Fast (Boiten el al, 1994) - Fast (Philippot et al, 2002)	- Fast (Bloch et al, 1991) - Slow (Boiten el al, 1994) - Normal (Philippot et al, 2002)
Amplitude (Deep / Shallow)	- Deep (Bloch et al, 1991) - Deep if excited, shallow if calm (Boiten el al, 1994) - Deep (Philippot et al, 2002)	- Deep (Bloch et al, 1991) - Deep (Boiten el al, 1994) - Slightly deeper than normal (Philippot et al, 2002)	- Shallow (Bloch et al, 1991) - Either Deep or Shallow (Boiten el al, 1994) - Normal, rather shallow (Philippot et al, 2002)	- Deep (Bloch et al, 1991) - Shallow (Boiten el al, 1994) - Normal (Philippot et al, 2002)
Mouth / Nose (Oral / Nasal)	- Nasal inspiration, Oral expiration (Bloch et al, 1991) - Nasal (Philippot et al, 2002)	- Nasal (Bloch et al, 1994)	- Oral (Bloch et al, 1994)	- Nasal inspiration, Oral expiration (Bloch et al, 1994) - Nasal (Philippot et al, 2002)
Diaphragmatic/ Thoracic	- Diaphragmatic or both (Philippot et al, 2002)	- Diaphragmatic expiration (Philippot et al, 2002)	- Thoracic (Philippot et al, 2002)	
I/E ratio	- baseline level (Philippot et al, 2002)	- longer than baseline (Philippot et al, 2002)	- longest (Philippot et al, 2002)	- longer than baseline(Philippot et al, 2002)
Regular / Irregular (tremors, sight, tension)	- Tremors in expiration (Bloch et al, 1991) - Regular, relaxed (Philippot et al, 2002)	- Regular (Bloch et al, 1991) - Irregular, highly tense (Philippot et al, 2002)	- Sometines long expiration (Bloch et al, 1991) - Irregular, highly tense (Philippot et al, 2002)	- Tremors in inspiration and expiration at one time (Bloch et al, 1991) - Slighly irregular and tense (Philippot et al, 2002)

Tab.2 Resume of previous findings on respiratory pattern associated with Joy, Anger, Fear and Sadness

Further analysis indicated that sadness induced the corresponding emotion when better performed (in particular when I/E ratio was longer). Fear-breathing pattern, instead, actually induce a blended emotional feeling. That could mean that breathing instructions were not adequate or that additional elements (like feedback from other expressive channel or more cognitive appraisal processes) are required to effectively induce the related emotion. Finally, ratings about the intensity of the emotional feeling induced by breathing were around 50 over 100; the amount of variance accounted for by this effect was 40% which is highly greater than the 13% accounted for by facial feedback (Matsumoto, 1987). These results partially support the hypothesis of an *implicit* influence of respiratory feedback on emotional experience.

Dependent variable	Fear	Study	Sadness	Study
Respiratory system				
Respiration rate	↗	Ax, 1953	↗	Levenson, Ekman, Heider, & Friesen, 1992
	↗	Bloch, Lemeignan, & Aguilera, 1991		
	↗	Boiten, Frijda, & Wientjes, 1994		
	↗	Etzel, Johnsen, Dickerson, Tranel, & Adolphs, 2006		
	↗	Krumhansl, 1997		
	↗	Levenson, Ekman, Heider, & Friesen, 1992		
	↗	Palomba, Sarlo, Angrilli, Mini, & Stegagno, 2000		
	↗	Palomba & Stegagno, 1993		
	↗	Rainville, Bechara, Naqvi, & Damasio, 2006		
	↗	Stemmler, 2004		
	↗	Stemmler, Heldmann, Pauls, & Scherer, 2001		
	↗	Van Diest, et al., 2001		
	↗	Wilhelm & Roth, 1998		
	↘	Ritz, Thöns, Fahrenkrug, & Dahme, 2005	↘	Boiten, Frijda, & Wientjes, 1994
			↘	Etzel, Johnsen, Dickerson, Tranel, & Adolphs, 2006
			↘	Gross & Levenson, 1997
			↘	Kunzmann & Grühn, 2005
			↘	Palomba & Stegagno, 1993
			↘	Ritz, Thöns, Fahrenkrug, & Dahme, 2005
	↔	Boiten, 1998	↔	Boiten, 1998
	↔	Stemmler, 1989		
Tidal volume/ respiratory depth	↗	Boiten, Frijda, & Wientjes, 1994	↗	Boiten, Frijda, & Wientjes, 1994
			↗	Etzel, Johnsen, Dickerson, Tranel, & Adolphs, 2006
			↗	Gross & Levenson, 1997
			↗	Kunzmann & Grühn, 2005
	↘	Boiten, Frijda, & Wientjes, 1994	↘	Ritz, Thöns, Fahrenkrug, & Dahme, 2005
	↘	Bloch, Lemeignan, & Aguilera, 1991	↘	Van Diest, et al., 2001
	↘	Ritz, Thöns, Fahrenkrug, & Dahme, 2005		
	↘	Van Diest, et al., 2001		
End-expiratory pCO_2	↘	Alpers, Wilhelm, & Roth, 2005		
	↘	Boiten, Frijda, & Wientjes, 1994		
	↘	Ritz, Wilhelm, Gerlach, Kullowatz, & Roth, 2005		
	↘	Van Diest, et al., 2001		
	↘	Wientjes, 1992		
Expiration pause			↘	Nyklicek, Thayer, & Van Doornen, 1997
Variability in respiratory period	↗	Bloch, Lemeignan, & Aguilera, 1991	↗	Rainville, Bechara, Naqvi, & Damasio, 2006
	↗	Boiten, Frijda, & Wientjes, 1994		
Tidal volume variability	↗	Wilhelm, Gerlach, & Roth, 2001		
	↗	Wilhelm, Trabert, & Roth, 2001		
	↗	Wilhelm, et al., 2005		
Total respiratory resistance			↗	Ritz, George, & Dahme, 2000
Oscillatory resistance	↗	Ritz, Steptoe, DeWilde, & Costa, 2000	↗	Ritz, Steptoe, DeWilde, & Costa, 2000

Tab. 3 - Overview of Studies on Peripheral Physiological Responding in Fear and Sadness, Disregarding Differences Between Emotion Induction Paradigma (Kreibig et al, 2007)

1.6.3 Breathing Interventions in anxiety treatments and emotional regulation

A last line of studies and interventions is the one dealing with stress an emotional regulation. Stressfull events generally induce an alarm reaction: the autonomic nervous system activates the sympathetic nervous system and excludes the parasympathetic one thus triggering a wode range of cardiovascular, respiratory, gastrointestinal, renal, and endocrine changes. The hypothalamus directs the release of the adrenocorticotropic hormone (ACTH) that stimulates the secretion of corticoids (glucocorticoids and cortisol) that prepare the organism's response to stress: the muscles contracts, heart rate and blood pressure increases, breathing become more rapid and shallow, sweating augments, the eyes dilate, digestion stops, veins constrict while arteries dilate. Since respiration can influence ANS activity, it could have an effective role in reducing this chain of physiological events. Breath-focused attention in particular seems effective in reducing emotional distress (Franck et al, 1994; Meuret et al, 2001; Arch et Craske, 2005; Goldin et Gross, 2010). Based on these evidences, increasing attention has been directed to practices like *yogic breathing* (Brown et Gerbarg, 2005a, 2005b; Harvey, 1983; Cappo et Homes, 1983), *breathing retraining in CBT treatments* (Clark et al, 1985; Grossman et al, 1985; Tweeddale et al, 1994; Jaycox et al, 2002; DeGuire et al, 1996) and *mindful breathing* (Kabat-Zinn, 1990; Linehan, 1993; Goldin et Gross, 2010), generally supporting the effectiveness of these in both anxiety and depression treatments.

As mentioned before, Weymouth (2007) suggested a categorization of therapeutic breathing techniques in three kinds of intervention:

1. *Affect inductive breathing interventions*: techniques used to deepen emotional experience and help o get in touch with repressed affects; this approach was pioneered by Reich and his students. The author argued that a strong relation exist between repressed emotions, patterns of muscle tension and breathing disturbance; in particular, by restricting breathing individuals functionally reduce negative affective and stress reactions (Reich, 1942) and cut off unpleasant body sensations (Lowen, 1967). Lowen (1965, 1988), following and broadening Reich’s work, develop specific exercises and postures aimed to deepen and free his client’s breathing and, by doing so, the related repressed emotions. However, the empirical validity of these therapies remains so far to be confirmed.
2. *Affect reductive breathing interventions*: techniques aimed to improve relaxation and reduce symptoms of anxiety; this approach has the widest range of applications and has been integrated in cognitive behavioural therapy treatments.

3. *Awareness breathing interventions*, that is techniques that engage breathing to help focusing on bodily and emotional experience in the present moment; they are used in mindfulness practices and Gestalt therapy.

1.7 Respiration and attument

Attunement is a complex process generally defined as the ability to "tune in" with another person. From a clinical perspective, attunement is "a felt *embodied* experience that can be individually as well as communal that includes a psychological, emotional and somatic state of consciousness" (Kossak, 2009). It's a feeling of union with other persons. Erskine (1998) emphasize the strong relation between emotional and physical connection defining attunement as "a kinestetic and emotional sensing of others, knowing their rhythms, affect and experience by metaphorically being in their skin". This feeling has been some time related to peak experiences, as if feeling this sense on connection with others could prelude to a more general sense of well being, self efficacy and to a strong engagement in present moment (Kossak, 2009). Ciceri and Biassoni (2006) present three different conceptions of this process. A first one is "intentional attuning", that that is conceiving others as "intentional Agents", with their own communicative intentionality and agentivity (Gallese, 2003, 2005). In a second meaning, attunement is the ability to manage one's behaviour in relation to the other's action, in an uninterrupted management of their co-presence. As a result they reciprocally influence each other, modulating some characteristics of their non-verbal behaviours in relation to the actions of their interlocutor (Giles, Shepard et al. 2001). From a third perspective, strictly communicative, attunement is a set of interpersonal behavioural aimed at the achievement of a joined intention through which the speakers arrange, maintain and coordinate their communicative interaction (Ciceri et Biassoni, 2006).

There by, a conceptual distinction could be drawn between *emotional* and *communicative* attunement. The former deals with the ability to "sense" each other's feelings, and could be thought as a precursor of empathy; the latter concerns management and mutual accomodation of communicative behaviours (Cappella, 1994; Giles et al, 1991; Ciceri & Biassoni, 2006). These two are actually strictly inter-connected. In a joint action participants need to manage consecutive behavioural adaptations in time; to reach this goal, they continuously share their reciprocal intentions and emotional state through a broad set of communicative signals, both verbal and non-verbal (Cappella, 1997).

Communicative attunement has both a temporal and a qualitative dimension. The former is concerned with *temporal co-ordination* along time; the latter, with the reciprocal accommodation of some of the partner's communicative behaviours in a convergent or divergent direction (Giles et Powesland, 1975; Giles, Coupland et Coupland, 1991).

Studies on mother infant interactions provided evidences that since early interaction we are able to attune to others. First, expressive behaviours (both vocal and gestured) of caregivers and newborns are organized in rhythmical patterns, to convey a sense of pulse that is used to co-ordinate action between partners partner (Kempton, 1980; Beebe, 1982). Yet, it has been recently claimed that human communicative nature itself might be based on this *innate time-sharing ability*, that is the automatic tendency to structure communicative behaviours by a shared temporal frame. (Trevarthen, 1984, 1998; Stern, 1977; Malloch, 1999) Moreover, the rhythm to which partners adapt their communicative signals has been shown to vary with the level of emotional engagement (Stern et al, 1985), being quicker when they are more aroused and activated. Not only emotion may influence communicational rhythm, but also the inverse direction is true: for example, considering again studies concerned with early interaction, irregular timing in the caregivers answer to the baby, leads to disinterest in the child and a decrease in positive expression (Murray & Trevarthen, 1985). These results emphasize again how strictly emotional and communicative aspects are.

Mutual accomodation seems to happen *unintentionally* also in cooperative tasks. Recent studies have shown that pairs of participants engaged in mental and verbal problem solving tasks, non-consciously *mimic* some of each other's actions and *synchronize* rhythmical movements (Richardson et al. 2005; Shockley et al., 2003; Schmidt et al., 1990). Although mimicry as well as synchrony implies coordinated actions, they show significant dissimilarities and it has been suggested they could serve different social functions (Valdesolo et al, 2010). Previous studies have shown that mimicry leads to positive social benefits when it occurs within an interpersonal context and as long as mimicked are not aware of being imitated (Ashton-Jamesetal, 2007). On the contrary, synchrony seems to elicit similar effects independently of awareness (Wiltermuth & Heath, 2009) and also outside interpersonal exchanges. In particular, mimicry can foster empathy, liking and pro-social behaviours (Van Baaren et al, 2004 a,b; Stel et al, 2005; Stel & Vonk, 2010); thereby, it has been argued that mimicry could serve as a sort of "social glue" that helps to bond people together (Chartrand et al., 2005).

When consciously and *strategically* used, behavioural mimicry facilitates negotiation outcomes (Maddux et al., 2007). In some counselling and therapeutic context (like client-centred therapy, NLP and humanistic music-therapy) matching the rate and quality of the client *breathing* would help "to assume his physiology", leading to or reinforcing emotional attunement (Bandler & Grinder, 1975; Sutton, 2002; Scardovelli, 1999; Sigel, 1984, 1986) However, as far as we know, this technique hasn't been rigorously tested thus it isn't clear whether mimicking breathing can actually improve rapport. Although few studies focused on respiration, others have actually dealt with automatic *physiological "attunement*" in social contexts. Levenson and Ruef (1997) argued that, since emotion is a strong embodied experience, "if one experience emotional rapport with another, there will be an element of physiological rapport too". A remarkable number of physiological systems have been noticed to synchronize across individuals, in particular when they experience close proximity, without any conscious attempt it: *monthly menstruation* in women that share the same room or are close friends (McClintock, 1971; Weller & Weller, 1993), *heart rate* between patients and therapists (DiMascio et al, 1955, 1956; Coleman et al., 1956) and mother and infants (Field et al, 1989), *cortisol* in mother and their adolescents sons (Papp et al, 2009), *skin conductance* in discussion groups characterized high scores of reciprocal dislike (Kaplan et al, 1964). As clinical setting is regarded, the study of autonomic synchrony between patient and therapist was carried out in particular within two approaches: the psychoanalytic setting and the Rogersian client-centered therapy setting but findings are controversial (Levenson et Ruef, 1997). Again, Levenson and Ruef (1992) found that people who accurately rated the *negative* emotions of a target person also evidenced patterns of autonomic activity similar to the target's pattern of autonomic activity. Levenson et Gottman (1983) coined the word "physiological linkage" to refer to patterned association between the physiology of social partners. This phenomenon has been observed first in spousal conflicts (Levenson & Gottman, 1983) then also in empathic interactions (Marci, Ham, Moran, & Orr, 2007) making it important for socio-emotional processes.

Also *developmental psychology* there has been interest in parent-infant autonomic synchrony. Some studies provided evidences for a bidirectional relation between physiological and interaction rhythms. On one side, mother-infant interaction rhythms appear to resemble the temporal rhythms of sucking, heart beating and respiration (Stratton, 1982; Wolff, 1967) and has lead to the idea that biological rhythms could provide the basis for *social* rhythms. On the other, some studies have shown that interaction synchrony seems to entrain the physiological rhythms of the infant (Beebe et al., 1985; Sander, 1969). The cyclic structure of face to face interaction seems to reflect the infant's physiological rhythms and it was argued that synchrony could express progressive adaptation of the dyad to endogenous cycle of affective involvement (Lester et al, 1985; Wolf, 1967). Feldman (2006) studied a sample of 122 mothers-infants couples in a face to face still face paradigm and found that pairs displaying high synchrony during free play, show also greater heart rate synchronization: acceleration and deceleration in infants heart rhythms were followed by the same in mother's heart within less than 1 sec. This would "*provide infant the only opportunity to match their own biological rhythms with those of another human being, co-creating not only a shared relational moment but a shared biology"* (Feldman, 2007i). In other words, parental interactive behaviour would serve as an "external regulatory function" for the organization of the baby's neurobiological, sensory, emotional, physical and relational systems (Feldamn, 2004; Hofer, 1995, 1996; Hrdy, 1999).

Anyway, so far only few studies focused on the neurobiological and physiological systems underpinned below social synchrony. Thus, although some evidences suggest there's an association between communicative, emotional and physiological attunement, further investigation are needed. In particular it would be interesting to investigate whether breathing together reinforce emotional attunement. We already discussed the results of previous studies about the effects of respiration manipulation on emotional feelings (Bloch et al., 1991; Philippot et al, 2002). Their results partially support the hypothesis of an *implicit* influence of respiratory feedback on emotional experience. Although these evidences pertain more to the field of emotion induction and social imitation, they are strictly related to attunement investigation too. In fact, breathing is a strongly *rhythmic physiological* process: based on findings related to previous investigations on the field of synchrony, imitation and physiological linkage, we can hypothesize that breathing "together" and "in the same way" could lead to higher perception of similarity, connection and affective closeness.

1.8 Conclusion

At the end of this review on the literature that dealt with respiration and major psychological processes, we return to Wientjes et (1998) remark: some important aspects of respiratory behaviour have been so far neglected by psycho-physiological research. A comprehensive picture of the topic would require on one hand focusing on key features that have been so far overlooked, on the other adopting and validating new measurements and assessment methods.

We believe that one of the aspects that hasn't be considered so fare and that can bring new interesting findings is the *expressive role* of *breathing sounds*. As said before, few studies have investigated the emotional expressive function of breathing (Bloch et al, 1991; Boiten et al, 1994; Boiten, 1998; Philippot et al, 2002) and the existing ones focused more on emotional *expression* and *induction* than on *identification* of emotional signals through breathing sounds of movements. Moreover, findings about the relation between breathing patterns and emotional states aren't so consistent and require more deep investigation. Besides, breathing has been most often measured using traditional indexes get from respiratory medicine, but breathing is not only a physiological process; is also something that can be *perceived* through different sensorial channels: it's possible to *listen to* the breathing of a person who's close enough, and it is possible to *see* his chest moving up and down. Plausibly, acoustic measurements could highlight significant features of breathing behaviour that couldn't be inferred by physiological ones alone. Since very few is known about what breathing sounds could express about the subject identity, activity and emotional experience, this research field could provide significant cues to be used either in therapeutic setting, interpersonal relations and, in particular, in dealing with persons with highly compromised communicative skills (Plotnik et al, 2010).

Moreover breathing sounds could have *a role in joint action management*: dancers, musicians and sportsman actually rely on them to manage interaction synchrony. Therefore it could be interesting to investigate how much respiration does actually serve interpersonal coordination. Being respiration strictly related to action, it is likely to be highly involve also in joint performances, in particular on temporal management of reciprocal actions, to maintain the required level of synchronization**.**

Finally, seen the literature concerning physiological and interpersonal attunement, and considering that few studies have dealt with respiration, it could be interesting to investigate whether "breathing together" could be an actual mean to *improve emotional attunement* in social interactions.

Introduction to the research plan

The research plan we are to present is arranged in three parts. Considering lack of previous studies, the first study aims to build a valuable and compound set of measurements that enable a reliable *respiratory and acoustic description of breathing sounds*, as well as to *relate partner's respiratory behaviour* during joint performances. To collect a wide sample of breathing sounds characterized by ample acoustic variability and to investigate a method that allow relating breathing behaviour of co-performers, audio-recordings of the respiration of individuals engaged in individual and joint activities requiring different degree of *physical* and *mental* demand will be carried out. Different *respiratory* and *acoustic* analyses will be tested and indexes of coordination between partners' respirations will be investigated. The most effective will converge in a multilayer analysis model of breathing sounds. This model will allow the description of breathing tracks used in the second study and collected in third one.

The second study investigates which information could be reliably inferred about a person's *identity*, *emotional state* and *activity* from his/her breathing sound. Moreover, it aims to verify whether mimicking those breathing patterns improve the identification accuracy compared to pure listening. Ecological tracks of breathing sounds related to different activities and emotional conditions will collect and brought to the attention of two experimental groups. One will just listen to the track and fill in a questionnaire, the second will imitate those pattern before responding.

Finally, the third study aims to provide a reliable description of the acoustic features of breathing in different emotional conditions, collected in a more controlled setting, and to investigate how "breathing together" influence the attunement process between participants, considering different dimensions: *emotional decoding, similarity of the emotional experiences*, *perspective taking, perceived physical activation*, and *synchronization.* 40 women will take part to the experiment and randomly coupled. One participant will read a narrative used to induce a specific emotion and will breath as if she was in that described situation. The other will listen to her breath and express her closeness breathing together with her in the same way. Both will be audio-recorded. Tracks analysis will be carried out both to describe breathing patterns related to 6 different emotions to investigate participants synchronization along time, while self report will provide data about emotional decoding and emotional attunement.

2

2.1 Introduction

A huge range of respiratory parameters shows significant changes under different behavioural conditions (Lorig, 2007; Wientjes et al.1998). It has been argued that this variability underlines the ability of the respiratory system to adapt to different physical, mental and emotional conditions in order to be as most efficient (Astrand and Rohdahl, 1986) or comfortable as possible (Chonan et al., 1990; Kikuchi et al., 1991). Anyway, although there is common agreement that psychological variable could induce changes in physiological parameters, psycho-physiological literature has failed for long to provide consistent findings about such correlation (Wientjes et al. 1998).

Breathing is often entrained by simultaneous rhythmical movements and it has been proven to influence both their rhythms and precision (Raßler and Kohl 1996; Raßler 2000; Raßler and Kohl 2000) but not attention have been brought to the role of respiration in joint performances, although actually used in high synchronized task to manage interpersonal coordination. Several ambulatory studies have also assessed respiratory responses to mental tasks (Harding, 1987; Bles et al, 1988; Brookings et al, 1996; Wientjes et al, 1996, 1997) but current findings are not always reliable, both because of the difficulty to isolate the influence of discrete cognitive function on respiration and to separate them from the effect of emotional experience. Few recent studies have finally investigated whether a specific relation between emotions and respiration could be drawn (Bloch et al, 1991; Boiten et al 1994; Boiten, 1998; Philippot et al, 2002). Some consistent findings emerged both on the existence of distinct respiratory pattern associated to specific basic emotions and on the possibility to induce them by mimicking those patterns (Philippot et al, 2002). Anyway more studies should be carried on to validate these results.

A problem that relies below the lack of studies and consistent findings about the relation between respiration and psychological variables is the employment of *inappropriate and unrefined measurements and data analysis procedures* (Wientjes et al 1998). Psycho-physiological research has relied for long on methods and indexes derived from respiratory medicine that are often too intrusive for psychological research setting and, what' more, serve different research goals. Wientjes et al. (1998) suggested that new respiratory assessment methods, based on multiple respiratory measures, would be necessary to better capture the correlation between behavioural demands and breathing changes. Among them, a new interesting perspective could be provided by the investigation of the *expressive role* of *breathing sounds*.

Analysis of breathing sounds has a significant role in the diagnosis of respiratory system diseases, but generally refers to sounds captured into the lungs (see par. 1.2). Few studies in the field of speech analysis and professional voice recordings have instead dealt with acoustic analysis of breathing sounds *out* the lungs, and they were aimed to improve speech segmentation (Price et al, 1989; Wightman et Ostendorf, 1991) and detection of badly pronounced or unwanted sounds (Ruinskiy et Lavner, 2007; Nakano et al, 2008). A part from them, as far as we know no studies have investigated whether breath sounds could provide, on their own, reliable information about *emotional experiences*, *mental concentration* or *physical activation*. Why this should be worth of interest? Since respiration is actually affected by those variables, is arguable that also breathing sounds would change and that, within close interpersonal distances, could assume a distinctive *communicative value*. For example, breathing sounds are actually used to manage interaction synchrony in performances requiring high degree of synchronicity (like musicians, dancers and sportsman) but so far no studies have investigated how much respiration does actually serve interpersonal coordination. Does breathing sounds convey usable information about the performance management? Moreover, breathing sounds are used by actors to convey *personality* and *emotional* cues about their character, call centre operators relies on them to gather information about the emotional state of their callers and the same did mothers with little children. Thus, it seems that studies on respiration and emotions could provide useful information about the subject identity, activity and emotional experience to be used either in interpersonal exchange, therapeutic setting and, in particular, dealing with persons with severe motor disabilities or highly compromised communicative skills. Plotnik et al. (2010) have already fallen back upon breathing to facilitate communication in paralyzed people. They realized a “sniffing device” that relies on a pressure sensor to detect breathing air pressure below the nostrils and convert it into electrical signals that can be read by a computer: by modulating their nasal pressure, people can trigger commands and select letters from a virtual keyboard and to compound sentences. The device was proved to be as easy and effective to control as a hand-held mouse or joystick and disabled people reported that it was easier to use than those based on eye movement or blinks detection.

Thus, it seems that investigation of emotional and expressive features of breathing sounds could provide new insight in the research field of affective and communication psychology. Anyway, whether acoustic analysis of breathing sounds could highlight significant features of breathing behaviour that couldn't be inferred by physiological ones alone still needs to be tested. First, a valuable and compound set of measurements should be built. Those indexes should enable to draw a consistent picture of the dynamic flow of respiratory behaviour in relation to different psychological demands.

2.2 Aims

Considering the lack of previous literature about the acoustic description of breathing sounds, the general aim of the study was to build a *set of acoustic indexes* that enable extract a range of respiratory and acoustic features from breathing sounds and to relate them to the kind of *action* performed by the subjects. In particular the study was aimed at:

1. Find reliable *acoustic* and *spectral* descriptors of breathing sounds;
2. Identify indexes that enable to *relate breathing behaviour* to a *simultaneous performance*;
3. Identify indexes that enable to *relate partner's respiratory behaviour* during *joint performances*.

2.3 Method

In order to build a wide sample of breathing sounds and to produce adequate variability among our data we chose to collect audio recording of respiratory events from persons engaged in activities requiring different degree of *physical* and *mental* demand. Including also the variable *emotional engagement* at this early stage of the study would have a brought relevant problem of complexity, thus we decide to exclude it in this preliminary sampling phase. In order to explore indexes that enable to relate respiratory behaviour to: 1. the management of a simultaneous action 2. the co-management of joint actions, breathing sounds had to be captured during performance that could be carried on both *individually* and *jointly*.

According to these criteria, we set the following sampling variables:

1. *Performance Demand*:
    a. Different degree of physical demand;
    b. Different degree of mental demand;

2. *Performance Condition:*
    a. Individual Action
    b. Joint Action

As experimental condition characterized by *quite low physical and high mental* demand we chose *musical performance* for the following reasons:

1. Musical performance allow both a joint and an individual performance on the same piece of music;
2. Several studies have proven the effect of music listening on the respiratory system in particular changes in respiratory rhythm induced by musical parameter such as tempo, rhythm and pauses (Bernardi et al. 2007, 2009; Koelsh & Siebel, 2005; Altenmuller et al, 2002).
3. Respiration, both as an action and a sound, has an important role in management of both individual and joint aspect of musical co-performance, in particular concerning temporal coordination of interpersonal behaviours.
4. The requirements of an improvisation section would increase the need to manage close interpersonal coordination and could influence breathing in return.

As experimental condition characterized by *quite high physical and quite low mental* demand we chose walking through an *obstacle course* carrying on a tray with some recipients filled with water for the following reasons:

1. It allows both a joint and an individual performance on the same course;
2. It is an ecological performance: carrying a tray with recipients filled with water, alone or helped by someone else, is something that could happen in everyday life.
3. It doesn't require covering long distances; that would have required the employment of radio-microphones, that haven't the same audio quality of cabled ones.
4. The introduction of some obstacle along the path would increase the need to manage close interpersonal coordination and could influence breathing in return.

Two duets of professional musicians took part to the study: a classical violinist and a classical guitarist (Duet A) and a jazz singer and a double bass player (Duet B). Each couple took part to **five experimental conditions**:

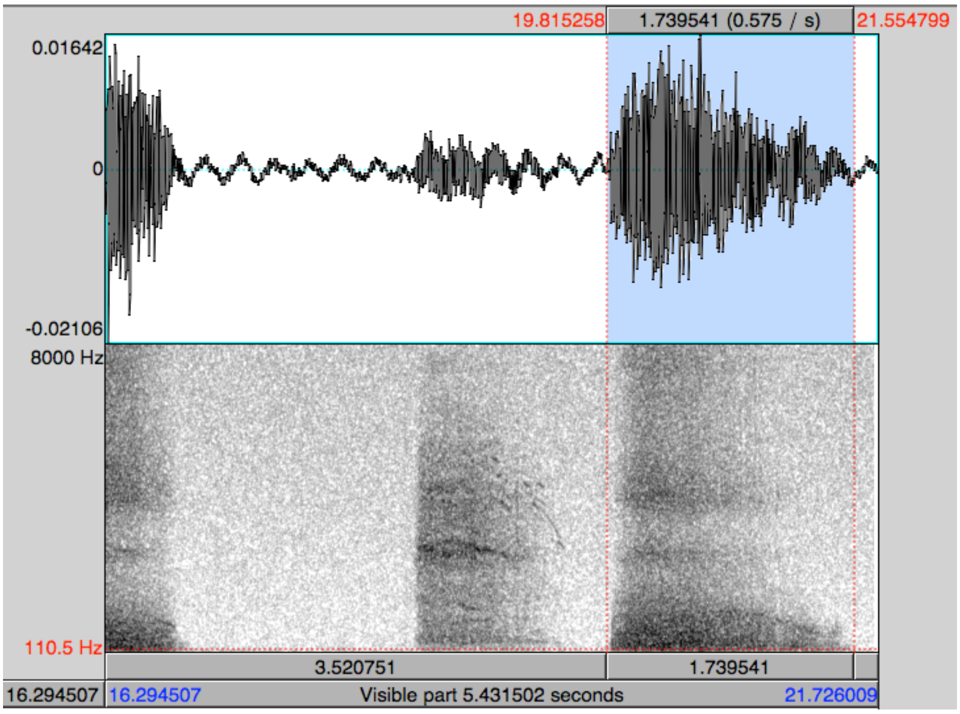
1) Resting Condition (baseline): each performer just sat silently on a chair, side by side, for 2 minutes.
2) Musical co-performance: each couple performed a piece of their repertoire that includes a joint musical improvisation.
3) Musical performance: each performer alone played the same piece, including the improvised section.
4) Joint non-musical activity: each couple carried on 7 recipients disposed on a tray along an obstacle course, standing one in front of the other. Recipients were different in size and shape and filled up with water and they had to spill less water as possible. Along the course they had first to step over a step, then to lay the tray down on the floor, to put it up again and, walking back, making the same course backward.
5) Individual non-musical activity: each performer completes the obstacle course alone, following the same rule.

20 audio tracks of breath sounds were recorded using a *Presonus Firestudio Project* computer recording system and two *Shure WH30 XLR* head-microphones. 4 musical tracks were recorded using a *ZOOM H2 Recorder*, one for each musical performance. All experimental conditions were video-taped using a *Canon Legria HF200* camera (HD).

2.4 Multilayer Analysis Model

2.4.1 Sample

Each audio track was screened using the software for acoustic analysis Praat. Starting and ending time (in ms) of each *respiratory event*, considered as *single expiration* (E) and *inspiration* (I), were manually detected using three reference frame: 1. the waveform representation of the audio track, 2. its synchronous spectrographic representation (view range: 0 - 8.000 Hz; window length: 0.03), 3. the corresponding audio signal.



A total sample of 1903 respiratory events was collected, spread as following:

Conditions		**Baseline**	**Joint Obstacle Course**	**Joint Musical Performance**	**Indiv. Obstacle Course**	**Indiv. Musical Performance**
Tot. Breath		199	381	595	219	509
Action Dur.	M	120.00	154.04	212.25	87.00	155.16
(sec)	SD	//	(37.31)	(21.18)	(31.61)	(39.59)

2.4.2. Breath Sounds Analyses

To capture the association between behavioural demands and breathing changes we need to built set of indexes that allow a *multilayer analysis of respiratory* behaviour, through multiple respiratory measures. In order to achieve this goal, the argued that the model should include:

- Indexes that describe the main traditional *respiratory features* (i.e. respiratory cycle, E/I duration, etc);
- Indexes that describe *breathing sounds features* (i.e. rhythm, timbre, etc);
- Indexes that relate breathing behaviours to the *simultaneous performance* carried on by the subject;

- Indexes that enable to relate changes in respiratory behaviour of both subjects during *joint performances*.

2.4.2.1 *Respiratory indexes*

An analysis of measurements, techniques and experimental methods relevant for psycho-physiological research on respiration was first carried on. Wientjes and Grossman (2005) identify two major respiratory assessment areas to be considered:

1) measurement of the contribution of depth and frequency of breathing to ventilation: tidal volume, respiratory rate, minute ventilation, inspiratory, expiratory and cycle duration, mean inspiratory flow rate and duty cycle time (see Wientjes, 1992)
2) measurement of parameters associated with gas exchange: they include the volume of oxygen consumed per time unit and the quantity of carbon dioxide produced.

Acoustic analysis alone couldn't provide any information about gas exchange process. Instead, we tested whether it could be associated with some of the conventional measurements of ventilation related to *temporal* features of respiratory signal (Boiten et al, 1998). In particular we took into consideration:

- **Number of breaths / min**: total amount of respiratory events (individual I ad E) occurring in one minute; dividing /min allow comparison of this index between different conditions.
- **Respiratory rate** (RR): number of respiratory cycles occurring in one minute.
- **Cycle duration** (Tt): total time for inspiration and expiration.
- **Inspiratory time** (Ti): time spent inhaling.
- **Expiratory time** (Te): time spent exhaling.
- **I:E ratio** (Ti/Te): the ratio of the duration of inspiration to the duration of expiration.
- **Pauses** (P): time between the onset of each breath and the following one.

Mean, *standard deviation* and *range* were extracted for each parameter listed above, for each subjects in each experimental condition.

Acoustic and Spectral indexes

As acoustic analysis of breath sounds are concerned, most are carried on through *stethoscope* examination and concerns *tracheal sound* (Elphick et al., 2000; Elphick et al.2004; Harper et al, 2001). Patterns of normal breath sounds are generally described in function of their *duration, intensity, pitch* and *timing.* Few studies have dealt with acoustic measurements of breath sounds *out of the lungs* (see Par.1.2). Between them, the study of Nakano et al. (2008) is focused on spectral analysis of breath sounds recorded from audio-performance of professional singers. They collect a total number of 1448 breath events extracted from song samples by hand-marking. The total length of the final dataset was 128 minutes. Using a cepstrum model, spectral envelope was calculated and then a long term average spectrum (LTA-S) was obtained. They found that breath events have relatively stable spectral features. A common spectral peaks is located at about 1.6 kHz for male singers an 1.7 kHz for female singers, probably a constant could be due to breathing mechanisms independent from body size, voice range and singing context. Moreover, a secondary peak exists in the range of 850Hz-1.kHz in female voice.

We decide to test the following acoustic indexes:

- **Formant Analysis**: In speech analysis and acoustic research formants are described as the spectral peaks in the spectrum envelope of a sound (Benade, 1976). They have not to be confused with the harmonic constituents of a sound. In human voice there are different formants, generated by specific chamber resonance in the vocal tract, and define the specific *timbre* of the sound. An explorative formant analysis of breath sounds could provide information that allows discriminating basilar acoustic difference between breath noises like the difference between inspiration and expiration sounds.
- **Long Term Average spectrum** (LTAs): it represents the logarithmic power spectral density as a function of frequency; in other words, it consists of a set of spectra taken at a given frequency (e.g. one every *ms*) over a given time period (about 40 sec) which are then averaged summarized as a set of spectral bands.
- **Spectral centroid**: It describes whether the spectral content of a signal is dominated by high or low frequencies. Since timbral quality of brightness correlates with increased power at high frequencies the spectral centroid is considered as an indicator of perceived sharpness of a sound. It is calculated as the

weighted mean of the frequencies present in the signal, determined using a Fourier transform, with their magnitudes as the weights:

$$Centroid = \frac{\sum_{n=0}^{N-1} f(n) x(n)}{\sum_{n=0}^{N-1} x(n)}$$

where x(n) represents the weighted frequency value, or magnitude, of bin number n, and f(n) represents the center frequency of that bin.

- **Tau analysis**: (Lee, 1998; Schogler, 2003; 2008), an analysis framework that describes how duration, size and shape of a sound *vary over time* and may be controlled by for expressive effect. General Tau Theory (Lee, 1998) is rooted in theory of intrinsic and perceptual guidance of movement of Bernstein (1967) and Gibson (1966). Their assumption is that activity involves both *intrinsic guidance*, knowing how to move, and *perceptual guidance*, perceiving how we are moving through our senses. Tau theory postulates that any purposeful movement requires *controlling the closure a gap* between a current state of body and a goal state. **Tau** is a measure of how a motion-gap is changing in time. It is the time-to-closure of the motion-gap at the current rate of closure, or, equivalently, the first-order time-to-closure of the motion-gap. Though tau is measurable in time units, the concept is not a purely temporal one. Tau is a blend of space and time:

$$\frac{\text{current size (x) of the motion-gap (m)}}{\text{current rate of closure (m/s) (velocity)}}$$

Purposeful movements require the closure of more than one gap at once, corresponding to the different physical dimensions involved (the *angular* motion-gap, the *force* motion-gap, the *distance* motion-gap, etc). All these gaps are coupled: that means that their relation is constant in time. Since the application of this theory is not limited to a specific physical dimension, it has been also applied to the investigation of sounds wave (Schogler, 2003; 2008) and aspires to provide a way to represent and analyze how sound physical vibrations are produced and controlled by the performer either in the field of pitch, amplitude, timbre. In other words, it represents a mean to investigate how duration, size and shape of a sound may be controlled by for expressive effect. These three sound dimensions are a natural result of the movement that is implied to produce the sound. Thus, the authors posit that duration, amplitude and kinematics of the movement are directly related to duration, size and shape of the acoustic wave.

- **Inspiration Intensity** (db);
- **Expiration Intensity** (db);
- **Amplitude Envelope.**

2.4.2.3. Coordination Indexes

Interactive indexes should enable to relate changes in respiratory behaviour of both subjects during *joint performances*. We argue that one the aspect of interpersonal coordination breathing serves is interaction synchrony. Thus, we need to identify indexes that measure the degree of synchronism between performer's breathing behaviour. First of all, when should two breathing events be considered *concurrent*? Synchronicity is measured according to different methods depending on the *nature* of the event under investigation (social, physiological, electronic, etc). Generally speaking synchronism could be assessed on the basis of *prefixed thresholds* or *relative measurement. Prefixed thresholds* require defining a fixed interval on the basis of the event's timing. *Relative measurements* provide estimates of the actual time-lag between two events without using any threshold. The formers allow categorizing events on a *range of classes*, providing a more sensitive description of the changes occurring along the stream of the action; anyway, since we were not able to find in literature reliable thresholds for respiratory synchrony in relation to joint actions, a preliminary exploration of the nature of our data was required. Relative measurements served this purpose, since they provide a synthetic description of the *actual* trend of the data.

A reliable measurement of simultaneity is the estimation of the *variance of co-occurrence in time*: the smaller the variance the higher the synchrony between considered events. Schogler (1999), studying the degree of synchronization of two musicians performing together, used two similar indexes: a) *the difference in the onset* of notes being played by the musicians during an improvisation (the smaller the difference between two corresponding notes, the more synchronous the performance of the two players); b) the *variance in the difference in the onset* of two corresponding notes (the less the variance in the distances, the more the synchronization between the musicians). Thus, we first estimated *mean, standard deviation and range* of the **lag between couple of *closest* breaths' onset.** Based on these results, that should give an idea of the general trend of the respiratory behaviour in baseline and joint actions, more reliable relative and fixed indexes could be set up. Some hypotheses about possible thresholds were done considering previous psychophysical studies about *auditory perception* and *conscious motor control*. First, since we were dealing with auditory perception, two breathing events could be considered as simultaneous on the basis of human ability to perceive two sound as distinct one from the other. It is known that:

1. **Below 20 ms** separation between tone onsets we are not able to **determine the order** of two different sounds (Hirsh, 1959);
2. **To hear two separate events** and not an individual one, two sounds must be **at least 50 ms apart** from event onset to event onset (Steudel 1933);
3. Nonetheless, two auditory events are **integrated in a bound unit** when they occur between 50 and 100 ms (Yabe et al., 1998);
4. Above 100 ms we **begin to discern rhythmic shapes and groups.** Durations in the 100-200ms range are too short to serve as beats, they just can serve as subdivisions of the beat (Roederer, 1995);
5. **250ms periodicity** is the **fastest rate at which we can discern a beat** or pulse (Westergaard 1975).

Thus, if we consider breathing sounds as perceivable acoustic signals, we could consider **100ms** as the minimal threshold. However, while engaged in a joint action, we presumably do not breath with purpose *to be heard* by the partner, rather in order to *manage* our performance. Thus, not only human perception threshold should be considered, but also the temporal interval needed to consciously control action. Libet's (2004) pointed out 500ms as the threshold for conscious experience. We hypothesized that two breathing sounds could be considered simultaneous if they occur **within a 500 ms** temporal integration window. In order to take into consideration both auditory perception and conscious motor control we thus hypothesized three increasing thresholds of synchrony:

- **0-100 ms** (above which two acoustic events are rhythmically distinguished);
- **100-250ms** (above which we can clearly discern a beat);

- **250-500 ms** (which is the threshold for conscious experience).

A forth category, including coupled-breaths' lag **upon 500 ms**, could identify non-simultaneous breath. These categories were then tested on our data.

2.4.3 Video-recording Analysis

Different analysis methods have been developed to describe respiratory behaviour in relation to different kind of performance. To relate changes in breathing behaviours to particular action unit, in specific moment of subject individual and joint non-musical performance, video recordings were analyzed. The task was split into 6 main action classes that represents following fixed moments in time; breathing indexes previously discussed were coded within each category:

1. <u>Raising the tray</u>: grabbing the tray and lifting it up from the table;
2. <u>Walking</u>: every time they were moving around the table holding the tray.
3. <u>Stepping over a step</u>: climbing over a step placed on the floor.
4. <u>Putting the tray on the floor</u>: kneeling down the floor, putting down the tray, and let it go.
5. <u>Picking up the tray from the floor</u>: picking up the tray from the floor, standing up.
6. <u>Putting the try on the table</u>: putting down the tray on the table and let it go.

Previously described *Respiratory, Acoustic* and *Interaction indexes* were extracted within each category.

2.4.4. Musical-Track Analysis

Musicians were asked to improvise a section of their performance to explore whether the need to *improve* interpersonal coordination could have influenced breathing behaviour. Thus, in the analysis a major distinction was made comparing the Standard performance of the piece compared to the Improvisation section. *Respiratory, Acoustic* and *Interaction indexes* were extracted for both sections.

Moreover, since recent studies have shown that respiration is entrained by music (Bernardi, 2009), we need to control the influence of musical structure on breathing behaviour, in particular **tempo** and **rhythm** (Bernardi, 2009; King, 2006). Thus, a musical analysis of the performance was carried out, considering three index categories:

- Formal structure*:* On the basis of a formal analysis of the actual performance, the musical piece was split into further musical sections (A – B – C).
- Rhythm: note onset; note durations.
- Dynamics; crescendo/decrescendo.

2.5 Results

The analysis of the database of breathing sounds through the described procedure allowed the development of an extraction method for individual respiratory events. This step first required on one hand solving some critical methodological issues (such as the identification of a reliable criterion to set starting and ending point of each breath-unit), on the other testing the effectiveness of the selected analyses (LTAs, Tau Analysis, etc). The explanation of these issues is not only preliminary but also inseparable from the aim to identify effective spectral and acoustic analysis of breathing sounds. Therefore, the extraction criteria and the selection of the indexes will be presented together.

2.5.1. Definition of Extraction Procedure

The extraction procedure required the manual screening of each audio track using Praat, in order to identify *starting* and *ending* time (in ms) of each respiratory event. Almost all breathing events could be excerpted through visual inspection of spectrogram and waveform of the respiratory track, in all sampling conditions. Sometimes, when breathing sounds intensity was too low, it was difficult to distinguish breath sound-wave from ground noise (see Fig.1 as example). This concerned primarily Inspirations, since their impact on the capsule of the microphone produce much less pressure than Expirations. When defining the exact onset and offset of breath sound was difficult by visual inspection of spectrogram and waveform alone, the audible onset of the sound was considered as principal reference, since description of *auditory perception* of breathing sounds was the central issue of this study. For that reason, also inspiration amplitude results significantly lower than expiration's.

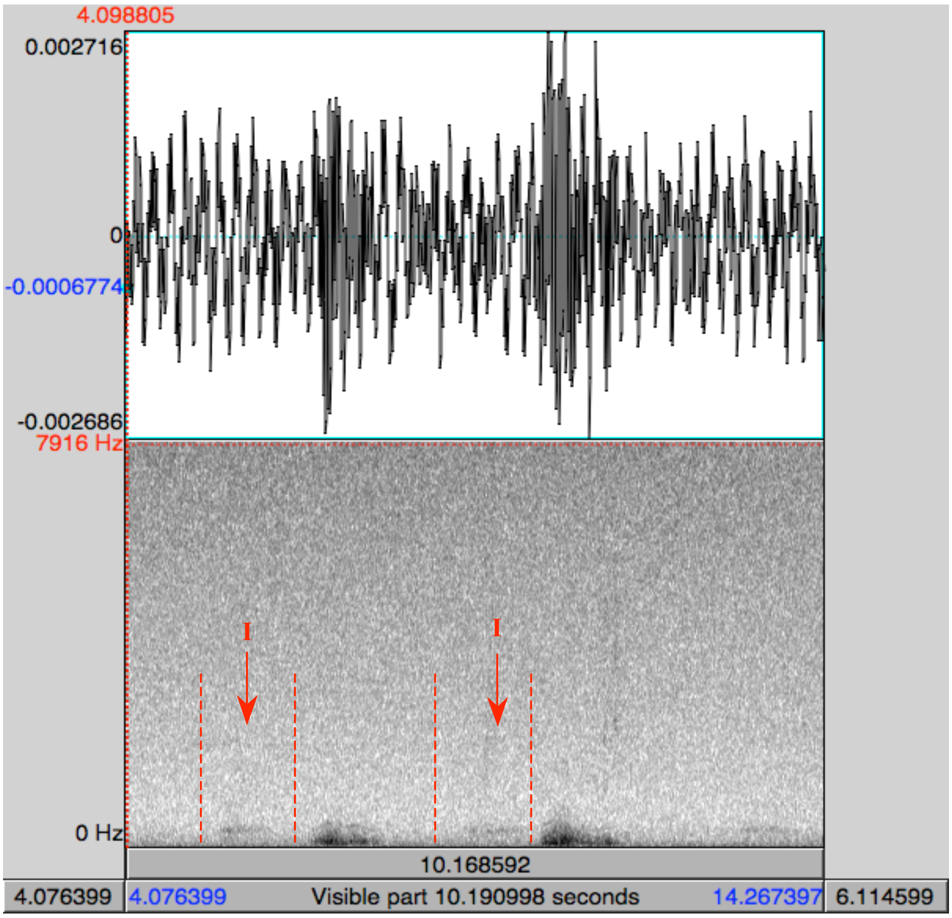


Fig.1 Section of Violinist' baseline with low Inspiration and Expirations.

A second extraction problem concerned the musical performance tracks. The Shure WH30 XLR headset microphone is characterized by a cardioids (unidirectional) pickup pattern that provides isolation from extraneous sound sources, but couldn't completely exclude the instrumental sounds, that interfere with breathing sound track. As shown below, the microphone was close enough to capture the breathing sounds, but: 1. sometimes music could be too loud, making difficult the extraction of precise onset and offset of breath sounds, in particular inspirations; 2. Spectral analysis couldn't be run, since results would have been compromised. To soften the musical interferences, a Low Pass Filter at a cut-off frequency of 600Hz was applied and resulted to be effective in cutting off most of musical interference, facilitating breaths excerption (See Fig.2). Other extraneous sound sources were effectively isolated by the set technical equipment.

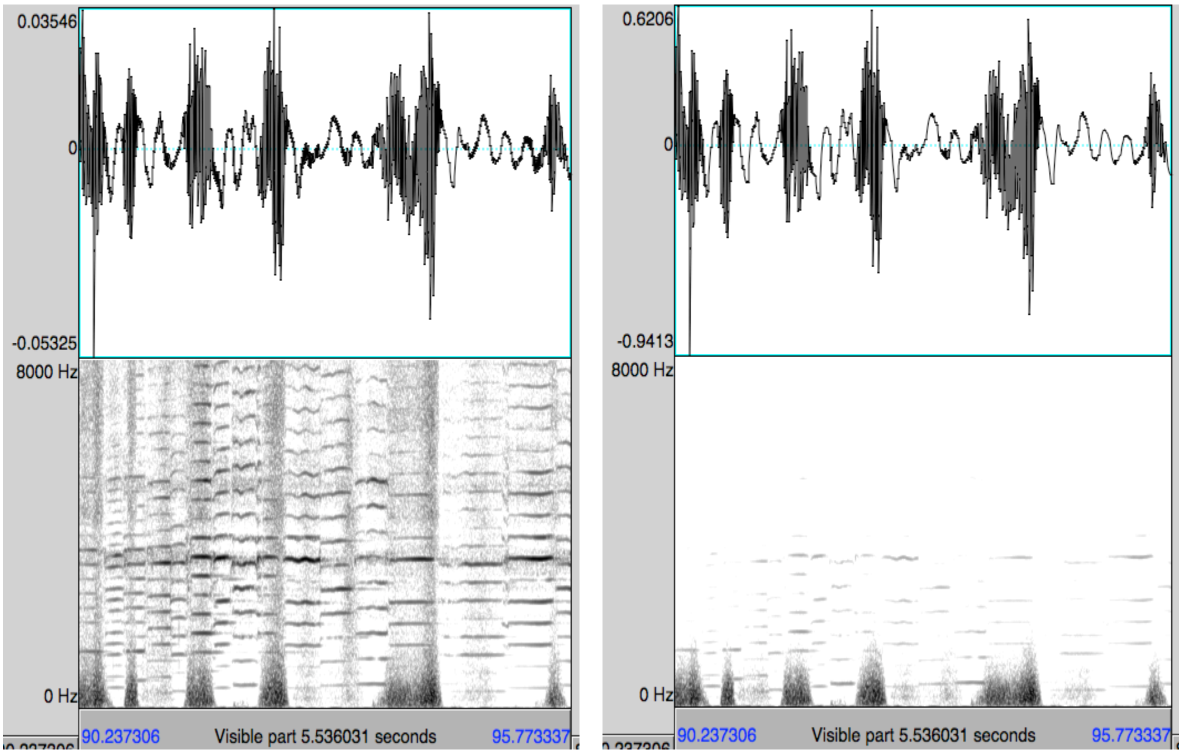


Fig. 2 - Section of Violinist' Musical Performance

<u>*2.5.2 Respiratory Indexes*</u>

Acoustic measurement of breathing sound turned to be effective in providing some of the conventional measurements of *temporal* features of respiratory signal (See Tab.1). Some remarks should be done:

- *RR* and *Tt* turn to be repetitive, measuring one the breathing frequency the other the cycle period; besides, RR could provide more immediate description of respiratory rhythm variation in different moment of the performance, while cycle duration was essential to determine other measurements (like Duty Cycle: *Ti/Tt*) and effectively comparable to other indexes like *Te* and *Ti*.
- As *Pauses Duration* are concerned, following analysis should split the index in **Expiratory Pauses Time** (*Pe*) and **Inspiratory Pauses Time** (*Pi*) to allow more detailed analysis of respiratory behaviour (Wientjes et al, 1998; Boiten, 1998).

	A	B	C	D	E	F	G	H	I
1	922322 - 90								
2	S_breath	reath qua	S_RE star	S_RE end	RI durati	I,E/min	Cycle	E/I	int I-E
3	1	I	2.567	4.048	1.481				2.567
4	2	E	4.096	5.409	1.313		1.397	0.887	0.048
5	3	I	5.409	6.747	1.338				0.000
6	4	E	6.785	8.601	1.816		1.577	1.357	0.038
7	5	I	8.789	10.115	1.326				0.188
8	6	E2	10.246	11.895	1.649		1.488	1.244	0.131
9	7	I	12.050	12.970	0.920				0.155
10	8	E	13.065	13.866	0.801		0.861	0.871	0.095
11	9	Iaccenti	15.060	16.434	1.374				1.194
12	10	E	16.550	18.342	1.792		1.583	1.304	0.116
13	11	I	18.795	20.229	1.434				0.453
14	12	E	20.399	21.845	1.446		1.440	1.008	0.170
15	13	I	22.426	23.955	1.529				0.581
16	14	E	24.150	25.667	1.541		1.535	1.008	0.195
17	15	I	26.018	27.559	1.565				0.351
18	16	Eaccenti	28.045	29.610	0.836		1.201	0.534	0.486
19	17	I	29.822	30.658	0.836	8 E - 9 I			0.212
20	18	E	30.742	31.554	0.812		0.824	0.971	0.084
21	19	I2	32.450	33.436	0.986				0.896
22	20	E	33.999	35.385	1.386		1.186	1.406	0.563
23	21	I2	36.137	37.260	1.123				0.752
24	22	E2	37.763	39.173	1.410		1.267	1.256	0.503
25	23	I	40.068	41.203	1.135				0.895
26	24	E	41.809	43.254	1.445		1.290	1.273	0.606
27	25	I2	43.422	44.724	1.302				0.168
28	26	Eaccenti	45.237	46.814	1.577		1.440	1.211	0.513
29	27	I	47.014	47.946	0.932				0.200
30	28	E	48.591	49.690	1.099		1.016	1.179	0.645
31	29	I	49.976	51.135	1.159				0.286
32	30	Eaccenti	51.215	52.684	1.469		1.314	1.267	0.080
33	31	I	53.700	54.763	1.063				1.016
34	32	E	55.689	56.716	1.027		1.045	0.966	0.926
35	33	I2	57.505	58.843	1.338				0.789
36	34	E	59.138	60.571	1.433	9 E - 8 I	1.386	1.071	0.295

Fig 3 - Coding Table example

In addition to the previous indexes, data exploration suggested to take into account some more indexes:

- **Number of expirations / min**: total amount of expirations occurring in one minute;
- **Number of inspirations / min**: total amount of inspiration occurring in one minute;
- **Number of breath-holding (BH)**: Breath-Holding were considered as pauses between two breath which duration was longer than M+2SD.

Dividing these indexes/min allow comparison of this index between different conditions. *Mean*, *standard deviation* and *range* were extracted for each parameter, for each subject in each experimental condition. N of expirations and inspirations / min were extracted beside N of breath/min and respiratory rate since the data inspection shown a frequent occurrence of fragmented expirations and inspirations, in particular (but not only) in the Musical Performance tracks (See Fig.4)

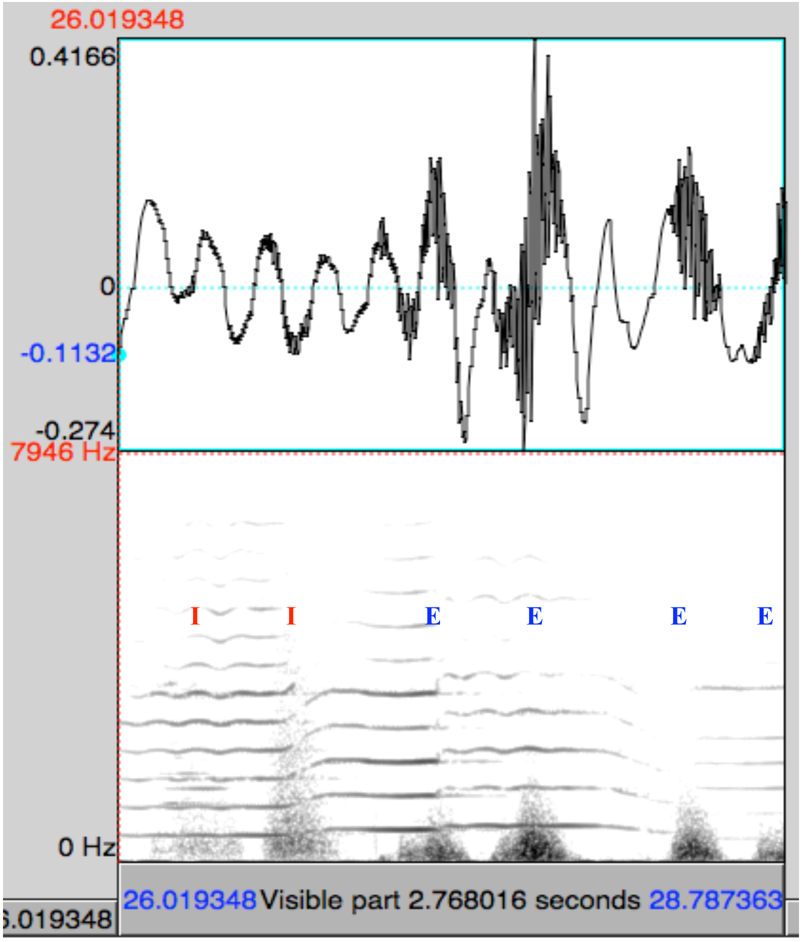


Fig 4 - Acoustic indexes - Global Conditions

BHs interrupt breathing rhythm as a response to deep concentration or physical effort. Moreover, in the musical performance, breathing seemed to be used to keep tempo of the performance (see par. 2.4.4). Resumption of natural breathing rhythm could complete the respiratory cycle or regain the interrupted respiration phase (that is, for example Expiration – BH – Expiration). In this case, the amount of total expirations estimated at the end of the track will be *more* than total amount of respiratory cycles and unbalanced compared to the total amount of inspirations. To define which Pauses should be considered as "breath-holding" events, three criteria have been used:

1. Pauses Duration should be longer than M + 2 St. D;
2. An interruption within the same inspiration/expiration;
3. Pauses Duration, athough shorter than M + 2 St. D, were followed by glottal noise, signalling previous interruption of respiratory cycle.

All these indexes have been calculated for each breathing condition providing *quantitative measurements* of respiratory behaviour that seem to enable comparison between performances (See Tab.1).

Respiratory Indexes		*Breathing Condition*				
		Baseline	**Joint Obstacle Course (JOC)**	**Joint Musical Performance (JMP)**	**Indiv. Obstacle Course (IOB)**	**Indiv. Musical Performance (IMP)**
Resp. Rate	Mean (SD) Range	11.92 (3.64) 7.84	18.23 (3.09) 6.92	19.65 (5.62) 12.06	18.08 (1.13) 2.58	19.24 (6.00) 14.33
Cycle Dur.	Mean (SD) Range	2.757 (0.682) 2.704	2.284 (0.845) 4.282	1.755 (1.439) 8.025	2.554 (0.561) 2.624	1.662 (1.199) 5.464
N. breaths /min	Mean (SD) Range	24.13 (1.94) 2.75	37.42 (3.12) 5.25	55.11 (4.70) 9.00	35.13 (3.36) 4.75	58.50 (7.34) 13.00
N E/min	Mean (SD) Range	12.25 (1.06) 1.50	18.75 (1.30) 2.25	32.00 (2.52) 5.00	18.13 (1.95) 2.75	28.43 (2.70) 5.33
N I/min	Mean (SD) Range	11.88 (0.89) 1.25	18.35 (2.22) 3.50	19.84 (2.50) 4.50	17.00 (1.42) 2.00	20.03 (2.61) 4.75
Insp. Time	Mean (SD) Range	1.184 (0.451) 1.827	0.873 (0.274) 1.593	1.268 (0.485) 2.729	0.991 (0.217) 1.087	0.394 (0.226) 1.111
Exp. Time	Mean (SD) Range	1.555 (0.590) 2.337	1.268 (0.371) 2.729	0.604 (0.371) 1.731	1.472 (0.451) 2.134	0.513 (0.307) 1.961
E/I Ratio	Mean (SD) Range	1.408 (0.556) 2.419	1.738 (0.951) 4.839	3.597 (3.789) 20.474	1.619 (0.532) 2.622	3.630 (3.597) 15.959
Pauses Time	Mean (SD) Range	1.175 (0.956) 3.803	0.535 (0.883) 5.875	0.629 (0.665) 3.937	0.358 (0.665) 3.937	0.594 (0.593) 3.651
N Breath Holding	Mean (SD) Range	1.75 (0.96) 2.00	4.00 (01.41) 3.00	20.00 (6.00) 12.00	3.25 (1.26) 3.00	17.33 (4.04) 8.00

Tab 1 - Respiratory indexes - Global Conditions

RR was higher in the performance condition (both Obstacle Course and Musical Performance) compared to Baseline; Cycle Duration differences are consistent with this index. Similarly, also N breath, Exp, Insp / min are greater in the performance conditions compared to Baseline while Pauses are shorter. There are not noticeable difference between N of E and I/min, made exception for Musical Performance (JMP: Exp= 32.00/min vs Insp=19.84/min; IMP: Exp= 28.43/min vs Insp=20.03/min). Also E/I Ratio was perceptibly higher in Musical Performance compared to other conditions, being expirations much shorter than inspirations; this condition was also characterized by a greater number of BH. More detail about particular trend characterizing Musical Performance and Obstacle Course will be discussed in the following paragraphs.

2.5.3. Acoustic indexes

Acoustic description of breathing sounds was the most challenging. First, preliminary analysis was carried out on the Baseline tracks to find indexes that could help drawing a distinction between inspiration and expiration sounds quality. To do that, all Pauses were removed and two separate files were created, one including all Inspiration, the other all Expiration sounds. A first explorative Format Analysis, concerning the first two formants, produced poor distinctive results (see Tab. 2).

Formant Analysis		Expiration Track	Inspiration Track
Formant I	Mean	3394.724	3331.705
	(SD)	472.806	307.043
	Range	5009.228	4200.377
	Bandwidth	1726.511	1636.754
Formant II	Mean	5854.435	5760.124
	(SD)	496.557	361.775
	Range	5440.935	4400.691
	Bandwidth	1917.250	1827.961

Tab 2 - Formant Analysis

Also **LTAs** doesn't turn to be effective. First, some tracks were much shorter than 40 sec (see for example Inspiration track in Fig. 5).

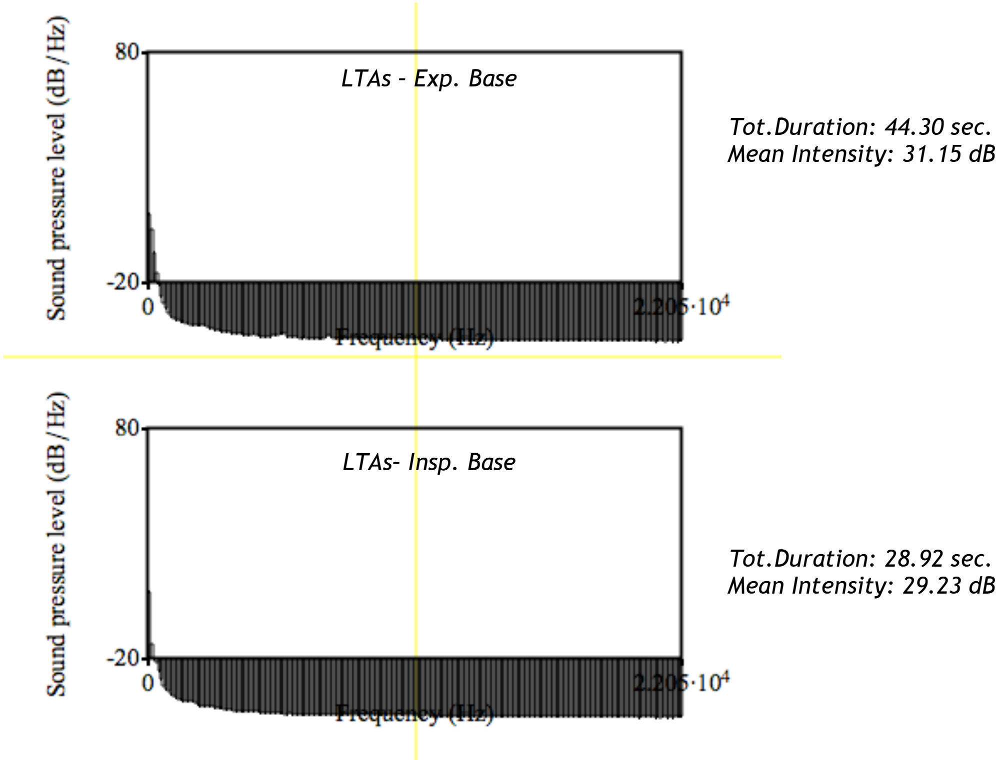


Fig. 5 - Example of LTAs output for baseline breathing sounds

Tau analysis (Lee, 1998; 2006; Schogler, 2003; 2008) was also tested on a preliminary sample of 60 breaths. Three parameters were extracted for each breath:

- **T=** a measure of the *duration* of each individual successive oscillation in a sound pressure wave, as recorded by the microphone diaphragm. 1/T turn out a measure of the "pitch" of each breath soundwave.
- **A**= a measure of the *amplitude* of each individual successive oscillation in a sound pressure wave, as recorded by the microphone diaphragm.
- **K**= a single value that describes the way of controlling the shape of each individual successive oscillation in sound pressure wave, as recorder by the microphone diaphragm. The higher the value of k, the more delayed is the peak velocity and the shorter and steeper the final deceleration.

Anyway, considering the difficulty to relate these indexes to the traditional physical and acoustic measures, they were dropped.

Concluding, only two indexes turned out to be actually measurable and to provide distinctive quantitative measures of breathing sounds: **Intensity** and **Spectral Centroid**. Spectral Centroid was calculated on separate audio tracks for Inspiration and Expirations of each subject for each condition using a MATLAB Gui application. Musical Performance tracks didn't undergo spectral analysis, because of the musical instruments interference. Besides, intensity was calculated for each individual breath using PRAAT. Moreover, a MATLAB program to extract the **Envelope Amplitude** of the entire tracks was written and turned to be useful both for representational aims and to carry out cross-correlation analysis in coordination analysis (See par. 2.5.5). Finally, we added another index actually not considered in a preliminary phase, the number of **accented breaths** in each track. In fact, breath sounds could be characterized by the presence of *more than one* amplitude peak; this "accents" within a single breath turned to be related to the action performed (see Fig.6). As an example, while running or walking, the movement of our body is reflected in corresponding accents in breath sounds.

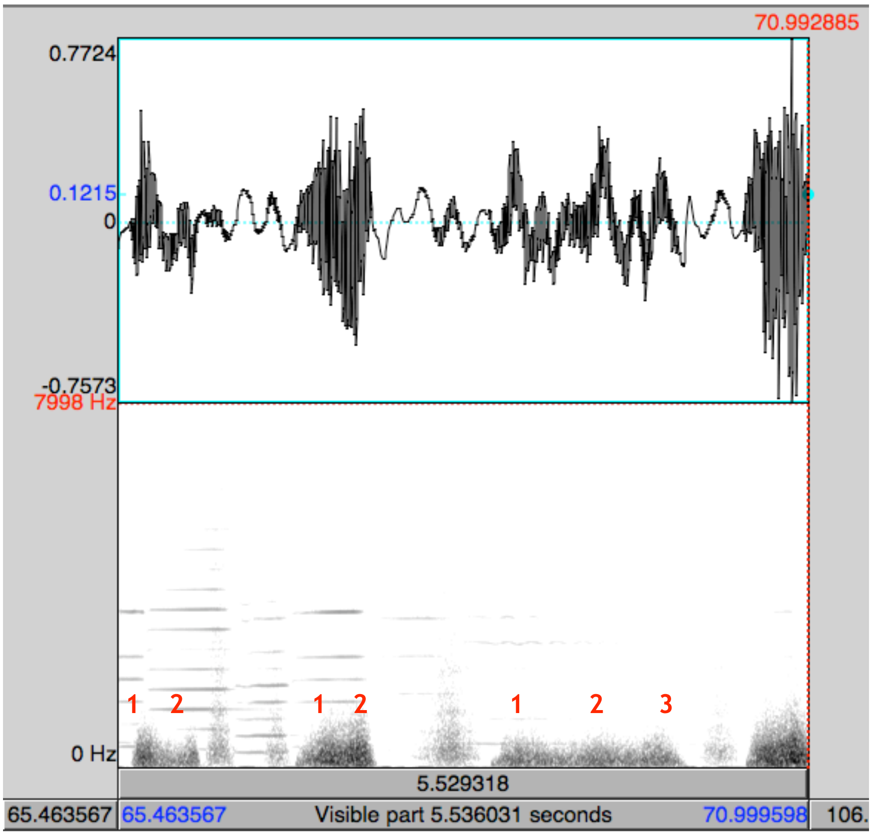


Fig. 6 - Example of accented breaths in violinist musical performance

The analyses of the previously discussed indexes provided quantifiable differences between inspiration and expiration (the former turning out to be sharper and softer than the latter, coherently with auditory perception) and between different performance conditions (see Tab.3). Intensity is evidently higher in Musical Performance compared to other conditions. In fact, is not uncommon to hear breath noise of musicians during their performance, while a stronger physical effort than walking is required to make audible breathing sounds in the obstacle course condition (for example running). As spectral centroid is concerned, the Obstacle Course condition seems to produce sharper sounds compared to Baseline, both as inspiration and expiration are concerned. Finally, accents in breath sounds were principally relevant in musical performance: as it was for interrupted breath among respiratory indexes, accents seemed to be used to keep tempo of the performance (See Par. 2.5.6.2). Accented breaths occurred also in baseline tracks, although in a limited amount and more irregular compared to the performance conditions where they seem to follow a quite precise and regular rhythm due to the musical or the action rhythm.

Acoustic Indexes		*Breathing Condition*				
		Baseline	**Indiv. Obstacle Course**	**Indiv. Musical Performance**	**Joint Obstacle Course**	**Joint Musical Performance**
E Intensity	Mean (SD) Range	35.98 (2.67) 11.23	36.82 (4.96) 19.30	42.24 (3.82) 17.43	35.72 (4.67) 16.14	40.47 (3.64) 15.68
I Intensity	Mean (SD) Range	32.90 (1.57) 6.67	31.24 (2.96) 12.11	37.13 (2.79) 15.97	30.16 (2.76) 9.49	36.54 (2.69) 14.30
E Spectral Centroid	Mean (SD)	420.29 (250.23)	483.10 (304.07)	// //	474.75 (303.11)	// //
I Spectral Centroid	Mean (SD)	525.01 (337.91)	710.23 (304.07)	// //	694.35 (398.04)	// //
N accented breaths	Mean (SD) Range	12.68 (2.15) 4.26	20.52 (5.09) 12.03	28.29 (7.87) 15.73	21.00 (3.40) 8.09	25.45 (9.13) 17.31

Tab 3 - Acoustic indexes - Global Conditions

2.5.4. Example of breath-tracks extracts in different conditions

To give an idea of how breath sounds changes in different conditions and what respiratory and acoustic indexes above could tell about them, below some example will be shortly illustrated.

In Fig. 7 respiration rate is regular and quite low (~ 12 cycle/min). There is the same number of inspiration and expirations (I=3, E=3) and no breath holdings interrupt respiratory flow. Inspiratory and Expiratory time are similar, being the former just a few shorter than the latter (M In= 1.595, M Ex=1.833). It is characterized by long pauses durations (M P= 1.331), in particular after expirations. Mean Intensity is low for both inspiratory and expiratory events (M In=24.01 vs M Ex=33.41 dB), which are also characterized by absence of visible accents. Global Spectral Centroid is averaged 223.34 Hz (S.D.= 156.35 Hz).

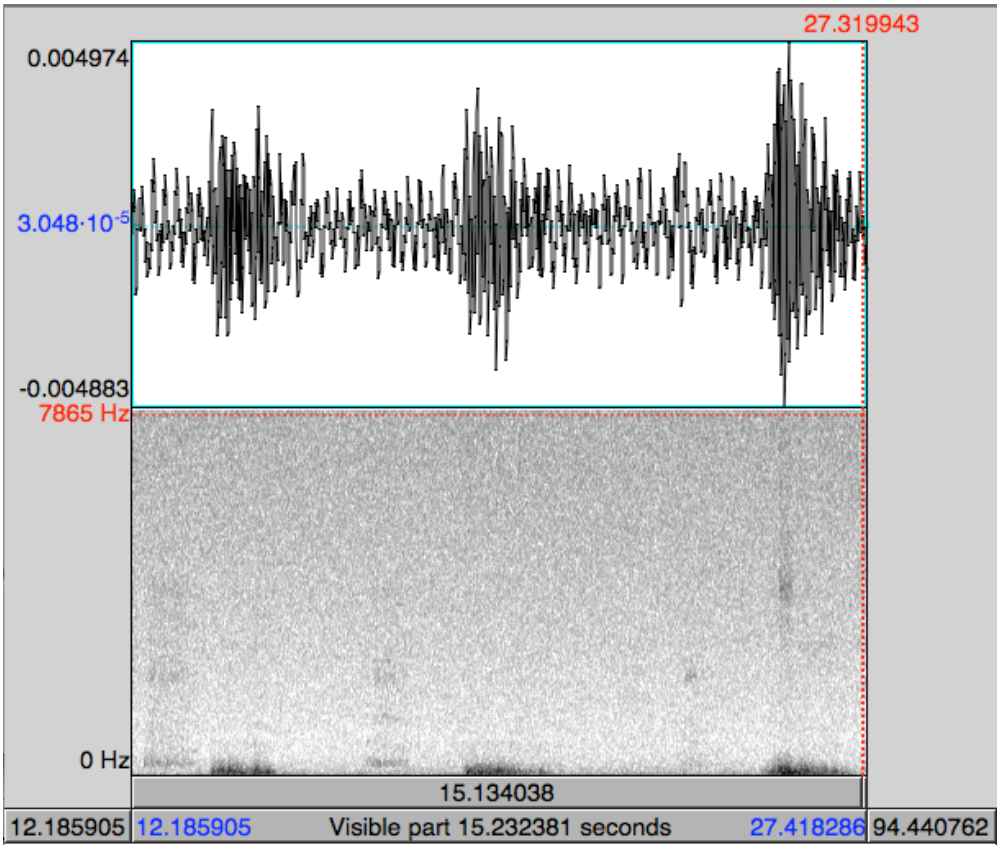


Fig. 7 - Baseline Extract - Duration 15.232 sec

This extract in Fig. 8 shows ~ 12 sec of the same subject's breathing while walking. Respiration rate is again regular but higher compared to baseline (~ 20 cycle/min). There is the same number of inspiration and expirations (I=4, E=4). Expiratory time becomes longer than inspiratory one (M In= 0.990, M Ex=1.513) while pauses durations almost disappear. Mean Intensity increase for both inspirations and expirations (M In=28.65 vs M Ex=36.07 dB), which are characterized by many, visible accents, not following a specific rhythmic pattern. Global Spectral Centroid increased too, indicating sharper sounds (M=249.54 Hz, S.D.= 141.35Hz).

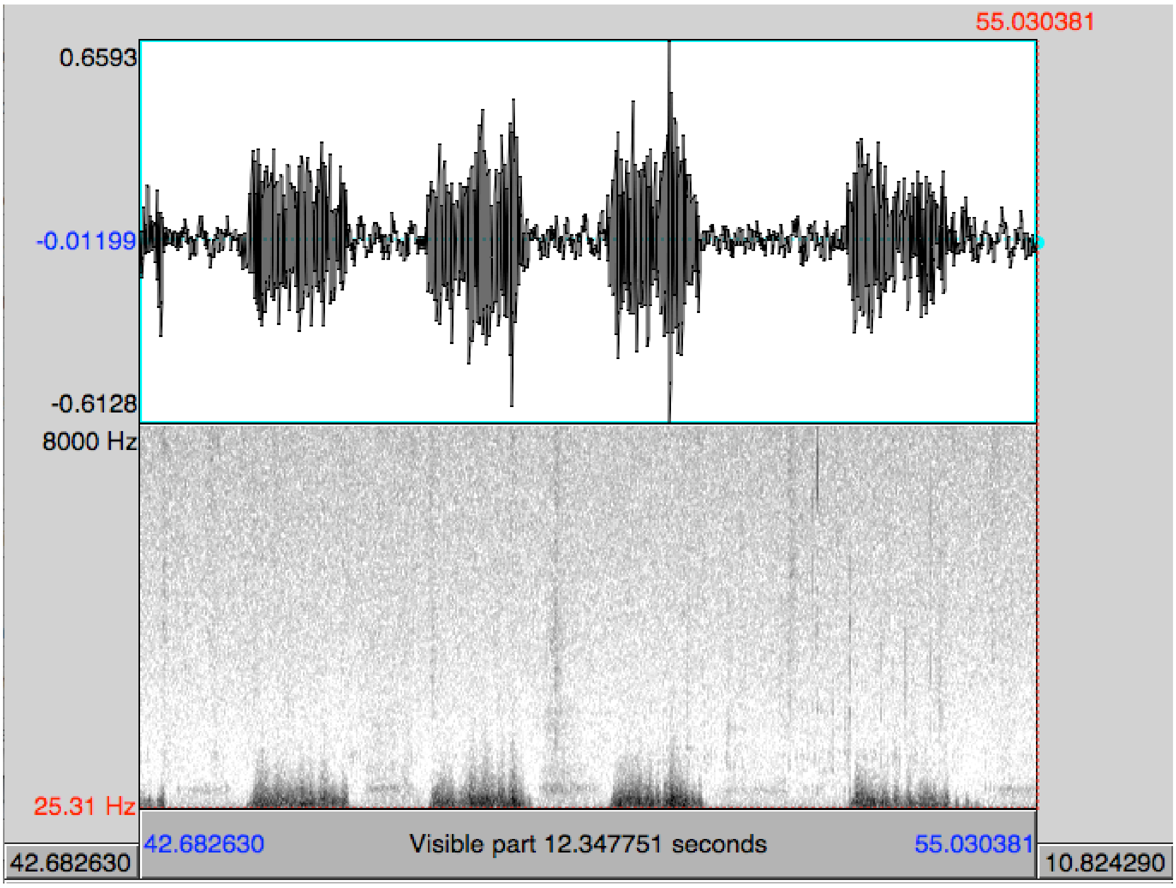


Fig. 8 - Obstacle Course Extract - Duration 12.347 sec

Finally, Fig. 9 shows ~ 11 sec of the musical performance task, both unfiltered and filtered. Respiration patterns are really irregular and respiratory rate increased dramatically (~ 30 cycle/min). Many short apnoeas interrupt breathing flow, making unbalanced total amount of inspirations and expirations: I=6, E=8. Expiratory and Inspiratory durations evidently shorten (M In= 0.360, M Ex=0.594) and their variability increases. There are many pauses whose duration varies a lot along time (M=0.298, S.D=0.484). Mean Intensity increase for both inspirations and expirations (M In=61.41 vs M Ex=69.34 dB), which are characterized by some visible peaks that appear to occur with note attacks.

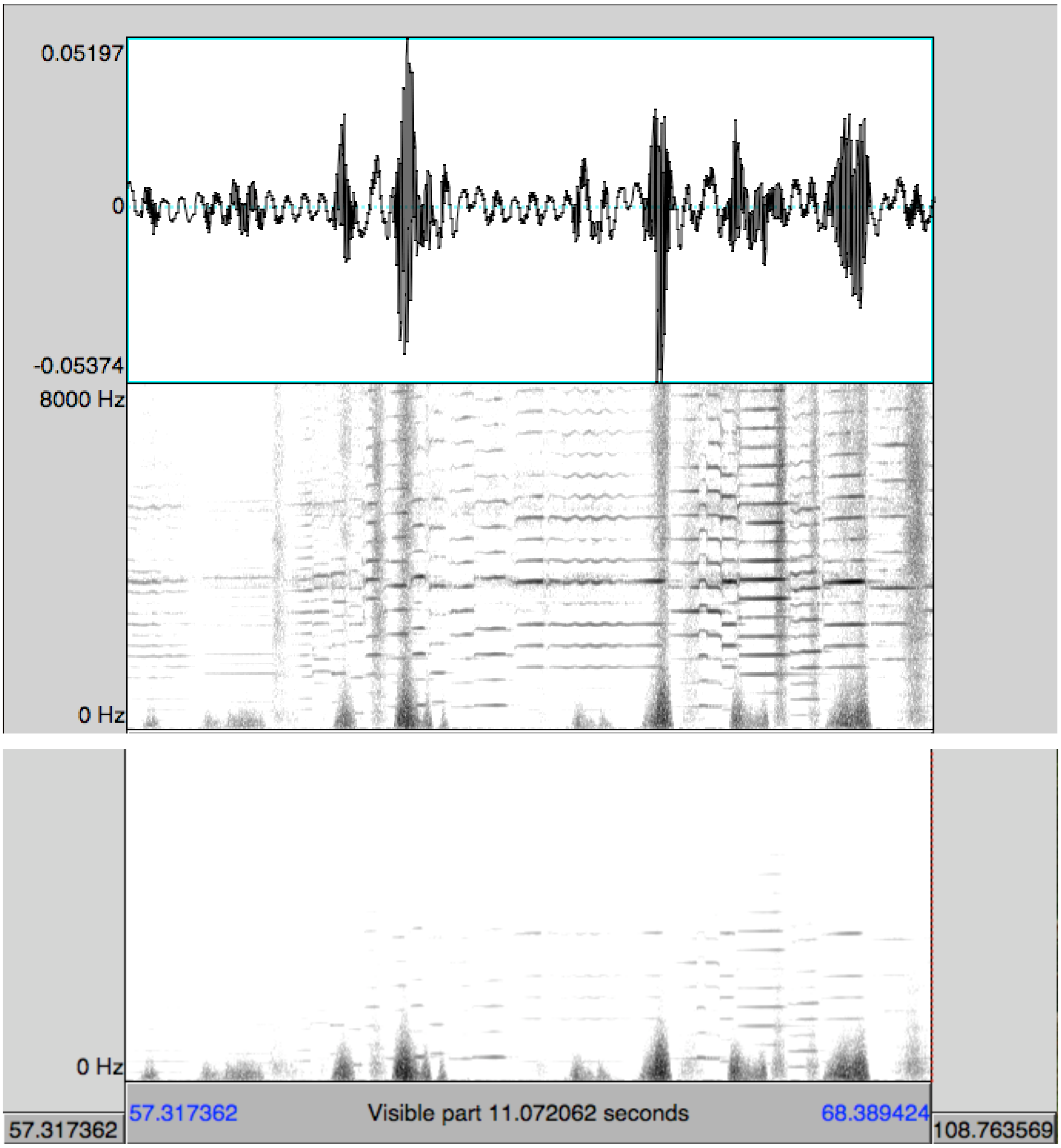


Fig. 9 - Musical Performance Extract - Duration 11.072 sec

2.5.5. Coordination Indexes

To test our *prefixed thresholds* of synchrony in joint actions relative measurements were first investigated, to explore the general trend of the data in either of baseline, individual and joint performances. *Mean, standard deviation* and *range* of closest breaths between subjects was calculated for either of baseline, individual and joint performances (see Tab. 4). Individual conditions were considered too in order to compare casual and real breath-coupling in similar performances.

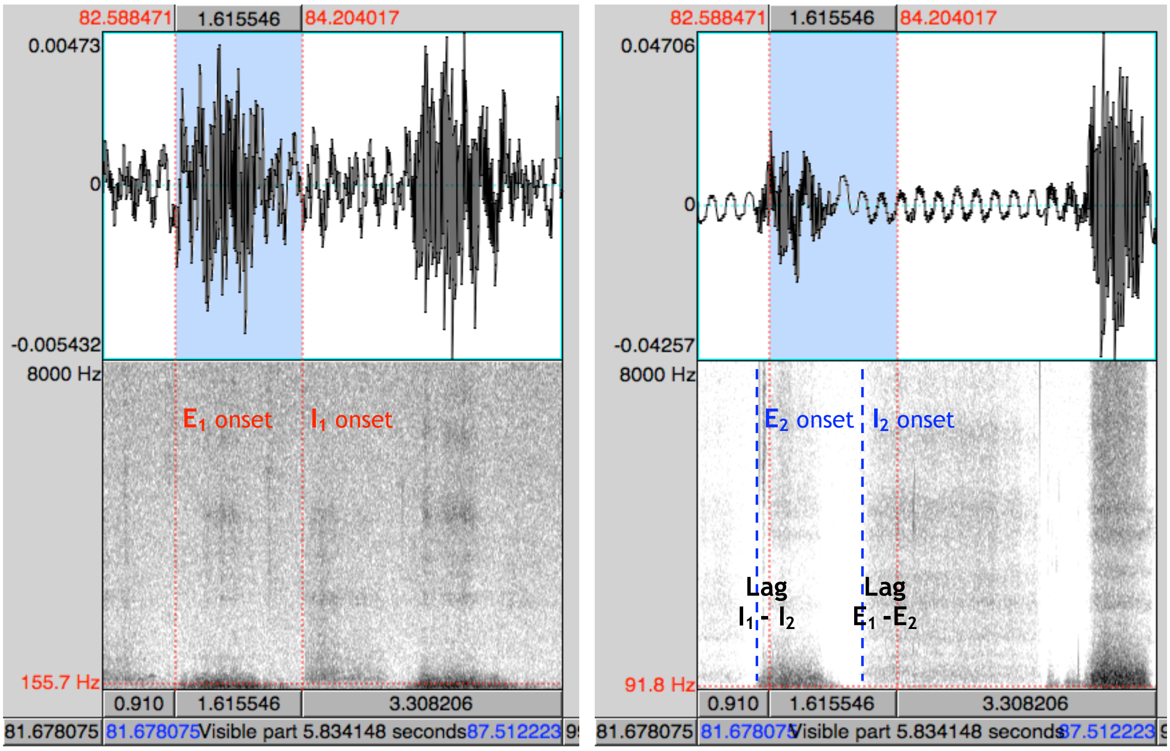
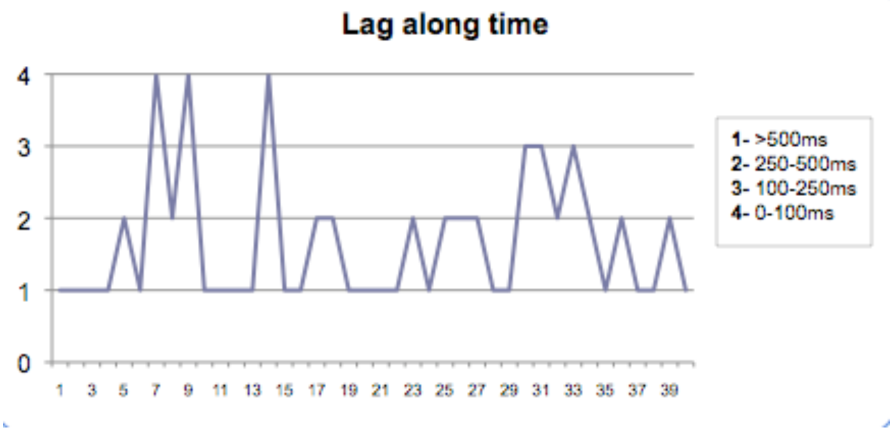


Fig. 10 - Extraction of the temporal lag between coupled breath

Baseline mean temporal lag between closest breaths was above 600 ms (M=0.631, SD=0.522), while in all performance conditions it resulted inferior to 500 ms. Percentage of coupled breaths lagged >500 ms in both baseline and joint conditions was calculated: 57.29% of coupled breaths' lag was upon 500ms in baseline, 33.77% in obstacle course and 25.76% in musical performance. Since more than half baseline's coupled-breath sample was upon 500 ms and this threshold reached 1/3 and 1/4 of coupled-breath sample in highly synchronized performance, we considered 500 ms a valuable threshold between simultaneous and non-simultaneous breaths. Then, other indexes were extracted for each lag-category (see Tab. 4):

1) N of simultaneous breaths within **0-100 ms**/ tot amount of breaths;
2) N of simultaneous breaths within **100-250ms/** tot amount of breaths;
3) N of simultaneous breaths within **250-500 ms**/tot amount of breaths;
4) N of non- simultaneous breaths (**>500ms**) / tot amount of breaths.

Dividing the amount of each category/tot amount of breaths allow comparison of this index between different conditions. As Tab. 4 shows, Joint Obstacle Course and Musical Performance turned to be characterize by different "style of synchronization", being the interval between coupled-breaths differently spread all four categories. The former is characterized by a similar amount of synchronized breaths in each category, while in the latter about 1/3 of coupled breaths falls in the highest two classes of synchronization and the other 2/3 in the lowest. These measures could provide more detailed information about the degree of synchronization between performers compared to a global mean of coupled breaths' lags and allow a representation of their respiratory synchrony along the action course (see graph. 1).



Graph. 1 - Example of distance between coupled breaths along time

Coordination Indexes		Baseline	Joint Obstacle Course	Joint Musical Performance	Indiv. Obstacle Course	Indiv. Musical Performance
Lag breaths onset	Mean (SD) Range	0.631 (0.522) 2.337	0.364 (0.311) 1.347	0.446 (0.385) 2.159	0.441 (0.316) 1.266	0.451 (0.505) 3.046
Sim. Index 0-100 ms	Mean (SD) Range	10.23 (4.33) 6.13	25.11 (17.24) 24.38	13.96 (1.68) 2.38	//	//
Sim. index 100-250 ms	Mean (SD) Range	15.94 (7.79) 11.02	23.34 (6.78) 9.59	20.36 (1.21) 1.71	//	//
Sim. index 250-500 ms	Mean (SD) Range	16.55 (7.51) 10.62	25.70 (0.99) 1.40	32.23 (1.75) 2.48	//	//
NO sim. index >500 ms	Mean (SD) Range	57.29 (4.04) 5.71	25.76 (23.16) 32.75	33.77 (4.90) 6.93	//	//

Tab 4 - Coordination indexes - Global Conditions

2.5.6. Relating breathing behaviour to Performance

Once explored the descriptive power of the set of indexes on the global conditions, we explored their explicative power considering the action flow. Since breathing behaviour turned out to be really different in the two experimental tasks, different methods have been applied to investigate the relation between breathing sounds and action performed.

2.5.6.1 Obstacle Course Condition

As far as Obstacle Course in regarded, all respiratory, acoustic and coordination indexes above discussed have been extracted in different phases of the performance, both in the joint and individual performance (See Tab.5 and Tab.6).

Respiratory Indexes		Obstacle Course									
		Lifting		Walking		Step		Laying down		Placing	
		Indiv.	Joint	Indiv.	Joint	Indiv.	Joint	Indiv.	Joint	Indiv.	Joint
Resp. Rate	Mean	18.33	12.00	18.38	17.26	20.92	20.80	16.93	14.90	20.39	19.34
	SD	5.83	1.36	2.82	3.41	1.63	1.60	.50	5.27	3.63	3.03
	Range	8.25	1.93	7.36	9.88	2.02	3.06	0.71	7.45	5.13	4.29
Cycle Dur.	Mean	2.758	2.802	2.370	2.290	2.464	2.498	2.948	2.850	2.646	2.348
	SD	.660	.709	.357	.827	.313	.386	.605	1.138	.544	.415
	Range	1.512	1.579	.721	1.118	1.389	1.249	1.817	3.457	.976	.932
N breath /min	Mean	35.2	25.08	36.66	35.16	41.85	41.00	33.85	30.98	40.72	39.84
	SD	9.21	6.57	10.68	6.70	5.52	3.10	1.64	7.32	9.53	20.71
	Range	15.80	9.84	30.21	19.12	12.61	6.98	2.02	12.41	14.23	16.49
N E/min	Mean	21.99	12.54	20.53	16.89	22.99	20.45	17.50	17.38	27.19	21.49
	SD	7.00	3.55	5.52	3.21	2.79	1.40	1.32	3.51	4.84	6.07
	Range	9.90	5.02	17.86	8.18	6.51	2.96	1.86	4.96	6.85	8.59
N I/min	Mean	13.21	12.54	20.14	18.27	18.86	20.55	16.35	13.6	19.53	21.49
	SD	2.43	3.55	5.53	4.28	3.02	1.95	.32	5.27	5.98	16.07
	Range	6.60	5.02	16.63	13.18	6.90	4.08	.45	7.45	8.46	8.59
Insp. Time	Mean	1.031	1.229	1.107	.987	1.026	.873	1.239	1.161	1.399	1.086
	SD	.263	.655	.158	.220	.078	.187	.518	.517	.459	.152
	Range	.372	.928	.462	.587	.143	.584	1.463	1.231	.649	.215
Exp. Time	Mean	1.570	1.596	1.522	1.356	1.610	1.380	1.687	1.662	2.529	1.134
	SD	.518	1.515	.205	.332	.215	.280	.516	1.003	.376	.380
	Range	1.017	2.387	.498	.946	.481	.699	1.434	2.923	1.107	.615
E/I Ratio	Mean	1.795	1.605	1.486	2.005	1.625	1.765	1.975	2.545	1.525	1.160
	SD	.360	.155	.208	1.069	.283)	.580	.875	2.140	.101	.520
	Range	.515	.585	.669	2.520	.645	1.863	2.110	5.210	.403	1.010
Pauses Time	Mean	1.307	3.341	2.111	4.165	1.835	3.544	3.508	4.414	//	//
	SD	0.00	1.370	.661	3.414	.301	1.596	1.910	2.627	//	//
	Range	1.307	4.309	2.578	1.596	2.048	5.190	3.933	6.179	//	//
N Pauses	Mean	.25	.50	.25	.31	.25	.50	1.50	1.50	//	//
	SD	.50	.58	.77	.60	.46	.76	.58	.58	//	//
	Range	1.00	1.00	3.00	2.00	1.00	2.00	1.00	1.00	//	//

Tab 5 – Respiratory Indexes – Obstacle Course Condition

Individual performances were generally shorter than joint ones, probably due to the difficulty derived from managing the action with another person. RR was higher in Individual action, probably related to the higher speed of the movements; pauses were shorter and less breath holdings occurred. In both conditions, different phase of the course induce differences in breathing behaviour: respiratory rate changes, become higher in correspondence of the step obstacle and of the final placing on the table. E/I ratio, as a result of changes in I and E durations, differ along time too. Highest number of breath holdings occurred when participants had to lay down the tray on the pavement and then lifted it again, in correspondence of the highest physical effort.

Acoustic Indexes		*Obstacle Course*									
		Lifting		**Walking**		**Step**		**Laying down**		**Posing**	
		Indiv.	***Joint***	***Indiv.***	***Joint***	***Indiv.***	***Joint***	***Indiv.***	***Joint***	***Indiv.***	***Joint***
E Energy	Mean SD Range	32.18 4.01 6.02	33.74 4.76 10.30	35.67 4.10 9.52	34.34 4.03 12.18	37.15 5.23 12.59	36.42 5.98 18.62	33.52 4.99 17.33	36.89 5.06 19.14	33.12 4.25 9.21	33.23 4.96 10.45
I Energy	Mean SD Range	28.96 2.90 7.34	29.47 2.96 8.14	30.11 3.11 6.53	31.24 3.01 7.45	32.78 6.05 11.48	30.03 5.03 12.15	33.55 3.16 10.23	32.16 4.76 14.49	29.81 2.64 6.35	29.78 2.85 9.32
E Spec. Centr.	Mean SD	476.35 300.1	478.20 303.07	480.98 301.34	480.10 310.34	478.87 323.67	476.23 337.12	485.23 312.10	484.75 333.11	474.12 305.52	478.58 304.34
I Spec. Centr.	Mean SD	699.32 344.12	696.35 376.04	705.63 312.36	703.27 355.41	711.93 372.17	710.23 314.07	698.22 365.24	700.93 398.67	695.38 310.32	699.46 303.93
Accent Breath	Mean SD Range	1.00 .00 .00	1.00 0.00 0.00	.75 .90 3.00	0.50 0.63 01.00	2.25 1.89 5.00	2.13 1.96 6.00	3.25 1.89 6.00	2.50 .58 1.00	.75 .50 1.00	.25 .50 1.00

Tab 6 - Acoustic Indexes – Obstacle Course Condition

Also acoustic indexes changes along time, but don't seems to differ significantly between conditions. Breaths were softer when lifting and placing the tray on the table, and were louder on the step condition. Spectral components didn't seems to vary significantly across conditions, a part when participants had to lay the tray down on the pavement: during this phase breath sounds become a bit more sharper and variability seems to increase in particular in joint condition. Finally, the highest amount of accented breath characterized step and laying down phase.

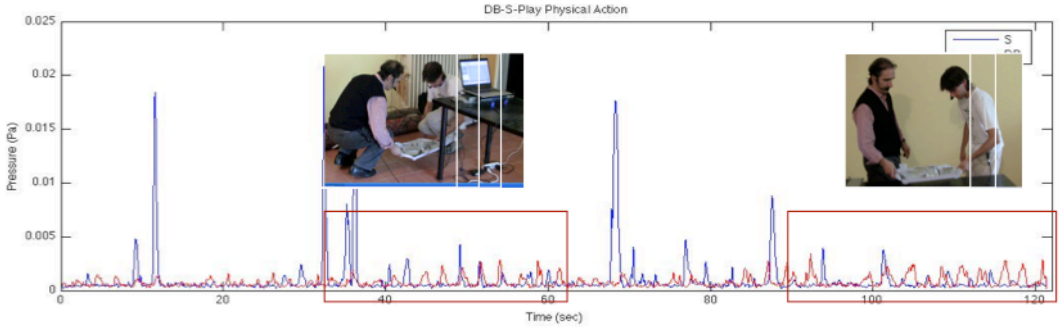


Fig.11 - Overlap of amplitude envelope of breath sound related to video analyses

To analyze coordination between participants across time, first amplitude envelope of both breathing tracks was extracted and they were overlapped. Then, the plot was examined in function of the different action-phases (see example in Fig.11). This representation allowed a more detailed analysis of how breath sound intensity changes across different moment of the performance, and enabled to find out moment where synchronism in breath sounds onset appear to be higher. Besides, coordination indexes discussed above were extracted (See Tab.7).

Coordination Indexes		*Joint Obstacle Course*				
		Lifting	**Walking**	**Step**	**Laying down**	**Posing**
Lag breaths onset	Mean	0.460	0.511	0.455	0.378	0.360
	(SD)	(0.224)	(0.379)	(0.343)	(0.195)	(0.264)
	Range	0.528	0.929	1.162	0.548	0.569
Sim. Index 0-100 ms	Mean	10.00	15.01	9.94	14.55	12.50
	(SD)	(14.14)	(11.73)	(3.78)	(7.71)	(17.68)
	Range	20.00	30.00	9.03	10.91	25.00
Sim. index 100-250 ms	Mean	//	16.65	19.32	4.55	**32.50**
	(SD)	//	(20.58)	(17.47)	(6.43)	(10.61)
	Range	//	50.00	40.59	9.09	15.00
Sim. index 250-500 ms	Mean	**70.00**	**23.61**	**33.49**	**43.64**	22.50
	(SD)	(42.43)	(20.94)	(10.66)	(23.14)	(3.54)
	Range	60.00	60.00	25.94	32.73	5.00
NO sim. index >500 ms	Mean	20.00	44.00	31.73	37.28	32.50
	(SD)	(28.28)	(26.76)	(9.91)	(24.43)	(10.61)
	Range	40.00	83.33	23.01	34.55	15.00

Tab 7 - Coordination indexes - Joint Obstacle Course Categories

Mean synchronism appeared to be higher when laying the tray down on the floor and when posing it on the table. Analysis of simultaneous indexes shows which category was prevalent in each phase: generally the prevailing was the 250-500 ms made exception in the last phase, where lag between 100-250ms overcome.

2.5.6.2. Musical Performance Condition

A different analysis was required by musical performances data to consider the influence of musical structure on breathing behaviour. Being particularly complex, a detailed analysis was carried on joust one couple of participants. We excluded the duet made up by the singer and the double bass player since singing have produced a smaller amount of breaths compared to the other couple; the other duet could thus provide more data along time. First a formal analysis of the performance was carried out. A ternary form was identified, which was and varied three times in the improvised section. For each part analysis of the melodic variations, of tempo/rhythm, structural complexity and dynamics were carried out.

Formal Structure		***Time***
Standard	A	0.000 – 18.301
	B	18.301 – 26.263
	C	26.263 – 46.491
Variation 1	A	46.491 – 62.327
	B	62.327 – 73.455
	C	73.455 – 93.909
Variation 2	A	93.909 – 106.138
	B	106.138 – 126.123
	A	126.123 –142.815
	Amin	142.815-161.006
Variation 3	A	161.006 – 178.220
	B	178.220 - 192.635
	C	192.635 – 212.594
Coda	A	212.594- 230.591

Tab 8 - Sections resulted from Formal Analysis of Musical Performance

First, since previous studies have shown that music could entrain respiratory rhythm, the amplitude envelope of either of respiratory and musical tracks were calculated and overlapped (see Fig.12). Before undergoing envelope extraction, background noise was removed from both respiratory tracks to make breath sounds more evident. To do that, all tracks sections out of identified breath sounds interval was set to zero. Then, a cross correlation was carried out in order to identify how much Violin and Guitarist Breathing Envelope tend to precede musical envelope. Both turned out to anticipate music by 231 ms, suggesting a high degree of interpersonal coordination.

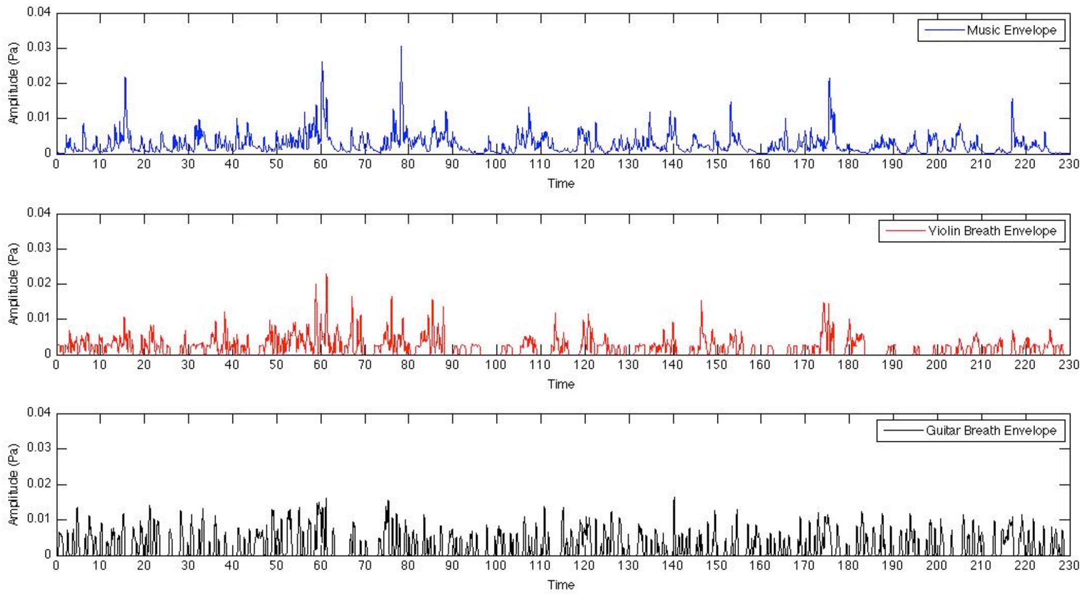


Fig. 12 – Plot of amplitude envelope of respiratory and musical tracks

The comparison suggested also that breath sounds intensity tended to vary along with musical dynamics (see also fig.13). Then, all musical crescendo and decrescendo were identified and breath sounds occurring within increasing and decreasing dynamics were split into two groups.

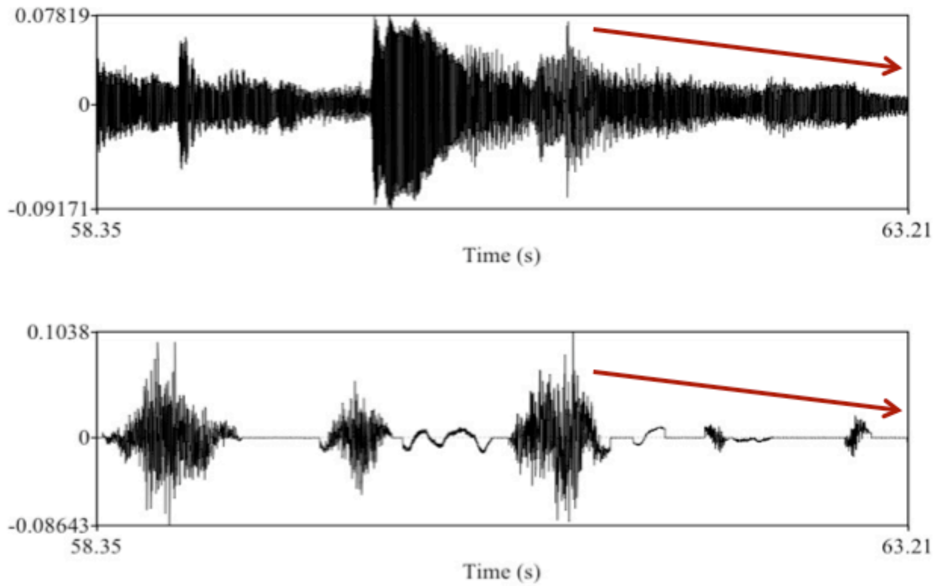


Fig. 13 – Example of the relation between music and breathing energy in a decrescendo

	N	Mean	St. D.	Range
Crescendo	54	49.966	4.794	19.01
Decrescendo	54	43.841	1.760	8.30

Tab.9 - Mean Energy (dB) of breaths corresponding to crescendo vs decrescendo phases.

The analysis underlined significant differences between the intensity of two groups ($T=8.189$; $p<0.001$), supporting the idea that breath sounds were louder during music crescendo and softer during music decrescendo.

Since from global condition analysis suggested that breathing *sound accents* and *breath-holdings* could be related to musical rhythm and tempo, we tested this correlation. All notes onsets of violinist performance were identified (N=179) and co-occurrence with breath onset were calculated: 79.33% of note onset co-occurred with breath attacks (N=142). A chi square analysis highlights the co-occurrence as significant ($\chi^2=59.598$, $p<0.001$). The same procedure was carried out with vibrato notes: 31 vibratos were identified and 59.37% (N=19) co-occurred with breath attacks (See Fig.14).

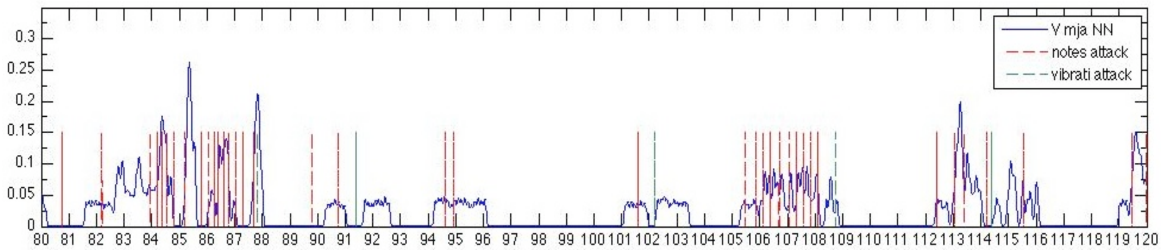


Fig. 14 - Extract: notes attacks occurring among breaths attacks (extract 80.120 sec)

Exploring the data, *breath holding* seemed to co-occur with sustained notes and musical pauses. To test this hypothesis, first all musical pauses, sustained notes and breath holdings were identified. All notes which duration was longer than M + 1 DS (that > 1.96 sec) were considered as sustained. 25 sustained, 7 pauses and 19 apnoeas were estimated and onset and offset of each individual event were noted down.

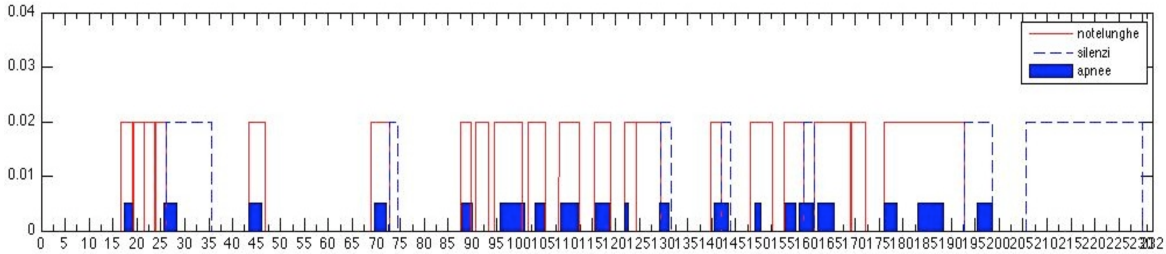


Fig. 15 - Example of Apnoeas occurring within sustained notes and pauses.

14 breath holdings occurred with sustained notes, 4 within a sustained note and the following pause, and 1 during a musical pause; a chi square analysis underline the co-occurrence of apnoeas and sustained notes as significant (χ^2=6.760, p=0.01).

Finally, coordination indexes were calculated. Tab.10 shows a comparison between improvised and standard section of the performance. This table takes into account mean values assessed on *both* duets.

As the mean lag between breath sound onsets is concerned, standard section turned to be related to more synchronized breaths compared to the improvised one. Anyway, it's interesting to notice that breath-lags included in the first category (0-100 ms) don't seems to differ significantly in the two conditions and delays occurring within 100-250 ms were more in the improvised section compared to the standard one.

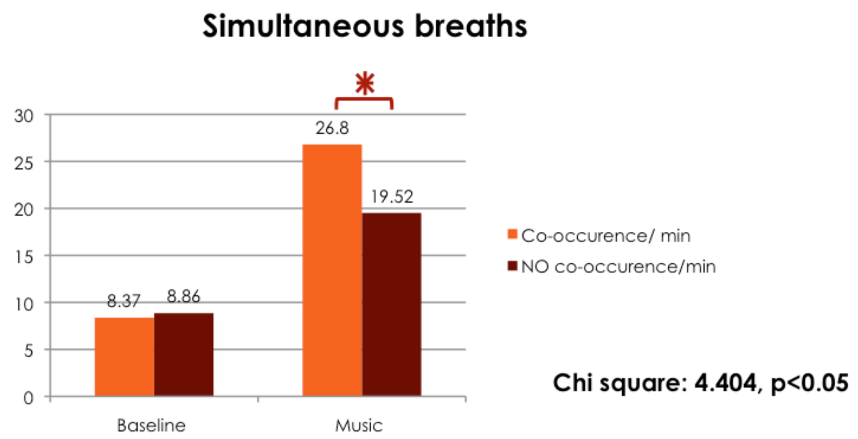
Coordination Indexes		*Joint Musical Performance*	
		Standard Section	**Improvised Section**
Lag breaths onset	Mean (SD) Range	0.334 (0.287) 1.030	0.406 (0.354) 2.049
Sim. Index 0-100 ms	Mean (SD) Range	26.41 (16.54) 23.39	24.43 (16.87) 23.86
Sim. index 100-250 ms	Mean (SD) Range	23.67 (0.20) 0.28	26.86 (13.44) 19.00
Sim. index 250-500 ms	Mean (SD) Range	29.55 (8.12) 11.48	25.79 (2.09) 2.96
NO sim. index >500 ms	Mean (SD) Range	20.38 (8.61) 12.18	22.92 (32.41) 45.83

Tab 10 - Comparison between standard and improvised musical sections

A more detailed analysis was carried on considering the guitarist and violinist duet. Total amount of simultaneous breath was compared to non-simultaneous ones in musical performance and in baseline condition. The formers appeared to be significantly higher than the latters in musical performance, but NOT in baseline (χ^2=4.404, p<0.05).

	Baseline	MJA
Tot breaths	35	178
Tot sim breaths	17	103
Sim breaths/min	8.37/min	26.80/min
NO-Sim breaths/min	8.86/min	19.52/min
Sim breaths %	48.57%	57.87%
NO-Sim breaths %	52.43%	42.13%

Tab 11 - Descriptive indexes of simultaneous and non-simultaneous breaths in Baseline and MJA



Tab 12 - Comparison between simultaneous and non-simultaneous breaths in Baseline and MJA

Finally, we tested whether simultaneous breaths were also louder than non-simultaneous but a T-test comparison turned out to be not significant.

	N	Range	Min	Max	Mean	St. D.
F - cresc	54	19.01	41.79	60.80	49.966	4.794
P - decresc	54	8.30	41.10	49.40	43.841	1.760

Tab. 13 - Intensity (dB) of simultaneous and non-simultaneous breath sounds

2.6. Discussion

The central issue of the present study was to develop a method to *extract* a set of acoustic measurements of breathing sounds and to test whether they could *describe* respiratory and acoustic features of breathing dynamic behaviour. As results show, an effective extraction method has been built up that allowed the excerption of a sample of 1903 respiratory events. The extraction procedure was based on both *visual screening* of spectrogram and waveform of respiratory track and on *audio inspection* of breathing sound recording. Sometimes detection of exact onset and offset of breath sounds was made ambiguous by *external sources of noise* or *low intensity* of breathing events. This concerned primarily Inspirations, since their impact on the capsule of the microphone produce much less pressure than Expirations. In such conditions, auditory perception was used as primary source of information.

We then evaluated the descriptive power of a proposed set of acoustic indexes and verified that they enable to underline different *respiratory*, *acoustic* and *interactive* features of breathing behaviour in various controlled performance conditions. Finally, this multilayer analysis model turned out to be effective in describing the relationship between *breathing sounds* and the *action flow* in specific experimental tasks; to do that, different descriptive methods had to be developed depending on the action under investigation. In the following paragraph each set of indexes will be discussed.

2.6.1 Respiratory Indexes

Acoustic measurements of breathing sound enable to extract some of the conventional measurements of *temporal* features of respiratory signal. The definitive set of respiratory indexes that made up this first level of our analysis model included: *Respiratory rate, Cycle duration, Inspiratory time, Expiratory time, I:E ratio, Expiratory Pauses Duration, Inspiratory Pauses Duration, Number of breaths / min, Number of Expirations / min, Number of inspirations / min, Number of apnoeas / min.*

Although *RR* and *Tt* give back similar information, RR could provide more immediate description of respiratory rhythm variation in different moment of the performance, while cycle duration allows effective comparison to other indexes like *Te* and *Ti*. N of expirations and inspirations / min were extracted to describe irregular breathing flow due to breaks (apnoeas) in expiratory or inspiratory air-stream. Since irregular breathing seems to increase under conditions of deep concentration, distraction and emotional excitement / upset (Stevenson and Ripley, 1952; Hormbrey et al, 1976; Tobin et al, 1983), these indexes could thus provide a description of respiratory phase segmentations along time. This imbalance characterized in particular the Musical Performance task where respiration varies mirroring musical rhythm, dynamics and note attacks. Apnoeas were again most frequent in musical performance, increasing significantly in correspondence of sustained notes, but occurred also in the Obstacle Course condition, in correspondence of the highest physical effort.

A significant respiratory index that could not be derived from acoustic concern detection of *thoracic or diaphragmatic* respiration. Video-analysis should be integrated to Audio recording in order to gain information about this specific aspect. Besides, acoustic analysis alone couldn't provide any information about *gas exchange* process.

2.6.2 Acoustic Indexes

The final set of *acoustic indexes* this study allow developing included: *Inspiration Intensity, Expiration Intensity, Envelope Amplitude of breathing sound-tracks, Insp. Spectral Centroid, Exp. Spectral Centroid and N of accented breaths.*

Intensity of breath sounds resulted to be louder for expirations compared to inspirations and varied across performance conditions, in particular from Baseline to Musical Performance. Breathing Energy varied also across the course of action, as shown in the Obstacle Course condition analyses: they were softer when lifting and placing the tray on the table, and louder on the step condition. This is consistent with real life experience, since when physical effort is stronger (like running) we are more likely to hear audible breath sounds. The same as musical context is regarded: is not uncommon to hear musicians breathing during their performance, both solo and in ensemble.

Envelope Amplitude of the total breath tracks was valuable both for representational aims and to carry out cross-correlation analysis in coordination analysis. Cross-correlation between breathing sounds tracks and musical track revealed that respiration profiles tend to mirror musical envelope and to anticipate performance by 0.231 sec, suggesting moreover a high degree of interpersonal coordination between performers; moreover, intensity of breathing sounds turner out to be related to dynamics of musical piece (breath sounds were louder during music crescendo and softer during music decrescendo) as if breathing sounds fulfilled and *anticipatory expressive function.* Relation between musical and respiratory amplitude profiles and occurrence of transitory increases in amplitude with crescendo are consistent with a previous study on the interaction between music listening and cardiovascular and respiratory rhythms (Bernardi et al. 2009).

Tau Analyses were not included due to the difficulty to relate these indexes to the traditional physical and acoustic measures. Among Spectral Descriptor, Format Analysis and LTAs were discarded. The former produced poor distinctive results between inspiration and expiration features, the second required longer tracks.

Only *Spectral Centroid* provided quantifiable differences between inspiration and expiration (the former turning out to be sharper and softer) and between different experimental conditions: Obstacle Course condition seems to produce sharper sounds compared to Baseline, both in inspiration and expiration. During the different phases of the Obstacle Course performance this index didn't vary significantly a part in the laying down phase, where breath sounds become a bit sharper and variability increased. Further studies should be carried on to identify other suitable spectral indexes that provide more detailed descriptions of breathing sounds.

Accented breaths are differently shaped according to the kind action performed. As shown in par. 2.5.6.2, accents in musical performance followed a quite precise and regular rhythm and seem to serve timing management while playing. In particular, note onsets significantly co-occurred with breathing sounds, suggesting that amplitude peaks in breathing sounds were related to musical performance. Accented breaths resulting from obstacle course are instead characterized by more a-rhythmic peaks, reflecting body movement (eg.: walking) and occurred in particular in the step and laying down phases.

Another interesting index that could give valuable information about acoustic nature of breath sounds is the analysis of the *attack of the sound*: some onsets are sharper and quicker, other are slower and softer. Onset velocity seems to be related to both timbre and intensity of breath sounds. Analyses of such aspects are still in progress.

2.6.3 Coordination indexes

As far as coordination indexes are regarded, the following descriptors were included in the final analysis model: *mean, standard deviation and range of the lag between couple of closest breaths' onsets; N of simultaneous breaths within fixed thresholds / tot amount of breaths (0-100ms / 100-250ms / 250-500 ms)*; *N of simultaneous breaths within fixed threshold / tot amount of breaths (>500ms).* In order to analyze coordination along time also *overlap of the amplitude envelops of performers' respiratory* turned out to be useful, allowing an effective an immediate comparison of breathing *frequency*, *intensity* and *synchronization* of both participants in different moment of the performance.

Relative measurements provided a synthetic description of the actual trend of breathing synchronization that allow the definition of four fixed thresholds. In baseline condition, average difference between closest was more than 600 ms while in all performance conditions it resulted inferior to 500 ms. More than half of coupled breaths' lags were upon 500ms (57.29%) while in the joint conditions only 1/3 and 1/4 of coupled breaths followed in this category (33.77% in obstacle course and 25.76% in musical performance). Thus 500 ms was considered a valuable threshold between synchronous and asynchronous breaths. The other three classes of synchronized breaths enable to draw a more sensitive description of the changes occurring along the stream of the action provide more detailed information about the degree of synchronization between performers along the action course. In the Obstacle Course mean synchronism appeared to be higher when laying the tray down on the floor and on the table. These are the only two moments when participants have to let go the plate on the same time: high coordination is actually required on order not to spill water from the glasses. The prevailing synchronization class was the 250-500 ms made exception in the last phase, where lag shorten to 100-250ms. As expected, in the Musical performance the improvisation section was characterized by less synchronized breaths compared to the standard one being more challenging in term of interpersonal coordination; the categorization in different classes allow again a more detailed description of the phenomenon: breath-lags included in the first category (0-100 ms) don't seems to differ significantly in the two conditions and, what's more, delays occurring within 100-250 ms were more in the improvised section compared to the standard one. Finally, a comparison between synchronous and a-synchronous breaths in baseline and musical conditions was carried out, confirming that simultaneous breaths were significantly more than non-simultaneous in the latter compared to the former.

2.6.4. Concluding Remarks

Tab. 14 resumes the three levels of the multilayer analysis model derived from this study and their corresponding indexes. These indexes allowed not only the extraction of some of the conventional measurements of ventilation but also the description of some acoustic features of breathing sounds. Anyway, acoustic description turned to be the poorest one, at this stage of the research. Following inclusion of new indexes able to catch some aspects of breath noise spectral components would be undoubtedly useful to enrich this level of the model. Finally, coordination indexes enabled to infer information about the relation between breathing behaviour and simultaneous performance on one hand, and between partners breathing during joint performance on the other. This model will serve the following two studies that are going to focus on expressive function on breathing sounds in different performances/emotional conditions.

Respiratory Indexes	**Acoustic Indexes**	**Coordination Indexes**
- Respiratory rate; - Cycle duration; - Inspiratory time; - Expiratory time; - I:E ratio; - Expiratory Pauses Time; - Inspiratory Pauses Time; - N breaths / min; - N Expirations / min; - N Inspirations / min; - N apnoeas / min.	- Inspiration Intensity; - Expiration Intensity; - Envelope Amplitude of breathing sound-tracks; - Insp. Spectral Centroid; - Exp. Spectral Centroid - N of accented breaths.	- Lag between couple of closest breaths' onsets (*M, S.D, Range*); - N breaths within 0-100 ms / tot amount of breaths; - N breaths within 100-250 ms / tot amount of breaths; - N breaths within 250-500 ms / tot amount of breaths; - N breaths > 500 ms / tot amount of breaths.

Tab.14 Final Multilayer Analysis Model

3

3.1 Introduction

In the previous study a three multilayer analysis model was presented and its descriptive power about respiratory, acoustic and coordination aspects was described. This model was built in order to investigated the expressive functions of breathing sounds, assuming that within close interpersonal distances, could assume a distinctive *communicative value*. We have already discussed how breathing sounds are actually used to manage interaction synchrony in performances requiring high degree of synchronicity (like musicians, dancers and sportsman) or to gather information about personality and emotional state of individuals in close social interactions (call-centers, mother infant exchanges, music-therapy interventions). Anyway, as far as we know, this question hasn't been addressed so far by previous psychological research. Few studies investigated the *emotional expressive function* of *breathing* (Bloch et al, 1991; Boiten et al, 1994; Boiten, 1998; Philippot et al, 2002; see par 1.6.2) but were concerned more with emotional *expression* and *induction* rather than on *identification* of emotional signals through breathing sounds. Interestingly, these studies suggested that quite distinct respiratory patterns could be related to specific basic emotions and, what's more, that *mimicking* such patterns induce correspondent emotional feeling state.

Is it then possible to infer reliable information about the *identity*, the *activity* performed and the *emotional feelings* felt by an individual *also* by his/her breathing sounds? Studies on the expressive functions of breathing sounds could provide useful information for voice-print identification processes, as well as for therapeutic purposes and interventions with people affected by severe motor or communicative disabilities. As an example, the study of Plotnik et al (2010) that brought to the realization of a "sniffing device" that allow paralyzed people to move wheelchairs and compound sentences on a virtual keyboard has been discussed in Par. 2.1. This topic arises a lot of new questions and opens new thriving opportunities in the field of communication and emotional research.

Previous studies on the relation between emotions and respiration have been already discussed in Par. 1.6.2. More is known about the effect mimicry on emotional understanding and social bonds. The following paragraph will address the results on previous studies about this subject matter.

3.1.2 Studies on Mimicry

First observations on automatic mimicry could be brought back up to half of 1700, when Adam Smith gave a first description of *motor mimicry*, the unintentional tendency to imitate overt behaviour of another person. He defined this tendency as a primitive form of "sympathy", being unconscious and almost reflexive. From this moment on mimicry has received huge attention from social and developmental psychology. Following researches have investigated *what* do we unconsciously imitate and have deepened the *mechanisms* that underpin mimicry, the *factors* that foster or inhibit such behaviours, its *effects* on both sides of the mimicker and the mimicked, social interaction and interpersonal bonding.

Unconscious mimicry happens without being aware of that: individuals have been observed mimicking others in speech (e.g., Cappella & Planalp, 1981; Giles & Powesland, 1975), facial expression (Hsee et al, 1990; Dimberg et al, 2000), postures and gestures (LaFrance et Broadbent, 1976; Bernieri et al, 1988; Chartrand and Bargh, 1999;) and also affective responses (Hatfield, et al, 1994; Neumann and Strack, 2000) (see Chartrand and Van Baaren, 2009 for a review). Unintentional imitation seems to be an *innate predisposition*, already observed in early interactions (Simner, 1971; Feldman, 2007i): Newborns imitate facial movements and expressions (Metlzoff et Moore, 1977; Field et al, 1982) and vocal sounds (Kugiumutzakis, 1993). Studies on "mirror neurons" (Gallese et al, 1996; Iacobini et al, 1999), that become active whenever we *observe* someone performing a specific action, and we *think* or *perform* it ourselves, provides new supports and explanations to this automatic tendency.

Association between perception and action actually seems one of the primary mechanisms that support imitation, and hs not only neurological but also cognitive basis. This principle have been first suggested by James (1890) who spoke about "ideomotors action" referring to the fact that just thinking about a specific behaviour increases the tendency to actually perform it. Later on, other researchers have related mimicry to this perception- action coupling mechanism (Chartrand & Bargh, 1999; Dijksterhuis & Bargh, 2001) suggesting that merely seeing a person engage in a behaviour activates the corresponding behavioural representation, which makes that behaviour himself more likely to be performed.

Mimicry occurs across a variety of naturalistic settings, particularly among individuals who have a bond with each other, for example romantic couples (Bernieri, 1988; LaFrance, 1979, 1982) and between mother and infant but mere social similarity increased the likelihood of this process (Bourgeois et Hess, 2008), like sharing ethnic (Heider et Skowronski, 2009) or religious identity (Yabar et al, 2006). By contrast, individuals mimic less people perceived as competitive rather than cooperative (Lanzetta et Englis, 1989). Thus, we do not imitate everyone at any time but we are more likely to individuals we want to affiliate with, for social or personal reasons (Stel et al, 2010)

Which kind of persons does exhibit a greater extent of interpersonal mimicry? As a natural consequence of what already said, individuals who have a *strong need to affiliate*, are more concerned with other or, generally, had an *affiliation goal* (Lakin & Chartrand, 2003); similarly, people who have an *interdependent self-construal* (Van Baaren et al, 2003) or are characterized by an *assimilative cognitive style*: *field dependent* persons have been proved to be more attuned to others than *field independent* (Van Baaren et al, 2004 a,b). Also people who are *high in perspective-taking* (Chartrand & Bargh, 1999) and self-monitoring (Cheng & Chartrand, 2003) exhibit more interpersonal mimicry. Finally, this phenomenon is manifest also in people who feel too different from in-group members, to find a good balance between desire for distinctiveness and for belonging (Brewer, 1991).

On another side, studies have dealt with the effect of mimicry. This processes is likely to foster *interdependence* and to increase *empathy, liking* and *rapport* between individuals. Chartrand et Bargh (1999) shown that mimickers and mimickees report smoother interactions and a more recent study of Stel et Vonk (2010) underline that they become more *affectively attuned* to each other reporting also more feelings of having bonded with each other. This happens also in early infancy: babies react better towards adults who imitate them rather then those who don't (Meltzoff, 1990; Asendorpf et al, 1996). Social psychology research revealed also that individuals who are mimicked by an in-group member show *more helping and pro-social behaviours*, not only toward the mimickers but in general (Van Baaren et al. 2004a,b; Stel et al 2005), while if the mimickers is an *out-group member* or, in general, an unpleased persons, they will like them also less than out-group members who don't mimic (Likowski et al, submitted).

If unconscious mimicry produce such results, what about the benefits of *intentional mimicry?* Most studies on strategic mimicry have generally focused on relatively simple behaviours such as tipping in a restaurant, or picking up dropped pens from the ground so it is currently unclear the extent to which mimicry can facilitate other types of more complex interpersonal interactions. Anyway, some studies provided results in support to the hypothesis that strategic mimicry could facilitate some desired social outcomes: Van Baaren et al (2003), for example, shown that waitresses instructed to verbally mimic their customers by repeating the orders back verbatim received bigger tips than those who were instructed not to mimic. Moreover, strategic behavioural mimicry is likely to facilitate also *negotiation outcomes* (Maddux et al., 2007). Some studies have also revealed that people become *more affectively attuned* when they mimic or they are mimicked (Stel, Vonk, 2010). Lipps, in 1907, suggested that imitation of postures, vocal and facial expression could trigger similar experiences of those felt by the mimicked persons, since in would activate the corresponding afferent feedback from those muscles to the brain. Thus, imitation would be responsible for *emotional contagion* (Hess et al, 1992; Hatfield et al, 1992). Stel et al. (2005) have also shown that mimicry enforces *perspective taking*, facilitating empathy. In some counselling and therapeutic context (client-centred therapy, NLP and humanistic music-therapy) matching the rate and quality of the client *breathing* has been suggested to reinforce emotional attunement (Bandler et Grinder, 1975; Sutton, 2002; Scardovelli, 1999; Sigel, 1984, 1986) However, as far as we know, this technique hasn't been rigorously tested thus it isn't clear whether mimicking breathing can actually improve rapport. The already cited work of Philippot et al (2002) provided some evidences about the possibility to induce specific emotional feeling by reproducing specific breathing pattern, related to distinct basic emotions. It's likely that respiration, being under control of both voluntarily and automatic control, could represent a crucial mean between physiological and psychological processes.

Some research have also brought evidences of an automatic process called *physiological "attunement*" (Levenson et Gottman, 1983) that is rising of patterned physiological association between social partners. This event has been observed first in spousal conflicts (Levenson & Gottman, 1983) then also in empathic interactions (Marci, Ham, Moran, & Orr, 2007). Levenson and Ruef (1992) also found evidences that people who accurately rated the *negative* emotions of a target person shown similar patterns of autonomic activity. Levenson and Ruef (1997) argued that, since emotion is a strong embodied experience, "if one experience emotional rapport with another, there will be an element of physiological rapport too". In the Introduction of this dissertation we have reminded the great number of physiological systems that have been noticed to synchronize across individuals, in particular when they experience close proximity. Autonomic synchrony has been found also in infant-parent early interaction (Stratton, 1982; Wolff, 1967; Feldman, 2007i) (see Introduction for a more detailed discussion). In particular, in this context *interactive behaviour* seems to entrain the dyad's physiological processes such as sucking, heart beating and respiration and has lead to the idea that biological rhythms could provide the basis for *social* rhythms (Beebe et al., 1985; Sander, 1969).

Anyway, few studies have dealt with this association between communicative, emotional and physiological attunement. In particular it would be interesting to investigate whether breathing together reinforce *emotional attunement*. We already discussed the results of previous studies about the effects of respiration manipulation on emotional feelings (Bloch et al., 1991; Philippot et al, 2002). Their results partially support the hypothesis of an *involuntarily* influence of respiration on emotional experience. Thus, it's likely that also *intentional* mimicry of breathing could lead to higher perception of connection and improve the decoding ability of the emotional state of another person.

In the present study participants were exposed to a variety of listening tasks to breathing audio-tracks of persons of different *gender* involved in various *performances* and *emotional* conditions. Depending on the assigned experimental condition, a first group had to listen to each track twice and then to answer a questionnaire that investigated what they could infer about subject's gender, performed activity and emotional feelings. The other group, had to listen to each track twice, to mimic twice that breathing pattern and then to answer a similar questionnaire. They both investigated what could be inferred from breathing sounds themselves and whether imitation improves decoding abilities.

3.2 Aims

The study was aimed to explore:

1) What could be inferred about a person's *identity*, *emotional state* and *activity* from the sound of his/her breathing;
2) To what extent *reproducing* the features of specific breathing patterns could improve the identification of those features compared to mere listening.

Our primary hypothesis is that breathing sounds could convey some cues about degree of *physical activation* and *mental concentration* of performed activity. Moreover, we expect that high physical demanding activities will be better identified compared to low demanding ones, having a more evident influence on breathing sounds features.

Secondly, we hypothesize that mirroring breathing sounds will improve decoding abilities compared to listening alone.

3.3 Method

3.3.1 Participants

Participants were 194 university students (89.49% women) enrolled during an introduction psychology course. The experiment was presented as a non-obligatory workshop about the relation between breathing and well-being. They didn't receive any course credit for their participation in the study. At the end of the experimental session they were told the real aim of the study and implications for their professional education were discussed. During the data analysis 5 participants were excluded due to missing responses or inaccuracy. Thus the final data sample cosseted of 189 participants: 89 in the first condition, 90 in the second one.

3.3.2 Materials

Apparatus. Both instructions and audio tracks were presented on a computer screen through a power point slide presentation. Participants used personal earphones and were provided with a paper-and-pencil version of the Questionnaire.

Audio-Tracks. 10 audio tracks of breathing sounds served as experimental stimuli in the study. All original tracks were recorded in ecological conditions using a *Presonus Firestudio Project* audio interface and a *Shure WH30 XLR* head-microphone. Breathing sound of 10 different persons (5 women, 5 men) were recorded while engaged in one among the following conditions:

1) *6 activities,* characterised by different degree of *physical activation* (PA) and *mental concentration* (MC):
    i. *Resting* on a chair: Male (M) - low PA, low MC;
    ii. Solving a *logical problem*: Female (F) – low PA, high MC;

iii. Playing a pick-up stick match (*shangai game*): M – medium-low PA, medium MC;
iv. Walking along an *obstacle course* (taken from the audio sample of the first study): M –medium PA, medium-low MC;
v. *Jogging* on place: F – high PA (aerobic effort), low MC;
vi. Performing a hard *stretching* exercise: M – high PA (anaerobic effort), low MC.

2) *4 emotional eliciting context*: Disgust, Amusment, Anger and Sadness.

All emotional tracks were extracted from the database of a previous study on vocal communication of empathy (Pellegrini et al, 2009) collecting ecological phone calls. Thus, this sampling condition assure efficacy of emotional induction (as the results of the cited study shown) and allow to collect emotional breathing tracks characterized by the same, low level of physical effort.

Activities	Gender
Resting	M
Logical Problem	F
Shangai game	M
Obstacle Course	M
Jogging	F
Stretching	M

Emotions	Gender
Amusement	M
Sadness	F
Anger	F
Disgust	F

Tab. 1 – Experimental Tracks – Activities and Emotions

A 20 sec recording period was extracted from part of each recorded tracks and were used as experimental stimuli. Using the indexes defined in Study 1, mean and standard deviation of the following respiratory and acoustic parameters were calculated for each breathing pattern: Cycle Duration, Expiratory Time, Inspiratory Time, E/I Ratio, Post breathing pauses time, Post Expiratory pauses time, Post Inspiratory pauses duration, N Apnoeas, Inspiratory Intensity, Expiratory Intensity, Spectral Centroid, Number of Accented Breaths. Data presented in Tab. 2 and Tab. 3 show the different respiratory and acoustic features of the final experimental breathing patterns.

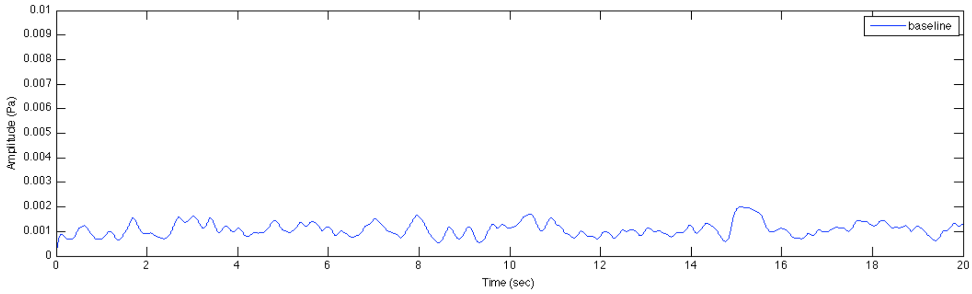
		Breathing Condition					
Respiratory Indexes		**Resting**	**Mental Task**	**Shangai**	**Obstacle Course**	**Jogging**	**Stretching**
Cycle Dur.	Mean SD Range	2.732 .361 .890	2.620 .713 1.570	2.180 1.045 2.830	2.720 .565 1.670	3.838 .568 1.340	5.265 0.658 1.590
Insp. Time	Mean SD Range	1.246 .110 .890	.898 .320 .680	0.775 .322 1.050	1.027 .300 .890	1.745 0.290 .800	1.975 .444 1.070
Exp. Time	Mean SD Range	1.300 .036 .090	.973 .261 .580	1.021 .686 1.950	1.589 .319 .930	2.036 .344 .960	2.323 .705 1.530
E/I Ratio	Mean SD Range	1.098 .101 .271	.778 1.041 2.231	1.329 .348 .931	1.577 .190 .533	1.190 .141 .374	1.183 .331 .545
Pauses Duration	Mean SD Range	.567 .428 1.210	1.806 2.578 7.151	.465 .462 1.255	.131 .074 .218	.080 .059 .164	.415 .357 .990
I Pauses Duration	Mean SD Range	.312 .268 .613	.778 1.041 2.231	.337 .407 1.179	.109 .075 .218	.087 .061 .161	.603 .357 .990
E Pauses Duration	Mean SD Range	.823 .421 1.210	3.177 3.658 1.939	.593 .509 1.176	.158 .070 .177	.071 .063 .154	.164 .161 .290
Apnoeas (m+2ds)	N Mean SD Range	 // //	3 3.897 2.906 5.140	3 1.285 .038 .076	 // //	 // //	1 1.050 //
Insp. Intensity (dB)	Mean SD Range	29.573 .570 1.560	39.108 2.142 4.500	40.921 0.485 1.380	48.807 .507 1.360	45.937 1.265 3.410	50.755 0.738 1.620
Exp. Intensity (dB)	Mean SD Range	32.162 .965 2.710	42.678 5.264 11.420	42.781 1.730 5.620	55.857 .730 2.060	69.852 2.799 7.540	67.383 11.468 24.880
Spectral Centr. (Hz)	Mean SD	559.80 345.69	786.04 365.85	804.41 410.33	231.16 179.87	938.06 732.59	531.11 309.69
N of Acc. Breaths / 20sec		//	3	6	9	11	4

Tab.2 - Description of Activity Tracks

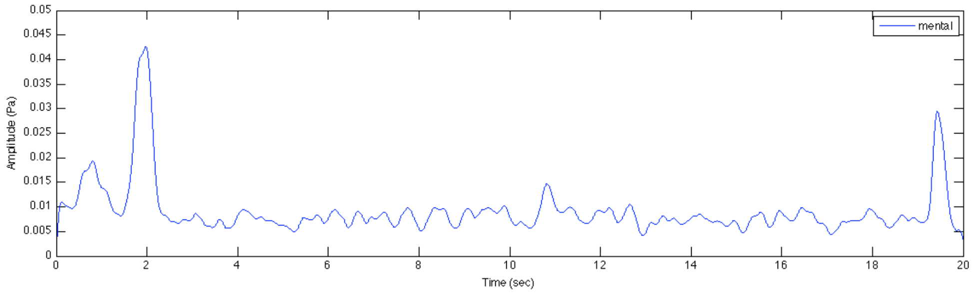
		Breathing Condition			
Respiratory Indexes		**Anger**	**Sadness**	**Disgust**	**Amusement**
Cycle Duration	Mean SD Range	4.100 1.196 2.590	2.516 1.388 4.330	3.648 1.097 2.490	3.032 .565 1.430
Inspiratory Time	Mean SD Range	1.055 .298 .630	.534 .310 1.030	1.218 .350 .870	.788 .307 .800
Expiratory Time	Mean SD Range	2.310 .980 2.230	.943 .673 1.860	1.720 .720 2.220	.900 .418 1.310
E/I Ratio	Mean SD Range	2.140 .333 .754	1.837 1.036 2.815	1.217 .239 .550	1.538 .590 1.334
Pauses Duration	Mean SD Range	.994 .777 1.936	.567 .654 2.574	.637 .512 1.496	1.058 .734 2.012
I Pauses Duration	Mean SD Range	.793 .858 1.936	.817 .766 2.424	.316 .107 .262	.834 .669 1.690
E Pauses Duration	Mean SD Range	1.263 .718 1.435	.233 .237 .625	.905 .571 1.496	1.338 .808 1.956
Apnoeas (m+2ds)	N Mean SD Range	1 2.050 //	4 .977 1.117 2.424	1 1.070 //	 // //
Insp. Intensity (dB)	Mean SD Range	48.513 1.506 2.110	49.148 6.013 20.650	39.148 7.714 14.770	41.958 1.574 1.720
Exp. Intensity (dB)	Mean SD Range	57.763 4.561 9.360	54.466 8.778 21.220	45.132 7.46 20.520	47.731 5.971 10.230
Spectral Centr. (Hz)	Mean SD	895.06 585.65	1380.68 951.26	915.02 392.35	976.77 554.39
N of Acc. Breaths / 20sec		4	7	2	6

Tab.3 - Description of Emotions Tracks

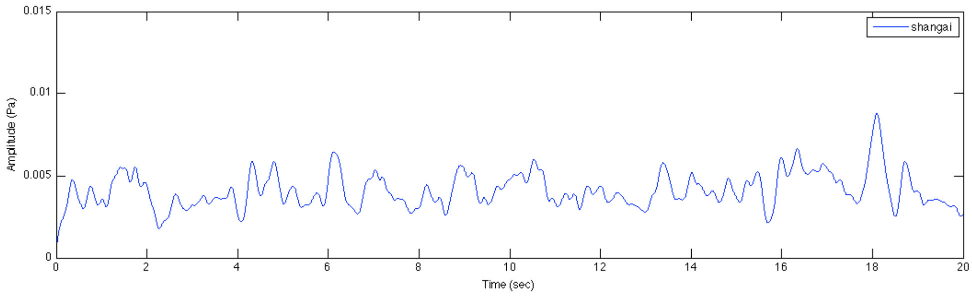
Fig.1 - Amplitude Envelopes of Breathing Tracks



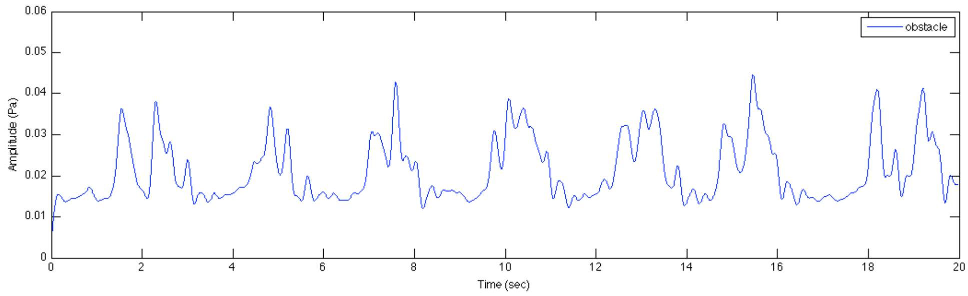
Resting



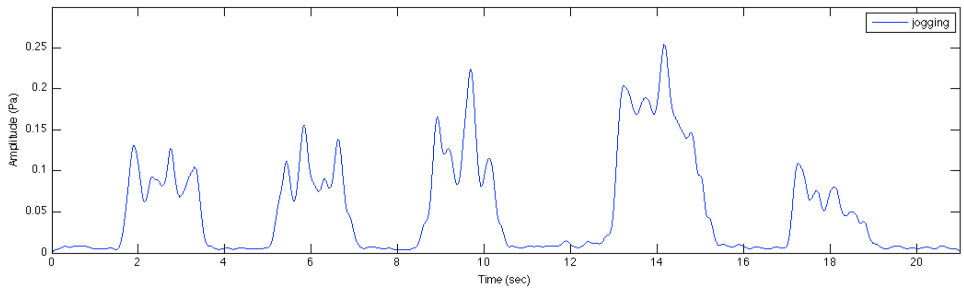
Mental Task



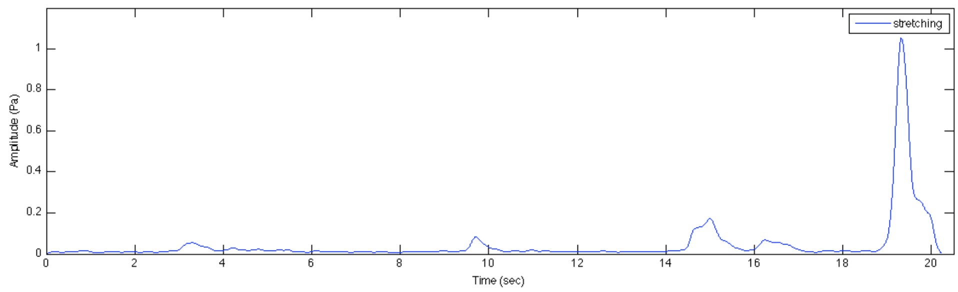
Shangai



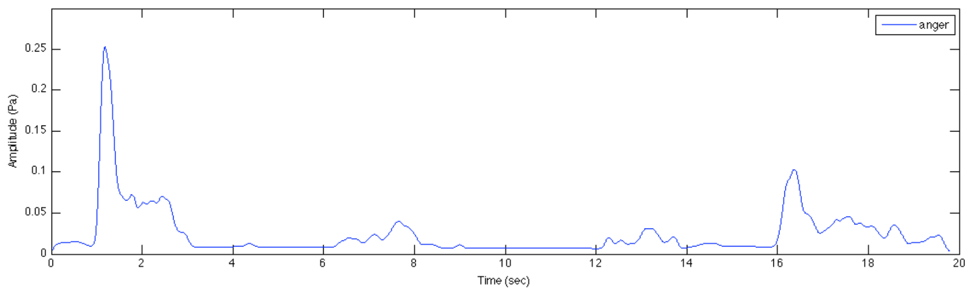
Obstacle Course



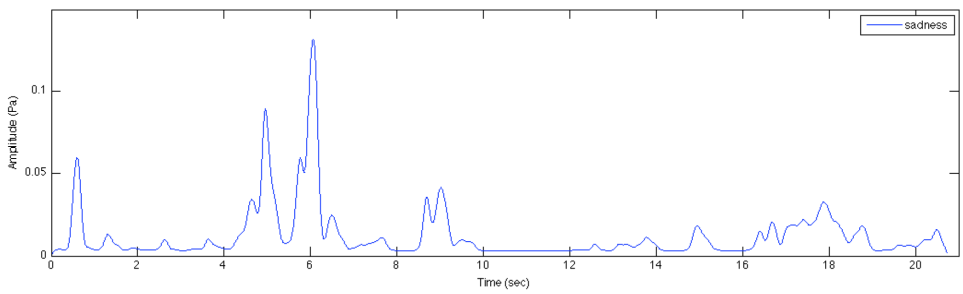
Jogging



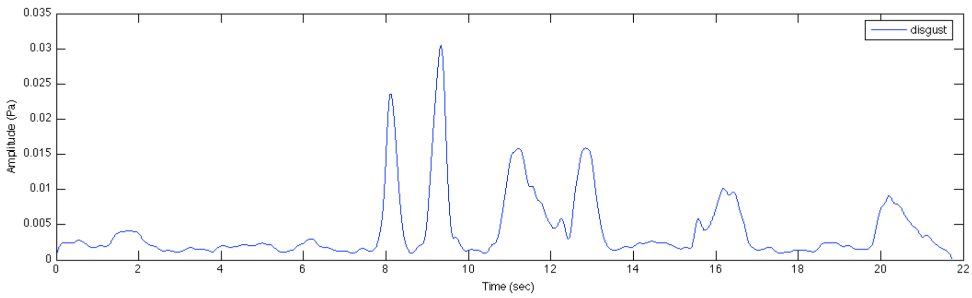
Stretching



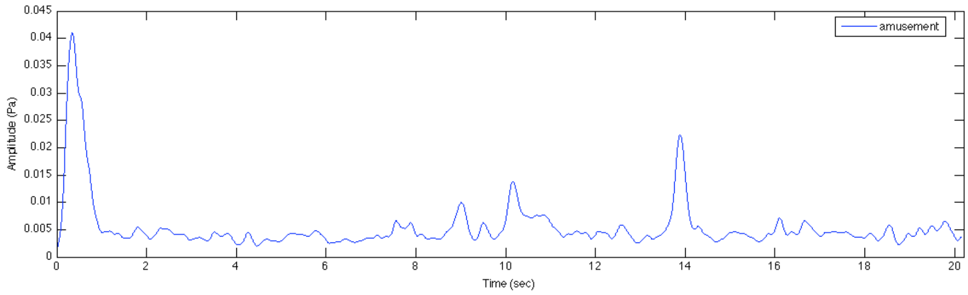
Anger



Sadness



Disgust



Amusement

<u>*Self-Report*</u>. After each task, a questionnaire was administered that include several items about what participant could infer from the audio tracks and about his/her feeling during the performance of the task. It includes different sheets for the *activity-tracks* and for the *emotional-tracks* (See Appendix 1)

The "*Activity Sheet*" require to:

- Indicate the *gender* of the person who was breathing;
- Rate the degree of *physical effort* and *mental concentration* of the performed activity on a 7 points Likert scales (0: none; 7: very intense).
- Chose among multiple-choices the *activity* he/she was engaged in. The labels included in random order the actual activities and 6 distracters, one for each track:

Activities	**Distracters**
Resting	*Sleeping*
Logical Problem	*Reading*
Shangai game	*Drawing*
Obstacle Course	*Housework*
Jogging	*Step*
Stretching	*Weight-lifting*

Tab. 4 – Activity Sheet – Targets and Distracters

- Indicate whether they thought the person was feeling any emotion, using the Italian adaptation (Ciceri, 2005) of Scherer's *Emotion Wheel* (Scherer, 2005). The *Geneva Emotion Wheel* requires the respondent to indicate the answer by choosing a single emotion or a blend of several emotions out of 20 emotion families, arranged in a wheel shape with the axes defined by two major appraisal dimensions: *high – low control / power appraisal* and *un pleasantness / obstructiveness – pleasantness /*

conduciveness appraisal. Each family is identified by two labels that stand for a whole range of similar emotions. Then, respondents have to check the *intensity* of the chosen emotion/s on a scale from 1 (very weak) to 5 (very strong). Circles in "spikes" corresponding to each emotion family represent different intensities: the bigger the circle, the stronger the emotional experience.

The "*Emotion Sheet*" require to:

- Indicate the *gender* of the person who was breathing;
- Rate the degree of *physical effort* and *mental concentration* of the performed activity on a 7 points Likert scales (0: none; 7: very strong).
- Indicate whether they thought *the person* was feeling any emotion, using the Italian adaptation of Scherer's *Emotion Wheel*.
- Indicate whether *they themselves* have felt any emotion during the task, always using Emotion Wheel.

- A final *Task Evaluation Form*, at the end of the entire Questionnaire, requires to rate on a 7 points Likert scales (0: not at lot; 7: a lot) the following aspects of the task:
    - o *Difficulty*: "Difficult, since I have never done that before"
    - o *Usefulness*: "Useful since to put myself on his shoes"
    - o *Discomfort*: "Annoying, because in wasn't my natural way of breathing"
    - o *Involvement*: "Involving, because I felt physically aroused"

In the first conditions participants were also asked whether during the task they ever *found themselves imitating* the breathing patterns they had listened to. In the second experimental conditions participants were instead asked to rate:

- o how much the task was *mechanical* ("Mechanical: I did it just because I had been required to")
- o how much they believe that imitating that breathing pattern helped them to experience *physical feelings* similar to those of the subjects.

3.3.3 Procedure

90 participants were randomly assigned to the first experimental condition and 90 to the second. Group of 30 participants at once were tested. They were welcomed in a wide university classroom provided with 33 desk-PCs. Nearby each station there was a pen-and-

pencil version of the questionnaire. First, the experimenter read aloud the written instructions. Participants to Condition 1 (Listening) were read:

"*You'll have to listen to some audio-recordings of the breathing of various persons and answer a questionnaire about what you heard, what do you think this persons were doing/feeling and what did you experience. Listen to each track three times, attentively. Then, move to the following slide and answer the corresponding page on the Questionnaire you have received. You'll have to answer all the questions before moving to the following slide*"

Participants to Condition 2 (Imitation) were read:

"*You'll have to listen to some audio-recordings of the breathing of various persons, to adopt you yourself that breathing way, than to answer a questionnaire about what you heard, what do you think this persons were doing/feeling and what did you experience. Listen to each track three times, attentively. Then try to put yourself in that person's shoes mirroring his way of breathing, as if you were him/her, for at least 20 seconds. Then move to the following slide and answer the corresponding page on the Questionnaire you have received. You'll have to answer all the questions before moving to the following slide*".

Before starting, participants were also shown how to use the Geneva Emotion Wheel and familiarised with the breathing audio-tracks listening to two examples of people at rest. Then, they start with the auto-administration. They were given 45 minutes to complete the task.

3.3.4 Dependent Variables

<u>Task Ratings Form.</u> Task reliability (difficulty, discomfort, involvement and usefulness and mechanic) was assessed through analysis of self report ratings in both conditions.

<u>Activities and Emotions Identification Accuracy.</u> Both *raw* and *unbiased hit rates* (Wagner, 1993) were extracted for each subject as a measure of identification accuracy. *Raw hit rate* (H) is ad index of the percentage of participants who correctly identified the target activity/emotion. This index was calculated for each stimulus and two different confusion matrixes were drawn for "emotion" and "activity" stimuli. However, this

measure of recognition accuracy is biased by the tendency to choose a particular multiple-choice category more than others (response bias) and moreover didn't take into account the number of choices participants have to deal with. *Unbiased hit rates* (Hu) allow both biases correction since it is "*an estimate of the joint probability both that a stimulus is correctly identified (given that it is presented) and that a response is correctly used (given that it is used)" (Wagner, 1993, p. 16)*. It is calculated by multiplying the hit rate for that label (the number of accurate uses of the label, divided by the number of times that label was presented) by the differential accuracy (the number of accurate uses of the label, divided by the total number of uses of that label). Since Hu is a proportion, arcsine transformed was calculated to allow statistical analysis. Values range from 0 to 1.57 (perfect score). Unbiased underwent ANOVA tests to compare *indexes of accuracy* in: 1) the two experimental condition, 2) the different emotional stimuli, 3) the different activity stimuli.

Self Report. gender identification accuracy, assigned level of physical effort and mental concentration, participants' emotional experience were assessed through analyses of Self Report ratings.

3.4 Results

3.4.1 Task Ratings Form

First we examined participants' responses to *Task Evaluation Form* (Tab.5) to verify the consistency and reliability of the experimental procedure. Inspection of these data shows that the task was considered *quite difficult* (M=4.33/7) and average *involving* (M=3.66/7) but not too *annoying* (M=2.54/7) neither *mechanical* (M=2.70/7). Both Listening and Mirroring were evaluated as *useful* in order to put themselves in the shoes of the "breather" (M=4.70/7). Thus, we can confirm the reliability of the experimental procedure.

A One-Way ANOVA was carried out to compare ratings to C1 and C2. C2 was judged as *significantly easier* compared to C1 (F=8.933, df=1, p<0.01) and, not surprisingly, more *annoying* (F=36.267, df=1, p<0.001). No differences emerged concerning *involvement* and *usefulness*.

		Mean	Dev.St
difficulty	C1	4.67	1.297
	C2	3.99	1.699
	Total	**4.33**	**1.548**
usefulness	C1	4.72	1.699
	C2	4.85	1.435
	Total	**4.79**	**1.568**
discomfort	C1	1.86	1.303
	C2	3.20	1.620
	Total	**2.54**	**1.615**
involvement	C1	3.64	1.721
	C2	3.67	1.483
	Total	**3.66**	**1.601**
mechanical	C2	2.70	**1.660**

Tab.5 . Task Evaluation Form

76.74% of participants to C1 affirmed to *have found themselves imitating* some of the breathing pattern they were listening to, although without any instruction. Finally, participants to C2 believe that imitating the listened breathing pattern didn't help them to experience *physical feelings* similar to those of the subjects that much (M=2.69/7, SD=1.660). These responses will be discussed later considering to the decoding results.

3.4.2 Gender Identification

In order to evaluate how much *gender* of the subjects who recorder the breathing tracks was identified, response frequencies were calculated on individual and both conditions and a chi square was carried out to determine whether recognition occurred at a significant level.

Statistic test underlined no significant difference between conditions. As total frequencies are considered, Gender was correctly identified in 7 conditions over 10: resting (M), shangai (M), obstacle course (M), stretching (M), sadness (F), anger (F), amusement (M). Jogging (F) was significantly confused with Male while Mental Task (F) and Disgust (F) had equally distributed responses and thus didn't show a specific trend.

	C1		C2		TOT		χ^2
	X	√	X	√	X	√	
Resting	32	56	39	51	71	107	χ^2 = 7.28; df=1; p<0.01
Mental	45	43	43	47	88	90	**NS**
Shangai	20	68	14	76	34	144	χ^2 = 67.98; df=1 ; p<0.001
Ostacoli	36	52	31	59	67	111	χ^2 = 10.88; df=1 ; p=0.001
Corsa	57	31	62	28	119	59	χ^2 = 20.22; df=1 ; p<0.001
Stretching	14	74	15	75	29	149	χ^2 = 80.90; df=1 ; p<0.001
Tristezza	4	84	2	88	6	172	χ^2 = 154.8; df=1 ; p<0.001
Disgusto	47	41	42	48	89	89	**NS**
Rabbia	3	85	5	90	8	170	χ^2 = 147.4; df=1 ; p<0.001
Divertimento	13	75	15	75	28	150	χ^2 = 83.61; df=1 ; p<0.001

Tab. 6 - Gender choices frequency

Since gender was balanced under the 10 experimental conditions (5 M / 5 T) and "Male" choice prevailed on 6 conditions over 10, we tested whether there was a significant tendency to overestimate this response. Male label was chose 971 times, while female one 809. A chi square highlighted this trend as significant (χ^2 = 14.57; df=1 ; p<0.001).

3.4.3 Activities Decoding

3.4.3.1. Unbiased Hit Rate Score

First unbiased hit rates were calculated in order to compare the degree of identification accuracy of the various activity-breathing tracks within each condition. Hu were first computed per judge for each stimulus separately. Tab.7 show Mean and Standard deviation for each Activity, in the two different conditions.

	N	COND 1		COND 2		Total	
		Mean	St.Dev.	Mean	St.dev	Mean	St.dev
Jogging	89	1.076	.707	1.282	.569	**1.178**	**.648**
Mental Task	89	.341	.632	.523	.736	**.384**	**.665**
Stretching	89	.270	.575	.427	.699	**.397**	**.670**
Resting	89	.241	.541	.245	.541	**.243**	**.539**
Shangai	89	.076	.330	.241	.558	**.159**	**.465**
Obst. Course	89	.024	.175	.159	.476	**.091**	**.364**

Tab. 7 - Descriptive Statistics of Activities Hu rates

To compare recognition between conditions, first a Repeated Measure ANOVA was carried out with *Activity* (Resting, Mental Task, Shangai, Obstacle Course, Jogging, Stretching) as within-subject variable, *Condition* (C1, C2) as between variable and the *Unbiased Hit Rate Score* per judge as dependent variable. Main effects of both *Activity* ($F(5,880) = 92.213$, $p<0.000$) and *Condition* ($F(1,176)=13.048$, $p<0.001$) emerged as significant, but not their interaction (Contrasts are shown in Tab.8). Thus, Imitation significantly improves the ability to correctly identify different kind of activities.

F	*Contrast*
Activity: F(5,880)= 92.213, p<0.001 Condition: F(1,176)=13.048, p<0.001 Activity*Condition: NS	J M St R Sh O

Tab. 8 - ANOVA on Activity Hu Rates

3.4.3.2. Confusion Matrices on Raw Hit Rates

Confusion Matrix of participants' responses allows exploration of which stimuli where more or less difficult to distinguish and examination of systematic confusion between activities. Different matrixes for each condition will be separately presented and discussed below.

<u>*Condition 1 – Listening*</u>

Tab. 9 shows % of Identification Accuracy calculated on raw hit rates for Activities in C1.

%	Resting	Sleeping	Logical Task	Reading	Shangai	Drawing
Resting	***19.10***	30.34	6.74	25.84	1.12	7.87
Logical Task	3.37	8.99	***24.72***	8.99	22.47	24.72
Shangai	5.62	38.20	5.62	5.62	***5.62***	7.87
Obstacle	8.99	12.36	10.11	7.87	4.49	2.25
Jogging	1.12	2.25	0.00	0.00	0.00	0.00
Stretching	4.49	5.62	8.99	1.12	2.25	0.00

%	Obstacle	Housework	Jogging	Step	Stretching	Weight-Lifting
Resting	1.12	0.00	0.00	0.00	4.49	1.12
Logical Task	0.00	1.12	0.00	0.00	2.25	1.12
Shangai	2.25	4.49	2.25	1.12	10.11	7.87
Obstacle	***2.25***	1.12	8.99	4.49	14.61	19.10
Jogging	7.87	2.25	***74.16***	5.62	4.49	1.12
Stretching	2.25	0.00	2.25	2.25	***21.35***	46.07

Tab. 9 - % Identification Accuracy for Activities in C1 - Listening

Percentage of identification was generally low, made exception for *Jogging*: 24.53% (SD 25.91%). Excluding the most recognized, mean identification accuracy falls to 14.62% (SD 10.01%).

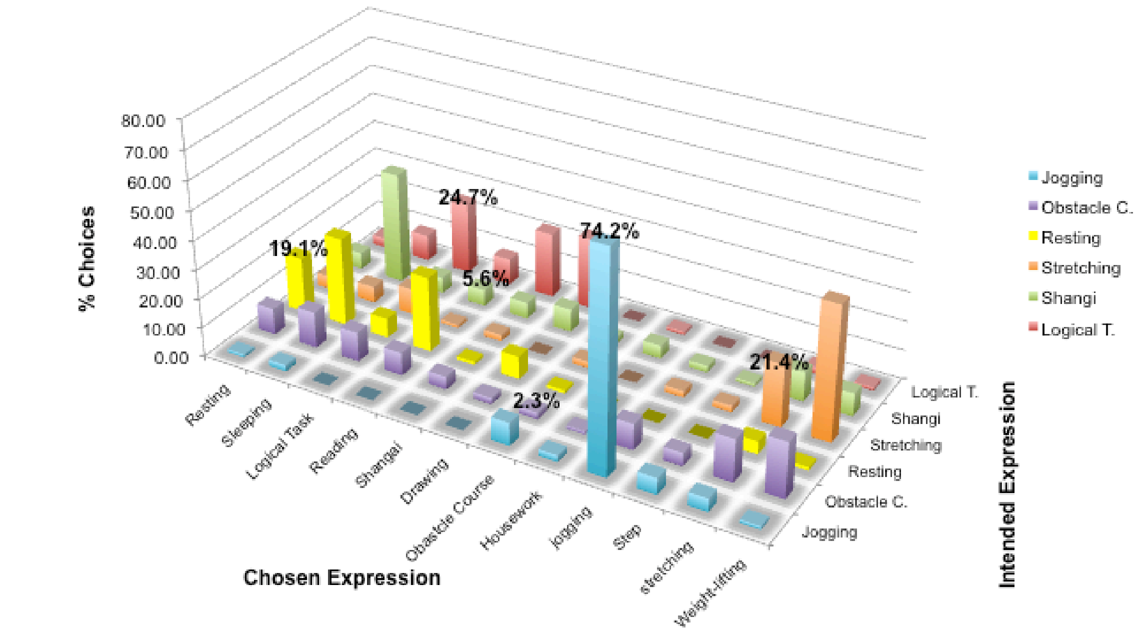
High physical demanding activities were the easiest recognized: *Jogging* identified on 74.2% of cases and the correct label was chosen significantly more than all others (χ^2=317.1, $p<0.001$). It was sometimes confused with *Obstacle Course* (7.87%), perhaps indented as high hurdles, but not at a significant level (χ^2 NS). *Stretching* was targeted 21.4% but was more often confused with its paired-alternative, *Weight-Lifting* (46.07%). Thus, it seems that participants were able to understand that the subject was performing an high demanding anaerobic task.

Logical Task was targeted 24.72% and was often confused with *shangai* (22.47%) and *drawing* (24.47%), again both low-activation activities and with comparable levels of mental concentration.

Resting was targeted 19.10% and was often confused with *Sleeping* (30.34%, $p<0.001$), which was its paired-alternative, and *Reading* (25.84%, $p<0.001$). They are both low-activation activities, although reading involve much more mental concentration

Shangai was targeted 5.62% and was one of the less identified; it was confused mostly with *sleeping* (38.20%, $p<0.001$) but also all labels were chosen, at least once.

Obstacle Course was targeted 2.25% and was the less recognized: it was highly confused both with low physical demanding activities, such both as *Sleeping* (12.36%) and high demanding ones, as *Stretching* (14.61%) and *Weight-Lifting* activities (19.10%). It is possible that the label was confused with high hurdles performance.



Graph.1 – Confusion Matrix – Activities C1

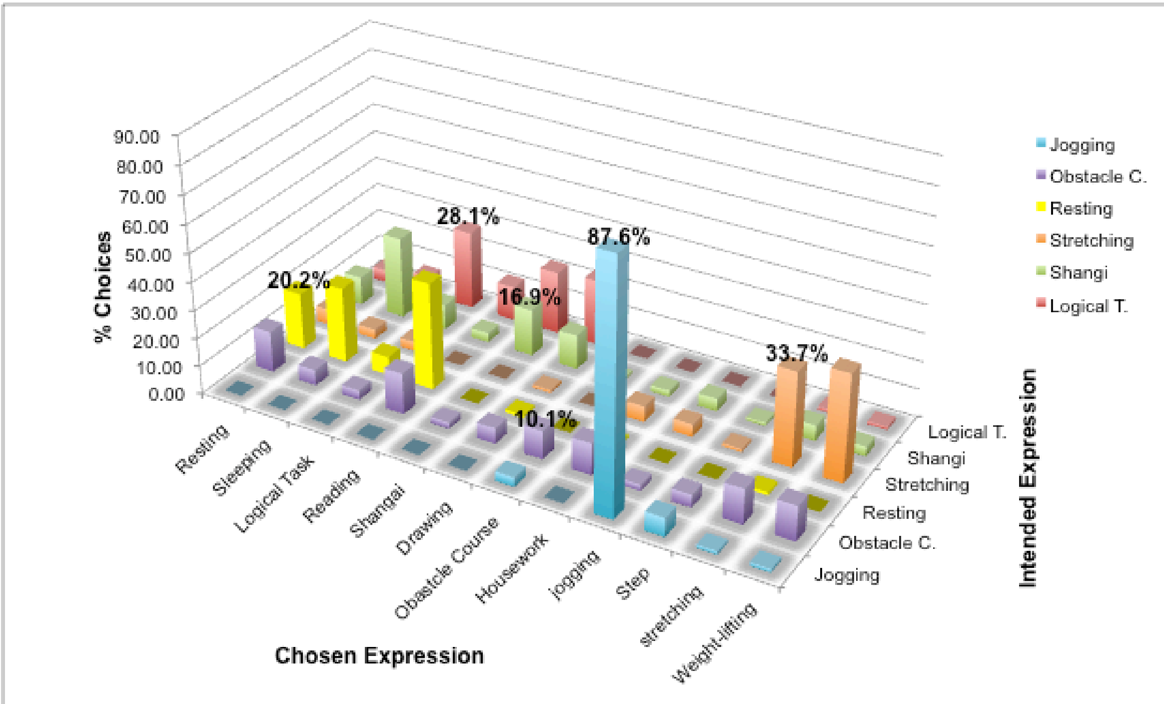
Condition 2 - Imitation

Tab.10 shows % of Identification Accuracy calculated on raw hit rates for Activities in C2.

%	Resting	Sleeping	Logical Task	Reading	Shangai	Drawing
Resting	***20.22***	26.97	6.74	38.20	0.00	1.12
Logical Task	4.49	6.74	***28.09***	12.36	22.47	23.60
Shangai	10.11	29.21	8.99	3.37	***16.85***	12.36
Obstacle	14.61	5.62	3.37	14.61	2.25	5.62
Jogging	0.00	0.00	0.00	0.00	0.00	0.00
Stretching	5.62	3.37	3.37	0.00	0.00	1.12

%	Obstacle	Housework	Jogging	Step	Stretching	Weight-Lifting
Resting	0.00	1.12	0.00	0.00	1.12	0.00
Logical Task	0.00	0.00	0.00	0.00	1.12	1.12
Shangai	1.12	2.25	4.49	1.12	5.62	3.37
Obstacle	***10.11***	11.24	2.25	4.49	12.36	12.36
Jogging	3.37	0.00	***87.64***	6.74	1.12	1.12
Stretching	0.00	5.62	4.49	1.12	***33.71***	38.20

Tab. 10 - % Identification Accuracy for Activities in C2 - Imitation



Graph.2- Confusion Matrix - Activities C2

All identification percentage increased, and generally less confusion was made with other labels. Participants were generally able to identify activities with a mean accuracy of 32.77% (SD 28.14%), which remains, anyway, quite low. Excluding the most recognized (again, *Jogging*), mean identification accuracy falls to 21.80% (SD 9.29%).

High activation activities were again the easiest recognized: *Jogging* was identified 87.6% and sometimes confused with its paired-alternative, *step* (6.74%, NS). *Stretching* was targeted 33.7% and was again confused at most with its paired-alternative, *Weight-Lifting* (38.20%).

Logical Task was targeted 28.1% and was mainly confused with *Shangai* (22.47%) and *Drawing* (23.6%), again both low-activation activities and with comparable levels of mental concentration. *Resting* was targeted 20.2% and, compared to Condition 1, it was less confused with *Sleeping* (26.97%), which was its paired-alternative, but more with *Reading* (38.20%). They are both low-activation activities, although reading involve much more mental concentration.

Shangai was targeted 16.85% and still mainly confused with *Sleeping* (29.21%). *Obstacle Course* identification dramatically increased compared to Condition 1 (10.1%), although confused at least once with all other labels. It was again often confused with both low physical demanding activities, as *Resting* and *Reading* (14.62%), and high demanding ones, like *Stretching* or *Weight-Lifting* (13.36%).

3.4.3.3. Reported level of Mental Concentration and Physical Effort

To investigate whether participants have been able to identify the degree of *mental concentration* and *physical effort* the subjects they listened experienced, mean and standard deviation of the score assigned to the related 7 points-Likert scales included in the *Activity Sheet* were calculated.

Mental Concentration

Tab. 11 shows descriptive statistics of assigned level of mental concentration in C1 nd C2. A Repeated Measure ANOVA was conducted with *Activity* (Resting, Mental Task, Shangai, Obstacle Course, Jogging, Stretching) as within-subject variable, *Condition* (C1, C2) as between variable and the mental concentration scores assigned by each judge as dependent variable.

	COND 1		COND 2		TOTAL	
	Mean	St.Dev.	Mean	St.dev	Mean	St.dev
Shangai	2.93	1.76	3.57	1.95	**3.25**	**1.88**
Resting	3.07	1.76	3.43	2.03	**3.25**	**1.91**
Jogging	3.29	1.57	3.13	1.59	**3.21**	**1.57**
Stretching	3.43	1.61	3.38	1.62	**3.40**	**1.61**
Obstacle	3.55	1.58	3.44	1.54	**3.49**	**1.56**
Mental Task	4.58	1.76	4.91	1.63	**4.75**	**1.71**

Tab. 11 - Level of Mental Concentration assigned in C1 and C2

The main factor *Activity* emerged as significant ($F(5,880)=25.122$, $p<0.001$). In particular *Mental Task* was considered as the most demanding activity. Contrast Analysis pointed out this activity as significantly different from all others, which on the contrary don't differ one from another. No significant differences emerged between the two Conditions.

Physical Effort

Tab. 12 shows descriptive statistics of assigned level of physical effort in C1 and C2. A Repeated Measure ANOVA was carried out with *Activity* (Resting, Mental Task, Shangai, Obstacle Course, Jogging, Stretching) as within-subject variable, *Condition* (C1, C2) as between variable and the physical effort scores assigned by each judge as dependent variable.

	COND 1		COND 2		TOTAL	
	Mean	St.Dev.	Mean	St.dev	Mean	St.dev
Resting	1.52	1.15	1.35	0.77	**1.44**	**0.98**
Mental Task	2.06	1.08	2.03	1.19	**2.05**	**1.13**
Shangai	2.65	1.79	2.36	1.75	**2.51**	**1.77**
Obstacle	3.58	1.95	3.33	1.83	**3.45**	**1.89**
Stretching	5.05	1.79	5.07	1.69	**5.06**	**1.74**
Jogging	6.18	1.03	6.26	1.08	**6.22**	**1.05**

Tab. 12 - Level of Physical Effort assigned in C1 and C2

The main factor *Activity* emerged as significant ($F(5,880)=310.465$, $p<0.001$). Contrast highlighted significant difference between all activities. In particular *Jogging* was labelled as the most demanding activity, and *Resting* the least. No significant differences emerged between the two Conditions.

Finally, we tested whether high physical demanding activities were more identifiable compared to low ones. First, we split the activities into three groups considering their degree of physical effort: 1. Low physical effort (Resting and Mental Task); 2. Medium-low physical effort (Shangai and Obstacle Course); 3. High physical effort (Jogging and Stretching).

Effort level	Grouped Activities	N	Mean	St.dev.
1	Resting / Mental	356	0.31	0.61
2	Shangai / Ostacoli	356	0.12	0.42
3	Corsa / Stretching	356	0.79	0.77
Total		**1068**	**0.41**	**0.67**

Tab. 13 - Level of Physical Effort to Low, Medium-Low and High Effort Activities

A One-way ANOVA was carried out to compare the three groups and the test underlined significant differences between them ($F(2,1065)=109.941$, $p<0.001$). Tukey's post hoc tests highlighted significant differences between all levels; in particular, high physical effort activities were actually rated as more demanding compared to all others while the other two levels tend to be confused, being low effort's activities rated as more demanding than medium ones

3.4.4 Emotional Decoding

3.4.4.1 Unbiased Hit Rate Score

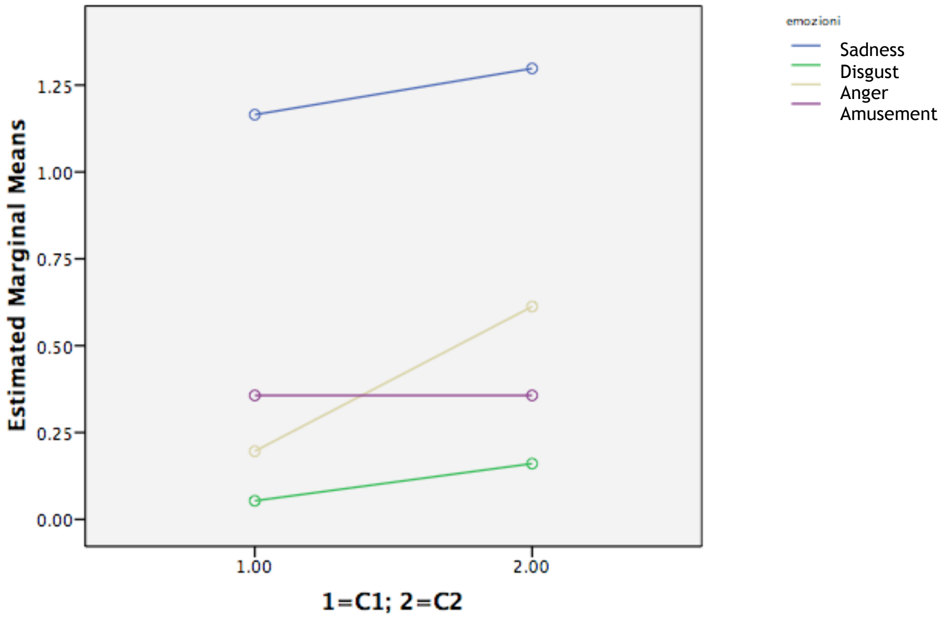
As done for the activities analysis, to correct the response bias that affect raw identification first rates unbiased hit rates were calculated in order to compare the degree of identification accuracy of the various emotions-breathing tracks within each condition. Tab.14 show Mean and Standard deviation for each Emotion, in the two different conditions.

	N	COND 1		COND 2		TOTALE	
		Mean	St.Dev	Mean	St.dev	Mean	St.dev
Sadness	88	1.16	0.60	1.30	0.48	**1.23**	**0.54**
Amusement	88	0.36	0.66	0.36	0.66	**0.36**	**0.66**
Anger	88	0.20	0.52	0.61	0.77	**0.40**	**0.69**
Disgust	88	0.05	0.29	0.16	0.48	**0.11**	**0.40**

Tab. 14 - Descriptive Statistics of Emotions Hu rates

To compare recognition between conditions, first a Repeated Measure ANOVA was carried out with *Emotion* (Sadness, Amusement, Anger, Disgust) as within-subject variable, *Condition* (C1, C2) as between variable and the *Unbiased Hit Rate Score* per judge as dependent variable. Both main effects of *Emotion* ($F(3,522) = 137.833$, $p<.001$) and *Condition* ($F(1,174) = 11.772$, $p=.001$) emerged as significant (Contrasts are shown in Tab.15). Thus, Imitation significantly improves the ability to correctly identify different emotional feelings. The interaction Emotion*Conditions came out as significant too ($F(3,522)=4.558$, $p<.01$). As show in Graph.3, this is due to the static trend of *Amusement*, whose identification rate didn't increase across conditions, while the other emotions did.

Graph.3 - Interaction Emotions*Condition



F	*Contrast*
Emotion: F(3,522) = 137.833, p<0.001 Condition: F(1,174) = 11.772, p=0.001 Emotions * Condition: F(3,522) =4.558, p<0.01	$\overline{S}$ $\overline{Am\ An}$ $\overline{D}$

Tab. 15 - ANOVA on Emotions Hu rates

A post-hoc comparison shows that *Anger* identification accuracy significantly increased (F=17.747, p<0.001) while *Disgust* didn't reach significance.

3.4.4.2 Confusion Matrixes on Raw Hit Rates

Two separate *Confusion Matrix* of participants' responses to emotion-tracks were built, one for each condition. Since the Geneva Emotion Wheel provided 20 different choices, to make the graphs easier to read, the emotions families that were never chosen were not reported. That is, *Pride*, *Elation*, *Love*, *Pity / Compassion* and *Envy / Jealousy* in the first condition; *Pride, Love, Wonderment /Awe*, *Envy / Jealousy* and *Contempt / Scorn* in the second. Tab. 16 shows % of Identification Accuracy calculated on raw hit rates for Emotions in C1.

<u>*Condition 1 - Listening*</u>

	Involv/ Inter.	*Amus/ Laugth*	*Pride*	*Elation*	*Happin/ Joy*	*Enjoy/ Pleasure*	*Tender.*	*Love*	*Wonder /Awe*
Sadness	1.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Disgust	4.55	0.00	0.00	0.00	1.14	4.55	0.00	0.00	1.14
Anger	4.55	0.00	0.00	0.00	0.00	1.14	0.00	0.00	0.00
Amusement	5.68	***21.59***	0.00	0.00	5.68	2.27	1.14	0.00	0.00

	Disburd /Relief	*Astonis/ Surprise*	*Conster nation*	*Longin/ Nostal.*	*Pity/Co mpass.*	*Sad/ Despair*	*Worry/ Fear*	*Embar/ Shame*	*Guilt/ Remors*
Sadness	0.00	0.00	0.00	1.14	0.00	***90.91***	2.27	0.00	1.14
Disgust	6.82	1.14	2.27	1.14	0.00	1.14	13.64	3.41	0.00
Anger	5.68	0.00	3.41	1.14	0.00	2.27	29.55	1.14	4.55
Amusement	1.14	0.00	1.14	1.14	0.00	22.73	7.95	1.14	4.55

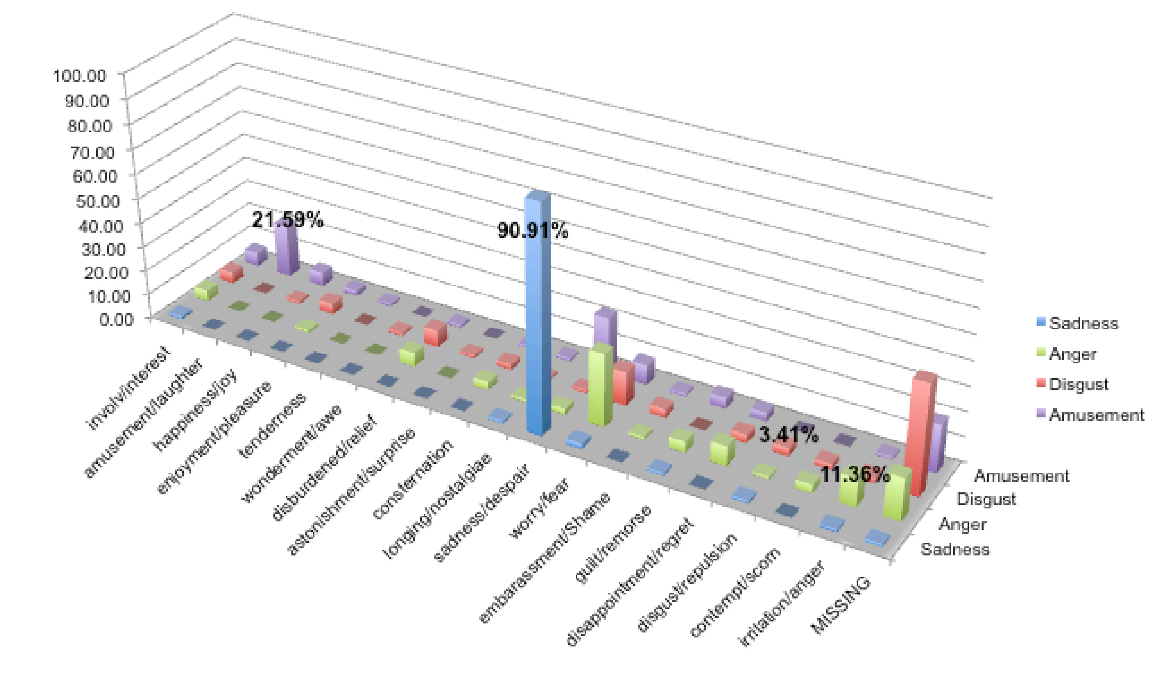
	Disap/ Regret	*Envy/Je alousy*	*Disgust/ Repul*	*Cont/ Scorn*	*Irrit/ Anger*	*MISSING*
Sadness	0.00	0.00	1.14	0.00	1.14	1.14
Disgust	3.41	0.00	***3.41***	2.27	2.27	44.32
Anger	7.95	0.00	1.14	3.41	***11.36***	17.05
Amusement	3.41	0.00	0.00	0.00	1.14	19.32

Tab.16 - % Identification Accuracy for Emotions in C1 - Listening

As for the *Activity* analysis, percentage of identification was generally low: 31.82% (SD 40.09%). Excluding *Sadness*, that was the most recognized, mean identification accuracy falls to 12.12%. (SD 9.11%).

*Sadness***,** which was clearly characterized by sobbing inspirations, has a mean identification rate of 90.9%. *Amusement* reaches 21.6% and, interestingly, it was frequently confused with its opposite, *Sadness* (22.7%). Often, participants were not able to choose any of the provided labels (missing: 19.3%). *Anger* was targeted 11.36% but was much more often confused with *Worry Fear* (29.6%), which is characterized by the opposite coping dimension. A high number of participants (17.1%) was not able to make any choice.

Disgust (targeted 3.4%) was the least identified: it was significantly confused with *Worry Fear* (13.6%), which is characterized by the same negative valence, but more often participants were not able to choose any label (missing: 44.3%).



Graph.4 – Confusion Matrix – Emotions C1

Condition 2 – Imitation

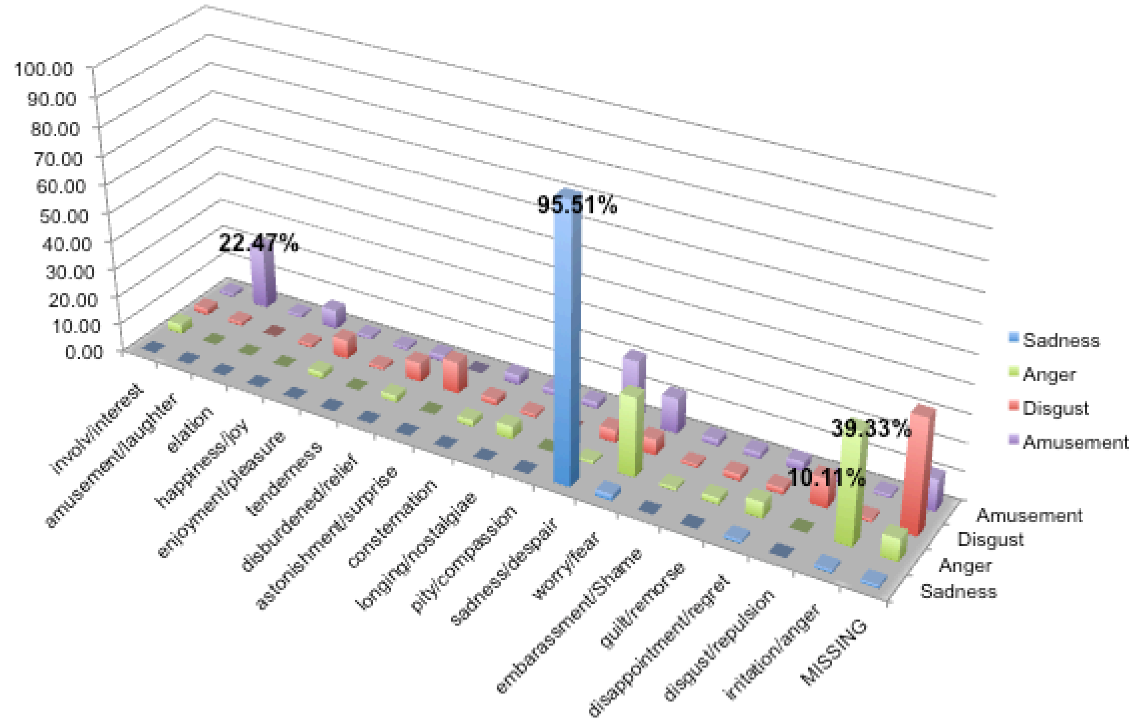
Tab.17 shows % of Identification Accuracy calculated on raw hit rates for Emotions in C2.

	Involv/ Inter.	Amus/ Laugth	Pride	Elation	Happin/ Joy	Enjoy/ Pleasure	Tender.	Love	Wonder/ Awe
Sadness	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Disgust	2.25	1.12	0.00	0.00	1.12	6.74	1.12	0.00	0.00
Anger	3.37	0.00	0.00	0.00	0.00	2.25	0.00	0.00	0.00
Amusement	1.12	***22.47***	0.00	1.12	6.74	1.12	1.12	0.00	0.00

	Disburd/ Relief	Astonis/ Surprise	Constern ation	Longin/ Nostal.	Pity/ Comp.	Sad./ Despair	Worry/ Fear	Embar/ Shame	Guilt/ Remorse
Sadness	0.00	0.00	0.00	0.00	0.00	***95.51***	2.25	0.00	0.00
Disgust	6.74	11.24	2.25	1.12	0.00	4.49	5.62	1.12	2.25
Anger	2.25	0.00	2.25	4.49	0.00	1.12	28.09	1.12	2.25
Amusement	2.25	0.00	3.37	2.25	2.25	21.35	12.36	2.25	2.25

	Disap/ Regret	Envy/Je alousy	Disgust/ Repul	Cont/ Scorn	Irrit/ Anger	MISS
Sadness	1.12	0.00	0.00	0.00	1.12	1.12
Disgust	2.25	0.00	***10.11***	0.00	1.12	40.45
Anger	5.62	0.00	0.00	0.00	***39.33***	7.87
Amusement	3.37	0.00	1.12	0.00	1.12	11.24

Tab. 17 - % Identification Accuracy for Emotions in C2 - Imitation



Graph.5 – Confusion Matrix – Emotions C2

All identification rates increased: participants were generally able to identify emotions from breath sounds with a mean accuracy of 41.9% (SD 37.72). Excluding *Sadness*, which was again the most identified, percentage falls to 23.97% (SD 14.67%).

Sadness was identified with a percentage of 95.5%. *Amusement*, targeted 22.5%, is characterized by a lower increment. It was again confused with *Sadness Desperation* (21.4%) and with *Worry Fear* (12.36%), while missing responses reached 11.24%. *Anger* identification dramatically increased (39.3%): missing responses decreased (7.9%) but it was still confused with *Worry Fear* (28.1%). *Disgust* increased too (10.11%) and was more often confused with *Surprise* (11.2%) that was actually one of the emotions experienced during the phone call from which it was extracted. Anyway, a great % of participants wasn't still able to make any choice (40.4%).

3.4.4.3 Participants' Emotional Experience

We finally explored participants' emotional experience in both conditions, investigating both the *complexity* of their reported feeling (*how many* emotions did they choose) and their *intensity* (how much intense did they rate them). Mean and standard deviation of the number of chosen emotions and assigned intensity (from 1 to 5) on the *Geneva Emotion Wheel* were calculated, separately for each condition

Complexity of Emotional Experience

Tab.18 shows Means and Standard Deviation of number of emotions reported for each emotion in both conditions. A Repeated Measure ANOVA was carried out with *Emotion* (Sadness, Amusement, Anger, Disgust) as within-subject variable, *Condition* (C1, C2) as between variable and number of emotions per judge as dependent variable.

	COND	N	Mean	St.Dev
Sadness	1	88	1.25	.887
	2	88	1.14	.776
	Total	176	1.19	.833
Disgust	1	88	.59	.825
	2	88	.45	.693
	Total	176	.52	.763
Anger	1	88	.68	.824
	2	88	.80	.664
	Total	176	.74	.748
Amusement	1	88	.77	.840
	2	88	.72	.660
	Total	176	.74	.754

Tab.18 - Descriptive Statistics of Number of Emotions reported for each emotion

Only main factor *Emotion* come out as significant ($F(3,522)=29.596$, $p<0.001$; Contrast: S An-Am D). Sadness aroused the more complex emotional experience compared to all other emotions, Anger and Amusement didn't differ significantly between them, and Disgust the least.

Intensity of Emotional Experience

Tab.18 shows Means and Standard Deviation of intensity of emotions reported for each emotion in both conditions. A Repeated Measure ANOVA was carried out with *Emotion* (Sadness, Amusement, Anger, Disgust) as within-subject variable, *Condition* (C1, C2) as between variable and intensity of emotions per judge as dependent variable.

Again, only main factor *Emotion* come out as significant ($F(3,522)=35.489$, $p<0.001$; Contrast: S An-Am D). Sadness aroused the more intense emotional experience compared to all other emotions, Anger and Amusement didn't differ significantly between them, and Disgust the softest.

	COND	N	Mean	St. Dev
Sadness	1	88	2.59	1.602
	2	88	2.67	1.617
	Total	176	2.63	1.605
Disgust	1	88	1.11	1.601
	2	88	1.02	1.576
	Total	176	1.07	1.584
Anger	1	88	1.38	1.642
	2	88	1.82	1.558
	Total	176	1.60	1.611
Amusement	1	88	1.51	1.612
	2	88	1.82	1.699
	Total	176	1.66	1.658

Tab.19 – Descriptive Statistics of Intensity of Emotions reported for each emotion

3.5 Discussion

This study provided evidences that it is possible to infer information about a person's *identity*, *emotional state* and *activity* listening to the sound of his/her breathing and that identification accuracy improves when *mimicking* it. Anyway, global percentages of *activity* and *emotions identification* are quite low. These results suggest that breathing sounds convey generally *poor* cues about a person's emotional state/activity. It is likely that participants were not used to rely on this kind of expressive signal, and this explanation would be consist with the *difficulty* assessments in the *Task Rating Form* results. However, we cannot exclude that, having collected breathing samples in ecological conditions, we relied on stimuli with ambiguous expressive features. Employment of ecological stimuli has the advantage of using breathing sounds that are not artificially reproduced, being instead collected in natural settings; anyway, it has the disadvantage of preventing any rigorous control and standardization of some important variables such as the *context* where each breathing track was produced and, as far as emotional tracks are concerned, the actual intensity of subject's feelings. This experimental choice could have lead to the generation of unclear stimuli that could have influenced the identification accuracy.

As expected, participants were able to extrapolate some cues about the degree of *physical activation* and *mental concentration* of subject's performed activity; in particular high physical demanding activities were better identified compared to low demanding ones, having a more evident influence on breathing sounds features. Moreover, as far as emotional tracks are concerned, breathing sounds also convey cues about *valence* and *arousal* of different emotional conditions. Finally, participants to the listening-condition were significantly less accurate in recognition tasks than participants to the imitation-condition both as activity and emotional stimuli are concerned.

These results are in line with the hypothesis that that imitation of postures, vocal and facial expression and, as far as this study is regarded, also breathing pattern, could trigger similar experiences of those felt by the mimicked person (Lipps, 1907; Hess et al, 1992; Hatfield et al, 1992). Being respiration strictly related to body-mind experience it's likely that breathing manipulation would induce physiological states similar to those of the mimicked activity/emotion inducing *closer identification*. This results are also consistent with the previous work of Philippot et al (2002) that provided some evidences about the possibility to induce specific emotional feeling by reproducing specific breathing pattern, related to distinct basic emotions. Another hypothesis is that the mimicry-conditions arouse *deeper concentration* on the stimuli, in order to reproduce them at best. As a consequence, identification accuracy increased.

These results are discussed more in detail in the following paragraph.

3.5.1. Task Evaluation Form

Analysis of the answers to the *Task Ratings Form* allowed verifying the reliability of the experimental procedure. The task was rated as just slightly *annoying* (M=2.54/7) and *mechanical* (M=2.70/7), while in reaches higher rates of *involvement* (M=3.66/7) and, in particular, *difficulty* (M=4.33/7). It is not surprising that difficulty reaches quite high ratings, being the task highly unusual to the participants to the study. Anyway, ratings don't reaches too high points, thus these results lead us to confirm the adequacy of the experimental procedure.

The imitation task was perceived as significantly *easier* compared to the listening one but also more *annoying*. Discomfort could be related to the request to adopt a way of breathing that wasn't natural to the mimickers, while reported ease is more surprising, also considering that there both conditions were rated as equally *useful* in improving identification. Probably the imitation task was experienced as more *involving* and gave a more *sense of control* compared to passive listening.

The second experimental group also believe that imitating didn't help them to experience *physical feelings* similar to those of the subjects (M=2.69/7). However, their actual performance was significantly better than that of the first experimental group. Considering that the task was not considered as excessively mechanic, it is possible that participants were too concentrated on both listening to the track and repeating breathing pattern as close as possible to be also aware of their physiological changes. Otherwise, it is possible that 20 sec imitation period assigned for each mimicking task was a too short period to induce perceptible physiological activation. Further studies could consider repeating the study with a smaller sample taking into account also physiological measures, to control the actual autonomic activation of participants.

As the first experimental group is concerned, 76.74% of participants affirmed to have found sometimes themselves imitating the breath patterns they were listening to. This is in line with the previously discussed evidences about unconscious mimicry, that is the unintentional tendency to imitate some behaviours of another person. Moreover, it suggests that *mimicking* was considered also by this group as a useful mean to understand what the breather was feeling and performing compared to pure listening. Considering the significant difference between the two groups, it is possible that participants to this condition didn't mimic with the same frequency or with the same carefulness. It was not possible to ask at the end of each task whether they mimicked or not, since this would have suggest them a strategy for the following tracks. Anyway, future research should consider a way to control how much un-required imitation occurred.

3.5.2. Imitation vs Listening

This study confirmed the hypothesis that mimicking breathing could facilitate identification accuracy of emotional experiences compared to pure listening. Mimicry significantly improves the ability to correctly identify both activities and emotions.

As far as *Activities* are concerned, apart from Mental Task and Resting, in all other tracks identification accuracy significantly increased. Besides, mimicry didn't increase significantly the ability to identify the degree of mental concentration and physical effort. It is likely that these general dimensions are easier to identify though acoustic cues, while identification of the specific activity requires an additional effort.

Regarding Emotions, all identification rates increased apart from *Amusement*, reached significance for *Anger*.

Stel et al. (2005) have shown that mimicry enforces *perspective taking*, facilitating empathy; besides in some counselling and therapeutic context (client-centred therapy, NLP and humanistic music-therapy) matching the rate and quality of the client *breathing* is said to strengthen emotional attunement (Bandler et Grinder, 1975; Sutton, 2002; Scardovelli, 1999; Sigel, 1984, 1986). Respiration (Beck & Scott, 1988; Boiten et al, 1994; Bloch et al, 1991; Philippot et al, 2002) has been already proven to affect mood and the amount of variance accounted for by breathing emotional induction pattern was estimated about 40% (Philippot et al, 2022), highly greater than the 13% accounted for by facial feedback (Matsumoto, 1987). Thus, breathing manipulation is likely to evoke emotional feelings similar to those mimicked, as suggested by the previous study of Philippot et al. (2002). As hypothesized by the The *Vascular Theory of Emotional Efference* (Zajonc, 1985; Zajonc et McIntosch, 1992; McIntosch, et al, 1991; McIntosch, et al, 1997) it is likely that breathing patterns not only influence autonomic nervous activity but also, altering the volume of air inhaled through the nose, influence brain temperature and by return affective state.

3.5.3 Gender Identification

Breathing seems to provide quite reliable cues about the gender of the breathers: it was correctly identified in 7 conditions over 10. Anyway, considering that the “male” response significantly prevailed compared, being the experimental tracks balanced it is likely that participant, when uncertain, tended to overestimate this choice. Further investigation should be carried on to confirm this result. Absence of differences between the two conditions suggests that gender recognition relies on acoustic features, and it is not improved by imitation.

3.5.4 Activity Decoding

Percentage of identification was generally low (C1=24.53%; C2=32.77%). Hu rates analysis underlined significant differences between activities identification independently from experimental conditions, and pointed out jogging and stretching as the most identified labels. It is possible that these tracks were most identified because they represented the most audible breathing stimuli also in everyday-life: it quite common to hear the sound of our breathing when we are doing jogging or stretching and, what’s more, we are often told how to breathe in order to better perform such activities. So, these could be the most familiar stimuli to the audience. They also represent more common situation compared to Obstacle Course and Shangai, that were the less identified. Obstacle Course, in particular, seems to have been confused sometimes with high hurdles performance thus also the chosen label could have been confusing. Resting is characterized by the slowest breathing rhythm and by softer sounds compared to other conditions; thus, it could be easily related to poor arousing situations. Finally, Mental Task could have been less identified than high demanding activities since it quite unlikely that we control our breath during mental performance, compared to physical ones; we are more focused on the task than on our way of breathing and it's uncommon to receive instruction on "how to breathe" to improve mental performance. This breathing pattern was characterized by slow, soft breaths and by a long apnoea at the beginning of the track; intense mental concentration may actually cause breath-holding or shallow breathing. This particular feature could have facilitated the identification of this track.

Confusion analysis shown that often the target activity was confused with its paired alternative, that were characterized by comparable levels of mental concentration and physical effort, suggesting that breathing sounds could provide higher and more reliable information about such dimensions. Analysis confirmed the ability to discern between activity requiring different degree of physical effort and mental concentration. Anyway, physical effort seems to be more easily recognized than mental effort. In fact, while *Mental Task* was actually identified as most mentally demanding, the others didn't significantly differ one from the other. Besides, physical effort seems to be more discriminative: participants were able to correctly range the experimental stimuli from the less demanding (Resting) to the most (Jogging/Stretching). In particular, activities requiring the highest physical effort were the easiest identified compared to low and intermediate ones. Moreover, it's interesting to notice that participants were able to discriminate between *aerobic* and *anaerobic* effort: jogging was mostly confused with step and stretching with weight lifting, but confusion didn't occur between those terms

3.5.5. Emotional Decoding

Percentage of identification was generally low (C1=31.82%; C2=41.9%). Results of Hu rates analysis indicate Sadness as the most identified emotion while Disgust the least. Sadness was actually characterized by sobbing inspirations, thus it could be easily brought back to the related emotion. This could justify the significant ease of participants in identifying this emotion compared to the others. Actually, sobs are an extreme respiratory reaction: Philippot et al (2002) already criticized Boiten choice (1998) to use as experimental stimuli overt laughter and cry since, although being emotional expressive components of respectively joy and sadness, they do not necessarily affect breathing patterns associated with these emotions. We included such stimuli since 1. we could be certain that the person recorded under previous ecological conditions was actually feeling that emotion; 2. Considering the little previous literature on the topic, we preferred to test first more marked emotional expression to see whether they could convey reliable information about the subject's feelings.

Also the *Amusement* stimulus was characterized by hold, soft laughter, but not in such a manifest expression. Thus, it was actually more identified than *Anger* and *Disgust*. Interestingly, it was frequently confused with its opposite, *Sadness*, in both conditions. It's likely that the subtle tremors in breathing sounds have been interpreted as sighs and sobs and not as laughter. In the imitation condition, Amusement was sometimes confused also with *Worry Fear*, probably again in reason of those tremors, that characterize also high tension in worrying situations.

Anger was more often targeted with *Worry Fear* than with the right label. The breathing pattern was characterized by the longest cycle duration and Expiratory time and by quite long expiratory pauses too. What was highly characteristic of such breathing pattern was the high intensity of expiration and their "dark" timbre, almost sonorous. Such timbre derived from little tension at the laryngeal level and a raised attack level of the sound, partially involving the arytenoids. *Anger* identification significantly increased in the mimicry-condition, and it's likely that imitation involve such distinctive proprioceptive feedbacks that enable to better identify the target emotion.

Disgust was the least identified and, although its identification rate increases in the imitation conditions, change was not significant. It was again significantly confused with *Worry Fear* in the first condition, while it was more often confused with *Surprise* in the second one. *Disgust* extract was characterized by quite long cycle duration, by the longest inspiratory time and by the shortest post inspiratory pauses time. Moreover, a sudden, loud inspiration occurred around sec. 8 and was followed by a loud, long expiration interrupted by 1 breath-holding. A timbre similar to that described for anger expiration characterized the onset of two expirations after this sudden event. From that moment on, intensity of breath sounds increase. This rapid and unexpected inspiration could be interpreted as a sudden fright or, more properly, as a reaction to a surprising event, that actually occurred during the pre-recorded phone calls. Thus, participants to the mimicry condition, are likely to have better distinguished between this two pattern. Worry Fear would have probably required not only louder sounds but also an increasing respiratory rate that didn't characterized this track.

Compared to the *activity decoding task*, global amount of missing responses was much higher. This could depend on the fact that number of given choices was much higher and generate greater confusion or, besides, that these pattern were actually harder to decode. Anyway, global identification rate is higher for these stimuli compared to the activities.

Confusion analyses suggest that breathing sounds are not always reliable cues to identify *valence* of the emotional experience, since *Amusement* was often confused with Fear and Sadness. Anyway it's not possible to draw reliable conclusions about such aspects, relying on jut one positive emotion compared to three negative ones.

3.5.6. Participants' Emotional Experience

Sadness aroused the more *complex* and *intense* emotional experience compared to all other emotions. Anger and Amusement didn't differ significantly, and *Disgust* evoked the *softest* and less *composite* one. Since intensity and complexity seems to mirror degree of identification rate, is possible that the more participants were able to understand the emotional stimulus, the more they are able to define their emotional reaction. This is in line with the *appraisal theory* of emotions. According to this perspective, the elicitation and differentiation of emotions are based on a process of appraisal of the situations that affect an individual's needs and goals (Arnold, 1960; Lazarus, 1991; Scherer, 1984). In this view emotions may be differentiated on the basis of continuous appraisal dimensions or criteria (and their patterns), according to which individuals evaluate situations and events: novelty, pleasantness, arousal and coping. The component-process model describes emotion as «the dynamic and constantly changing affective tuning of organisms as based on the continuous evaluative monitoring of their social and physical environment» (Scherer, 2005). Variations in any of the appraisal dimensions entail a shift in the emotion experienced by the individual.

3.5.7. Limitations and further Investigation

A first remark should be done about our set of *experimental stimuli*. As said before, employment of ecological stimuli has the disadvantage of making difficult to control and standardize important variables such as the *context* where each breathing track was produced or the intensity of subject's emotional experience. This experimental choice could have lead to the generation of ambiguous stimuli that could have influenced the identification accuracy.

What's more, it is not possible to make any generalization about the acoustic features of breathing pattern related to a specific activity/emotion. To make a reliable and well-founded description of each distinct acoustic profile, a wider sample of breathing patterns should be collected for each performance/emotional condition. The realization of a pilot study aimed to collect a broader sample *of ecological data* to carry on a preliminary validation of the stimuli was anyway excessively complex, expensive and sometimes also ethically questionable (for example the production of emotional events aimed to induce strong negative emotions).

Besides, for experimental reasons it wasn't possible to record participants' imitation tasks; this prevent testing whether mimicking quality was related to higher identification accuracy or not. To do a higher number of audio interfaces, microphones and recording software would have been necessary; moreover, recording synchronization problem should have solved, since different persons could have needed different listening and imitation times. Thus, to answer such requirements, a significant reduction of the sample would have been necessary, reducing in return sample dimension and variability of the data. This remains anyway an important point to be deal with.

Finally, as suggested before, correlation of such data with physiological measurements could provide higher control on the actual autonomic activation of participants.

4

4.1 Introduction

Study 2 has shown that breathing sounds can assume a communicative function conveying reliable cues about gender, performed activity and felt emotions of a breather; moreover, it provide evidences that mimicking breathing improve identification accuracy of such features. However percentages of identification were quite low, probably due to the employment of unrefined ecological stimuli that generated ambiguity. Moreover, it prevents any reliable description of distinct acoustic patterns related to specific emotions, since a wider sample of breathing patterns would have been required. Finally, the decoding task performed in that experiment didn't involve the presence of another actual person breathing, as it occurred in everyday interactions.

In this third study we intend first to deepen the investigation of the "emotional features" of breathing sounds, exploring whether distinctive breathing patterns related to 6 different emotions could be reliably defined. Moreover, we inted to go beyond mere imitation task to see if participants co-presence, giving the opportunity to reciprocally attune, will promote emotional responding.

Compared to imitation, *attunement* (Stern, 1985; Murray et Trevarthen, 1985; Ciceri et Biassoni, 2006) is a more subtle and complex process. As discussed in the Introduction to this dissertation (see par.1 and par. 1.7), attunement is generally conceived as the ability to tune in with another person. Kossak (2009) defined it a strongly embodied experience, since it involves psychological, emotional and somatic dimensions and Erskine (1998) defined it as "a kinestetic and emotional sensing of others, knowing their rhythms, affect and experience by metaphorically being in their skin". Thus, this process is really composite and its boundaries difficult to tie. Generally, a conceptual distinction could be drawn between *emotional* and *communicative* attunement. The former deals with the ability to "sense" and "attune to" each other's feelings, and is conceived as a precursor of empathy; the latter concerns management and mutual accomodation of communicative behaviours (Cappella, 1994; Giles et al, 1991; Ciceri et Biassoni, 2006). Both are strictly inter-related in any kind of interaction: participants have to continuously share their reciprocal intentions and emotional state through a broad set of communicative signals to finely manage consecutive adaptations in time (Cappella, 1997).

Ciceri and Biassoni (2006) outlined three major conceptions of attunement: 1) *intentional attunement* (Gallese, 2003, 2005) that includes the awareness of other's agentivity, the understanding of others' intentions, imitation and empathy; 2) attunement as *reciprocal accommodation* during action planning and realization, managing one's behaviour in relation to the other's in an uninterrupted management of co-presence (Giles, Shepard et al. 2001); 3) *behavioural attunement* is a set of interpersonal behavioural aimed at the achievement of a joined intention through which the speakers arrange, maintain and coordinate their communicative interaction. This last perspective includes a qualitative dimension, called "mutual tuning in" and a temporal one, synchronization. The former refers to the tendency to reciprocally shift and modulate some behaviour features (like frequency and intensity) in a convergent or divergent direction to signal the need to change or maintain the communicative behaviour. The latter concerns the strategic use of the chronological dimension during the interactive flow (Siegman, A. W., Feldstein, S., 1979; Ciceri, 2004).

Particular attention has been brought to this second dimension (Schuts, 1971; Zerubavel, 1981, 1982; Goffman, 1967), arguing that it could be more relevant compared to the other. For example, mutual tuning in could not be independent from strategic timing ability, since it requires understanding and planning *when* to make a *change* of state and how long remaining there before shifting. In this sense, the management of the chronological dimension during the interactive flow undertake a crucial semantic function (Ciceri, Biassoni, 2006). Moreover, infants shows an incredible ability to follow and participate to the interactive rhythms of early communicative exchanges and such rhythm seems to change as a function of the degree of involvement and emotional arousal of the communicative partners (Beebe, 1982; Stern, 2004).

Stern conceives attunement as the most important way of sharing subjective experiences between mother and infant and the primary medium of communication. Carrying on observational studies on babies engaged in free-play sessions with their mothers, he suggested three principal dimensions below such process: *temporal organization* (beat, rhythm and duration matching), *intensity* (absolute level of energy, intensity contour) and *shape* of their behaviour (changes in shape quality or direction of the action). One his major findings was the intensity profile (intensity changes over time) was the most frequent dimension of matching (97% of overt attunement behaviours), followed by timing

(76%) and then by shape (37.9%) (Stern, 1985).

Also Scardovelli (1988, 1992) consider *temporal organization* (rhythm and duration), *energy* (intensity and movement) and *space* (height, intervals and timbre) as the principal dimensions of matching process in music-therapy sessions as well as in all kind of verbal and non-verbal communicative exchanges, and claim that time and energy are the most important ones. He argued that being deficient in matching of such aspects is more serious than pitch, overlapping in turn taking and level of complexity of the interaction. This is consistent with previous studies on early mother-infant interactions that underlined how timing irregularity and dynamic inconsistency in mother's responses to their babies lead gradually to lack of interest from the infants, decreasing of positive expressions (Beebe, 1982; Murray & Trevarthen, 1985) and increasing of distress demonstrations (Tronick & Weinberg, 1997; Papousek, 1997).

Finally, Malloch and Trevarthen (2008) recently argued that coordination and action sharing are based on an innate *Communicative Musicality* of interpersonal behaviour. Communicative Musicality consists of the elements Pulse, Quality and Narrative – features that are particularly important in the temporal arts (e.g. music and dance) and that allow arising of co-ordinated companionship. In all sorts of human communication, also the more refined and elaborated, they argued that it is possible to find dynamic sequences of rhythmic-musical patterns through which interlocutors signal their agentivity and their ability to coordinate with others. *Pulse* defines the regular sequence of behavioural events through time; *quality* refers to the modulation of the expressive profiles along time; finally, *narrative* concerns the combinations of such timing and quality patterns in narrative format that allow to share emotions, actions and intentions. Again, Pulse is considered the parameter that allows coordination of communicative behaviours, reciprocal predictability and strategic action management.

Synchronization seems to have a crucial part not only in allowing interpersonal communication but in enhancing rapport, reciprocal liking, cooperation and prosocial behaviours (Bernieri, 1988; Miles et al, 2009; Wiltermuth & Heath, 2009). Engagement in highly synchronized actions increase emotional responding and altruistic behaviour to synchronous others compared to asynchronous ones (Valdesolo et al, in press); moreover, motor synchrony increases sense of interpersonal similarity (Valdesolo et al, 2010), joint identity and group affiliation without the need of positive emotions to be generated (Wiltermuth & Heath, 2009). Resuming, synchronized actions seem to serve two primary functions: increasing social cooperation (Haidt et al. 2008; McNeill, 1995; Wilson et al, 2008; Wiltermuth & Heath, 2009) and joint-action management (Valdesolo et al, 2010).

Physiological attunement and autonomic synchrony are founded on temporal features too, that is on bidirectional relation between *physiological and interaction rhythms,* as discussed in Par.1.7. Anyway, although some evidences suggest there's an association between communicative, emotional and physiological attunement, further investigation are needed.

Another focus of interest of this study is to collect a wider the sample of emotional acoustic patterns of breathing, compared to Study 2, in order to see whether specific features could be related to distinct emotions. In the research field of vocal communication of emotions, a widely accepted assumption is that emotional arousal induce a series of physiological changes that, in turn, will affect respiration, phonation and articulation producing emotion-specific patterns of acoustic parameter of vocal production (see (Scherer, 1986, 2009 for a detailed description). Since also respiration is affected, is possible that also breathing sounds show perceivable changes. To test whether different type of emotional breathing are actually characterized by a distinctive pattern of acoustic cues, the same experimental procedures used in the research of vocal communication of emotion could be used, that is *natural expression*, *induced* and *simulated* emotional expression (Scherer, 2003).

In the previous work, the acoustic tracks were recorded during naturally occurring emotional states in ecological phone calls. Anyway, these stimuli were collected from a small number of breathers, and it was not possible to determine the real the intensity of subject's emotional experience. In this study we used a blended methods that relies on an emotional induction procedure using narratives, followed by the request to portray the felt emotions. Text based stories have been proven to be among the most effective induction techniques (Westermann et al., 1996; Gerrards-Hesse et al., 1994). Moreover, simulated emotional expressions are much more intense and prototypical than induced and natural emotions and, although more stereotyped, if highly controlled they are generally considered a reliable investigation methods (Scherer, 2003).

In this study, two positive emotions (joy and tenderness) were considered beside four negative ones (sadness, anger, fear and disgust). Investigation of positive emotions is less common than negative ones. One reason is that they seem to evoke less specific action tendencies (Fredrickson & Levenson, 1998). Moreover, they are characterized by a relative lack of autonomic reactivity (Levenson, et al., 1990). As Fredrickson suggests (2005): "*To the extent that autonomic reactivity supports specific action tendencies, these two observations go hand-in-hand: If no specific action is called forth during positive emotional states, then no particular pattern of autonomic reactivity should be expected*" (p.314). Thus, two positive emotions characterized by different arousal levels were considered, to assess whether they would have elicited different breathing patterns and whether participant would have been able to correctly identify the underlying emotions.

As far as attunement is regarded, this study will take into account several dimensions using different investigation techniques: *emotional decoding, similarity of emotional experiences*, *perspective taking ability, perceived physical activation*, and *interpersonal synchrony.* Assuming the component process nature of emotions (that include appraisal, physiological arousal, action tendencies, expressive behaviours, and subjective emotional experience) a comprehensive measure of an emotional event require the employment of multiple, convergent measurements (Scherer, 2005). In this study two different methods were used: *breathing audio-recording* and *self-reports*. The first allows the analysis of *emotional breathing patterns* and of *interpersonal synchrony* between participants in each breathing attunement task. Coordination Indexes developed in Study 1 will serve this purpose (See par. 2.4.2.3). They determine the temporal distance that occurs between couple of closest breaths in participants' breathing patterns, returning a measure of the "time lag" between the two onsets. Moreover, classification in different, fixed classes of synchrony allows a more detailed description of synchrony along time. The second enable the investigation of participants' *subjective experience*. Both their ability to reciprocally understand what their partner was feeling and their own emotional experience will be evaluated. Physiological attunement will be assessed through self reports items: previous studies provided evidences about people's ability to report fine description of their body sensation during emotional experiences, (Lyman et Waters, 1986; Philippot et Rimé, 1997; Rimé et al., 1990) and also of specific body sensations including breathing changes (Philippot et al, 2002).

4.2 Aims

The study was aimed to:

1) Broaden the "emotional breathing" sample in order to allow a more precise and reliable *description of the acoustic features of breathing in different emotional conditions*;
2) Going beyond the "decoding" task of the second study, *describing the attunement process between participants*.

As the first point is regarded, we expect to find some consistent features characterizing distinct emotional breathing patterns, as previous studies did. Moreover, we argue that acoustic breathing patterns could convey cues about underlying dimension of the emotional experience, such as *valence* and *emotional intensity*.

As the second point is concerned, we hypothesize that the more synchronized the imitation of the partner's breathing, the more accurate the understanding of her emotional experience.

4.3. Method

4.3.1 Participants

Participants were 44 women (M age: 30.2) randomly coupled in 22 pairs who voluntarily took part to the study. We chose to have only females for two reasons: 1) gender balancing would have required a wider amount of participants; 2) the experimental setting required a certain degree of intimacy that could have create some resistances with mixed couple / male couple. The experiment was presented as a research on the relation between *narration* and *identification skills.* They were told at the end of the study they would have received a personal feedback on their performance. At the end of the study they were told the real aim of the study.

During the data analysis 2 couples were excluded due to inaccurate task performance; thus the final sample consisted of 20 couples.

4.3.2 Materials

Apparatus. Either of instructions, narratives and Self Report were provided on a paper and pencil version. Audio tracks of breathing sounds were recorded a *Presonus Firestudio Project* audio interface and two *Shure WH30 XLR* head-microphone. Both participants' faces were video-taped during all experimental tasks using two *Canon Legria HF200* cameras (HD).

Narratives. Narratives were chosen as emotion induction technique. Text based stories have been proven to be among the most effective induction techniques (Westermann et al., 1996; Gerrards-Hesse et al., 1994). Inducing emotions through standardized stimuli rather than asking to reproduce a specific emotion prevents responses due to experimenter's demand bias and elicits more realistic responses. Moreover, since the stimuli are the same for each participant, the emotion-arousing context is controlled and standardized.

Six narratives, pre-tested for emotional valence and intensity (anger, sadness, fear, positive surprise) were used in the experiment; four adapted form a previous study on vocal communication of emotion (Ciceri et Anolli, 1997), while two (disgust and tenderness) were built on purpose (see Appendix 2 for the entire texts). Original narratives were modified:

1. turning the story in 2^{nd} singular person, to ease identification;
2. removing the last sentence placed at the end each story for previous experimental aims ("Non è possibile, non ora!")
3. adding some cues about the *physiological activation*, *physical sensations* and some *expressive behaviours* related to those emotions (ex.: "you clench your sweaty fists" "your heart is running faster" "you both start laughing" "you felt a shiver down your spine" etc).

The stories never express overtly the emotion felt by the character, but describe a certain situation and her reactions to it. Below a brief summary of each narrative:

- *Anger*: you are travelling along a desert and bumpy road to reach you boyfriend on you sport car and suddenly you have a puncture on way. Your get off the car to take out your jack but you are unable to find it. When you also stain your wonderful, white dress you loose control and boot the tyre, screaming loudly.
- *Joy*: you are walking along the street thinking with satisfaction to the meeting you just had with you boss: you just got this great job opportunity, to go with him to London! You are heading toward the travel agency to confirm your tickets when

you suddenly hear someone screaming out your name. You turn back and you see a women running toward you. You realize she's an old friend you haven't meet for such long time, and enthusiastically you decide to meet later, for lunch. They, you walk away thinking this is a wonderful day.

- *Sadness*: You haven't been able to sleep since he's gone away. You try to prepare your breakfast, doing something familiar that ease the pain. But you can't stop thinking he is no more here with you; anything seems completely meaningless… Memories and thought of loss crowded into your mind until you had to stop and sit on chair, silently crying.
- *Fear*: you can't stop thinking about that terrible anonymous message full of threats… It should be a joke, what else? You've never annoyed anyone, you are always on your own… so, what? And why? These thoughts are flooding your mind while you are closing the shutters of you shop, late in the evening. The street is deserted and suddenly you catch sight of three mean characters heading toward you, as they have been waiting just for that… You would run away but you feel trapped, unable to react; you babble something while one of them put his hand under the jacket… you're completely speechless, with no way out.
- *Disgust*: you enter a café to have a coffee and immediately perceive an awful smell. You ask for the coffee, but the pong is so strong that it makes you feel sick. You ask for the toilet but as you enter the room the stink become unbearable. You suddenly turn back when you feet slip on something viscid; you look to the floor and see that yellowish and evil-smelling stain… you hold a sudden retch and try to get out of the bath, but the door just got close behind you and are unable to find the key. You get trapped into the toilet, searching for that damned key into your pockets and holding the nausea.
- *Tenderness*: You and your friend sit on the grass, leaning on the same tree. You give a quick look to each over and then start laughing as two little girls: she never changes. You close your eyes, enjoying the warmth of the sun and let old memories flooding your minds: how many wonderful moments you have spent together! And how strong is your friendship: you trust her as no one else! Then you realize that sunset is coming. You turn toward her: she's smiling, her eyes still closed; you start joking again, and think about what to do in the evening.

At the end of each narrative, readers were asked to indicate the principal emotion they thought the character was feeling, using the *Geneva Emotion Wheel* (Scherer, 2005). The *Geneva Emotion Wheel* requires the respondent to indicate the answer by choosing a single emotion or a blend of several emotions out of 20 emotion families, arranged in a wheel shape with the axes defined by two major appraisal dimensions: *high – low control / power appraisal* and *un pleasantness / obstructiveness – pleasantness / conduciveness appraisal*. Each family is identified by two labels that stand for a whole range of similar emotions. Then, respondents have to check the *intensity* of the chosen emotion/s on a scale from 1 (very weak) to 5 (very strong). Circles in "spikes" corresponding to each emotion family represent different intensities: the bigger the circle, the stronger the emotional experience.

Emotional attributions to each narrative was assessed. Responses concerning the principal emotion of each narrative were counted. Frequencies for reported choices are shown in Tab.1

Target Emotion	**Chosen Emotions**	**Occurence**
Anger	Irritation / Anger	20/20
Fear	Worry / Fear	20/20
Sadness	Sadness / Desperation	20/20
Disgust	Disgust / Repulsion	20/20
Tenderness	Tenderness Happiness / Joy Enjoyment / Pleasure Disburdened / Relief	7/20 6/20 4/20 3/20
Joy	Surprise Happiness / Joy Elation Enjoyment / Pleasure	2/20 9/20 8/20 1/20

Tab. 1 – Frequencies for reported choices in Emotional Connotation of the Narratives

No confusion emerged for negative emotions (all were correctly identified 20/20). More composite was instead the emotional space of both positive narratives. A χ^2 test was run for each of them to assess whether any prevalence emerged between different choices. The test didn't' reach significance for *Tenderness*, while *Joy* was primarily defined with the target labels (happiness/joy) ($\chi^2(3)= 10.00$; $p<0.05$). Positive narratives didn't identify only ONE emotion but a more emotional experience, although always characterized by positive labels. This is consistent with previous literature on positive emotions: they don't lead to specific action tendencies, rather they widen the range of potential actions body and mind are prepared to do (Fredrickson et Branigan, 2005).

The consistence between the *emotional label assigned to the narrative and their actual emotional experience performing the task* was also assessed. The emotion assigned to the story and that actually experienced were the same or very similar. Moreover, consistently with the emotional connation of the experimental Narratives, positive narratives were associated with more diversified emotional labels, although always positively connoted.

Then, after the question about the emotional connotation of the story, a brief instruction was reported to facilitate the identification task:

"When do you feel ready, close your eyes: your partner will do the same. Your are the main character of the story you've just read: you are (in that place) you are thinking (those thoughts), you are feeling (those sensations)… and you start breathing as if you were her. Only your breath will express what you are feeling, you can't use your voice. Your partner will listen to your breath and will try to stay with you, breathing with you."

<u>*Self-Report*</u>. After each task, a questionnaire was administered to each participant that include several items about: 1) the emotions they felt; 2) the emotion they thought their partner was feeling; 3) ratings of degree of difficulty, intimacy, discomfort, involvement, usefulness of the task and physical activation. Two different versions were written for the *mirroring position* (RISP-Q) and for the *identification position* (RESP-Q) (See Appendix 2).

The "*Identification Questionnaire* - RESP-Q" requires to:

- Indicate what emotion/emotions they were feeling while *performing the task* using the Italian adaptation (Ciceri, 2005) of Scherer's *Emotion Wheel.* This question was set in order to control if they were actually able to punt themselves into the shoes of character of the narrative.
- Specify whether they had felt any emotion/s *hearing their partner breathing together with them* and, if so, indicate *which ones* using the Scherer's *Emotion Wheel*.
- Rate how much they thought their partner *has understood* what they were feeling on a 7 point Likert scales (0: not at all; 7: completely).

- *Task Evaluation Form*: Rate on a 7 point Likert scales (0: not at all; 7: a lot) how much *hearing their partner breathing together with them* had been:
    - o Difficult, because it was distracting;
    - o Intimate, because it fosters closeness;
    - o Annoying, because the situation was un-natural;
    - o Involving, because I felt her participation.

The "*Mirroring Questionnaire* - RISP-Q " requires to:

- Indicate what emotion/emotions they thought their partner was feeling using the *Emotion Wheel*;
- Indicate if they have felt any emotion/emotions while breathing together with their partner and, if so, check *which ones* using the Scherer's *Emotion Wheel*.
- *Task Evaluation Form*: Rate on a 7 point Likert scales (0: not at all; 7: a lot) how much *hearing their partner breathing together with them* had been:
    - o Difficult, because I've never done something like that before
    - o Useful to put myself on her shoes;
    - o Intimate, because it fosters closeness;
    - o Mechanic: I did it just because I had been required to.
    - o Annoying, because in wasn't my natural way of breathing;
    - o Involving, because I felt physically aroused;
- Rate how much they believe that mirroring that breathing pattern helped them to experience *physical feelings* similar to those of their partner.

4.3.3 Procedure

40 participants were randomly coupled. They were welcomed in a room provided with the recording system and two chairs, closely arranged one beside the other but in two opposite direction, since this position ease breath sounds listening.

First, the experimenter gave participants the informed agreement form that also included some general instructions:

"*Dear participant, we are carrying on a research on the relation between narration and identification skills. We will ask alternatively you and your partner to read six narratives: each of them tells the story of a character living a specific experience. The stories are not related to each other. Later you will be given more precise instructions about what you are* *asked to do. During the experiment you will be asked to fill in some questionnaires and audiovisual data will be collected to undergo succeeding analysis. With this form we ask your authorization for the recordings and the following analyses*".

Once signed the forms, participants were settled down and wore the head-microphones. Before giving them the following instructions, a 90 sec baseline of their breathing at rest was recorded. Then, each of them was given a different instruction sheet. Participants that first perform the identification task (RESP) read:

"*Read carefully the story. Then write the principal emotion you think the character was feeling using the Emotion Wheel. Then, read the story a second time and try to put yourself into her shoes, focusing on the emotion she's feeling. Take your time: concentrate on the feeling you would experience, imagine which thoughts would flood you mind and focus on how your body would react (facial expressions, posture, breath, etc). When you feel ready, close your eyes (your partner will do the same). You are the character of the story you have just read, you are in that place, in her same situation… e you start breathing as if you were her. Only you breathing will express what you are feeling, you can't use your voice during the task. You partner will listen to you breath and try to stay close to you, breathing with you.*"

Beside, participants that first perform the attunement task (RISP) read:

"*Your partner is going two read twice the narrative and will take some times to put herself into the character's shoes. When she will be ready, she will close her eyes and you'll do the same. Then, she will start breathing as id she was the main character of the story. Listen to her breathing and stay with her, breathing as she's doing. You'll have only her breath to understand what she's feeling and you'll have only yours to express your closeness. You can't use your voice during the task."*

The recording session lasted 90 sec. Breathing of both participants was separately *audio recorded*, and their faces were *videotaped*. After each task, they both filled in a questionnaire. Then, they exchange their role and read the next story, following the same procedure for 6 times.

4.3.4. Dependent Variables

Task Evaluation Form. Narrative emotional connotation and task reliability (difficulty, discomfort, involvement and intimacy) were assessed through analysis of self-report ratings.

Breathing pattern. 7 audio-tracks were recorded for each participant within each couple, each lasting 90 sec: one baseline, before reading the instructions, and one for each of the six experimental conditions. Hence, a Total of 420 minutes or breathing sounds recording was collected. The multilayer analysis model developed in the first study was applied. The following indexes were thus extracted:

- *Respiratory indexes*: Respiratory rate, Cycle duration, Inspiratory time, Expiratory time; I:E ratio; Expiratory Pauses Time; Inspiratory Pauses Time; N breaths / min; N Expirations / min; N Inspirations / min; N apnoeas
- *Acoustic Indexes*: Inspiration Intensity; Expiration Intensity; Insp. Spectral Centroid; Exp. Spectral Centroid; N of accented breaths.
- *Coordination Indexes*: Lag between couple of closest breaths' onsets (*M, S.D, Range*); N breaths within 0-100 ms / tot amount of breaths; N breaths within 100-250 ms / tot amount of breaths; N breaths within 250-500 ms / tot amount of breaths; N breaths > 500 ms / tot amount of breaths.

Mean respiratory parameters, their standard deviations and ranges were calculated for the 90 sec recording period for each participant. In addition also *coefficient of variation* was calculated to assess respiratory variability in breathing pattern within each subject in each experimental condition, as Boiten suggested in his previous study (1998). This index return a measures of breathing irregularity, that appears to increase under condition of emotional upset or excitement (Stevenson and Ripley, 1952; Hormbrey et al., 1976; Tobin et al., 1983). Coefficient of variation is a normalized measure of variability that expresses standard deviation as a percentage of the mean:

$$CV = \left(\frac{\sigma}{|\mu|}\right) \times 100\% \qquad \mu \neq 0$$

Since this index take into account the mean of the distribution, it is a useful measurement when comparison between parameters with different ranges of variations have to been carried on.
Analyses of *synchrony* between participants along time, given by coordination indexes, were used as a measure of communicative *attunement*.

Emotions identification accuracy. Both *raw* and *unbiased hit rates* (Wagner, 1993) were extracted for each subject as a measure of identification accuracy (see par. 3.3.4). Scores were used to draw two different confusion matrixes for each emotion. *Identification accuracy* as much as the *emotions felt by participants* in the attunement task were considered two measures of *emotional attunement*.

Self Report. Participants' emotional experiences, perceived physical activation and reciprocal predictions of (and reactions to) felt emotions were assessed through analyses of Self Report ratings.

4.4 Results

4.4.1 Acoustic Analysis

420min of breathing audio-tracks were collected. All RESPs sample of acoustic tracks (210 min) undergo acoustic analysis. Tab** resume Mean, Standard Deviation, Range and Coefficient of Variation of respiratory and acoustic parameters by emotional condition.

Analyses regarding respiratory and acoustic indexes were separately introduced. Finally, a resuming description of individual emotional breathings pattern will be provided, discussing more in detail results of contrast analyses.

4.4.1.1 Respiratory Indexes

A series of within subjects ANOVA were carried out for each respiratory index with *Emotions* (Baseline, Fear, Sadness, Anger, Joy, Tenderness, Disgust) as within-subject variable. Descriptive Statistics, F values and correspondent p are presented in Tab.15.

Significant main effect were obtained for Respiratory Rate, Cycle Duration (Ti), Expiratory duration, Inspiratory duration, E/I Ratio, Pauses Time, post inspiratory pauses duration, post expiratory pauses duration. Number of Inspiration and Expiration /min instead don't reach significance. Due to wide variations within the data the ANOVA was not conducted on the Apnoeas index. Anyway, disgust appears to have the greatest number of interrupted breaths compared to others. The following respiratory indexes also shown significant differences in their *variability*, as reflected by their coefficients of variation: Cycle Duration, E/I ratio, Pauses Time.

RR and Ti return quite similar results: Tenderness is characterized by the slowest RR and the longest Ti. Fear, by contrast, has the fastest RR and the shortest Ti, significantly different than all other patterns. After Baseline, Tenderness is characterized by the lowest variability, while Fear, Anger and Disgust by the highest. As far as E/I ratio is considered, being in Expirations significantly longer than Inspirations in all conditions, this index is always >1. Anger is associated with the lowest values and Sadness with the highest, anyway contrast underline poor differences between close patterns.

Resp. Parameters		*Breathing Condition*									
		Baseline	*Tenderness*	*Joy*	*Anger*	*Fear*	*Sadness*	*Disgust*	*F (6, 114)*	*p*	*Contrast*
Resp. Rate	Mean	14.36	12.05	20.44	27.57	34.70	18.18	22.63	*19.117*	*0.001*	*T B S J D A F*
	(SD)	3.11	3.81	8.37	12.38	14.99	7.76	11.80			
	Range	9.7	15.4	25.6	49.00	52.00	27.4	37.3			
	C.Var	21.74	31.61	40.95	44.90	43.19	42.68	52.14			
Cycle Dur.	Mean	2.817	3.893	2.514	2.260	1.759	2.773	2.261	*14.315*	*0.001*	*F A D J S B T*
	(SD)	0.499	1.448	1.007	1.003	.656	.860	.871			
	Range	1.476	5.914	3.850	1.003	2.256	3.413	2.652			
	C.Var	17.71	37.19	40.05	4.060	37.29	31.01	38.52			
Cycle Cf.Var	Mean	16.95	24.74	29.62	26.12	26.77	34.21	34.13	*5.685*	*0.001*	*B T J S A D F*
	(SD)	7.61	10.42	12.51	9.94	15.39	144.47	15.73			
	Range	29.47	36.22	39.22	48.71	48.78	47.65	55.38			
N E /min	Mean	50.20	49.82	49.67	50.16	50.16	50.75	50.92	*NS*	*NS*	*/ /*
	(SD)	.96	.54	1.16	.73	.82	2.51	2.41			
	Range	3.75	2.18	4.79	3.21	3.87	12.22	11.42			
N I /min	Mean	49.78	50.20	50.33	49.83	49.83	49.73	49.06	*NS*	*NS*	*/ /*
	(SD)	.95	.53	1.16	.72	.82	4.56	2.41			
	Range	3.70	2.13	4.79	3.21	3.87	24.59	11.42			
E Dur.	Mean	1.541	2.116	1.374	1.165	.971	1.612	1.156	*12.558*	*0.001*	*F D A J B S T*
	(SD)	.314	0.858	.589	.509	.355	.695	.441			
	Range	1.056	3.512	2.026	2.039	1.281	2.849	1.473			
	C.Var	14.78	40.54	42.86	43.69	36.56	43.11	38.14			
I Dur.	Mean	1.268	1.703	1.107	1.064	.803	1.248	.981	*12.929*	*0.001*	*F D A J B S T*
	(SD)	.243	.543	.435	.463	.349	.308	.368			
	Range	.859	1.919	1.864	1.630	1.404	1.057	1.226			
	C.Var	19.16	31.88	39.29	43.51	43.46	31.88	37.51			
E/I Ratio	Mean	1.251	1.254	1.267	1.186	1.287	1.383	1.359	*2.292*	*0.05*	*A B T J F D S*
	(SD)	.174	.156	.161	.161	.139	.328	.239			
	Range	.610	.536	.597	.596	0.536	1.148	.949			
	C.Var	13.91	12.44	12.70	13.58	10.80	23.71	17.58			
E/I ratio Cf.Var	Mean	23.19	28.18	32.07	33.50	30.22	30.48	42.64	*3.832*	*0.01*	*B T F S J A D*
	(SD)	9.34	11.46	13.31	16.90	13.35	20.43	17.56			
	Range	38.18									
Pause Dur.	Mean	.778	.786	.361	.139	.087	.389	.536	*21.772*	*0.001*	*F A J S D T B*
	(SD)	.372	.372	.274	.110	.063	.353	.455			
	Range	1.274	1.315	.932	.333	.192	1.039	1.444			
	C.Var	47.81	48.98	75.90	79.14	72.41	90.75	84.88			

Resp. Parameters		Breathing Condition									
		Baseline	*Tenderness*	*Joy*	*Anger*	*Fear*	*Sadness*	*Disgust*	*F (6, 114)*	*p*	*Contrast*
Pause D. Cf.Var	Mean	82.02	82.91	111.46	144.13	196.61	123.73	165.59			
	(SD)	17.19	26.13	31.70	57.46	79.36	39.24	69.22	*21.772*	*0.001*	*B T J S A D F*
	Range	68.34	98.62	116.53	202.15	292.3	141.78	205.28			
Post E Pauses	Mean	1.223	1.203	.568	.313	.128	.582	.390			
	(SD)	.593	.673	.476	.336	.121	.493	.299	*10.612*	*0.001*	*F A D J S T B*
	Range	2.107	2.205	1.515	1.095	.342	1.376	.901			
	C.Var	48.48	55.94	83.80	107.35	94.53	84.70	76.66			
Post I Pauses	Mean	.305	.361	.150	.085	.078	.156	.664			
	(SD)	.187	.190	.097	.067	.066	.123	.691	*24.325*	*0.001*	*D T B S J A F*
	Range	.489	.667	.356	.356	.211	.372	2.219			
	C.Var	61.51	52.63	64.66	78.82	84.61	78.84	104.06			
N of Apnoeas	Mean	.15	.45	1.00	.45	.35	.85	2.50			
	(SD)	.37	.89	1.62	1.10	.93	1.27	2.91	*//*	*//*	*//*
	Range	1	3	5	4	3	4	10			
E energy (dB)	Mean	33.15	41.75	41.63	50.40	50.51	47.15	46.38			
	(SD)	4.57	5.65	7.85	8.06	8.95	6.74	8.04	*23.914*	*0.001*	*B J T D S A F*
	Range	16.60	24.07	30.74	30.15	33.6	24.51	25.88			
	C.Var	13.78	13.53	18.85	15.96	17.71	14.29	17.33			
I energy (dB)	Mean	29.14	31.00	31.44	33.21	35.98	31.47	33.42			
	(SD)	3.12	3.25	3.66	4.57	6.55	4.16	5.69	*6.643*	*0.001*	*B T J S A D F*
	Range	11.10	12.63	14.49	18.87	27.47	14.83	20.53			
	C.Var	10.70	10.48	11.64	13.76	18.20	13.21	17.03			
E Spec. Centr.	Mean	483.53	448.81	318.13	434.64	485.65	484.4	545.97			
	(SD)	52.56	61.53	62.43	106.45	98.65	102.0	123.38	*15.561*	*0.001*	*J A T D B S F D*
	Range	191.22	243.62	228.48	392.83	335.37	403	458.51			
	C.Var	10.87	13.70	19.62	24.49	20.31	21.05	22.59			
E S.Cen. Cf.Var	Mean	53.82	47.53	36.48	35.58	36.20	38.83	42.41			
	(SD)	6.75	7.29	7.38	3.83	7.48	6.57	7.12	*26.500*	*0.001*	*A F J S D T B*
	Range	28.66	25.22	28.32	13.28	24.47	20.77	26.84			
I Spec. Centr.	Mean	602.04	622.61	688.89	958.45	1016.98	904.85	770.59			
	(SD)	85.07	104.24	121.16	359.28	427.9	320.78	173.45	*12.934*	*0.001*	*B T J D S A F*
	Range	349.49	352.42	448.8	1238.13	1594.94	944.54	536.04			
	C.Var	14.13	16.64	17.58	40.98	23.87	35.45	22.50			
I S.Cen. Cf.Var	Mean	56.69	52.57	46.64	46.43	45.14	48.01	47.09			
	(SD)	7.66	9.04	8.23	6.22	6.56	9.46	7.38	*6.501*	*0.001*	*F A J D S B T*
	Range	29.07	34.00	27.18	23.85	26.20	36.34	24.96			

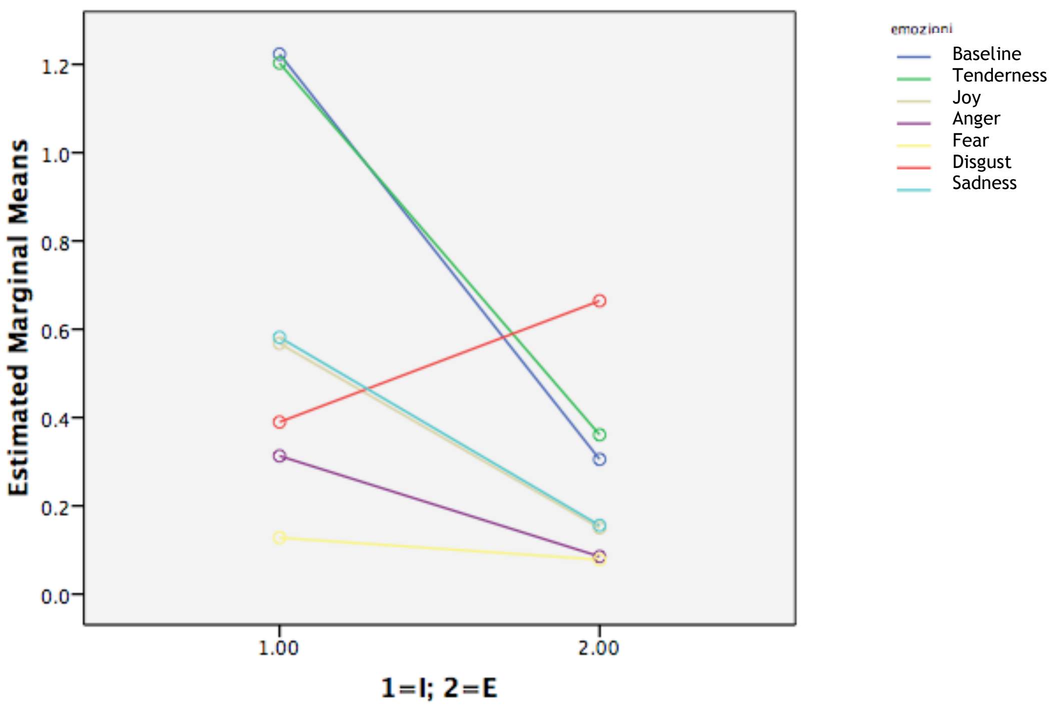
Resp. Parameters		*Breathing Condition*									
		Baseline	*Tenderness*	*Joy*	*Anger*	*Fear*	*Sadness*	*Disgust*	*F (6, 114)*	*p*	*Contrast*
Nasal / Oral	N/O	N	N	N	N	N	N	N	//	//	//
E Accented	Mean (SD) Range	37.49 24.23 87.58	30.49 23.82 92.30	40.61 23.86 82.03	28.29 25.42 82.14	38.86 20.48 67.62	53.77 26.45 100	36.41 26.31 94.44	*2.707*	*0.05*	*A T D B F J S*
I Accented	Mean (SD) Range	11.60 11.70 40.90	24.80 20.13 65.38	21.69 17.56 61.53	23.06 18.59 60.71	23.06 18.59 60.71	43.36 26.17 91.00	36.84 19.55 71.90	*8.677*	*0.001*	*B T S D J A F*

Tab. 15 - Respiratory parameters as a function of emotional condition

Repeated measures ANOVA were carried out to compare separate duration and separate post pauses times for I and E, with *Emotions* (Baseline, Fear, Sadness, Anger, Joy, Tenderness, Disgust) and *Breath* (Inspiration, Expiration) as within-subject variables. As far as duration are concerned, main effects came out as significant (*Emotion*: $F(6,114)=24.676$; $p<0.001$; *Breath*: $F(1,38)=7.333$; $p=0.01$) but not the interaction. Expirations are significantly longer than Inspirations in all conditions. *Tenderness* is associated to the longest I and E durations while *Fear* with the shortest ones, both significantly more than all other conditions. Both *Baseline* and *Sadness* significantly differ from *Tenderness* on one side, and *Joy* on the other, and could be paired together. Beside, *Joy* could be paired with Anger but it is significantly different from Disgust ($F= 5.508$, $df=1$; $p<0.05$) while Anger could be associated to both.

As far as pauses time are concerned, both main effects and their interaction came out as significant but not the interaction (*Emotions*: $F(6,114)=24.325$, $p<0.001$; *Breath*: $F(1,38)=153.869$; $p<0.001$; *Emotions*Breath*: $F(6,114)= 15.712$, $p<0.001$). Graph.10 show the interaction between the two factors.

Graf.10 - Pauses Time - Interaction Emotions * Breaths



Post Expiratory Pauses are generally longer than *Post Inspiratory Pauses*, made exception for *Fear* and *Disgust*, that don't shown significant differences between the two. *Baseline* and *Tenderness* have the longest expiratory and inspiratory pauses and show highly similar patterns; moreover, they are significantly different from all other conditions. Besides, *Anger* and *Fear* have the shortest expiratory and inspiratory pauses; they are significantly different from both *Baseline-Tenderness* and *Joy-Sadness*. However, they could be distinguished one from the other since *Fear* has significantly shorter post inspiratory pauses. Finally, *Joy* and *Sadness* have intermediate expiratory and inspiratory pause durations and have rather identical pattern. Their values are significantly different from both *Baseline-Tenderness* and the *Anger*-*Fear*. Finally, *Disgust* has a peculiar pattern, being the only breathing pattern characterized by longer Post I pauses compared to Post E ones (p=.058). Inspiratory pauses are the longest one, while Expiratory pauses have intermediate values significantly different from *Anger-Fear* on one side, and *Joy-Sadness* on the other.

4.4.1.2 Acoustic Indexes

First, prevalence of Nasal vs Oral breathing was assessed. Table 16 show occurrence of Nasal or Oral breathing by emotional condition.

	N	Nasal	Oral
Tenderness	20	19	1
Baseline	20	20	0
Sadness	20	18	2
Joy	20	20	0
Disgust	20	20	0
Anger	20	16	4
Fear	20	18	2

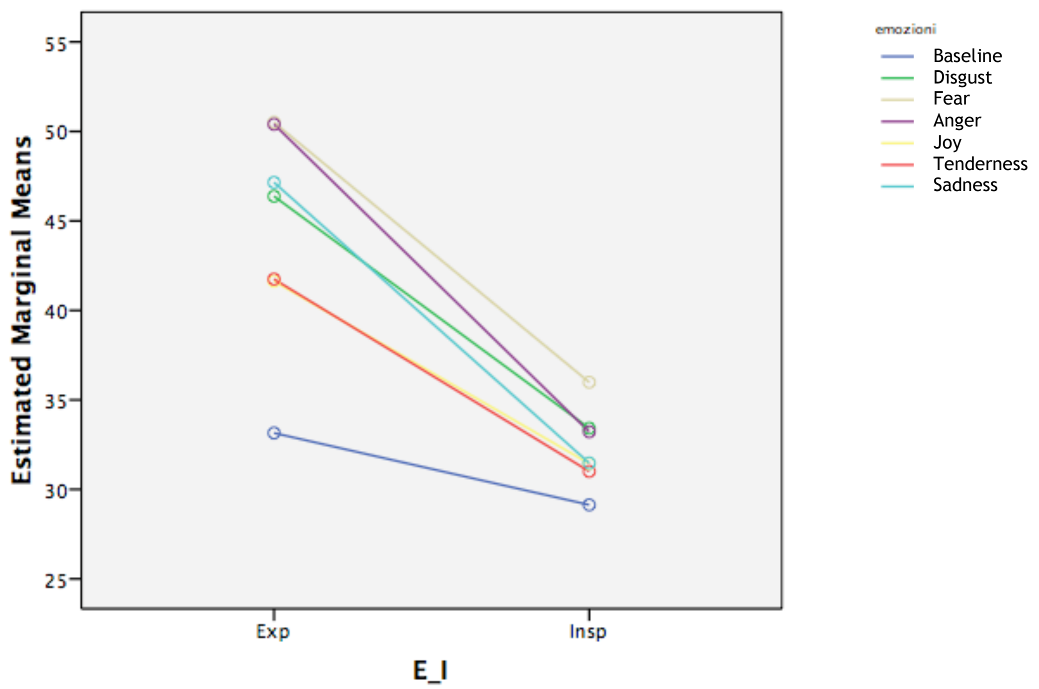
Tab. 16 - occurrence of Nasal or Oral breathing by emotional condition

A χ^2 test was conducted to point out possible differences but it doesn't reach significance. All respiration are more nasal than oral. Anger is more often associated with oral respiration than other emotional conditions, but not in a significant way.

A series of within subjects ANOVA was carried out for each acoustic index with *Emotions* (Baseline, Fear, Sadness, Anger, Joy, Tenderness, Disgust) as within-subject variable. Contrasts, F values and correspondent p values are always presented in Tab. 15. Significant main effects were obtained for E Energy, I Energy, E Spectral Centroid, I Spectral Centroid and N of Accented Breaths. Both I and E Spectral Centroids shown also significant differences in their *variability*, as reflected by coefficients of variation. Repeated measures ANOVA were carried out for each acoustic index with *Emotions* (Baseline, Fear, Sadness, Anger, Joy, Tenderness, Disgust) and *Breath* (Inspiration, Expiration) as within-subject variables for more detailed analyses.

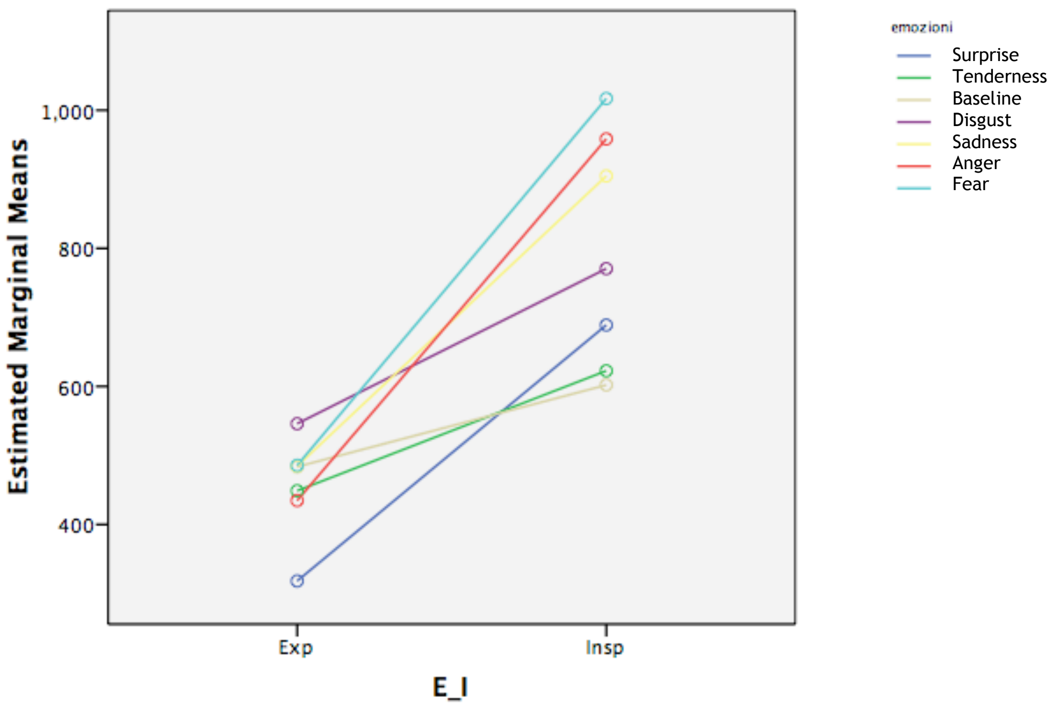
As far as *Energy* is concerned, both main effects (*Emotion*: $F(6,114)=28.554$; $p<0.001$; *Breath*: $F(1,38)=86.802$; $p<0.001$) and their interaction (*Emotion*Breath*: $F(6,114)= 8.419$, $p<0.001$) came out as significant. Expirations were always louder than Inspiration, as expected by results of our First Study. Only Baseline seems clearly differentiated from the other, being both expirations and inspirations significantly softer than all other pattern. The other breathing pattern, instead, grouped in quite close clusters. This clusters and significance of the interaction will be discussed further on in the description of individual breathing patterns (see Discussion).

Graf.11 - Energy - Interaction Emotions * Breaths



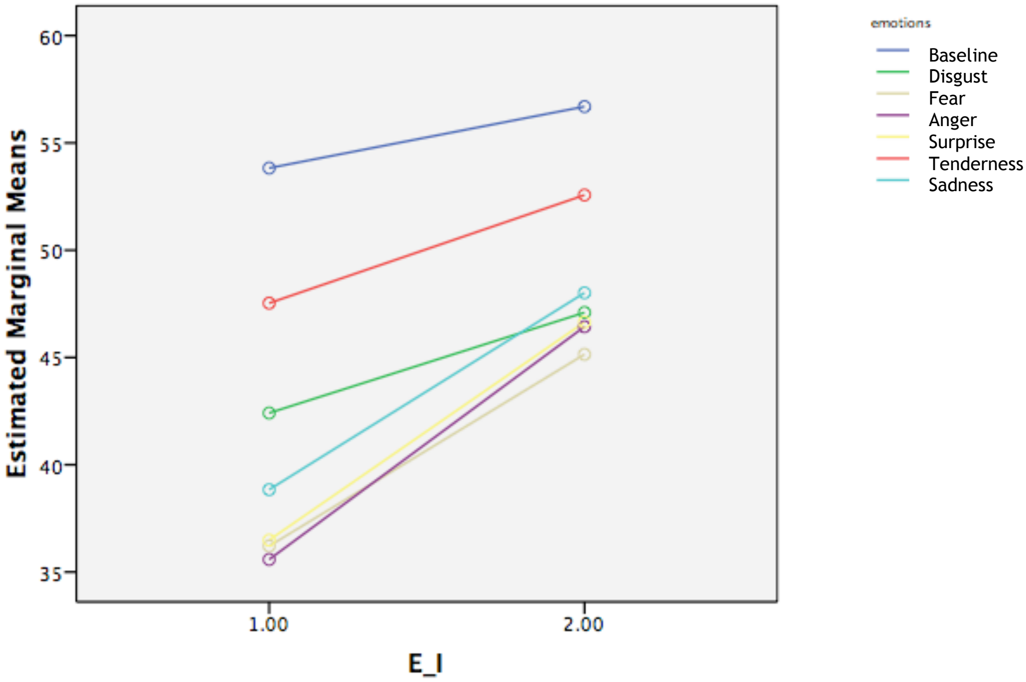
Analyses of *Spectral Centroid* pointed out both main effects (*Emotion*: F(6,114)= 15.242; p<0.001; *Breath*: F(1,38)=66.905; p<0.001) and their interaction *(Emotion*Breath*: F(6,114)= 11.311, p<0.001) as significant. Inspiration are characterized by brighter sounds compared to Inspirations. As far as emotions are concerned, Joy is characterized by the brightest inspirations, while Disgust and Fear by the darkest. Beside, Baseline and Tenderness have the brightest expirations and Sadness, Anger and Fear the darkest. Interaction (graph.12) is significant due to quite different trends of different emotions that will be discussed further on in the description of individual breathing patterns

Graf.12 - Spectral Centroid - Interaction Emotions * Breaths



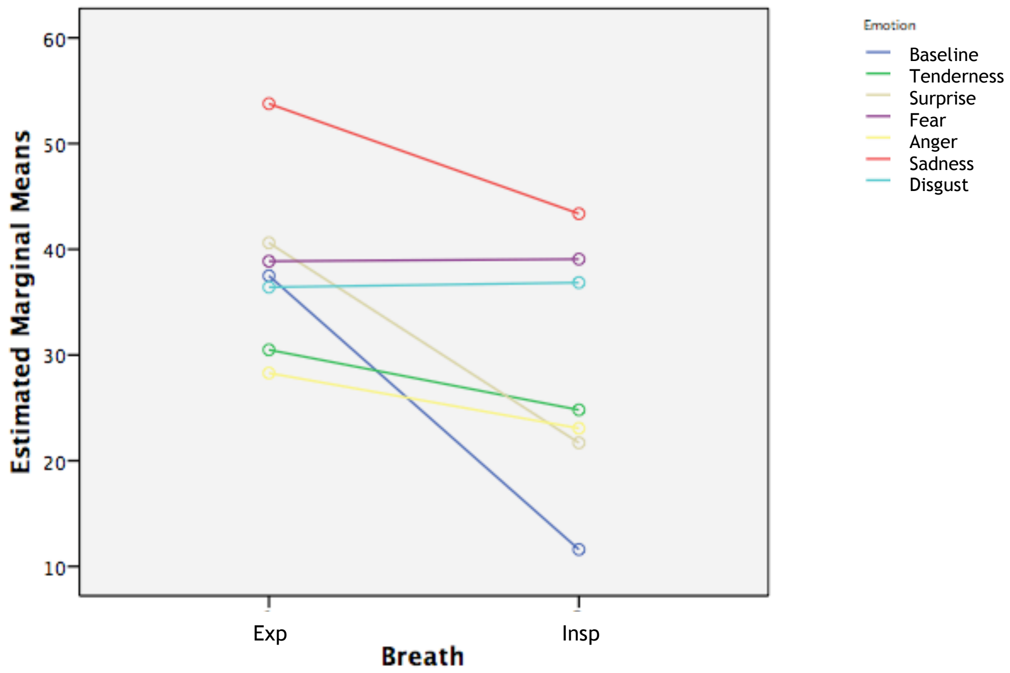
As said before, the ANOVA pointed out significance difference between *variability* of *Inspiratory and Expiratory Spectral Centroid*. The test pointed out both main effects (*Emotion*: F(6,114)= 26.911; p<0.001; *Breath*: F(1,38)=34.744; p<0.001) and their interaction *(Emotion*Breath*: F(6,114)= 2.196, p<0.05) as significant. See graph 13 for the interactions. Variability is higher for inspirations compared to expirations. Greatest variations are represented in Baseline, both as Expiration and Inspiration are regarded. Following, Tenderness show greater variability compared to the other emotional breathing pattern. The others share similar trends, not significantly different between them.

Graf.13 – C. Var Spectral Centroid – Interaction Emotions * Breaths



Finally *Accented Breaths* were analyzed. Both main effects (*Emotion*: $F(6,114)=5.079$; $p<0.001$; *Breath*: $F(1,38)=14.731$; $p=0.001$) and their interaction (*Emotion*Breath*: $F(6,228)= 4.509$, $p<0.001$) came out as significant (see Graph.14). Made exception for *Fear* and *Disgust*, generally Expirations are characterized by a greater amount of accents (sight, sobs, tremors) compared to inspirations. In the former emotional breathing pattern, instead, expirations and inspirations have a similar trend. Sadness shows the greatest amount of accented breaths, while other emotions didn't show significant difference between them. As Inspirations are regarded, Baseline show the least amount of accented inspirations; following, Joy, Anger and Tenderness group together, while the higher number of accents characterize Disgust, Fear and Sadness.

Graf.14 – Accented breaths – Interaction Emotions * Breaths



Concluding, these analysis allow the identification of quite specifici features of breathins pattern in relation to distinct emotions, and similare clusters seems to emerge. These aspects will be discussed more in detailed in the Discussion paragraph.

4.4.2. Synchronization – Coordination Indexes

Tab17 show Means, Standard Deviations, Range and coefficient of variation of the Lag between pairs of closest breaths' onsets within couples by emotional condition. All are characterized by lags below 500 sec made exception for Tenderness, underlying good synchronization ability.

	N	Mean	Std. D.	Range	C.Var
Fear	20	.232	.109	.367	46.98
Anger	20	.261	.123	.413	47.12
Joy	20	.395	.199	.657	50.37
Disgust	20	.442	.256	.820	57.91
Sadness	20	.465	.259	.815	55.69
Baseline	20	.632	.187	.644	29.58
Tenderness	20	.681	.253	.863	37.15

Contrast		
T B	**Sa D Su**	**A F**

Tab. 17 – Lag between pairs of closest breaths' onsets within couples, by emotional condition

A within subjects ANOVA was conducted with *Emotions* (Baseline, Fear, Sadness, Anger, Joy, Tenderness, Disgust) as within-subject variable and lag times per couple as dependent variable and significant differences emerged between emotions ($F(6,114)=24.393$, $p<0.001$). In particular, Anger and Fear were the more synchronous conditions while Tenderness and Baseline the most asynchronous one.

To see whether different strategy of coordination along time characterized individual emotional conditions, N of breaths in each synchro category (0-100, 100-250, 250-500, >500 ms) were computed every 30 sec. Three different moment of synchrony were thus identified. Tab. 19 shows descriptive statistic of each dependent variable.

A within subjects ANOVA was conducted with *Emotions* (Baseline, Fear, Sadness, Anger, Joy, Tenderness, Disgust), *Time* (30', 60', 90') and *Synchro* (0-100, 0-100, 100-250, 250-500, >500 ms) as within-subject variables and raw data as dependent variable. Among main effects, *Emotion* and *Time* came out as significant, while all interactions were pointed out by the test (see. Tab 18 for F, p values and interactions). Interactions and presented in graph 15-16-17.

Effects	***F, p***
Emotion	$F(6,114)= 12.149$; $p<0.001$
Time	$F(2,38)= 6.958$; $p<0.01$
Synchro	NS
Emotion*Time	$F(12,228)=36.927$; $p<0.001$
Emotion*Synchro	$F(18,342)=6.410$; $p<0.001$
Time*Synchro	$F(6,116)=5,533$; $p<0.001$
Emotions*Time*Synchro	$F(36,684)=1.883$; $p<0.01$

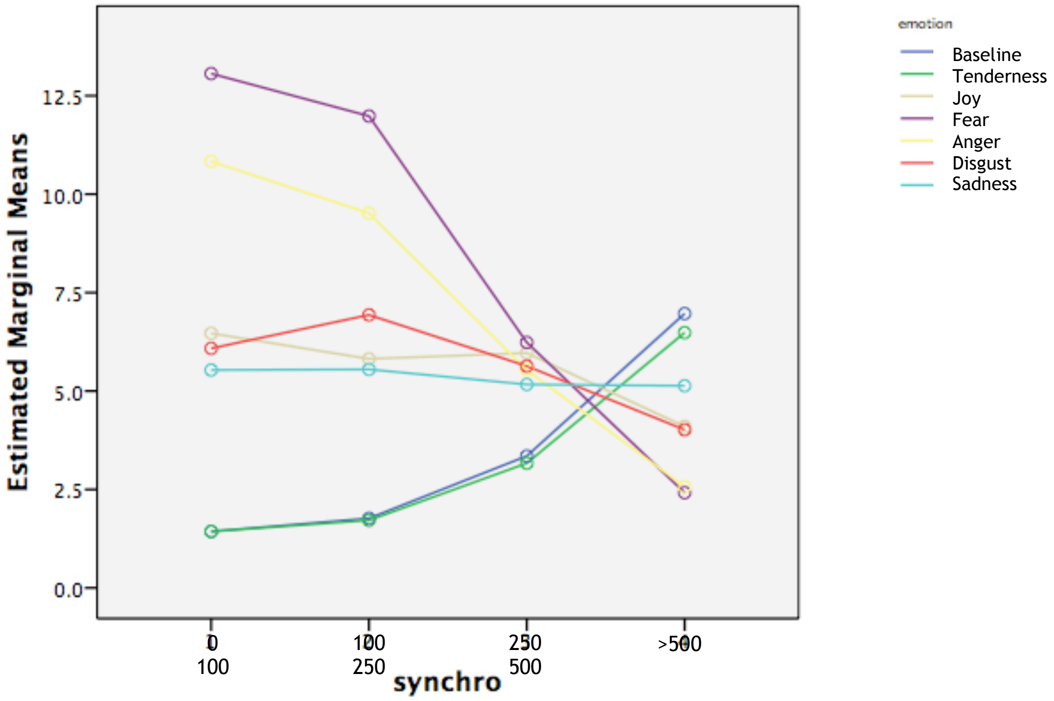
Tab. 18 – Synchrony – Results of Repeated Measure ANOVA

	Mean	St. D	N
base_syn1_30	1.15	1.226	20
base_syn2_30	1.70	1.593	20
base_syn3_30	3.25	1.916	20
base_Nosyn_30	7.35	2.834	20
base_syn1_60	1.50	1.100	20
base_syn2_60	1.85	1.663	20
base_syn3_60	3.55	1.905	20
base_Nosyn_60	6.90	3.227	20
base_syn1_90	1.65	1.531	20
base_syn2_90	1.75	1.517	20
base_syn3_90	3.25	1.743	20
base_Nosyn_90	6.65	3.031	20
ten_syn1_30	1.65	1.631	20
ten_syn2_30	1.65	1.496	20
ten_syn3_30	3.20	2.331	20
ten_Nosyn_30	7.15	2.346	20
ten_syn1_60	1.50	1.573	20
ten_syn2_60	1.65	1.631	20
ten_syn3_60	2.95	1.877	20
ten_Nosyn_60	6.05	2.188	20
ten_syn1_90	1.15	1.137	20
ten_syn2_90	1.85	2.110	20
ten_syn3_90	3.35	2.815	20
ten_Nosyn_90	6.25	3.059	20
surp_syn1_30	5.25	9.819	20
surp_syn2_30	4.55	5.844	20
surp_syn3_30	6.45	3.720	20
surp_Nosyn_30	4.50	3.171	20
surp_syn1_60	6.40	11.673	20
surp_syn2_60	6.45	5.530	20
surp_syn3_60	6.00	3.509	20
surp_Nosyn_60	3.90	3.417	20
surp_syn1_90	7.75	13.595	20
surp_syn2_90	6.45	6.320	20
surp_syn3_90	5.45	3.804	20
surp_Nosyn_90	3.90	3.698	20
fear_syn1_30	7.35	9.499	20
fear_syn2_30	8.85	6.107	20
fear_syn3_30	6.25	3.919	20
fear_Nosyn_30	3.10	3.093	20
fear_syn1_60	13.09	13.789	20
fear_syn2_60	13.95	8.217	20
fear_syn3_60	6.65	4.184	20
fear_Nosyn_60	2.45	2.781	20
fear_syn1_90	18.75	24.059	20
fear_syn2_90	13.15	7.322	20
fear_syn3_90	5.80	5.406	20
fear_Nosyn_90	1.70	2.716	20

	Mean	St.D	N
ang_syn1_30	6.30	9.658	20
ang_syn2_30	8.30	5.823	20
ang_syn3_30	6.30	2.736	20
ang_Nosyn_30	3.45	3.576	20
ang_syn1_60	12.55	21.581	20
ang_syn2_60	10.25	8.447	20
ang_syn3_60	5.50	3.332	20
ang_Nosyn_60	2.40	2.563	20
ang_syn1_90	13.65	24.457	20
ang_syn2_90	10.00	6.424	20
ang_syn3_90	4.80	3.412	20
ang_Nosyn_90	1.85	2.641	20
disg_syn1_30	4.10	5.025	20
disg_syn2_30	5.70	4.450	20
disg_syn3_30	5.55	3.845	20
disg_Nosyn_30	4.40	2.583	20
disg_syn1_60	5.60	8.882	20
disg_syn2_60	7.25	7.063	20
disg_syn3_60	5.70	4.402	20
disg_Nosyn_60	3.95	2.762	20
disg_syn1_90	8.55	13.060	20
disg_syn2_90	7.85	9.092	20
disg_syn3_90	5.65	3.543	20
disg_Nosyn_90	3.70	2.227	20
sad_syn1_30	3.90	7.454	20
sad_syn2_30	5.45	6.065	20
sad_syn3_30	4.85	3.083	20
sad_Nosyn_30	5.65	3.392	20
sad_syn1_60	6.15	14.027	20
sad_syn2_60	5.90	4.898	20
sad_syn3_60	5.40	3.952	20
sad_Nosyn_60	4.45	4.161	20
sad_syn1_90	6.55	16.656	20
sad_syn2_90	5.30	5.212	20
sad_syn3_90	5.25	3.354	20
sad_Nosyn_90	5.30	4.780	20

Tab. 19 – Mean and Standard Deviations for each dependent variable of the synchrony comparisons along time

Graf.15 – Synchrony – Categories * Emotions

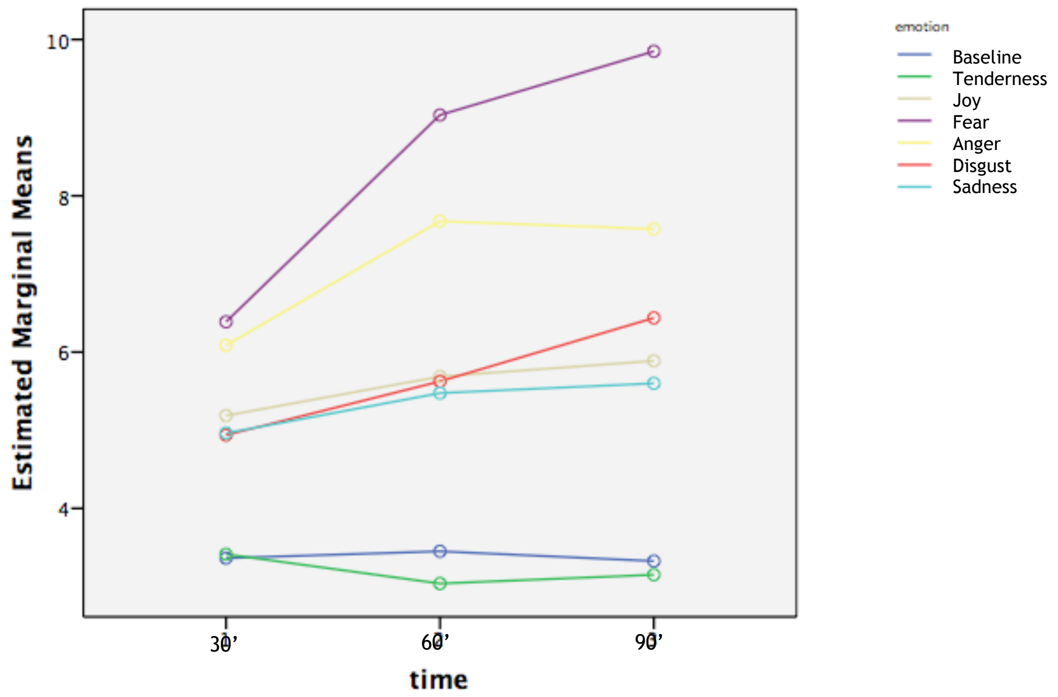


Concerning the interaction between *synchro categories* * *different emotions*, Anger and Fear are characterized by the greatest amount of occurrences in the most synchronous categories, and the least in the most asynchronous.

Sadness, Disgust and Joy show similar trends, characterized by a balanced amount of breaths in the three synchronous categories. However, while Disgust and Joy fall down in the asynchronous one, Sadness keeps its trend constant.

Finally, Baseline and Tenderness are the most asynchronous emotions, with the greatest amount of breaths in the last two categories.

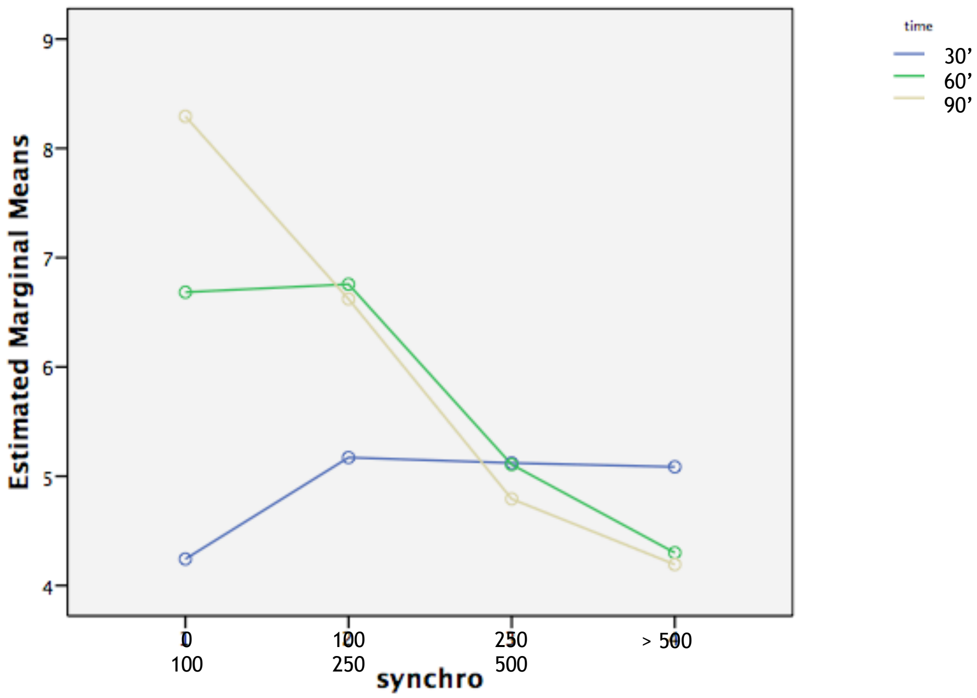
Graf.16 - Synchrony - Time * Emotions



As far as *synchronism through time * Emotion* is regarded, an increasing trend characterized almost all emotions, made exception for Tenderness and Anger. Fear starts as the most synchronous from the beginning and increase as time goes on, while Anger increase during the fist '60 min, then falls down. Joy and Sadness show quite identical trends characterized by a slight raise along time, while Disgust show a more pronounced increase in the first phase. Finally, Tenderness is characterized by the worse synchronization performance.

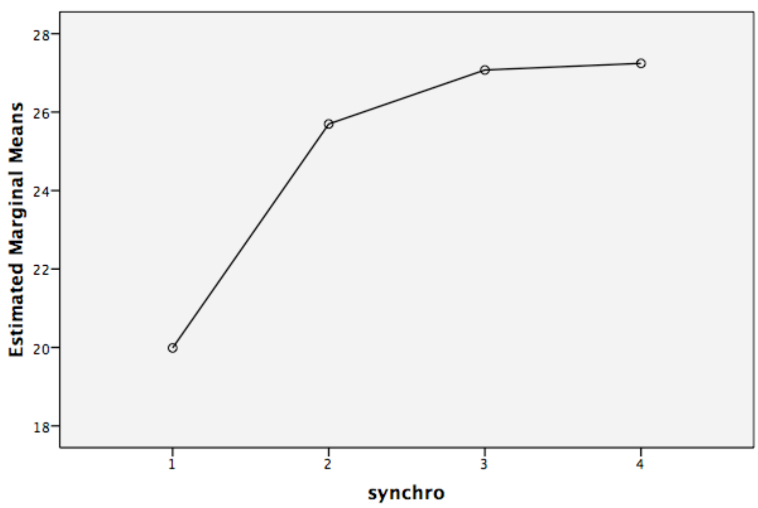
The following graph, finally, illustrates the interaction between *synchronism through time*synchro categories*. It shows a great increase of occurrence in first two categories from the first to the third moment; the third category remains more or less at the same level along time, while the total amount of asynchronous breaths tend to diminish.

Graf.17 – Synchrony – Categories * Time



To balance the amount of breaths in each category in function of the actual amount of breaths produced in each phase (that is, keeping into account respiratory rate), N of breaths in each synchro category were computed *over the tot amount of breaths,* every 30 sec. Graphs 18 shows that generally asynchronous breath prevailed and that synchronous ones tends to concentrate in the central categories (100-250 ms, 250-500 ms), compared to the first, which count the less number of occurrences.

Graf.18 – Weighted synchro-categories



4.4.3 Emotional Decoding

This section includes the analyses about confusion matrixes on raw hit rates and unbiased hit rates.

4.4.3.1. Unbiased Hit Rate Score

To correct the response bias that affects raw identification rates, unbiased hit rates were forst calculated in order to compare the degree of identification accuracy between different emotions. Hu were first computed per judge for each stimulus separately, considering only first choice. Tab.11 show Mean and Standard deviation for each Emotion.

A within subjects ANOVA was conducted with *Emotions* (Fear, Sadness, Anger, Joy, tenderness, Disgust) as within-subject variable and the *Unbiased Hit Rate Score* per judge as dependent variable. Main effect of *Emotion* emerged as significant ($F(5,440)= 4.430$, $p<0.001$) highlighting considerable differences among the identification of individual emotions. In particular *Fear* is the most recognized breathing pattern, significantly more than all other conditions (see contrasts) while *Disgusts* is the less identified.
(Contrast: D T J S A F)

	N	Mean	St.D.	Range
Fear	20	.994	.738	1.57
Sadness	20	.523	.720	1.57
Anger	20	.497	.730	1.57
Joy	20	.471	.738	1.57
Tenderness	20	.236	.575	1.57
Disgust	20	.157	.483	1.57

Tab. 11 – Mean and Standard Deviation of Hu rates in emotion decoding

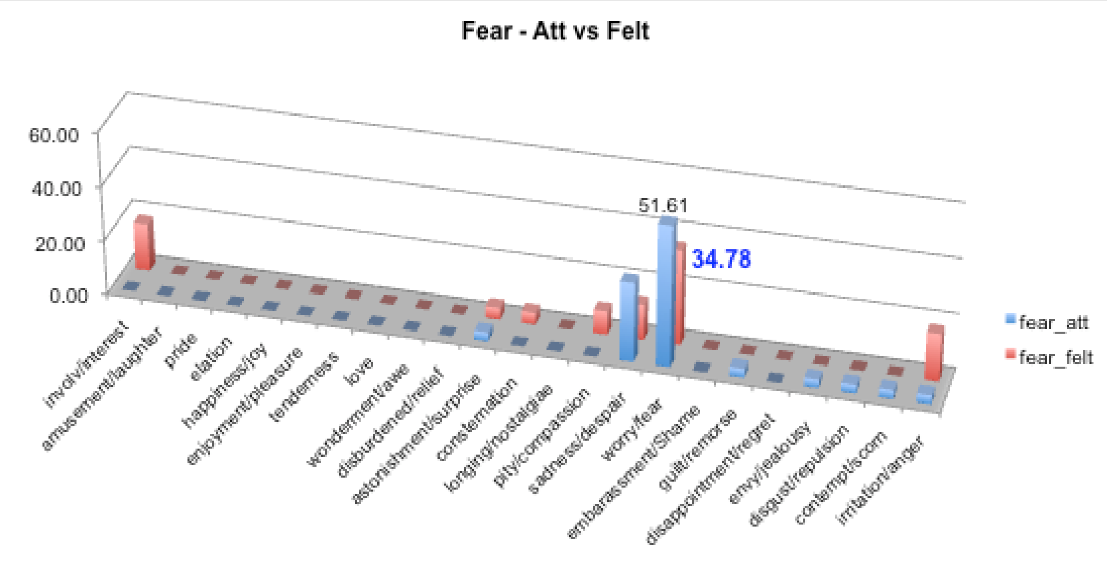
In contrast with previous remarks, contrast analyses don't underline significant difference between identification of the two positive emotions compared to the negative ones, made exception for Fear (Fear vs Tenderness: $F=13.538$, $df=1$; $p<0.01$; Fear vs Joy: $F=7.028$, $df=1$; $p<0.05$).

4.4.3.2. Confusion Matrixes on Raw Hit Rates

Tab. 12 and Tab 13 show both Felt and Assigned emotional rates given by RISP sample for each separate emotions. The first one consider only the first choice, the second all the judges' choices. Global percentage of identification is 34.17% with a high range of variation (S.dev.=22.23%; Range: 60%). Following graphs (4-9) illustrate in detail emotional saturation for each target emotion, taking into account both Felt and Assigned choices. *All choices* have been represented in the graphs. Comments, instead, are related to *first choices only*, in order to allow further comparison with unbiased hit rates analyses.

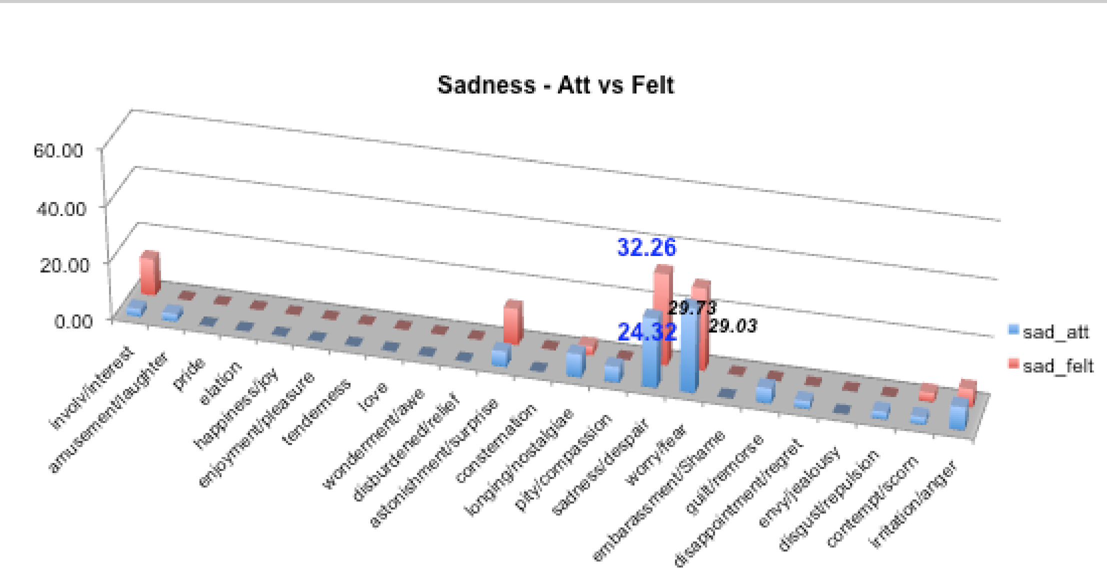
Tab.12 % I choice	*involv/interest*	*amusement/laught*	*Pride*	*Elation*	*happiness/joy*	*Enjoy/pleas.*	*Tenderness*	*Love*	*Wond./Awe*	*disburdened/relief*	*Astonish./surprise*	*Consternat.*	*Longing/nostalgia*	*pity/compassion*	*sadness/despair*	*worry/fear*	*Embarrass./Shame*	*guilt/remorse*	*Disapp./regret*	*envy/jealousy*	*disgust/repulsion*	*contempt/scorn*	*irritation/anger*
sad_att	0	0	0	0	0	0	0	0	0	0	10.00	0	0	0	***40.00***	*45.00*	0	0	0	0	0	0	5.00
sad_felt	21.5	0	0	0	0	0	0	0	0	0	0	0	0	0	***42.11***	*31.58*	0	0	0	0	0	5.26	0
disg_att	0	5.00	0	5.00	5.00	10.00	0	0	0	0	0	0	0	0	10.00	*25.00*	5.00	20.00	0	0	***10.00***	0	5.00
disg_felt	**28.57**	0	0	0	0	14.29	0	0	0	0	7.14	0	0	7.14	7.14	14.29	7.14	7.14	0	0	***0***	0	7.14
anger_att	5.00	0	0	5.00	0	0	0	0	0	10.00	0	0	5.00	0	5.00	*25.00*	0	0	0	0	0	0	***45.00***
anger_fel	15.79	0	0	0	0	0	0	0	0	10.53	10.53	0	5.26	5.26	5.26	*21.05*	0	0	5.26	0	0	5.26	***15.79***
fear_att	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25.00	***70.00***	0	0	0	0	0	0	5.00
fear_felt	15.00	0	0	0	0	0	0	0	0	0	5.00	5.00	0	10.00	15.00	***40.00***	0	0	0	0	0	0	10.00
joy_att	10.00	5.00	0	0	***25.00***	0	5.00	0	0	10.00	0	0	0	5.00	5.00	10.00	10.00	5.00	0	0	0	0	10.00
joy_felt	17.65	5.88	0	5.88	***5.88***	17.65	5.88	0	0	0	5.88	0	11.76	5.88	5.88	0	0	0	0	0	0	0	11.76
tend_att	0	0	0	0	10.00	10.00	***15.00***	0	5.00	*30.00*	0	0	0	0	10.00	10.00	0	0	0	5.00	0	0	5.00
tend_felt	*33.33*	0	0	0	5.56	0	***11.11***	0	0	*27.78*	0	0	0	0	5.56	5.56	0	0	0	0	0	0	11.11

Tab.13 % ALL choices	*involv/interest*	*Amus./laught*	*Pride*	*Elation*	*happiness/joy*	*Enjoy/pleas.*	*Tender*	*love*	*Wond./Awe*	*Disburd./relief*	*Astoni/surprise*	*Constern.*	*Long./nostalgia*	*pity/compass.*	*Sadness/desp.*	*Worry/fear*	*Embarr./Shame*	*guilt/remorse*	*Disap p./regret*	*envy/jealousy*	*disgust/repuls.*	*contempt/scorn*	*Irrit. anger*
sad_A	2.70	2.70	0	0	0	0	0	0	0	0	5.41	0	8.11	5.41	***24.3***	*29.73*	0	5.41	2.70	0	2.70	2.70	8.11
sad_F	12.90	0	0	0	0	0	0	0	0	0	12.90	0	3.23	0	***32.3***	*29.03*	0	0	0	0	0	3.23	6.45
disg_A	3.45	3.45	0	3.45	3.45	6.90	0	0	0	0	6.90	0	0	0	6.90	*20.69*	10.34	13.79	0	0	***6.90***	6.90	6.90
disg_F	*21.05*	10.53	0	0	0	10.53	0	0	0	0	10.53	0	0	5.26	10.53	10.53	5.26	5.26	0	0	***0***	0	10.53
anger_A	2.56	0	0	2.56	2.56	0	0	0	0	5.13	2.56	0	5.13	0	10.26	*25.64*	0	0	7.69	0	2.56	5.13	***28.2***
anger_F	16.00	4.00	0	0	0	0	0	0	0	8.00	8.00	0	8.00	4.00	4.00	*20.00*	0	0	4.00	0	0	8.00	***16.0***
fear_A	0	0	0	0	0	0	0	0	0	0	3.23	0	0	0	29.03	***51.6***	0	3.23	0	3.23	3.23	3.23	3.23
fear_F	17.39	0	0	0	0	0	0	0	0	0	4.35	4.35	0	8.70	13.04	***34.8***	0	0	0	0	0	0	17.39
joy_A	5.88	2.94	0	2.94	***17.7***	5.88	8.82	8.82	0	8.82	0	0	0	2.94	2.94	11.76	5.88	2.94	5.88	0	0	0	5.88
joy_F	*17.39*	8.70	0	4.35	***4.5***	3	4.35	0	0	0	13.04	0	13.04	4.35	4.35	4.35	0	0	0	0	0	0	8.70
tend_A	0	2.78	0	0	11.11	13.89	***13.9***	2.78	2.78	*19.44*	5.56	2.78	2.78	0	5.56	8.33	0	0	0	2.78	0	0	5.56
tend_F	*30.43*	0	0	0	4.35	0	***8.7***	0	0	*26.09*	0	0	0	0	8.70	13.04	0	0	0	0	0	0	8.70



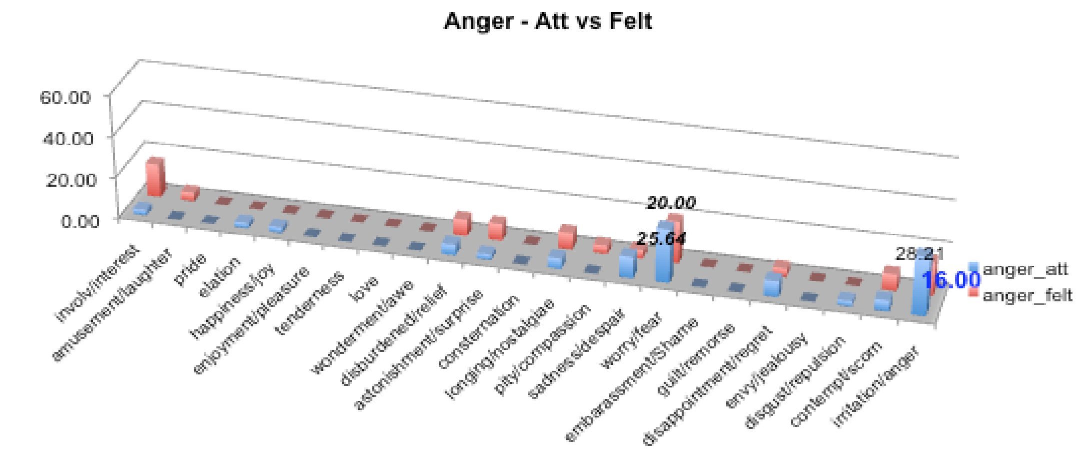
Graf.4 – Fear: emotional saturation considering ALL choices

Comment of first choice: Fear is *the most identified pattern* (70% of first choices). *Sadness* is often frequently chosen (25%) but doesn't reach significance; nonetheless, it's weigh increases considering ALL the chosen labels (29%). As far as *felt emotions* are considered, the right choice tends to prevail on the other emotions, reaching 40% of choices. Thus, RISPs emotional experience seems to be similar to that attributed to their partner.



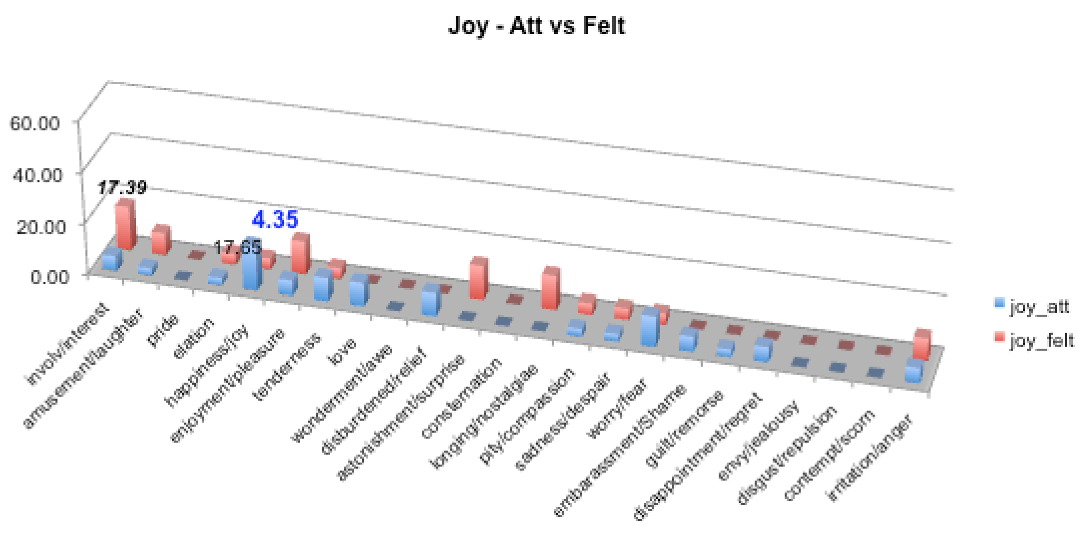
Graf.5 – Sadness: emotional saturation considering ALL choices

Comment of first choice: After *Fear*, *Sadness* is one of the most identified pattern (40%) although most often targeted as *Worry Fear* (45%). As far as *felt emotions* are considered, *Sadness* prevails followed by *Worry/Fear*. The correct emotional label trend to be better represented by the primary *felt* emotion rather than by the *attributed* one.



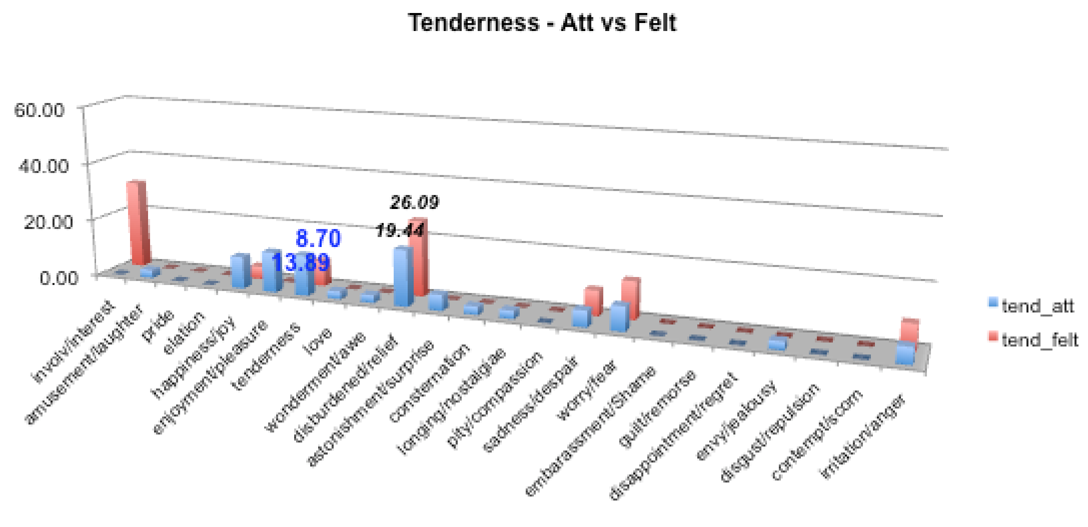
Graf.6 – Anger: emotional saturation considering ALL choices

Comment of first choice: Also *Anger* is well represented by the participants' first choices (45%) followed by *Worry Fear* (25%). Considering all choices saturation of the emotional space changes, and Anger gets down to 28.21%. As far as *felt emotions* are considered, the prevalent choice are still *Worry Fear* (21.25%) and *Irritation Anger* (15.79%). Partner's emotional experience is thus less coherent to breather's one, but prevailing emotions are the same.



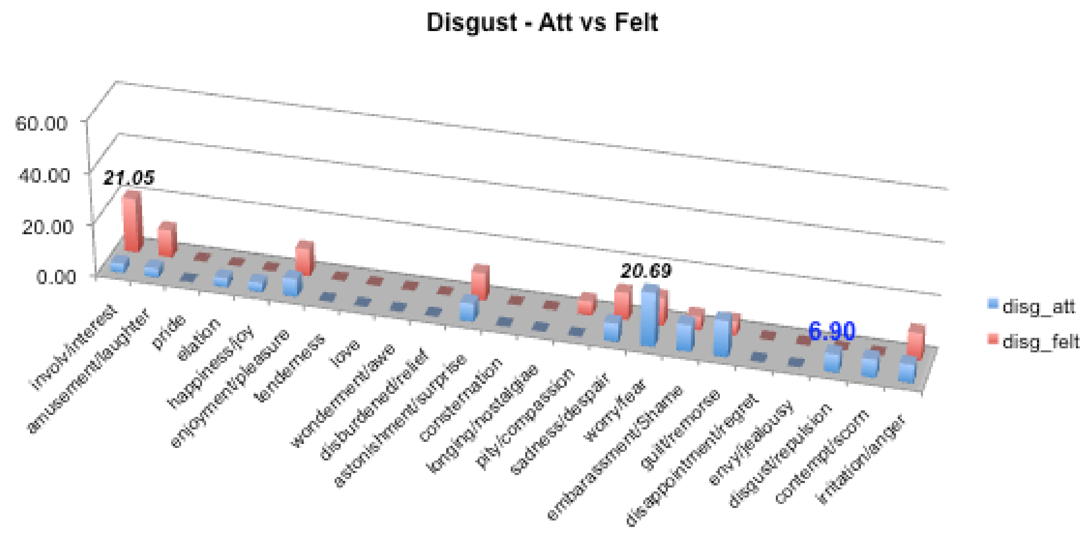
Graf.7 – Joy : emotional saturation considering ALL choices

Comment of first choice: Joy is less identified than the previous emotions. Anyway, the correct labels was the most often chosen, representing 25% of first choices and 17.65% of all. As *felt emotions* are considered, emotional space is still wider than previous emotions, 17.65% of first ones fall into *Involvement Interest* label and only 5.88% into *Joy.*



Graf.8 – Tenderness: emotional saturation considering ALL choices

Comment of first choice: As Joy, also Tenderness emotional space is more complex but most choices fall into emotions characterized by positive valence. The right label represents 15% of first choices and 13.89% of all, but the prevailing label is *Feeling Disburdened Relief* (30.00% first, 19.44% all). As *felt emotions* are considered, emotional space tend to saturate more positive than negative valence. Involvement Interest is the principal choice (33.33% of first, 30.43% of all), followed by *Feeling Disburdened Relief* (27.78% of first, 26.09% of all).



Graf.9 – Disgust: emotional saturation considering ALL choices

Comment of first choice: Disgust is the less identified emotion (10% of first, 6.90 of all). Interestingly, the principal choice is *Worry Fear* (25% of first, 20.69% of all), which was actually one of the emotions evoked by our narrative (when the character find herself lock into a disgusting toilet and is unable to get out). Finally, *negative valence seems to prevail* on positive one. As felt emotions are considered, emotional space is characterized by different emotions, and no trend neither regarding valence seems to emerge. First choice generally falls into *Involvement Interest* (28.57% of first choice, 21.05 of all).

On the basis of matrix and valence analysis, negative emotions appear to be generally easier to identify than positive ones (made exception for Disgust). In fact, in matrix analysis χ^2 tests don't reach significance for Joy and Tenderness, and they are characterized by a broader and more confused emotional space than Fear, Sadness and Anger (See Tab.14). To investigate whether participants have been able to identity the emotional valence characterizing target emotions, χ^2 tests were carried on considering ALL chosen labels within each emotional conditions and comparing positive to negative valence assignments.

Emotions	**Valence +**	**Valence -**	*$\chi^2(1)$*	*p*
Fear	1	30	*27.129*	*p<0.001*
Sadness	4	33	*22.730*	*p<0.001*
Anger	6	33	*18.692*	*p<0.001*
Disgust	8	21	*7.111*	*p<0.01*
Tenderness	26	10	*5.828*	*p<0.05*
Joy	21	13	*NS*	*NS*

Tab. 14 - χ^2 results on assigned emotional valence

Participants were *significantly able to identify the valence* of the target emotions, made exception for Joy (that, anyway, tend to evoke more positive labels than negative ones). Also emotional valence of Disgust, that was the less targeted breathing pattern, was correctly identified. Results also show that positive valence tend to be less easy to identify than negative one (Joy: NS, Tenderness p<0.01 VS Sadness, Anger, Fear: p<0.001).

4.4.4 Self-Report

4.4.4.1 Task Evaluation Form

First we examined participants' responses to *Task Evaluation Form* to verify the consistency and reliability of the experimental procedure, for both RESPs and RISPs sample. Mean and Standard Deviation for each item by emotions are presented in Tab.2 and Tab.3.

Identification Task

Inspection of RESPs ratings shows that the task wasn't considered *difficult* (M=1.61/7) neither *annoying* (M=1.86/7). Besides, it was rated as *quite involving* (M=3.67/7). A Repeated measures ANOVA was carried out to compare ratings in the different emotional conditions but it doesn't reach significance. The analysis could not include "difficuly" ratings because it didn't distribute normally.

RESP	Anger	Sadness	Disgust	Fear	Joy	Tender.	TOT
Intimate, because it fosters closeness	M= 3.5 S.D=1.7	M=4.1 S.D=1.9	M=3.5 S.D=1.7	M=5.7 S.D=2.1	M=3.4 S.D=1.7	M=3.6 S.D=1.9	**M=3.59 S.D=1.85**
Difficult, because it was distracting	M= 1.3 S.D=.65	M=1.8 S.D=1.24	M=1.5 S.D=0.83	M=1.6 S.D=1.04	M=2 S.D=1.37	M=1.4 S.D=.75	**M=1.61 S.D=1.02**
Annoying, because the situation was un-natural	M= 1.5 S.D=1.1	M=1.9 S.D=1.3	M=2.1 S.D=1.3	M=2.3 S.D=1.7	M=2 S.D=1.5	M=1.4 S.D=.5	**M=1.86 S.D=1.29**
Involving, because I felt her participation	M= 3.9 S.D=1.9	M= 4.2 S.D=1.9	M= 3.4 S.D=1.8	M=4 S.D=2.1	M=3.3 S.D=1.7	M=3.4 S.D=2	**M=3.67 S.D=1.91**

Tab. 2 - Task Evaluation Form - Mean ratings on RESPs ratings by emotion

Attunement Task

This task obtained low rates of *difficulty* (M=2.96/7) and *bother* (M=2.62/7) and *mechanical* (M=2.72/7). Besides, it was rated as *quite highly involving* (M=4.29/7). These results are anyway higher than those assessed in the Identification Task.

RISP	Anger	Sadness	Disgust	Fear	Joy	Tender.	TOT
Mechanic: I did it just because I had been required to	M= 3.30 S.D=1.83	M=2.25 S.D=1.33	M=2.20 S.D=1.64	M=1.50 S.D=.76	M=2.15 S.D=1.50	M=2.10 S.D=1.55	**M= 2.72 S.D=1.57**
Intimate, because it fosters closeness	M=4.65 S.D=1.76	M=4.10 S.D=1.97	M=4.00 S.D=2.22	M=4.25 S.D=1.71	M=3.85 S.D=1.78	M=3.60 S.D=1.67	**M=4.08 S.D=1.85**
Difficult, because I've never done something like that before	M= 3.60 S.D=2.08	M=3.10 S.D=2.32	M=2.60 S.D=1.84	M=2.50 S.D=1.85	M=2.45 S.D=1.96	M=3.50 S.D=2.14	**M=2.96 S.D=2.01**
Annoying, because in wasn't my natural way of breathing	M= 3.75 S.D=2.34	M=2.60 S.D=1.96	M=2.50 S.D=1.82	M=2.30 S.D=1.45	M=2.45 S.D=1.67	M=2.10 S.D=1.52	**M=2.62 S.D=1.86**
Involving, because I felt physically aroused	M=4.75 S.D=1.86	M=4.15 S.D=1.95	M=3.90 S.D=1.97	M=4.95 S.D=1.57	M=3.60 S.D=1.90	M=4.40 S.D=1.39	**M=4.29 S.D=1.81**

Tab. 3 - Task Evaluation Form - M and SD of ratings on RISPs ratings by emotion

A Repeated measures ANOVA was carried out to compare ratings in the different emotional conditions but it doesn't reach significance made exception for *Mechanical* ($F(5,95)=3.259$, $p<0.01$) since the *Anger* condition was rated as significantly more mechanic. The other condition didn't significantly differ one from the other.

Comparison between RESP and RISP rates

Tab.4 shows Mean and Standard Deviation of *Annoying*, *Involving* and *Intimate* ratings in both Task Evaluation Forms. To test whether the two roles were considered significantly different, a One Way ANOVA was run comparing the ratings to the *Annoying*, *Involving* and *Intimate* items in both Task Evaluation Forms.

		N	Mean	St.Dev.
Annoying	RE	120	1.86	1.285
	RI	120	2.62	1.857
	Total	240	2.24	1.638
Involving	RE	120	3.67	1.907
	RI	120	4.29	1.812
	Total	240	3.98	1.882
Intimate	RE	120	3.59	1.854
	RI	120	4.08	1.852
	Total	240	3.83	1.865

Tab. 4 – Task Evaluation Form –
M and SD of common items comparing RESPs and RISPs ratings

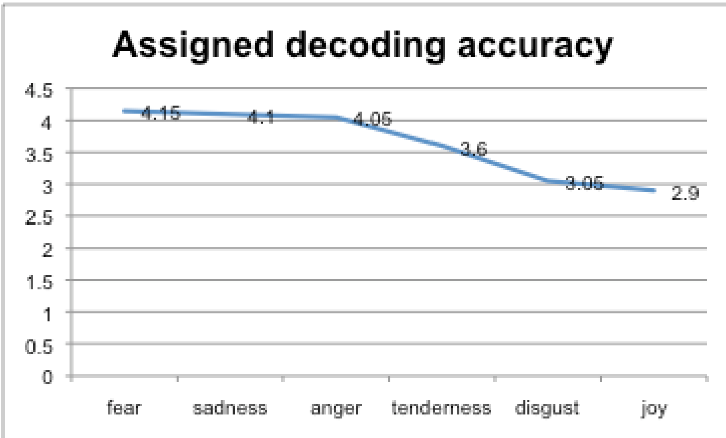
Before performing the analysis, we assessed through a Repeated Measures ANOVA that no significant differences occur between emotions, in order to use the entire sample of ratings as one. Significant differences actually emerged between the two tasks. Participants in the Attunement Role (RISP) experienced higher *Involvement* ($F(1,238)=6.774$, $p=0.01$) and *Intimacy* ($F(1,238)=4.082$, $p<0.05$) compared to those in the Identification Role (RESP), but also much more *annoyance* ($F(1,238)=13.504$, $p<0.001$)

4.4.4.2 Attunement Items

The Questionnaire also included some items that give information about the perspective taking ability of both participants during each task. RESPs had to rate how much they think their partners understood what they were feeling. Besides, RISPs have to rate how much useful was breathing with her partner to put themselves into her shoes, and how much do they believe to have felt similar physical feelings. Tab.5 shows Mean and Standard Deviation for each item by emotion.

	Anger	Sadness	Disgust	Fear	Joy	Tender	TOT
How much you partner *has understood* what you were feeling? (RESP)	M= 4.05 S.D=1.7	M=4.1 S.D=1.77	M=3.05 S.D=1.23	M=4.15 S.D=1.39	M=2.90 S.D=1.39	M=3.6 S.D=1.60	**M=3.64** **S.D=1.57**
Useful to put myself on her shoes (RISP)	M= 4.60 S.D=1.60	M=4.90 S.D=1.33	M=4.25 S.D=1.77	M=4.65 S.D=1.84	M=3.80 S.D=2.04	M=4.15 S.D=1.49	**M= 4.39** **S.D=1.70**
Similar physical feelings to those of your partner (RISP)	M=4.50 S.D=.173	M=4.85 S.D=1.63	M=3.65 S.D=2.23	M=4.90 S.D=1.59	M=3.90 S.D=1.77	M=3.55 S.D=1.54	**M=4.23** **S.D=1.81**

Tab. 4 – M and SD of ratings on Attunement Items by emotions



Graph. 1 – RESPs Prediction on RISPs decoding ability by emotion

Inspection of these data shows that RESPs rated the identification accuracy of their partner on an average level (M=3.64). A Repeated Measures ANOVA underlined significant differences between Emotions (F(5,95)=3.918, p<0.01): Joy was considered the hardest to understand, Fear the easiest, significantly more difficult than Anger, Fear and Sadness.

RISPs, instead, considered breathing together as *useful* to improve identification (M=4.39/7) and think that this actual lead them to feel *similar physical feelings* to those of their partner (M=4.23/7). A Repeated Measures ANOVA underlined significant differences between Emotions (F(5,95)=3.259, p<0.01) in the "physical feelings" item: participants affirmed to have felt more similar feelings in the Fear, Sadness and Anger conditions compared to Joy, Disgust and Tenderness.

4.4.4.3 Participants' Emotional Experience

We explored participants' emotional experience, investigating both the *complexity* of their reported feeling (*how many* emotions did they choose) and their *intensity* (how much intense did they rate them). Mean and standard deviation of the number of chosen emotions and assigned intensity (from 1 to 5) on the *Geneva Emotion Wheel* were calculated, separately for each condition.

Complexity of Emotional Experience

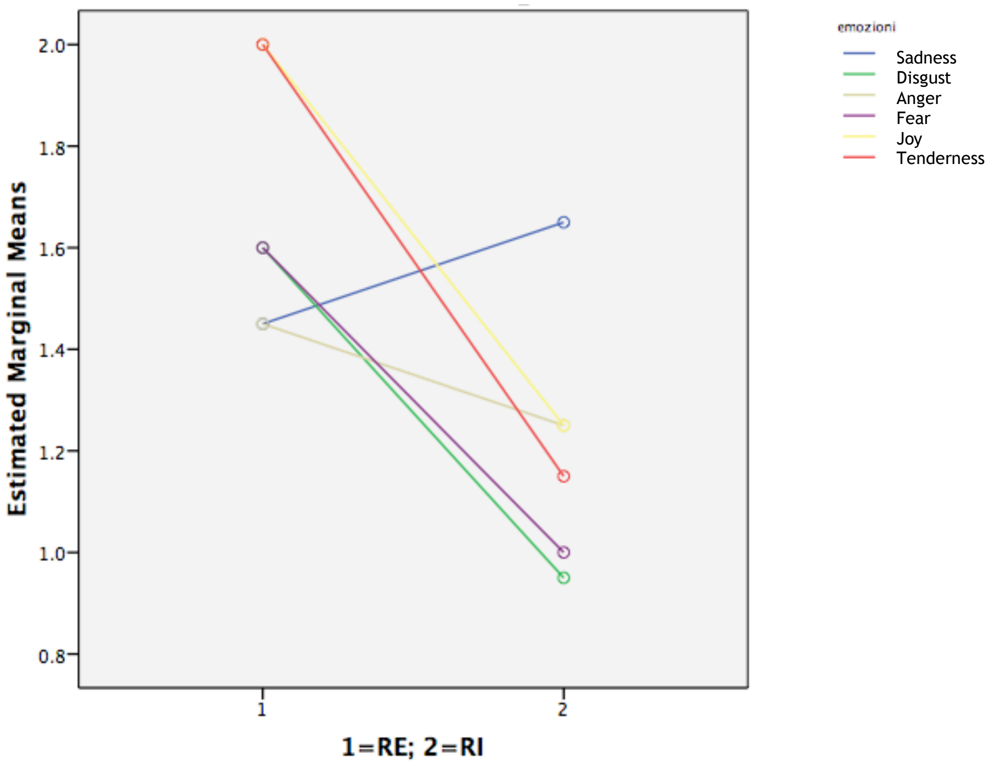
Tab.5 presents Mean and Standard Deviation of reported number of emotions by both participants in each emotional condition. First we tested whether significant differences emerged between different emotions and between the two different roles.

	Role	N	Mean	St. Dev.
Sadness	RESP	20	1.45	.686
	RISP	20	1.65	.745
	Total	40	1.55	.714
Disgust	RESP	20	1.60	.821
	RISP	20	.95	.759
	Total	40	1.28	.847
Anger	RESP	20	1.45	.605
	RISP	20	1.25	.716
	Total	40	1.35	.662
Fear	RESP	20	1.60	.821
	RISP	20	1.00	.562
	Total	40	1.30	.758
Joy	RESP	20	2.00	.858
	RISP	20	1.25	.851
	Total	40	1.63	.925
Tenderness	RESP	20	2.00	.858
	RISP	20	1.15	.587
	Total	40	1.58	.844

Tab. 5 – M and SD of reported N of emotions by both participants in each emotional condition

A Repeated Measure ANOVA was carried out with *Emotion* (Sadness, Disgust, Anger, Fear, Joy and Tenederness) as within-subject variable, *Role* (RESP, RISP) as between variable and number of emotions per judge as dependent variable. Either of main factors *Emotion* ($F(5,190)=3.410$, $p<0.01$) and *Role* ($F(5,190)=13.330$, $p<0.001$) and their interaction Emotion*Role ($F(1,38)=3.420$, $p<0.01$) came out as significant. Graph.2 show the interaction. Emotional Experience was generally more complex for RESPs, who actually read the story, and less for RISPs, who had to guess what their partner was feeling, a part from *Sadness* that shows an opposite trend. The emotions that evoked the widest range of emotional experience were *Tenderness* and *Joy*, the least were instead *Sadness* and *Anger*.

Graph.2 – Emotions*Role Interaction



The differences between *Role* in each conditions were deepened through post hoc pairwise comparisons. *Anger* and *Sadness* are the only two conditions that didn't show significant differences between RESP and RISP.

Next, we investigated whether there were differences between the number of emotions *felt* by RISP and those they *assigned* to their partner. We also assessed whether the number of assigned emotions differ as a function of the emotional condition. Tab.6 presents Mean and Standard Deviation of reported and assigned number of emotions in each emotional condition by RESPs. A Repeated Measure ANOVA was carried out with *Emotion* (Sadness, Disgust, Anger, Fear, Joy and Tenederness) as within-subject variable, *attribution* (Felt, Assigned) as between variable and number of emotions per judge as dependent variable.

Both main factors *Emotion* ($F(5,190)= 4.101$, $p<0.01$) and *Role* ($F(5,190)= 12.161$, $p<0.001$) came out as significant, but not their interaction. RISPs tend to assign more emotions to their partner compared to those they assigned to themselves. Moreover, they assigned a significant wider range of emotions to *Sadness* and more limited to *Disgust*.

		N	Mean	St.D.
Sadness	RISP_felt	20	1.65	.745
	RISP_att	20	1.95	.887
	Total	40	1.80	.823
Disgust	RISP_felt	20	.95	.759
	RISP_att	20	1.45	.686
	Total	40	1.20	.758
Anger	RISP_felt	20	1.25	.716
	RISP_att	20	1.90	.912
	Total	40	1.58	.874
Fear	RISP_felt	20	1.00	.562
	RISP_att	20	1.55	.759
	Total	40	1.28	.716
Joy	RISP_felt	20	1.25	.851
	RISP_att	20	1.70	.865
	Total	40	1.48	.877
Tenderness	RISP_felt	20	1.15	.587
	RISP_att	20	1.80	.834
	Total	40	1.48	.784

Tab. 6 – M and SD of reported and assigned N of emotions by RISPs in each emotional condition

Intensity of Emotional Experience

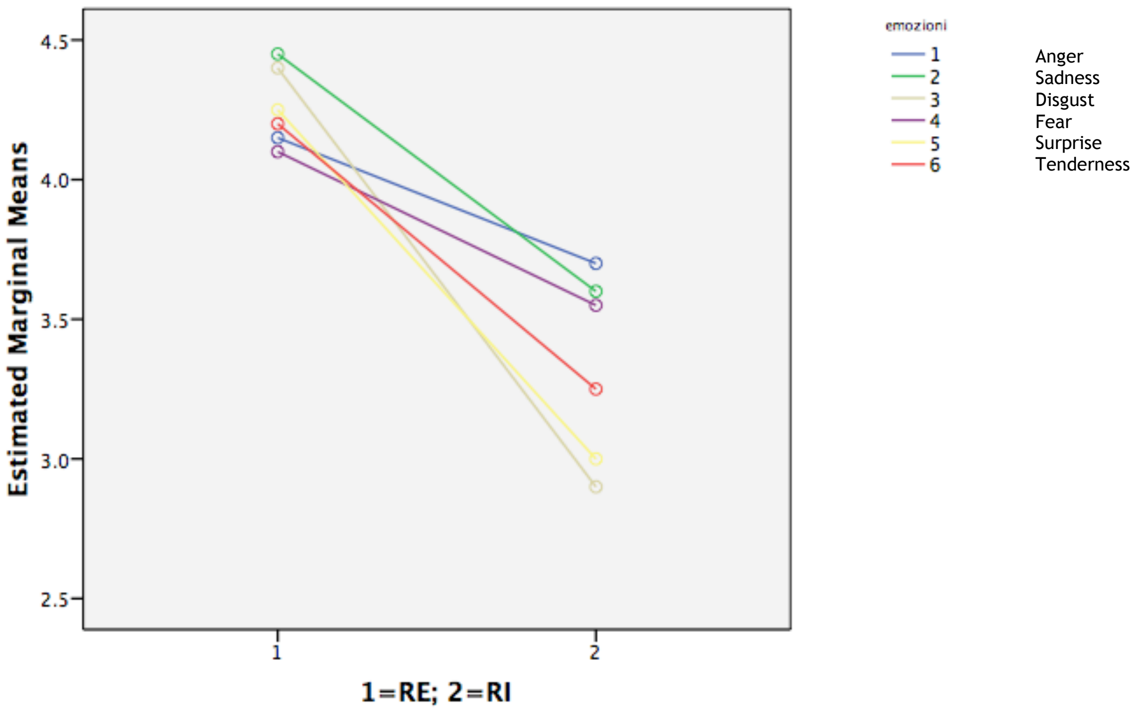
Tab.7 presents Mean and Standard Deviation of reported intensity of emotions by both RESPs and RISPs in each emotional condition.

		N	Mean	St.Dev
Anger	RESP	20	4.15	.933
	RISP	20	3.70	1.342
	Total	40	3.93	1.163
Sadness	RESP	20	4.45	.510
	RISP	20	3.60	1.314
	Total	40	4.02	1.074
Disgust	RESP	20	4.40	.681
	RISP	20	2.90	1.651
	Total	40	3.65	1.460
Fear	RESP	20	4.10	1.210
	RISP	20	3.55	1.317
	Total	40	3.82	1.279
Joy	RESP	20	4.25	.716
	RISP	20	3.00	1.257
	Total	40	3.62	1.192
Tenderness	RESP	20	4.20	.834
	RISP	20	3.25	1.118
	Total	40	3.72	1.086

Tab. 7 – M and SD of reported intensity of emotions by RESPs and RISPs in each emotional condition

To verify whether significant differences emerged between different emotions and between the two different role as intensity of emotional experience is concerned, a Repeated Measure ANOVA was carried out with *Emotion* (Sadness, Disgust, Anger, Fear, Joy and Tenederness) as within-subject variable, *Role* (RESP, RISP) as between variable and principal emotion chosen by each judge as dependent variable. Only the between main factors *Role* ($F(5,190)= 23.459$, $p<0.001$) came out as significant. RESPs tend to report a more intense emotional experience compared to RISPs.

Graph.3 – Reported intensity of emotions by RESPs and RISPs in each emotional condition



We investigated more in detail the differences between *Role* in each conditions through post hoc pairwise comparisons. *Anger* and *Fear* are the only two conditions characterized by similar intensity of emotional experience between RE and RI.

Finally we checked whether RISPs were able to identify the degree of emotional activation of their partners comparing the emotional intensity marked by RESPs in the first chosen emotion and the emotional intensity assigned by RISPs in the attributed emotion. Tab. 8 shows Mean and Standard Deviation of both ratings.

A Repeated Measure ANOVA was carried out with *Emotion* (Sadness, Disgust, Anger, Fear, Joy and Tenederness) as within-subject variable, *Intensity* (felt, assigned,) as between variable and intensity ratings as dependent variable. Only main effect of *Intensity* came out as significant ($F(1,38)=7.395$, $p=0.01$). Post-hoc pairwise comparisons revealed that significant differences occurred in the disgust, tenderness and joy condition.

	intensity	Mean	Std. D.
Anger	RE_felt	4.15	.933
	RI_assigned	4.10	.788
	Total	4.13	.853
Sadness	RE_felt	4.45	.510
	RI_assigned	4.05	.945
	Total	4.25	.776
Disgust	RE_felt	4.40	.681
	RI_assigned	3.70	.801
	Total	4.05	.815
Fear	RE_felt	4.30	.979
	RI_assigned	4.35	.813
	Total	4.32	.888
Joy	RE_felt	4.25	.716
	RI_assigned	3.70	.865
	Total	3.98	.832
Tenderness	RE_felt	4.20	.834
	RI_assigned	3.65	.813
	Total	3.93	.859

Tab. 8 – M and SD of reported intensity of emotions by RESPs and predicted by RISPs

<u>*Similarity of Emotional Experience*</u>

Finally, we investigated the degree of similarity between emotional labels chosen by RESPs and RISPs' to denote their own experience on one side, and that between RISPs felt emotions and those assigned to their partners (RESPs). For each emotion, the amount of time participants used the *same* emotional labels, labels denoted by the *same valence* and finally *different* labels were calculated. A χ^2 test was performed to assess whether any differences occur between the three groups in each emotional condition.

As far as the emotional experiences reported by RESPs and RISPs are concerned (see Tab.9), significant differences emerged ($\chi^2(10)=24.47$, $p<0.01$): number of identical choices were much less than employment of same valence or different labels. Anyway, these last two didn't differ significantly. Compared to expected counts, occurrence of identical labels were significantly less in *Disgust* and significantly more in *Fear*. Considering emotions with the same valence and identical labels, these results anyway suggested a similar emotional experience between the two samples.

RE felt VS RI felt			Attunement			
			Different	Valence	Identity	Total
Emotions	Anger	Count	8	9	3	20
		Expected Count	8.0	7.8	4.2	20.0
		Std. Residual	.0	.4	-.6	
	Sadness	Count	5	7	8	20
		Expected Count	8.0	7.8	4.2	20.0
		Std. Residual	-1.1	-.3	1.9	
	Disgust	Count	13	7	0	20
		Expected Count	8.0	7.8	4.2	20.0
		Std. Residual	1.8	-.3	***-2.0****	
	Fear	Count	7	4	9	20
		Expected Count	8.0	7.8	4.2	20.0
		Std. Residual	-.4	-1.4	***2.4****	
	Joy	Count	9	10	1	20
		Expected Count	8.0	7.8	4.2	20.0
		Std. Residual	.4	.8	-1.6	
	Tenderness	Count	6	10	4	20
		Expected Count	8.0	7.8	4.2	20.0
		Std. Residual	-.7	.8	.0	
	Total	Count	48	47	25	120
		Expected Count	48.0	47.0	25.0	120.0

Tab. 9 – Chi square Results of comparison between RISPs and RESPs felt emotion.

RI assigned VS RI felt			Attunement			
			Different	Valence	Identity	Total
Emotions	Anger	Count	6	4	10	20
		Expected Count	5.8	6.2	8.0	20.0
		Std. Residual	.1	-.9	.7	
	Sadness	Count	5	4	11	20
		Expected Count	5.8	6.2	8.0	20.0
		Std. Residual	-.3	-.9	1.1	
	Disgust	Count	9	5	6	20
		Expected Count	5.8	6.2	8.0	20.0
		Std. Residual	1.3	-.5	-.7	
	Fear	Count	6	3	10	20
		Expected Count	5.5	5.9	7.6	20.0
		Std. Residual	.2	-1.2	.9	
	Joy	Count	6	10	5	20
		Expected Count	6.1	6.5	8.4	20.0
		Std. Residual	.0	1.4	-1.2	
	Tenderness	Count	3	11	6	20
		Expected Count	5.8	6.2	8.0	20.0
		Std. Residual	-1.2	1.9	-.7	
	Total	Count	35	37	48	120
		Expected Count	35.0	37.0	48.0	120.0

Tab. 10 – Chi square Results of comparison between RISPs felt and assigned emotion

Besides, as far as the emotional experiences reported and assigned by RISPs (see tab.10), no significant difference emerged, although there is a tendency to report similar emotions to those assigned to the partner. Moreover, no significant differences between actual occurrences within each emotional condition and expected ones emerged.

4.5 Discussion

This study yielded two relevant findings: first, it was possible to derive a quite detailed acoustic description of breathing patterns related to distinct emotions. Differences and similarities are discussed in the following paragraph and some clustering will be suggested.

Secondly, breathing together actually influences many of the considered attunement dimensions: *emotional decoding, similarity of the emotional experiences*, *perspective taking ability, perceived physical activation*, and *interpersonal synchrony.* Main findings highlighted that participants closely match up the timing of their partner's breathing and this ability improves along time. They were quite able to identify valence, complexity of emotional experience and some specific emotions conveyed by breathing pattern. Finally, they tend to feel a sense of interpersonal similarity and to actually experience similar emotions, in particular for the most identified emotions. Negative emotions were better identified than positive ones and elicited higher levels of emotional intensity and higher perception of similarity with RESPs' experience.

First, assessment of the procedure reliability will be discussed. Then, description of acoustic breathing pattern will be illustrated. Finally, discussion will weave links between the several dimensions of the attunement process to describe their mutual influences: first the behavioural measurement (interpersonal synchrony) will be discussed, then self reports that include identification accuracy results and investigation of participants emotional experience.

4.5.1 Task Evaluation Form

First, the consistence between the *emotional label assigned to the narrative and participants' actual emotional experience performing the task* was assessed and turned out to be identical or at least similar. Consistently with the emotional connation of the experimental Narratives, positive narratives were associated with more diversified emotional labels, although always positively connoted. Thereby, the task was correctly performed.

Analysis of the answers to the *Task Ratings Form* allowed verifying the reliability of the experimental procedure. Similarly to Study 2 the task was judged as a just a little *annoying* (M=2.24/7) and *mechanical* (M=2.70/7) but also much *easier* (M=2.3/7). It was rated as *highly involving* (M=3.98/7) and *intimate* (M=3.83/7). These results prevent us from considering that the task was too difficult o mechanical becoming unnatural or more much cognitive than emotional.

Participants in the attunement role (RISP) were significantly more *involved* and feel more *intimacy* than those in the identification role (RESP) but also more *annoyance*. Thus, the two roles elicited different experiences. These differences could depend on the nature of the task. Previous studies on positive psychology have highlighted the influence perceived skills and challenges on task quality and involvement (Csikszentmihalyi et Massimini, 1985; Massimini et al, 1996; Massimini et Delle Fave, 2000). A fine balance is perceived between personal skills and challenges is one of the main aspect that lead to a fully immersive, focused and successful activity. As the former point is regarded, RISPs have a *clearly defined assignment*, that required an *high degree of concentration* on a *limited field of attention* and rated their assignment as *not too difficult* (M=2.97/7) but more challenging than RESPs did (M=1.61/7); thus, the higher balance between experimental requirements and perceived skills could have foster involvement. Discomfort given to un-natural way of breathing emerged also in the Study 2.

4.5.2 Breathing patterns

This study also yielded to the description of differentiated acoustic breathing patterns among the chosen emotional conditions, in part congruent with previous findings of Boiten et al (1994) and Philippot et al. (2002).

Fear is associated with *regular, fast* (actually the *fastest pattern,* along with Anger), *nasal breathing* and with the *shortest pauses durations* (again not different from Anger), paralleling previous findings (Boiten et al, 1994; Bloch et al, 1991). It was also characterized by the *highest variability among pauses durations*. Actually, being associated with the shortest pauses durations, just small longer pauses are able to make the variations rouse up significantly, although they are not clearly detectable through hearing, being on average 0.087 sec. The same as Anger pattern is concerned. Thus, Variability is much more interesting to make distinction between Disgust and other emotional pattern, since it has a much higher mean (0.536 sec) and wider range of variation (1.444 sec), thus in perceptual terms it is much more noticeable. In fact, it is significantly different from all other emotional patterns. From an acoustic point of view, it is characterized by the *loudest expiratory* (along with Anger and Sadness) and *inspiratory sounds* (along with Anger). It is characterized by *highly differentiated Expirations and Inspirations timbre*, since it is associated with *average E brightness* and by the *brightest Inspirations* (however not significantly different from Anger and Sadness). Variations in Expirations are among the lowest along with Anger and Joy, while Inspirations variability is on average. Finally, a *high number of accented inspirations*, together with Sadness and Disgust, and an *average number of accented expirations* (not different from Anger, Disgust, Baseline, Tenderness and Joy) were reported.

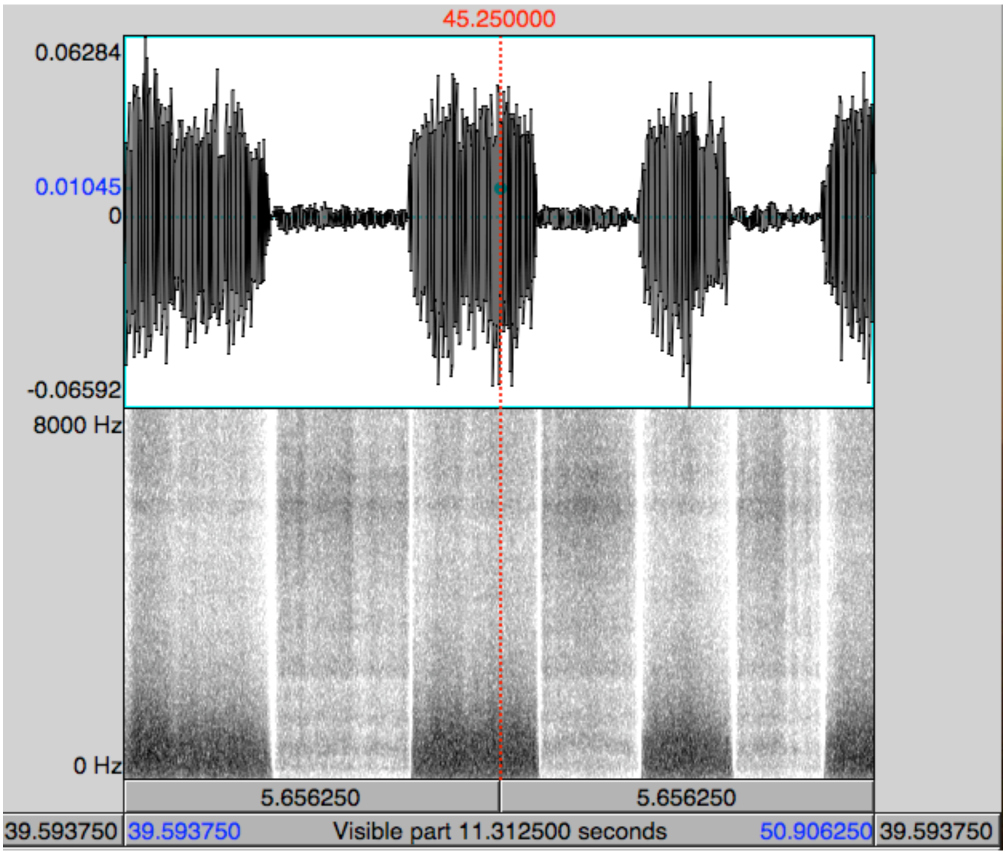


Fig.1 - Example of Fear breathing pattern

As previously mentioned, *Fear* pattern is close to ***Anger****'s one*, that is equally characterized by *regular, fast, nasal breathing* and with the *shortest pauses duration*, again consistently with previous descriptions (Boiten et al, 1998; Bloch et al, 1991 and Philippot et al, 2002). They share also *similar I durations* and *post inspiratory pauses durations*. Anyway, Anger is characterized by significantly *longer Cycle Duration*, *longer inspirations* (resulting in *higher E/I ratio*) and *wider pauses variations*. As acoustic indexes are concerned, Anger is associated with the *loudest expiratory sounds*, softer but no significantly different from Fear, but with significantly *lower inspirations*. Concerning Energy, Anger is also similar to Sadness: they are characterized by quite identical Inspiration and, although Anger's Expirations sound louder, the difference doesn't reach significance. Anger's is associated with the *brightest Inspirations* (along with Fear) and *quite dark Expirations* (while Fear is characterized by bright ones). Expiration timbre is not significantly different from the others, made exception for Disgust and Joy. Spectral centroid doesn't show great variations: Expirations are among the lowest along with Fear and Joy, while Inspirations are on average. This particular feature of Anger breathing sound emerged also in Study 2: loud expiratory sounds and "dark" timbre, almost sonorous. Such timbre derived from little tension at the laryngeal level and a raised attack level of the sound, partially involving the arytenoids. Finally, it is associated with an *average number of accented expirations* (as for Tenderness, Disgust, Baseline and Fear) and a low of accented inspirations (together with Tenderness and Joy).

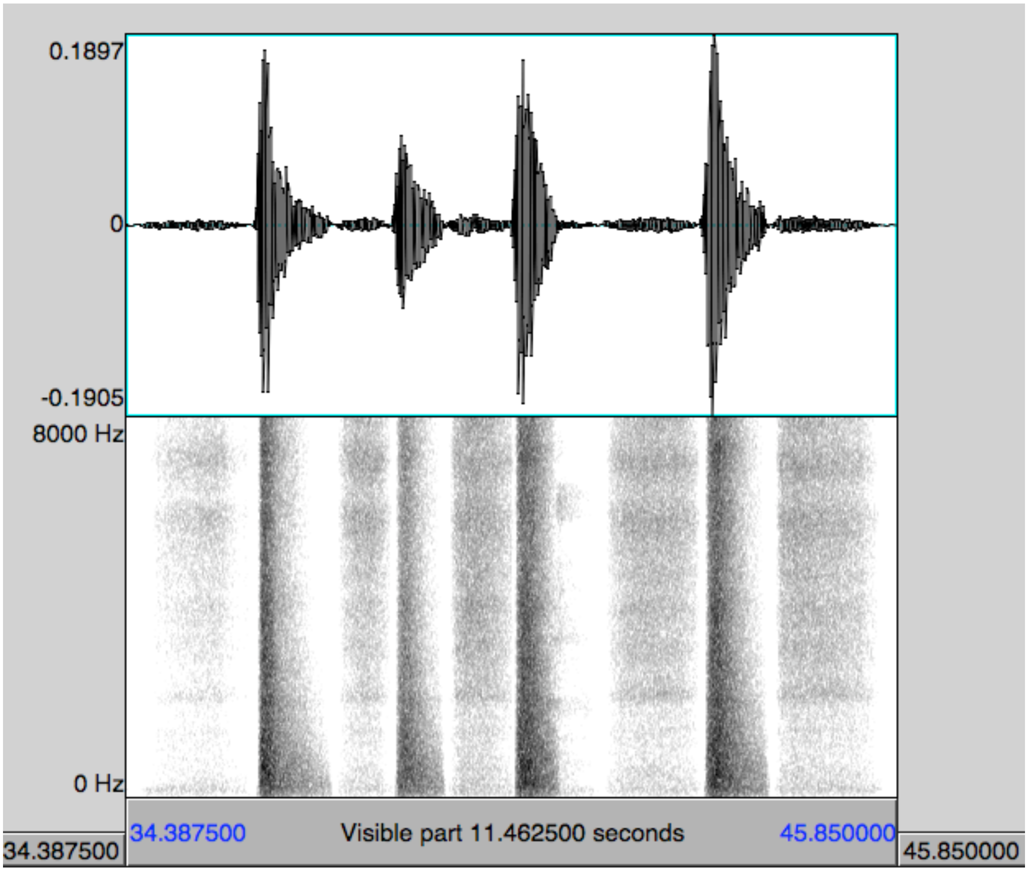


Fig.2 – Example of Anger breathing pattern

With respect to ***Sadness***, it shows a *quite regular nasal pattern with average frequency*. It is associated with *quite long Inspiration and expirations* and with *the lowest E/I ratio*, significantly different from Anger's one but not from the any of the other previous conditions. *Pauses are on average*, as much as their variability: their duration is not significantly different than the previous one characterizing Joy and the following one characterizing Disgust but significantly longer than those associated with Fear and Baseline. Its sound is associated with *loud Expiration sounds,* similar to Anger and Fear and Disgust, and with average Inspiration levels, as for Tenderness and Joy. *Expirations sound bright* (not different from Baseline and Fear but brighter than Joy and Disgust) *and Inspiration highly bright* (similar to Anger and Fear), both characterized *by average variability.* As far as accented breath are concerned, Sadness is characterized by an high number of accented inspirations, together with Disgust and Fear, and by the highest number of accented expirations, more than all other conditions, resembling the small jolts described by Bloch's et al. Thus, normal frequency is consistent with all previous works, while tremors in expirations were not reported before.

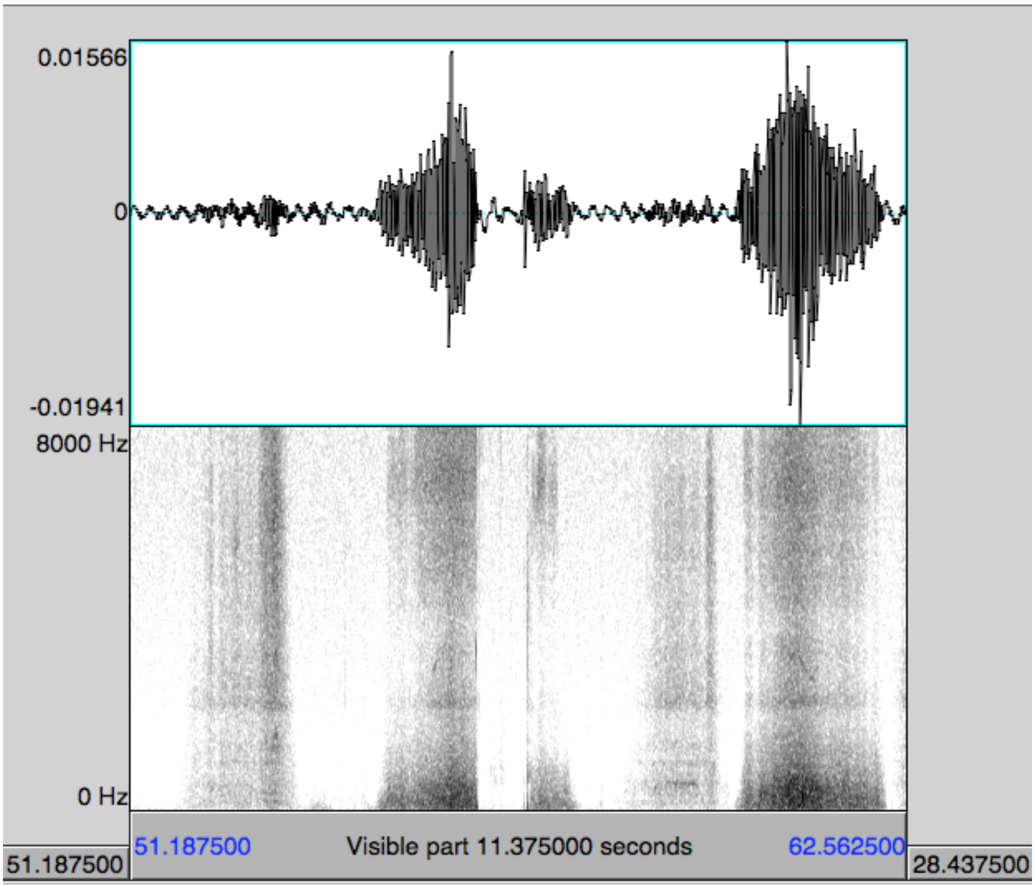


Fig.3 - Example of Sadness breathing pattern

Joy is associated with *nasal, quite regular, and quite fast pattern*, significantly more than Tenderness and Baseline. These results parallel Boiten et al. distinction between calm happiness (tenderness) and excited joy (joy), being respectively associated with slow and fast breathing. It is associated with an *average E/I ratio* and *quite short pauses duration*, although not significantly different from Disgust and Sadness. From an acoustic point of view it is characterized by generally soft sounds both in Expirations and Inspirations, significantly louder than Baseline but not different from Tenderness, neither in Expiration and Inspiration sounds. Joy is characterized by the *darkest Expiration sounds* ($p<0.001$) and *dark Inspiration values* too (similar to Tenderness). Variations in brightness are on average. As far as *accented breath* are concerned, Joy is characterized by a low number of accents in inspirations, together with Tenderness and Anger, and by an average number of accented expirations, not different from Disgust, Baseline, Fear and Tenderness.

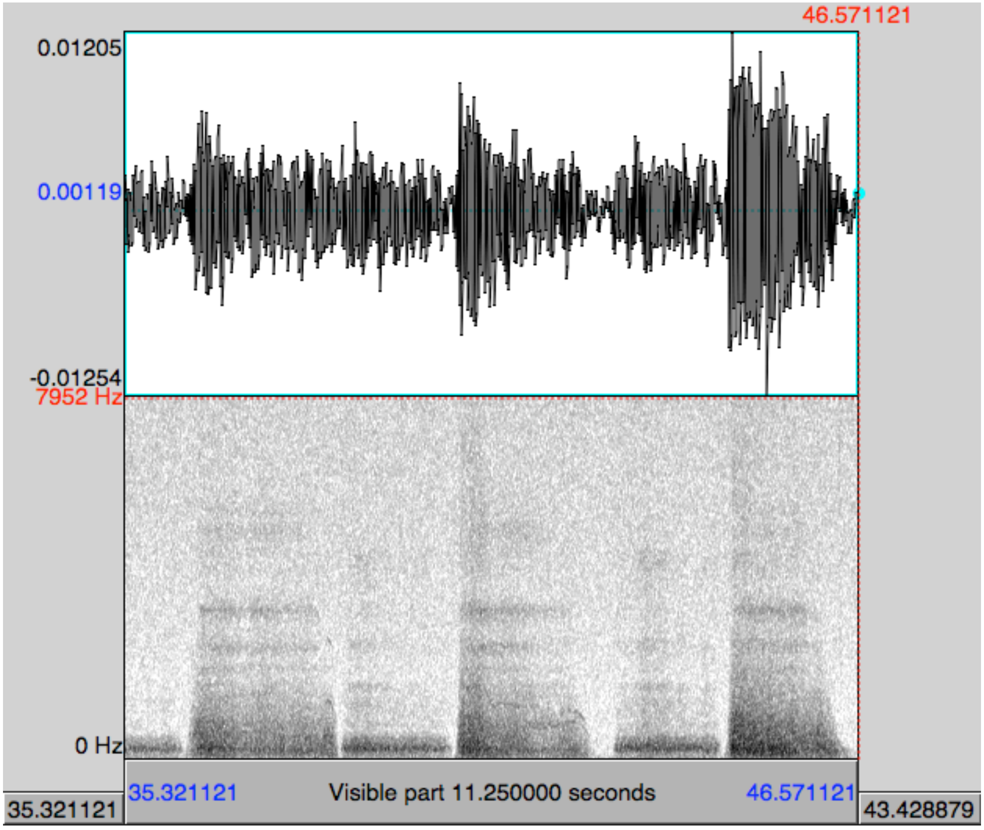


Fig.4 – Example of Joy breathing pattern

Tenderness could be thus distinguished from Joy pattern: it is the *slowest pattern* (even significantly slower than Baseline), *highly irregular* and associated with the *longest pauses durations*, in particular after expiration, again characterized by with *high variability*. It is associated by the *longest inspirations and expirations* and by a high, but not distinctive, E/I ratio. As acoustic parameters are concerned, Tenderness is characterized by *soft Expirations and Inspirations,* although significantly louder than Baseline. It could not be significantly differentiated from Joy neither in Expiration and Inspiration intensity. Expirations have an *average brightness values*, significantly more than Joy and less than Baseline, and by *low inspiration value* (similar to Joy and Baseline). Beside, *brightness* *variability* is much more pronounced than all other emotions, although not than Baseline. Inspirations and Expirations sounds are more similar compared to other patterns, as it happens for Baseline and Disgust. Finally, Tenderness is characterized by a *low number of accents in inspirations,* together with Joy and Anger, and by an average number of accented expirations, not different from Disgust, Baseline, Fear and Joy. Thus, it could be differentiated from Joy being associated with brighter expirations and much greater timbre variability.

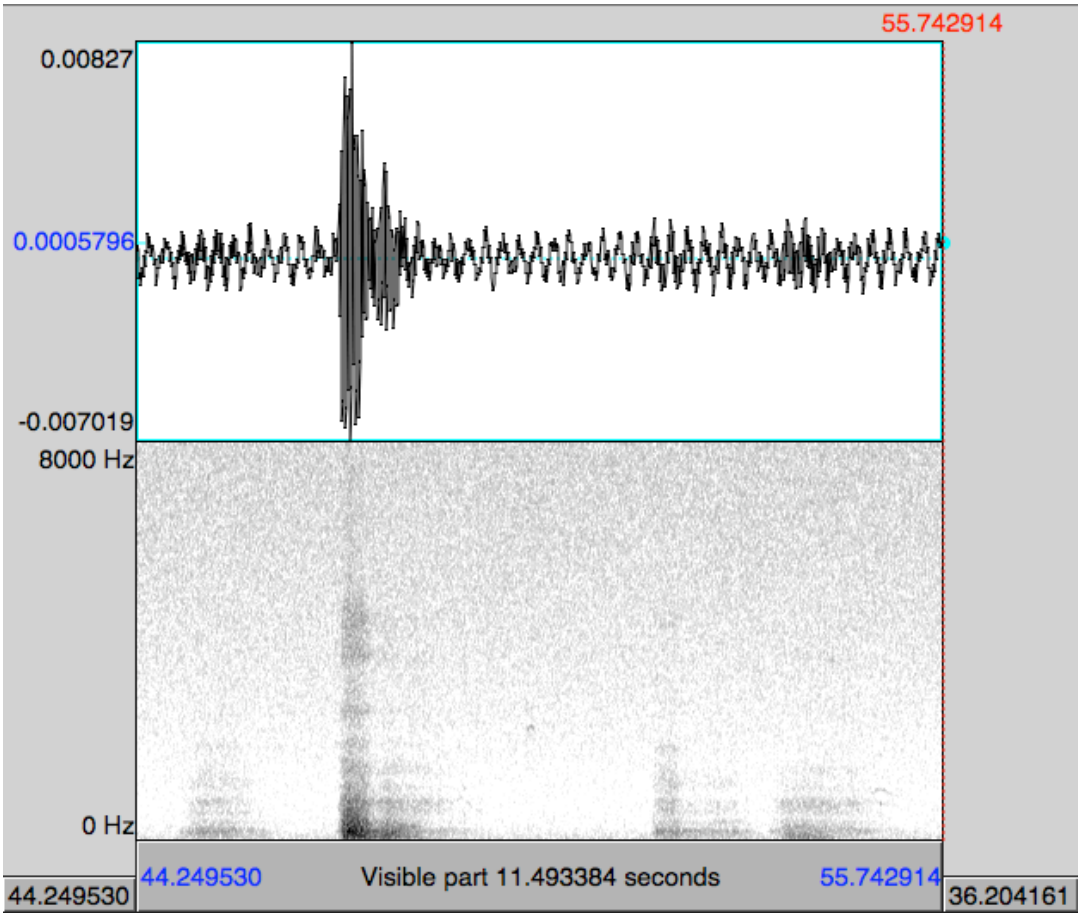


Fig.5 – Example of Tenderness breathing pattern

Finally, ***Disgust*** is associated with a *nasal*, *rather fast pattern*, together with Joy, and *highly irregular* along with Anger and Fear. Anyway, as already said for pauses duration in Fear discussion, Anger and Fear are characterized by the shortest breath durations so that even small, unperceivable increases make the variations rouse up significantly. Beside, this variability is much more evident and perceivable in Disgust. Both *expirations and inspirations are short*, and it is characterized by one of the highest *E/I ratio* (not distinctive) associated with the *widest amount of variability*, more than all other emotions. *Pauses durations are on average*, together with Joy and Sadness. Moreover, it has the longest post inspiratory pauses and it is *the only pattern* where these are longer than post expiratory, although it doesn't reach complete significance (p= .058). The reason is that disgust seems to be associated with the greatest number of interrupted breaths and often breath-holdings occurred after inspirations, in contrast with all other conditions. This pattern is characterized by *quite loud Expiration sounds* (although not significantly higher than Fear and Anger) and *one the highest Inspiration intensity* that anyway appears to be not significantly different than Anger, Sadness and Joy. As *Spectral centroid* is concerned, Disgust shows a specific pattern: it is associated with the *brightest Expirations* (made excepted for Fear) and by an *intermediate but exclusive inspiration value*, different from all other patterns. Inspirations and Expirations sounds are more similar compared to other patterns, as it happens for Baseline and Tenderness. Spectral centroid variations are characterized by a central value, that is specific for Expirations but not distinctive for Inspirations. Finally Disgust is characterized by a high number of accented inspirations and by an average number of accented expirations.

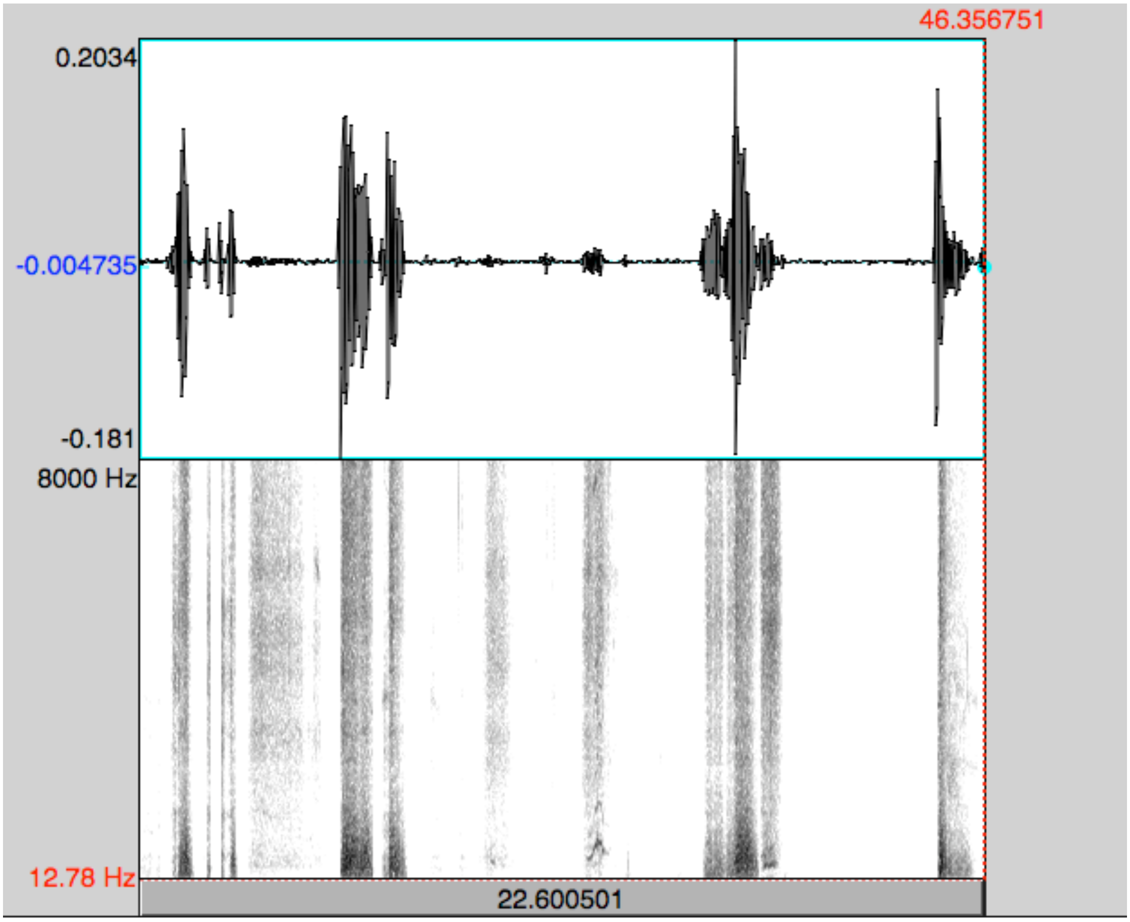


Fig.6 - Example of Disgust breathing pattern

Generally speaking, on the basis of their acoustic and respiratory features, previously described emotions could be grouped in three clusters: one includes baseline and tenderness, another anger and fear and the last disgust, sadness and joy.

Consistently with Boiten's work (1998), *Tenderness* was quite similar to *Baseline*. It could be differentiated having a slower RR, more marked cycle duration variability, longer and louder inspirations and expirations, darker and less variable expirations.

Anger and *Fear* are characterized by regular, fast, nasal breathing and by the shortest pauses duration. From an acoustic point of view, they are both associated with the loudest expiratory sounds, the brightest inspirations and a similar number of accented inspirations. They could be differentiated since Anger is characterized by longer inspirations (resulting in higher E/I ratio), wider pauses variations, lower inspirations and quite dark Expirations.

Disgust, *Sadness* and *Joy* share less features but are generally characterized by *intermediate values* compared to the other two groups.

4.5.3. Synchronization patterns

Synchronization analyses pointed out that participants tend to synchronize their breathing to the partner's: all emotions were in fact associated with lag between paired breaths below 500 sec, made exception for Tenderness.

Differences emerged between emotional conditions. In particular, participants were more able to synchronize with their partner in Fear and Anger, while Tenderness arise the greatest difficulty. The formers were the quicker patterns, while the latter was the slowest. Therefore the fastest the respiration rate, the easiest the ability to go along together. Moreover, while synchronization trend reflects quite well cycle duration one, it doesn't seem to be correlated to emotional identification accuracy; that is, respiratory synchrony didn't facilitate emotion recognition. Sadness, for example, was one of the less synchronous (M=0.465) but also one of the most identified. Disgust, beside, was more synchronous but worse decoded.

Generally, three groups could be delimited: fear and anger were the most synchronous, followed by Sadenss, Joy and Disgust, and finally by Tenderness and Baseline. Interestingly, these clusters group emotions that also share similar acoustic and respiratory characteristics (see following paragraph). Fear and Anger are the fastest, the most regular and loudest patterns, being as a result easier to mirror. Tenderness and Baseline, besides, are the slowest, softest and most irregular patterns, being much more difficult to hear and to follow. Finally, the third group is characterized by mean values both as breathing and synchronization pattern are considered.

Analyses of synchronization trends along time highlighted significant dissimilarities between different moment of the task and allow a more precise description of trends characterizing different emotions.

In Fear and Anger conditions, RISPs were able to follow their partner really closely, being the greatest amount of occurrences in the most synchronous categories (0-100 ms and 100-250 ms), and the least in the most asynchronous. Tenderness shows an opposite trend, also worse than Baseline although not at a significant level. Finally, Sadness, Disgust and Joy are quite equally distributed in the three synchronous categories. However, while Disgust and Joy are characterized by less asynchronous breaths, Sadness show a similar trend.

As synchronism through time is considered, participants *show an improvement from the first to the third moment* in almost all emotional conditions, made exception for Tenderness and Anger: the former tend to get worse in the central part of the task, while the latter, after a first evident improvement, show a slight worsening. More detailed description of acoustic features of breathing patterns along time could provide more data to interpret these two exceptions. Consistently, as time goes by an *increasing number of synchronous breaths occurred between 0 and 250 ms*.

4.5.4. Identification Accuracy

As mentioned before, RESPs were quite able to predict the actual ranking of the emotions decoding: Anger, Fear and Sadness were marked as the most identified, Tenderness, Disgust and Joy the least. Global percentage of identification accuracy was again quite low, also lower than Study 2 (32.6% vs 41.9%). Sadness identification decrease (40% vs 95%) but this is due to due employment of a more reliable stimulus, that excluded extreme expressions of crying. Disgust obtained the same result (10%) while Anger increased (45% vs 39%). However, considering that quite distinct breathing patterns related to different emotions could be drawn, this result could depend on the fact that participants were not used to rely on such cues to infer emotional information. Anyway, it is not possible to make more in depth comparison, since the emotional stimuli and the sample size where too different. Further investigations are needed to spread light on this point, involving a wider sample of participants.

As unbiased hit rates are regarded, Fear was the most identified emotion, followed by Anger, Sadness, Joy, Tenderness and Disgust. Made exception for Anger, that was significantly more recognized than Disgust, the other didn’t differ significantly one from. Moreover, participants were *significantly able to identify the valence* of the target emotions, made exception for Joy (that, anyway, tend to evoke more positive labels than negative ones). These results are not consistent with the study on breathing manipulation carried out by Philippot et al. (2002): they reported higher degree of identification in Joy and Anger, while *fear* induced feeling of anger as much, and *sadness* positive feelings. Raw hit rates allowed a deeper analysis of confusions in each emotional condition. The most frequent confusion in *Fear* condition was "sadness despair" choice. Beside, *Sadness* was more often target as "worry fear" that with the right label. Interestingly RESP attribute more often to themselves Sadness Despair than to their partner. These two breathing patterns actually share similar E/I Ratio, E energy and I and E Spectral Centroid. Thus, the most confusing aspects seem to regard more acoustic than respiratory features.

Anger is often confused with Worry Fear too. This result is consistent with previous studies (Philippot et al 2002) and, looking and the breathing pattern features, they share many similarities both among respiratory and acoustic indexes: similar Respiratory Rate, E durations, Post inspiratory pauses duration, E energy, I spectral Centroid and Accented inspiration.

Joy emotional space is wider than previous emotions and no significant differences emerged among chosen labels. This is the only emotion which valence was not recognized: targeted emotions ranged from "enjoyment pleasure" to "irritation anger". Also Tenderness emotional space is complex and not focused on a single emotion, but the positive valence was successfully identified. This breathing pattern was in fact mainly confused with "feeling disburdened relief", followed by, "enjoyment pleasure" and "happiness joy". Therefore, positive narratives tend to evoke broader and less defined emotional feelings, resulting in a more general sense of well-being, while negative emotions that tend to be associated with less and more specific emotional labels (made exception of disgust). This is consistent with previous literature on positive emotions: they don't lead to specific action tendencies, rather they widen the range of potential actions body and mind are prepared to do (Fredrickson et Branigan, 2005).

Finally, as it happened in Study 2, Disgust was the less identified emotion. The emotional space is characterized by many difference choices, anyway mainly characterized by negative valence Interestingly, "worry fear" was the prevailing label, which was actually one of the emotions evoked by the experimental narrative (when the character find herself lock into a disgusting toilet and is unable to get out). Among negative labels, it was also targeted as "guilty remorse", "embarrassment shame", "irritation anger" and "contempt scorn".

Thus, RISP's decoding ability change considerably as the emotion is concerned.

Negative emotions were better identified than positive ones and, as previously mentioned, elicited higher levels of emotional intensity and higher perception of similarity with RESPs' experience. As said before, this analyses allowed also a comparison with the emotion felt by the judges, that tend to be similar those assigned to the partner.

Finally, weighting synchrony in function of respiratory rate, it emerged that participants generally *tended to synchronize their breath within 250-500ms or more*. Since such indexes have only descriptive power and could not be run in strong inferential analyses, further analysis will be carried on be using a weighted index that consider both RR and synchrony along time.

Concluding, although synchrony seems not to be related to identification accuracy, participants generally asked to breath "as their partner" *actually tend to closely match up timing of their partner's breathing. Increased synchrony through time suggests that it improves participants timing ability and better predict partner's breathing behaviour.* Moreover, considering our data on emotional attunement, synchronization, consistently with previous literature, appear to be correlated to emotional responding and sense of interpersonal similarity; anyway these data don't allow inferences about its power to increase or enhance such features, (Valdesolo et al, 2010).

Since synchronization seems not related to emotional decoding, beside temporal features of breathing pattern other acoustic characteristics, such as energy and timbre should be considered. It is likely that not only "breathing as the same tempo", but also "breathing in the same way" provided useful cues to our participants in order to correctly identify different emotions. Asynchronous participants could be anyway able to closely mirror specific timing patterns or distinctive acoustic features of breathing sounds, and this could turned out to be more relevant to improve attunement quality. Therefore, further, more detailed analysis of the qualitative dimension of communicative attunement could provide new insights on the balancing between qualitive and quantittave dimension of such process and on the relation between emotional and communicative attunement.

4.5.5. Emotional Experience, Perspective Taking and Perceived Physical Activation

The *Attunement Items* analyses include questions that required making hypothesis on what the partner was feeling. First, RESPs *rated* the *identification accuracy* of their partner on an average level (M=3.64) and significant differences between emotional conditions emerged: Joy was considered the hardest to understand, significantly more difficult than Anger, Sadness and Fear, while this one was reputed the easiest. Actually, mean identification accuracy was quite low (34.67%), although with a high range of variation. Thus, RESPs seemed to have overestimated the emotional decoding skills of their partner. Interestingly they were quite able to predict the actual ranking of the emotions decoding: Anger, Fear and Sadness were marked as the most identified, Tenderness, Disgust and Joy the least. They rated Fear as the most recognized and Joy as the least. Fear is actually the most identified emotion, both as raw and unbiased hit rates are considered. Joy is one of the less recognized but it was significantly more recognized than Disgust; besides, it was one of the emotions that aroused the *highest emotional complexity* in both roles (significantly more than Disgust), thus RESPs could have been considered this one as more difficult compared to disgust.

From the *analysis of the complexity of participants' emotional experience* other interesting evidences emerged: RESPs generally reported more composite emotional experience compared to RISPs, made exception for Sadness that elicited the widest number of felt emotions. Disgust instead, evoked the most limited number of emotions in RISPs. RESPs actually marked Sadness as the emotional condition that aroused the most complex experience and Disgust the least in their partners. *Thus, although RESPs overrated the global decoding ability of their partners, they were anyway quite able to predict more subtle aspects, related to identification of individual emotions and to complexity of their emotional experience.*

RISP considered *breathing together as useful to improve identification* (M=4.39/7) and think that this led them to *feel physical feelings similar* to those of their partner (M=4.23/7). Regarding the benefit of breathing together in enhancing identification, RISPs overrate their decoding performance since their actual *global identification rates* is much lower. Anyway, considering *emotional experience analyses* and *comparison between felt and attributed emotions*, *RISPs actually tend to report similar emotions to the partner*. The breathing pattern that aroused most similar emotional experience was Fear, while Disgust evoked the most dissimilar; these two emotions were also, respectively, the most and the least identified. In an appraisal perspective (Arnold, 1960; Lazarus, 1966; Scherer, 2001) the kind of emotions individual experience depends on the result of his/her *evaluation* of the stimulus event. Moreover, correct identification of other's affective states is considered one of the primary prerequisite for empathy (Feshbach, 1975). Thus, it is likely that participants who were able to correctly identify the underlying emotion were also more likely to empathically react to their partner. This is also consistent with the high rates of perceived intimacy. Otherwise, they react differently, basing their attribution on other cues.

This is also consistent with Schacter and Singer's Theory (1962), according to people that have no immediate explanation for a felt physiological arousal, will label the feelings based on cues available to them. When cues were not enough, responses variability increased, as *comparison between felt and attributed emotions* in the confusion matrix analyses shown. Consistently, participants reporter to have felt more similar physical feelings in Fear, Sadness and Anger conditions compared to Joy, Disgust and Tenderness. Again, the formers were the most identified. Moreover, emotional intensity was actually similar to that reported by RESPs in Anger and Fear conditions.

The matrices analyses also underline that RISPs tend to felt similar emotions to those assigned to their partner. This result underlines, from another perspective, the same *tendency to feel similar to the partner*.

RISP's were also able to identify the *valence* of the emotional breathing patterns above chance, made exception for Joy. As *intensity* of emotional experience is regarded, RESPs generally felt more intense emotions than RISPs, made exception in Anger and Fear that are not only among the most identified but also those characterized by higher Respiratory Rate, that could induce more physiological activation. Beside, RISPs were not always able to deduce the correct emotional intensity of their partners: attributions were correct as far as Sadness, Fear and Anger are concerned, but *lower* for the others. Actually, Tenderness RR was generally slow being associated with low level of arousal: therefore, feeling high level of tenderness does not coincide with high level of activation, and his could have generate some confusion in the attribution task. Joy and Disgust, instead are characterize by quite fast RR, although not as quick as anger and fear. These breathing patterns were among the less identified and highly confused with other labels. It possible that such indeterminateness, associated with middle values of RR, leads participants to rate intensity at a lower level. Thus, while our data suggest that respiratory pattern could convey reliable cues about emotional *valence*, consistently with previous works (Cohen, 1975; Umezawa, 1992; Boiten, 1988), they are less reliable in conveying information about emotional intensity, in particular as positive emotions are regarded. This could stems from confusion between emotional intensity and arousal levels.

Thus, RISPs felt similar experiences compared to their partner, and this was mediates by the their understanding of the emotion conveyed by specific breathing patterns and by respiratory frequency, that could induce more physiological arousal.

5.

Conclusions

The Thesis was articulated in three studied aimed to investigate expressive functions of breathing sounds in imitation and emotional attunement.

The first study was aimed to build an effective *multilayer analysis model* of breathing sounds. Beside the development of a valuable extraction method, the final model is made up of three set of indexes: *respiratory, acoustic and interactive indexes.* The first includes some of the conventional measurements of *temporal* features of respiratory signal, derived from acoustic measurements: *Respiratory rate, Cycle duration, Inspiratory time, Expiratory time, I:E ratio, Expiratory Pauses Duration, Inspiratory Pauses Duration, Number of breaths / min, Number of Expirations / min, Number of inspirations / min, Number of apnoeas / min.* The acoustic level includes: *Inspiration Intensity, Expiration Intensity, Envelope Amplitude of breathing sound-tracks, Insp. Spectral Centroid, Exp. Spectral Centroid and N of accented breaths.* Finally, a set of coordination indexes that allow to determine the temporal distance that occurs between couple of closest breaths in participants' breathing patterns was developed. The following descriptors were included in the final analysis model: *mean, standard deviation and range of the lag between couple of closest breaths' onsets; N of simultaneous breaths within fixed thresholds / tot amount of breaths (0-100ms / 100-250ms / 250-500 ms)*; *N of simultaneous breaths within fixed threshold / tot amount of breaths (>500ms).* This model turned to be effective in the description of breathing pattern that made up the experimental stimuli of the second Study and the collected emotional breathing patterns in the Third Study. Moreover, it enables a valuable and subtle description of interpersonal synchrony in the attunement tasks. The enrichment of the model with new indexes, in particular able to deepen the investigation of timbral aspects, could provide new information on breathing sounds features.

The second study was set in order to see what could be reliably convey by breathing sounds about a person's *identity*, *emotional state* and *activity* and to test whether *mimicking* those breathing patterns would have enhanced identification accuracy compared to *mere listening*. Ecological tracks of breathing sounds related to 6 *activities* and 4 *emotions* were used as experimental stimuli. Activities differ for degree of mental concentration and physical effort: jogging, stretching, obstacle course, shangai game, mental task and resting.

Emotions differed for hedonic valence: anger, sadness, disgust and amusement. One experimental group listen to set of breathing patterns and fill in a questionnare investigating identification accuracy and emotional experience, while another mimicked them before responding. Results provided evidences that acoustic breathing pattern convey reliable information about a person's *identity*, *emotional state* and performed *activity* and, moreover, that imitation significantly improves identification accuracy compared to listening. Results on mimicry efficacy are consistent with previous literature. First, eith the hypothesis that that imitation of expressive behaviours (e.g., facial and vocal expressions) could trigger similar experiences of those felt by the mimicked person (Lipps, 1907; Hess et al, 1992; Hatfield et al, 1992). Moreover, to Phillippot et al study (2002) that underlined the effectiveness breathing manipulation in inducing physiological states similar to those of the mimicked emotion. A problem that emerged from this study was that global percentages of *activity* and *emotions identification* were quite low. Besides, since a wider sample of breathing patterns would have needed, it was not possible to make any reliable description of distinct acoustic patterns related to specific emotions.

The third study was thus directed to collect a wider sample of breathing sounds in order to see whether distinctive patterns could be related related to different emotions (anger, fear, sadness, disgust, joy and tenderness). Secondly, it was aimed to investigate if participants co-presence would have promoted emotional responding, giving opportunity of reciprocal attunement that was instead prevented in mere listening to audio tracks. To see how "breathing together" influences the attunement process between participants, different dimensions were controlled: *emotional decoding, similarity of the emotional experiences*, *perspective taking, perceived physical activation*, and *synchronization.* Narrative were used as a mean of emotional inductions, then participants were asked to breath as if they actually were in that described situation. Her partner had to listen to her breathing and to express her closeness breathing together with her, in the same way. Different data collection technique were used: audio recording of breathing sounds provided information about features of distinct *emotional breathing patterns* and about *interpersonal synchrony* between participants in the attunement task. Self-reports allowed the investigation of participants' *subjective experience.* The study yielded two relevant findings: first, thanks to the analysis model derived from the first study, it was possible to draw detailed acoustic descriptions of breathing patterns related to distinct emotions. Secondly, breathing together actually influences many of the attunement dimensions under investigation: participants closely match up the timing of their partner's breathing become more able as time goes through; they were quite able to correctly define valence and some specific emotions conveyed by breathing pattern. They were able to predict their partner experience and what's more, they tend to feel a sense of interpersonal similarity and to experience similar emotions.

This work as a whole provide evidences that, far from being only a physiological process, could also be *perceived* and could convey reliable information about the person identity and emotional experience that could not be derived from physiological indexes alone. Moreover, being strictly related to body and mind and being under both automatic and intentional control, it could be manipulated in order to improve emotional understanding and foster interpersonal attunement. These result could have wide applications in therapeutic settings and interpersonal relations management, like help lines that could rely only on vocal cues; moreover, they could provide new insights to promote advances in devices for facilitated communication, like that realized by Plotnick et al (2010): this system is cheap, simple and effective and could probably become more effective if it was able to provide emotional and paralinguistic cues too by modulation of breathing features.

Being a new field of research, further investigations are needed, both to confirm and widen the discussed results. Anyway it is likely to provide new, significant understanding is the fields of affective, communication and positive psychology.

Appendix 1 - Study 2

Activity Sheet

1) Secondo te la persona che hai sentito era: ☐ Maschio ☐ Femmina

2) Il soggetto che hai udito sta svolgendo una certa attività. Secondo te quanto essa lo impegna da un punto di vista *fisico* e *mentale*? Valutalo da 1 a 7 (1=poco; 7=molto):

   a. Grado di *sforzo* fisico 1 2 3 4 5 6 7

   b. Grado di *concentrazione mentale* 1 2 3 4 5 6 7

3) In che tipo di attività pensi che la persona sia coinvolta? Seleziona una risposta:

☐ Inattività	☐ Step
☐ Sollevamento pesi	☐ Percorso a ostacoli
☐ Gioco di Shangai	☐ Jogging
☐ Lettura	☐ Rassettaggio di una stanza
☐ Disegno	☐ Sonno
☐ Stretching	☐ Problema di logica

4) Pensi che il soggetto stesse provando un'emozione? ☐ SI ☐ NO

   Se sì, utilizzando la ruota delle emozioni, scegli quali e di ciascuna specifica *l'intensità* attribuendole un punteggio da 1=pochissimo a 5=moltissimo. Cerchia poi l'emozione per te principale.

Emotion Sheet

1) Secondo te la persona che hai sentito era: ☐ Maschio ☐ Femmina

2) Pensi che il soggetto stesse provando un'emozione? ☐ SI ☐ NO

   Se sì, utilizzando la ruota delle emozioni, scegli quali e di ciascuna specifica *l'intensità* attribuendole un punteggio da 1=pochissimo a 5=moltissimo. Cerchia poi l'emozione per te principale.

3) Secondo te quanto il soggetto è impegnato da un punto di vista *fisico* e *mentale*? Valutalo da 1 a 7 (1=poco; 7= molto):

   a. Grado di *sforzo* fisico 1 2 3 4 5 6 7

   b. Grado di *concentrazione mentale* 1 2 3 4 5 6 7

4) Pensa a come ti sei sentito tu mentre ascoltavi questo respiro: hai provato delle emozioni?

☐ SI ☐ NO

Se sì, utilizzando la ruota delle emozioni, scegli quali e di ciascuna specifica *l'intensità* attribuendole un punteggio da 1=pochissimo a 5=moltissimo. Cerchia poi l'emozione per te principale.

Task Evaluation Form - Listening

"Ripensa a come è stato per te **nel complesso** l'ascolto di questi respiri:

1) Ascoltare questi stimoli è stato:

   a. Difficile perché non l'avevo mai fatto prima 1 2 3 4 5 6 7
   b. Utile per mettermi nei panni dell'altro 1 2 3 4 5 6 7
   c. Fastidioso perché non era il mio modo spontaneo di respirare 1 2 3 4 5 6 7
   d. Coinvolgente perché mi sono sentito attivato fisicamente 1 2 3 4 5 6 7

2) Per rispondere alle domande ti è capitato di ritrovarti a imitare il respiro che avevi ascoltato? ☐ SI ☐ NO"

Task Evaluation Form – Mimicry

"Ripensa a come è stato per te **nel complesso** imitare questi respiri:

1) Imitare la respirazione delle persone che hai udito è stato:

   a. Difficile perché non l'avevo mai fatto prima 1 2 3 4 5 6 7
   b. Utile per mettermi nei panni dell'altro 1 2 3 4 5 6 7
   c. Fastidioso perché non era il mio spontaneo di respirare 1 2 3 4 5 6 7
   d. Meccanico: l'ho fatto perché mi è stato chiesto 1 2 3 4 5 6 7
   e. Coinvolgente perché mi sono sentito attivato fisicamente 1 2 3 4 5 6 7

2) Quanto imitare il respiro dell'altro ti ha aiutato a provare sensazioni fisiche simili alle sue? 1 2 3 4 5 6 7"

Appendix 2 - Study 3

Narratives

Anger

Il viaggio comincia male. Detesti guidare con il sole contro! La strada è brutta e accidentata e, all'improvviso, su di un tratto deserto di strada uno pneumatico si sgonfia.

Marco è stato chiaro: questa volta ti aspetterà soltanto fino alle tre.

Inizi a sentirti terribilmente nervosa.

Proprio oggi che avevi fretta, accidenti!

Scendi, ti togli il tuo copri-spalle elegante e apri il piccolo bagagliaio.

Ti irrigidisci: non c'è il cric.

Impossibile!!

Il sole picchia forte, inizi a girare nervosamente avanti e indietro, spremendoti le meningi: "Ma dove li mettono i cric su queste stupide macchine sportive, porco cane!!"

Digrigni i denti e stringi a pugno le mani sudate.

Sulla strada non passa anima viva.

Guardi sotto il sedile posteriore e nell'eseguire questa operazione ti sporchi l'immacolata gonna bianca. A quel punto perdi definitivamente il controllo: col viso in fiamme, dai un calcio alla gomma bucata e gridi: "Ma dove li mettono i cric quei ladri. Porco Giuda! Con tutto quello che mi è costata sta cretina! Proprio qui doveva lasciarmi a piedi, in mezzo a sto deserto!! Come accidenti faccio ad arrivare in tempo!? E poi così conciata, porca miseria!!!". Fissi la gomma a terra vorresti incenerirla, col viso infuocato, il cuore a mille.

QUALE EMOZIONE STAVA PROVANDO IL PROTAGONISTA DEL RACCONTO?

Utilizzando la ruota delle emozioni, scegli quale e specifica *l'intensità* attribuendole un punteggio da 1=pochissimo a 5=moltissimo.

Quando ti senti pronto, chiudi gli occhi (il tuo compagno farà lo stesso). Sei la protagonista della storia che hai letto: ti trovi davanti a quella macchina, davanti a quella dannata gomma bucata, stai pensando a quello che ti ha detto Marco, ... e inizi a respirare come se fossi lei. Sarà solo il tuo respiro a esprimere ciò che provi, non dovrai in alcun modo usare la voce.

Il tuo compagno ascolterà il tuo respiro e proverà a starti accanto, respirando con te.

Joy – Positive Surprise

Cammini con calma, ripensando soddisfatta al colloquio appena avuto con il tuo capo. Sarai tu a partire con lui per Londra tra due giorni! Evviva, è fatta! Stai andando all'agenzia a confermare il biglietto intestato a te e poi a casa, la giornata è finita. Improvvisamente senti gridare dietro di te, per ben tre volte, il tuo nome. Ma chi sarà mai quella balorda che urla a quel modo in mezzo alla strada?!?!
Ti volti incuriosita e ti vedi correre incontro, trafelata, una tipa distinta in completo grigio…. Ma… Santo cielo!.... non la vedi da anni ma è tale e quale, non puoi sbagliarti… Sì! E'… è proprio lei!.... ti si spalanca il cuore e ti apri in un luminoso sorriso: "Elena! Che magnifica sorpresa!! Ma sai che non credo ai miei occhi?! Non ci posso credere, deve essere la mia giornata fortunata!! Ma cosa fai a Milano, e poi così in tiro? E… sbaglio o sei più…bionda?!" Scoppiate a ridere fragorosamente, passanti vi sbirciano incuriositi ma voi, incuranti, andate avanti a scambiarvi abbracci, gesticolando e chiacchierando animatamente. Devi passare dall'agenzia ma quando ti ricapita un'occasione così!? "Senti, mangiamo insieme? Mi dai dieci minuti entro in quell'agenzia e arrivo subito. E… come ai vecchi tempi… offri pure tu!". Scoppiate di nuovo a ridere. Mentre vai verso l'agenzia, ridi da sola, sei ancora incredula: per come è cominciata, questa giornata non può che proseguire al meglio!

QUALE EMOZIONE STAVA PROVANDO IL PROTAGONISTA DEL RACCONTO?

Utilizzando la ruota delle emozioni, scegli quale e specifica *l'intensità* attribuendole un punteggio da 1=pochissimo a 5=moltissimo.

Quando ti senti pronto, chiudi gli occhi (il tuo compagno farà lo stesso). Sei la protagonista della storia che hai letto, stai camminando per strada, hai appena incontrato Elena, stai ripensando a tutto quello che ti è appena successo… e inizi a respirare come se fossi lei. Sarà solo il tuo respiro a esprimere ciò che provi, non dovrai in alcun modo usare la voce.

Il tuo compagno ascolterà il tuo respiro e proverà a starti accanto, respirando con te.

Sadness

Non hai dormito tutta notte. Non riesci a staccare il pensiero da lui. Chiudi gli occhi un momento e ingoi a fatica il pesante groppone che ti si stringe in gola.
Ti imponi di concentrarti sulla preparazione della colazione, su quei gesti lenti e rassicuranti di ogni mattina. Ma lo stomaco è un sacco vuoto, chiuso, serrato. Che senso ha prepararsi per uscire? La realtà è che lui non c'è più. Se n'è andato. Possibile che non sia di qua con te a preparare la colazione, pasticciata ed abbondante come al solito?
Chi ha cancellato il suo sorriso? Ti fermi, di nuovo: lo puoi vedere nitidamente davanti a te… Basta, non ce la fai più, ti siedi; ti senti completamente svuotato/a e privo di energia.
"Ma dove sei – ti sorprendi a domandarti – non puoi essertene andato così. Non puoi lasciarmi in questo modo. Non puoi abbandonarmi! Non puoi! Ed io come faccio da sola? Senza di te mi sento sperduta, sola nella nebbia. D'un tratto non riesci più a trattenere le lacrime: le senti scorrere, calde, lungo il tuo viso… "Sono distrutta, a pezzi. Non posso aver perso tutto questo, tutto ciò che abbiamo vissuto giorno dopo giorno insieme. Mi sembra di impazzire… Non puoi essertene andato per sempre… non è possibile… non ora… Che sarò io senza di te?"
Senti il suono flebile della tua voce risuonare nella casa vuota e ti senti ancora più sola, estraneo anche a te stessa.

QUALE EMOZIONE STAVA PROVANDO IL PROTAGONISTA DEL RACCONTO?
Utilizzando la ruota delle emozioni, scegli quale e specifica *l'intensità* attribuendole un punteggio da 1=pochissimo a 5=moltissimo.

Quando ti senti pronto, chiudi gli occhi (il tuo compagno farà lo stesso). Sei la protagonista della storia che hai letto, ti trovi in quella casa vuota, stai pensando a lui, ti senti sola e sperduta coi tuoi pensieri… e inizi a respirare come se fossi lei. Sarà solo il tuo respiro a esprimere ciò che provi, non dovrai in alcun modo usare la voce.

Il tuo compagno ascolterà il tuo respiro e proverà a starti accanto, respirando con te.

Fear

Da giorni non fai altro che pensare a quel biglietto anonimo pieno di minacce.
Uno scherzo idiota, non poteva essere altro.
Sei un tipo tranquillo, tu, che badi ai fatti tuoi, non conosci bande o altra gente strana. Eppure… qualcuno doveva pur averlo scritto. Ma con quali intenzioni? Un brivido ti scorre lungo la schiena. Non vuoi nemmeno immaginarlo…
Hai la testa occupata da questi pensieri mentre stai chiudendo la serranda del negozio, come al solito ad un'ora tarda.
D'un tratto scorgi tre tipacci, giovani, con le giacche nere di pelle là fuori, sulla strada. Capisci dagli sguardi che si scambiano che aspettano proprio te. Ti irrigidisci: "Dio mi che facce!" pensi, e ti senti gelare, inizi a sudare freddo.
I tre giovani vengono verso di te, vedi tutto quel nero e quelle borchie, tenti di parlare, vorresti fuggire ma ti senti preso in trappola, incapace di reagire. "… non capisco cosa volete. Io non ho fatto nulla di male. Così all'improvviso… Ma cosa volete? Io non so niente, cos'è tutta questa storia. Ma cosa volete farmi…….!" Uno di loro porta la mano alla tasca interna della giacca, senza sorridere. Sgrani gli occhi, il cuore batte all'impazzata: senza neanche più un filo di voce per urlare, cerchi disperatamente una via di scampo che non c'è.

QUALE EMOZIONE STAVA PROVANDO IL PROTAGONISTA DEL RACCONTO?
Utilizzando la ruota delle emozioni, scegli quale e specifica *l'intensità* attribuendole un punteggio da 1=pochissimo a 5=moltissimo.

Quando ti senti pronto, chiudi gli occhi (il tuo compagno farà lo stesso). Sei la protagonista della storia che hai letto, ti trovi in quella strada buia, di fronte a quei ragazzi, senza nessuna apparente via di scampo… e inizi a respirare come se fossi lei. Sarà solo il tuo respiro a esprimere ciò che provi, non dovrai in alcun modo usare la voce.

Il tuo compagno ascolterà il tuo respiro e proverà a starti accanto, respirando con te.

Disgust

Appena entrato nel bar ti accorgi della puzza di vomito. Arricci il naso: l'odore pungente ti entra diretto nelle narici, penetrandoti fin nel cervello. Ti avvicini riluttante al bancone. “Un caffè” chiedi, con voce rotta dalla nausea. Una nuova improvvisa zaffata ti prende alla gola e ti fa contorcere lo stomaco. “Il bagno, per favore” chiedi con voce soffocata. La signora ti allunga seccamente una chiave annerita e appiccicosa. Appena dentro la toilette la puzza si fa improvvisamente più intensa. Trattieni a stento un conato e fai per voltarti di scatto verso la porta quando il tuo piede scivola su qualcosa di viscido. Istintivamente abbassi lo sguardo e ti accorgi della chiazza di liquido giallastro e maleodorante. Un nuovo conato ti afferra violentemente lo stomaco: il reflusso ti brucia l’esofago e ti riempie la bocca; lo ricacci in gola a fatica, il viso ti si contrae in una smorfia e fai per prendere la porta quando… “Accidenti, si chiude dall’interno!! Dove accidenti ho cacciato quella lercissima chiave?!” Rimani costretto in quel maleodorante stanzino, rivoltandoti le tasche e lottando contro la violenta nausea.

QUALE EMOZIONE STAVA PROVANDO IL PROTAGONISTA DEL RACCONTO?

Utilizzando la ruota delle emozioni, scegli quale e specifica *l’intensità* attribuendole un punteggio da 1=pochissimo a 5=moltissimo.

Quando ti senti pronto, chiudi gli occhi (il tuo compagno farà lo stesso). Sei la protagonista della storia che hai letto, ti trovi in quello stanzino, stai lottando contro la nausea… e inizi a respirare come se fossi lei. Sarà solo il tuo respiro a esprimere ciò che provi, non dovrai in alcun modo usare la voce.

Il tuo compagno ascolterà il tuo respiro e proverà a starti accanto, respirando con te.

Tenderness

Ti siedi sul prato anche tu, accanto a lei, appoggiandoti allo stesso tronco. Vi scambiate uno sguardo d'intesa, come ragazzine, e scoppiate a ridere! Non cambia davvero mai!!
Ti volti e chiudi gli occhi. Il caldo tepore del primo sole primaverile ti scalda il viso, Ti gusti quel momento, silenziosamente. Con lei puoi: non c'è altra amica al mondo con la quale puoi godere pienamente del totale silenzio; anche per interminabili mezzore… Sorridi, ripensando al pomeriggio trascorso insieme: le confidenze, i progetti, le risate a crepapelle, le piccole follie che ti fanno sentire ancora bambina. Sai che potrai sempre contare su di lei, che per te sarà comunque e sempre un luogo sicuro… come in tutti questi anni. Come quando passavate intere nottate a parlottare sottovoce mangiando patatine e nutella, come quando tutti i lunedì iniziavate la dieta - che finiva martedì!, come quando hai rotto con Fabio, come quando… Non sai per quanto rimanete così, a sfogliare ricordi. Percepisci il battito lento del tuo cuore e ti senti piacevolmente scarica. D'un tratto un brivido ti percorre la schiena: apri gli occhi e ti accorgi che sta calando il sole. Ti volti: lei è ancora lì, gli occhi chiusi e un leggero sorriso dipinto sul viso. Ti giri e ti abbandoni piacevolmente sul prato. "Cosa facciamo stasera, Cri?" in quel momento conosci già la risposta: "Quello che facciamo tutte le sere, cara: cercare di conquistare il mondo!!"

QUALE EMOZIONE STAVA PROVANDO IL PROTAGONISTA DEL RACCONTO?

Utilizzando la ruota delle emozioni, scegli quale e specifica *l'intensità* attribuendole un punteggio da 1=pochissimo a 5=moltissimo.

Quando ti senti pronto, chiudi gli occhi (il tuo compagno farà lo stesso). Sei la protagonista della storia che hai letto, sei su quel prato, Cri è di fianco a te, in quest'atmosfera di sintonia e abbandono… e inizi a respirare come se fossi lei. Sarà solo il tuo respiro a esprimere ciò che provi, non dovrai in alcun modo usare la voce.

Il tuo compagno ascolterà il tuo respiro e proverà a starti accanto, respirando con te.

Questionnaire - RESP

1) Pensa a come ti sei sentito: quale emozione stavi provando **mentre svolgevi il compito?** Utilizzando la ruota delle emozioni, scegli quali e di ciascuna specifica *l'intensità* attribuendole un punteggio da 1=pochissimo a 5=moltissimo. Cerchia poi l'emozione per te principale.

2) Pensa a come ti sei sentito tu **sentendo il tuo compagno respirare insieme a te**: hai provato delle emozioni?

   ☐ SI ☐ NO

   Se sì, utilizzando la ruota delle emozioni, scegli quali e di ciascuna specifica *l'intensità* attribuendole un punteggio da 1=pochissimo a 5=moltissimo. Cerchia poi l'emozione per te principale.

3) Secondo te, il tuo compagno ha capito cosa stavi provando? (1= pochissimo, 7=moltissimo)

   1 2 3 4 5 6 7

4) Sentire il tuo compagno che respirava con te è stato (1= pochissimo, 7=moltissimo):

   f. Difficile, perché distoglieva la mia concentrazione 1 2 3 4 5 6 7
   g. Intimo, perché si è creata vicinanza 1 2 3 4 5 6 7
   h. Fastidioso perché non sentivo la situazione spontanea 1 2 3 4 5 6 7
   i. Coinvolgente, perché percepivo la sua partecipazione 1 2 3 4 5 6 7

Questionnaire - RISP

1. Quale emozione pensi che stesse provando il tuo compagno? Utilizzando la ruota delle emozioni, scegli quali e di ciascuna specifica *l'intensità* attribuendole un punteggio da 1=pochissimo a 5=moltissimo. Cerchia poi l'emozione per te principale
2. Pensa a come ti sei sentito tu mentre respiravi con lui: hai provato delle emozioni? ☐ SI ☐ NO

   Se sì, utilizzando la ruota delle emozioni, scegli quali e di ciascuna specifica *l'intensità* attribuendole un punteggio da 1=pochissimo a 5=moltissimo. Cerchia poi l'emozione per te principale.

3. Respirare come il tuo compagno è stato (1= pochissimo, 7=moltissimo):

   a. Difficile perché non l'avevo mai fatto prima 1 2 3 4 5 6 7
   b. Utile per mettermi nei suoi panni 1 2 3 4 5 6 7
   c. Fastidioso perché non era il mio spontaneo di respirare 1 2 3 4 5 6 7
   d. Meccanico: l'ho fatto perché mi è stato chiesto 1 2 3 4 5 6 7
   e. Coinvolgente perché mi sono sentito attivato fisicamente 1 2 3 4 5 6 7
   f. Intimo, perché si è creata vicinanza 1 2 3 4 5 6 7

4. Quanto pensi che respirare come il tuo compagno ti abbia aiutato a provare *sensazioni fisiche* simili alle sue (1= pochissimo, 7=moltissimo)? 1 2 3 4 5 6 7

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