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From Vibrotactile Sensation to Semiotics. Mediations for The Experience of Music

Gabriela Patiño-Lakatos, Hugues Genevois and Benoît Navarret

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All knowledge takes its place within the horizons
opened up by perception.
(Merleau-Ponty, *The Phenomenology of Perception*)

1. Introduction

- 1 Interest in technical and scientific research into haptic and vibrotactile perception has grown over the past ten years, in particular in the area of experimental music [Daud *et al.*, 2004 ; Birnbaum, 2007 ; Gandhi *et al.*, 2011 ; Wollman, 2014 ; Criton, 2014 ; Katz, 2015 ; Hopkins *et al.*, 2016 ; Paté *et al.*, 2012 ; Patiño-Lakatos, 2016]. The development of new digital tools boosted research into the vibrotactile experience, which is promising for possible uses in the areas of sensory augmentation and substitution. Another way to listen – not only to music but, on a broader level, to the sound of the world, can be explored through touch. The results of this research are relevant to both able and disabled people (hearing and vision impaired) and can be applied in various situations (support in everyday life, in leisure activities and in the workplace). The conference organised in 2013 by the French agency for education and inclusion of special needs groups, INSHEA, at the Quai Branly museum in Paris, in tandem with the French Ministry of Culture and Communication on the theme of accessibility to education and artistic activities for special needs groups, led to an examination of the possible applications of perception through touch. At the conference, psychologist Édouard Gentaz explained the importance of research into the area of sensory augmentation in the development of cultural mediation for the visually impaired [INSHEA, 2014].

- 2 This article presents the results of exploratory studies into vibration sensitivity through the use of new digital tools, with the intention of encouraging another means of accessing collective, shared practices such as music. The experiments were carried out in tandem with a number of partners by the LAM (Lutheries-Acoustique-Musique) team at the Institut Jean le Rond d'Alembert (Sorbonne University, CNRS, MCC) and the CIRCEFT education science research unit (University Paris 8). What makes these exploratory tests so interesting is that they are attempting to adapt the scientific and technological advances that, up until now have been limited to vibro-acoustics, electroacoustics and music, to the area of sensory experience.¹ The results, in a relatively new area, are promising and provide good reasons to carry out more in-depth research to broaden knowledge in the area of sensory perception, in light of current technological progress and potential applications in the subjective, social and cultural spheres.

2. Vibrotactile stimulation and sensitivity

- 3 Vibrotactile sensitivity is part of the sensory modality of touch. This modality is necessary to the conscious or unconscious regulation of motor activity and it is omnipresent in the way we experience the world as it helps us to find our direction, to identify and to recognise the elements of our immediate environment. Touch is also the main conduit for feelings of pleasure and displeasure – a foetus' somatosensory system starts working in the third month of pregnancy. The child psychiatrist and psychoanalyst Bernard Golse [2010] explains that the first sense a human foetus develops *in utero* is the sense of touch – the last is the sense of hearing. In addition, research² led by linguist and specialist in sensory disability Bertrand Verine, shows the importance and the particularities of the cognitive and experiential organisation of the sense of touch *in* and *by* the language used in discourse: “alternative representations should be the common prerogative that is easiest to share between the visually impaired and those who can see” [2014, p. 11]. Nevertheless, sight and hearing are traditionally the dominant senses in the way an individual interacts with their environment – and this means an explicitly language-based cultural education –, the sense of touch is rarely taught in a conscious and explicit manner. While touch is involved “in more overall processes” and is indeed omnipresent,³ we tend, in terms of cognition and conscious language, to minimise its role [Verine, 2014, p. 19]. This means it has traditionally been studied as a sensory modality that is not or very rarely codified: vibrotactile sensations are seen as a background information, in a pre-conscious manner and as such, not really subject to codification or to the development of a socialised language.
- 4 Vibrotactile sensitivity is seen as being mainly “skin-deep” [Gentaz, 2018, p. 9], but it actually involves many deep and varied parts of the body. It is a sensory modality that involves a wide-ranging and complex map of the whole body. The reception of exterior vibratory stimulations does not just involve the skin, it involves an individual's muscles, bones, tissues and organs, both passively and actively. As a result, vibrotactile sensitivity is fundamentally exteroceptive while also being intimately connected to channels of proprioception (the deep-felt sensitivity of body organs) such as somesthesia (feelings of pressure, temperature or pain) and kinaesthesia (the position and movements of the body's organs). So, for example, sensitivity to vibrations “does

not exclude” muscle movement; on the contrary, it is “affected” by the activity of parts of the body [Paillard, 1976].

- 5 Vibrotactile *stimulation* is fundamentally sequential, diachronic, and subject to variations over time; it is an active form of stimulation that can be relatively stable or variable, and is, in essence changing. It is said to be “active”, in particular in the experiments we carried out, in as much as the transducer used to transmit the vibrations is a “motor”. When switched on, the transducer manifests a form of mechanical activity that echoes human expression (motor, for example). The vibrations used in the experiments we carried out were produced and transmitted by computer software using an animated electronic transducer, via an amplifier. As such, we must take into consideration the fact that the digital vibrotactile output (the signal is processed digitally) is already mediated and not equivalent to a traditional mechanism, that, in the causal chain, produces the vibrations. There is a lot at stake in this type of research as the digital tools use not only spontaneous modalities of sensory experience, but transform them, opening up various possibilities that may provide solutions to certain personal needs and practical questions.
- 6 Vibrotactile *sensitivity* is said to be “passive” when we consider that it can take place without needing any parts of the body to be active. For example, a subject could be inactive yet be affected by the vibrations of a plane flying over their house. Vibrotactile *sensitivity* is different from haptic sensitivity (from the Greek *haptomai*) which is defined as a form of active sensitivity that requires a form of kinaesthetic commitment such as exploration by a hand or a leg [Hatwell, Streri and Gentaz, 2000; Gentaz, 2018]. However, in many situations, vibrotactile sensitivity overlaps with haptic sensitivity as the subject can explore a vibrating body with their hands and legs. This is why we work from the basis that in vibrotactile sensitivity, beyond the fact that the individual can be either active or passive, the subject is instrumental in their sensitivity as they are animated by an intention, however implicit.
- 7 Consequently, we can define vibrotactile sensitivity as a situation where the vibratory event (like a buzzer) “touches” the subject without the subject necessarily touching it.⁴ In addition, and just as importantly, the sensory experience of vibrations is not usually, in everyday life, separated from the other sensory modalities that allow the subject to interact with their environment. As a result, the way vibrations are felt happens in a very complex manner that we could term “holisensorial” [Cance, 2008] that not only integrates various elements that come from different sensory modalities but also involves interferences between modalities that must be taken into account by the subject in the construction of the overall experience [Dubois and Cance, 2012].
- 8 As a result, even though it is necessary to study physiological channels when trying to understand vibrotactile sensitivity, it is by no means limited to the workings of sensory receptors. It is just as important to examine the experience from the point of view of the receiving subject, that is also an *actor* and above all *producer* of meaning. This approach centred on the subject of the experiment calls on “ascending” cognitive processes constrained by the stimulations on the one hand, and “descending” processes such as the interpretation, knowledge and recognition of the stimulations on the other. This is why the cognitive processes involved in the sensory experience of vibrations are deeply dependant on semiotic systems (signs, be they language based or not) built by a community of subjects in their interaction with the sensory world [Farina, 2014; Despret 2007; Uexküll, 1965]. These semiotic systems – where the categories that are

pertinent to sensitivity are built – are part of the semantics of the particular languages and are partially shared in verbal communication. Consequently, possible categorisations of the vibrotactile experience are ultimately identifiable in verbal expression. This means that the study of the sensory experience of vibrations can benefit from research into categorisation and the relationships between semantic categories and linguistic analysis of verbal data [Dubois, 2009].

3. Cultural and social mediations of the vibrotactile experience

- 9 There is much at stake with vibrotactile sensitivity, in particular in the area of computer assisted music, where there is a movement afoot to reintroduce more bodily involvement in the “man-machine-man” relationship, in a context of social sharing. Integrating sensory elements, such as vibrotactile signals complements the virtuality that is inherent to the computers that are increasingly common in music. In this domain in particular, sensitive and expressive interfaces must be designed that are accessible to different sensory situations. In group musical performances, (for a mixed public of disabled and non-disabled people for example), having different types of sensory mediation could prove to be very useful: intermodal mediations can give rise to inter-semiotic associations between different sensory elements and motors to accompany the subject who seeks to produce incarnated and complex meaning.
- 10 In fact, vibrotactile sensory feedback allows the subject to adjust their movements to control its production in activities that require coordination and precision. In this way, music is an ideal field of study, as it demands instrumental *synchronisation* and *precision*, and these objectives, at times, can create sensory and motor difficulties for the subject. In this area, it has been shown that sensory feedback other than auditive is part of the way musicians regulate their practice and the way they evaluate their instruments [Navarret, 2009; Fritz, 2015; Wollman, 2015; Paté, 2012; Paté, Givois, Le Carrou and Vaiedelich, 2016]. In this particular case, vibrotactile sensitivity is more general but can be honed through practice. In addition, vibrotactile signals, received in a process of semiotic construction, can become potential signs⁵ relevant to the adjustment of the subject’s movements, in particular for the coordination of a collective activity. This potential semiosis can, through quick communication, encourage the integration of different categories of people in complex social interaction contexts. However, a semiotic use of vibrations requires more discriminating capacities of sensory analysis and, as a result, learning and structuring easily identifiable vibratory signals.
- 11 The sensory experience always takes place in a cultural setting, connected to different types of instrumental techniques within a dynamic process where the subject *adapts* to the instruments and progressively *adapts* the instruments to their needs and intentions [Wallon, 1973; Leroi-Gourhan, 1964; Gehlen, 2009; Tomasello, 1999]. As such, new string instrument makers can make experiences, like music, more accessible to disabled people, by integrating vibrotactile tools to artistic and educational activities aimed at specific and mixed publics [Genevois and Criton, 2011].

4. Research into the way vibrations are felt and received

- 12 The main question about vibrotactile signal sensitivity is finding out how subjects construct their own vibrotactile experience and according to which language categories they organise, interpret and express their sensations. Today, research into the possible semiotic dimension of the vibrotactile experience is of great interest, and we have examined the communicative potential of vibrotactile signals through the study of participants' sensitivity during individual and collective experiments in the laboratory and in the field.
- 13 Two previous research experiments carried out by our team set us on this path. The first was a vibrotactile exploration experiment⁶ carried out by Hugues Genevois and Errika Manta (LAM) in June 2012 with the Athens-based sign-language theatre company Θέατρο Κωφών Ελλάδος with the much-appreciated participation of Sophia Roboli, actress and group leader. This experiment led to the development of the *Pallophone*⁷ and served to highlight the significant difference in sensitivity to vibrotactile stimulation, according to whether they are in an individual or collective situation. The second, was part of the PANAM⁸ project financed by the French national research agency (Agence Nationale de la Recherche) between 2012 and 2015, where H. Genevois worked at the LAM to develop educational vibrasound devices (sono-tactile tables and software developed using the Max/MSP programme). Between October 2012 and June 2013, it resulted in the "*Histoires sensibles*" educational and artistic experiment in tandem with the Paris young deaf people's institute (Institut National de Jeunes Sourds de Paris). This innovative experiment was designed by the composer and educator Pascale Criton with teaching input from Elsa Falcucci, a teacher of deaf students at the INJS in Paris. The experiment was initially directed at deaf and hearing-impaired students, but also at a mixed public with varying degrees and types of perceptive abilities (hearing, hearing-impaired, deaf; seeing, visually impaired and blind). In both of these experiments on sensitivity to sound stimulation through a channel that is not the ear, the shared, social dimension proved to be fundamental in the way vibrotactile stimulation was felt and categorised. The way vibrotactile signals are received is, on the surface, intuitive and immediate, but in fact, the conscious elaboration of sensations through language requires a learning process and technical tools must be appropriated [Criton, 2014; Criton *et al.*, 2014; Patiño-Lakatos, 2016].
- 14 In 2015, we carried out an empirical study on sensitivity to vibratory signals transmitted by a prototype vibrotactile bracelet designed by H. Genevois. The prototype implemented a transducer⁹ piloted by a software interface developed by Max/MSP. From June 24 to July 13 2015 at the LAM, a sensitivity test that lasted on average one hour and thirty minutes was carried out over five days. The experiment was devised by Gabriela Patiño-Lakatos (CIRCEFT) and H. Genevois, in collaboration with Pascale Criton on coding signals and their possible uses, Gérard Uzan (Laboratoire THIM – Université Paris 8) on ergonomics and uses for the device and Benoît Navarret (Laboratoire IReMus – Sorbonne Université and LAM) on operating the device in the laboratory and analysing the results.
- 15 The corpus of vibratory signals was established according to seven semiotic categories: partitive reference signals¹⁰; tempo signals; pulsation signals; preparation signals; starting signals; tempo and starting signals; ending signals. Most of the signals used

were chosen and produced by Pascale Criton and Benoît Navarret from an existing sound bank.¹¹ These signals were devised with a view to creating a vibrotactile language adapted to the different sensitivity conditions and its application to the way musicians synchronise when playing together.

- 16 Ten people, aged between 25 and 58, with various educational and professional backgrounds,¹² took part in the study. The panel included eight non-disabled people (seven men and one woman), one blind man, one visually-impaired man and one hearing-impaired woman¹³. With the exception of two people, they all had previous musical experience as amateurs or professionals (harp, singing, guitar, drums, piano, double bass and saxophone). With the exception of the hearing-impaired person, all were experiencing vibration sensitivity for the first time. Each participant wore a vibrotactile bracelet on their dominant arm.
- 17 The vibrotactile signal sensitivity test was devised according to four sensitivity and motor situations, with the tasks getting progressively more difficult: a) a *sensitivity complementarity* situation where the hearing participants had a sound transmitted through their headphones that corresponded to the vibrotactile signal; b) an *auditive isolation* situation where all of the participants were transmitted only the vibrotactile signals (the hearing subjects wore noise-cancelling headphones); c) a *sensitivity interference* situation for the hearing participants, with a simultaneous transmission of a musical sequence through the headphones at the same time as the vibrotactile signal; d) a *perceptive interference* situation with an added *motor task*: while the vibrotactile signals were being transmitted, the participant had to tap a pulsation¹⁴ on the table with the dominant hand (on the bracelet arm).
- 18 After the initial phase meant to familiarise the participants with the device, the test involved four main phases: 1. *Sensitivity*, to evaluate participants' sensitivity levels to four series of fifteen signals in the four situations cited above (a, b, c, d); each stimulus was transmitted at two settings (10 dB apart). 2. *Differentiation*, in order to analyse spontaneous categorisation strategies of sixteen signals that the participants were free to choose in the auditive isolation situation (b). 3. *Recognition*, to evaluate participants' aptitude for memorisation and recognition upon hearing twenty pairs of signals (AA, AB), in a non-reversible linear timeframe, in three sensitivity situations (b, c, d). 4. *Description*, to analyse the participant's capacity to qualitatively describe the four signals heard in the auditive isolation situation (b).
- 19 During the first three phases (1, 2 and 3), the participants were required to fill out a form on a computer¹⁵. The fourth phase (4) comprised of a recorded and transcribed semi-structured interview. The answers gathered from the form and the semi-structured interview were analysed quantitatively (mean, median, mode and range) and qualitatively (analysis of answers to extract underlying semantic categories).

5. Results

5.1 Perception of intensity

5.1.1 Sensitivity according to signal intensity

- 20 With regard to the perception thresholds of vibrotactile signals, the high overall number of positive answers to the signals (from 85% to 97.5% for all signals) shows that

the wrist is the most pertinent part of the body for receiving signals. However, reception seems to be more fine-tuned, intense or intimate on the anterior surface of the wrist; on the posterior surface, the signal is perceived to be more distant in the psycho-physical relationship. The participants showed a good capacity for discriminating between stimuli that were transmitted at two different levels. Responses to fake stimuli (where no vibration occurred) and to actual stimuli (where there was an actual vibrotactile stimulation), indicated that they were able to differentiate very distinctly between even a light vibrotactile stimulation on the wrist and the absence of stimulation in that zone.

5.1.2 Sensitivity according to the speed of amplitude modulation and signal structure

- 21 Regular, repetitive pulsations were the easiest to detect. However, high frequency signals with only one impulsion or a short, homogeneous vibration proved to be much more difficult to detect at lower intensity levels in the auditive isolation (b) and perceptive interference (c) situations.
- 22 Low level signals that only caused “a light feeling on the skin”, also proved to be difficult to describe. Nevertheless, the semi-structured interview phase revealed another sensory reaction according to the intensity of the signals, with sensations of *pleasure* and *displeasure*. So there is a clear duality between a cognitively more informative description of strong signals, that are at times felt to be unpleasant, and a less precise description of the low level, but more comfortable signals.

5.1.3 Sensitivity according to the participant's perceptive situation

- 23 Comparing results from one perceptive situation to another does not allow us to establish a logical link between the number of participants who detected signals and the difficulty of the perceptive tasks to be carried out. Participants did mention that the motor activity task (d) was the most complicated, while the success levels for this task were better than for the auditive isolation (b) and perceptive interference (c) tasks. The surprise effect in tasks (b) and (c) might explain the lower rate of detection of vibrotactile signals. However, when it came to the motor activity task (d) there was apparently a learning process – or training effect – with a progressive realisation of the difficulty and the participants probably getting used to repeated exposure to various vibratory signals.

5.2 Categorisation of the signals

- 24 In this phase of the experiment, the participants manifested their aptitude in differentiating among a varied range of stimuli, and were able to group them together according to their perceived resemblances. One of the expectations of the free categorisation of vibrotactile signals was to find out if the signal groups defined by the participants were similar to the functional categories that had guided the researchers' choices in the preparatory phase. Yet, the participants classified the groups of signals according to *descriptive*¹⁶ criteria, as opposed to the *functional* criteria that were based on what the guidelines might mean for group music playing. This is understandable as the participants were not informed as to the possible use of the stimuli before the test.

5.2.1 The vocabulary used

- 25 The professional or educational areas of the participants had a strong influence on the way they categorised or expressed the sensations. Most of them were involved in acoustics or signal treatment in some form and this led to the use of *objective language* when describing the properties of the stimuli, that is to say, centred on the object, without any explicit *subjective* marks.¹⁷ Nevertheless, 20% of the subjects did use subjective expressions such as “the way the signal touches me”; “I feel”; “I get the impression that I feel”; “feels like it goes through you”. Some also used technical vocabulary from their own particular area of expertise (“constant simple pattern”; “attack”; “resonance length”; “progressive amplitude drop”; “spiralling”), in comparison to the more graphic vocabulary used by the other participants (“rising”, “dropping”, “spinning”, “engine vibrations”, “rain”, “waves”).

5.2.2 Groups of signals

- 26 From a basis of 16 signals, the median number of groups constituted by the participants was 4 (mode de 4 and mean of 4.9); the minimum number of groups was 3 for one subject and the maximum number was 8 for another. The level of coincidence between the median and the mode, and their relative proximity to the mean indicates that data distribution was relatively normal. The median number of groups constituted showed the participant’s capacity for discrimination in their vibrotactile perception; the number of categories was generally discriminating and relevant (not too low and not too high relative to the number of stimuli). Even in the most extreme cases¹⁸–, the constitution of 7 or 8 groups was not excessive and remained discriminating relative to the number of stimuli.

5.2.3 Categorisation criteria

- 27 Each participant used approximately 5 criteria to categorise the signals (the mean was 5.4; the mode was 5 and the median was 5). The most common spontaneously-used criteria were those connected to the signal’s morphology (its temporal envelope), texture, composition and temporal recurrence: 9 participants out of 10 explicitly used these criteria.
- 28 Two experiential categories emerged for the ‘morphology’ criteria: *continuous* signal (through the use of words such as “continuous”, “ongoing sound”) and *discontinuous* signal (“percussion”, “pulsation”, “bangs”). The ‘signal composition’ criteria led to two categories of responses: *homogeneous* signal (“similar signals”, “identical sounds”, “only one sensation”) and *heterogeneous* signal (“different signals”, “mix”, “a few different sensations”, “compound element”, “continuous + pulsation”). The ‘signal texture’ criteria lead to the most figurative language with quite varied terms according to the sensations produced by the stimuli (“shiver”, “radiate”, “spinning”, “spiralling”, “waves”). The ‘temporal recurrence’ criteria focused on the *one-off* (“one pulsation”, “one bang”) or the *repeated* nature of the signal (“constant simple pattern”, “many”, “series”, “repeated a number of times”) of the signal, at times even pointing out the number of repetitions (“two bangs”, “pattern repeated three times”) or the detection of rhythms (“rhythmic passage”, “blend of rhythms”).

- 29 Given these answers, it seemed relevant to us to differentiate between the ‘signal composition’ criteria and the ‘temporal recurrence’ criteria. The ‘signal composition’ criteria referred to the participant’s overall ability to distinguish a homogeneous signal or a heterogeneous signal in the composition as a whole. However, with regard to the ‘temporal recurrence’ criteria, the quantitative description became explicit and, as such, discriminating. Thus, the participant went from an overall perception of an object to the perception of a number of elementary units of the object. While this type of analytical and quantitative perception was encouraged by the types of signal chosen, the categorisation tasks and professional backgrounds, the participants’ answers indicate that one discriminating criteria for vibrotactile sensitivity was the possibility to count.
- 30 In second position we find the use of the ‘signal’s tendency to change’ criteria (8 out of 10 participants). This shows an ability to identify certain variations in the properties of the same signal. Participants referred to the *uniform* (“monotonous”, “constant”, “uniform”) or *changing* character of the signal (“rising”, “falling”, “varying intensities”).
- 31 Criteria such as ‘intensity’ (weak/strong), ‘length’ (short/long) and ‘speed’ (slow/fast) were mentioned less frequently. In addition, one participant used bodily criteria to categorise his perception of the stimuli. He then differentiated them according to the degree of penetration and the dynamics of the vibrations in his body. He distinguished the more *superficial* vibrations (“skin deep”) from the *deeper* ones (“travelling through me”, “more internal”) relative to the thickness of his body. Two blind participants created the ‘empty’ category (with no corresponding positive criteria), to include, by default, the signals they couldn’t identify, categorise or detect precisely.
- 32 The seven semiotic categories for the signals that we implicitly suggested in this experiment can be whittled down to four, even three big categories according to their structure: 1/ Categories of tempo, pulsation and partitive references; 2/ Categories of starting, ending and sometimes of tempo *and* start; 3/ The category of preparatory signals seems to stand out from others. Three groups emerged from the answers given by the participants, which is in line with the nature of the stimuli proposed. On the one hand, they tended to associate the tempo, pulsation and partitive reference categories; on the other hand, the starting, ending categories and sometimes the tempo *and* ending ones. The preparatory category of signals (continuous vibrations, like a “layer”) stand out from the others. We can therefore maintain four fundamental categories of vibrotactile signals, according to whether their structure is continuous, discontinuous, grainy or pulsed (figures 1 to 4)¹⁹.

Fig.

The changing intensity in a high frequency, 'impulsion' vibratory signal

Fig. 2

The changing intensity in a low frequency, 'impulsion and resonance' vibratory signal

Fig.

The changing intensity in a low frequency, 'continuous and grainy' vibratory signal

Fig. 4

The changing intensity in a 'continuous in perception and resonance' vibratory signal, with a progression from low to high frequency

- 33 So, our analysis revealed that participants' categorisations corresponded *overall* to the real structure of the signals we had built. This would seem to indicate that the differences in the "form" of the vibrotactile stimuli (the morphology of the signal) are *overall* detectable without any explicit learning process, which is, however, not the case for the most subtle differences (for example, in terms of texture and composition). As such, the partitive signals (that indicated the sequences) and the tempo signals may have been confused with one another due to their similar morphologies. However, given the number spontaneous classifications by certain participants, this learning process should not constitute an obstacle to the use of the semiotic categories we propose.

5.2.4 Memorising and signal recognition

- 34 In the *Recognition* phase, the percentage of answers that aligned with the pairs of stimuli oscillated between 53% and 73%. We must consider that the sequence of signals per series was quite fast and a second turn was not an option. "Wrong" answers that did not align with the stimuli²⁰ happened logically on pairs of signals that were close in terms of morphology and structure. Yet, we are not to judge the "right" or "wrong" answers, or blame them on the participant's inability, we must take them as a statement that allows us to question the construction of the signals and their transmission conditions. In other words, are our signals effective? Do they work under various transmission conditions?
- 35 Participants were able to distinguish *tempo signals* and *pulsation signals* of the same speed, in other words, signals that are quite close structurally (between 73% and 86% for pair 17). They managed to more precisely recognise the repetition of the same pulsation signal (96% for pair 6) and to distinguish the different signals inside the same category, while remaining sensitive to differences in speed (93% for pair 1). They were also able to discriminate between *pulsation signals* and *preparation signals* (96%). With regard to the *partitive reference signals*, only 63% of the participants managed to distinguish two different signals inside the same category. They were relatively good at detecting reference signals and tempo signals at different speeds. They could distinguish certain *preparatory signals* (between 60% and 83%) but had problems recognising repeated signals in this category. The repetition of the same *starting signal*

was easily identified (80%) but, on the other end of the scale, there were problems distinguishing different signals within this same category (53%). Starting signals were hard to separate from *ending signals* (between 56% and 70% for pair 16). Differences (80%) and repetitions (93%) in ending signals were spotted by most participants.

5.2.5 Language used to describe vibrotactile sensations

- 36 The number and type of criteria used to describe a vibrotactile signal varied from one participant to the next according to each participant's perceptive make-up²¹, profession, centres of interest, attention span and emotional disposition. The explicit and spontaneous use of description criteria also depended on the nature and structure of the stimulus. Participants could consider a criterion more relevant than others for a given signal. In the *Description* phase, the 'signal morphology' (temporal envelope) criteria remained the first dimension expressed. The 'tendency for the signal to change' was the second most-frequent dimension. Participants were very sensitive to changes or the lack thereof in the temporal evolution of the signal, from the point of view of the intensity and the sensation of speed in signal structures. The overall intensity and the 'temporal recurrence' were then the most common criteria used. However, the 'texture' and the 'composition' of the signal were less explicitly mentioned.
- 37 Participants' verbal and non-verbal data (movements, for example) in the qualitative descriptions of their vibrotactile sensations were implicitly structured by criteria. They follow on from the criteria that emerged during the free categorisation task (*Differentiation* phase)²². In addition, the learning effect was an essential factor in the conception and analysis of this sensory experiment. The characterisation, verbal expression and structuring of the feeling of touch depended greatly on the participant's learning process throughout these experiments. In addition, the number and names of the criteria used to evaluate the signals tended to become formalised and applied somewhat systematically.
- 38 Characterising the language of vibrotactile sensations is a demanding exercise²³, and as such, it was scheduled as the last phase of the experiment. The subjects we met with seemed to be unaccustomed to describing vibrotactile sensations and communicated, at times explicitly, the problems they had with finding the precise terms to describe their sensations. This experiment confirmed that we have significant capacities to detect, differentiate and recognise well delineated vibrations, but we encounter problems when it comes to describing our vibrotactile perceptions in words. We have probably not been trained to take this perceptive modality into account and to formulate it through language categories. This meant that the verbal interview encouraged the use of figures of speech and analogies, as well as very clear hand movements [Cuxac, 2003], such as *banging on the table*, or the use of *onomatopoeia* to describe the perceptions caused by the signals. Analogies and metaphors were also used to express the potential communicative function attributed to the signals.²⁴

6. Conclusion

- 39 The results of this exploratory experiment confirm the potentially significant dimension of vibrotactile stimulations for an incarnate subject, the perceptive and semiotic possibilities of putting these stimulations into a system of vibrotactile signs,

and the overall relevance of the device used as a technical support. The diversity of the criteria collected and the capacities of discrimination observed initially revealed that the wrist is the most relevant place on the body for transmitting vibrotactile signals. The position of the sensor on the wrist seems to be adapted to the use we initially envisaged, that of electronic music played in a group.

- 40 Subjects can easily detect the vibrations on their wrists with a variable sensitivity according to the intensity of the signals, their morphology, their frequency content and their temporal recurrence. However, the ability to identify, discriminate and recognise the signals depends in particular on the level of the transmission. A subject may detect a weak vibration, but in qualitative terms, this might be more delicate to understand and describe. In addition, the relevance of the intensity levels of the vibrotactile signal depends on the function attributed to that signal. If the vibrotactile signal is transmitted for *semiotic purposes* (the communication of coded messages for collective interpretation), it is fundamental that the signal be detected in a very precise manner from a structural point of view, so as it fulfils its communicative function with no room for ambiguity. If the signal is used for *feedback* when playing music, there seems to be a certain tolerance in terms of precision in the accompaniment and support of the sensory-motor experience, consciously or subconsciously.
- 41 The diversity of criteria also shows the complexity and potential wealth of vibrotactile perception, which can be worked on through learning and allows us to envisage its use in cultural mediation between the participant and their environment. The subject's aptitude to categorise vibrotactile perceptions depends to a great extent on their past experience in the sensory modality of touch and vibrations (education, training, practices, profession, handicap, etc.). Yet the majority of participants claimed never to have had any experience with vibrations that required any conscious reflection on their part or the verbalisation of their perceptions²⁵. Nevertheless, people have fine-tuned perceptions and are capable of categorising them.
- 42 The criteria that the participants chose spontaneously for the categorisation and description of the signals were the signal's 'morphology', its 'composition', 'texture', 'temporal recurrence', 'tendency to change', 'intensity', 'length' and the feeling of 'speed' it gives off. These perceptive criteria do not appear to mutually exclude one another, but more to overlap in such a way that we cannot clearly posit the existence of a hierarchy. In addition, the differentiation between 'composition' criteria and 'temporal recurrence' criteria of the vibrotactile signal give an idea of the level of detail the subject is potentially capable of in the structuring of their perception, in particular in their capacity to count the discreet elements that make up a vibrotactile signal. The differentiation of these two perceptive criteria seem to refer, on a perception level, to an intermediary state between the discreet and the continuous, where the participant detects discreet elements without necessarily being able to count them.
- 43 In the context of new technological and perceptive "augmentations" of the body, this type of research centred around the subject's sensory experience allows us to examine the intimate experience of subjective body sensations, in the multiple dimensions of perception, categorial representation, emotions and expressions (verbal and non-verbal) linked to the sensory experience of vibrations. Our methodological approach thus contributes to a reading of new technologies linked to the individual issues at stake for the incarnated subject. New technologies do not only solicit bodily experience, they transform it. Carrying on this type of research on vibrations will

propose to study these transformations, in connection with the evolution of contemporary instrumental practices in artistic practice [Cance *et al.*, 2009 ; Genevois, 2009]. The study of the transformations of the bodily experience through innovation has an important impact in a plural society that can encourage the integration of diverse populations and in particular of the disabled.

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NOTES

1. Our understanding of the subject here is as an incarnated, complex and dynamic formation, the existence of which is partially conscious and unconscious and is the result of a social, historic, semiotic and cultural construction. From the point of view of their bodily experience, "The subject of the sensation is neither a thinker who takes note of a quality, nor an inert setting which is affected or changed by it, it is a power which is born into and simultaneously with it." [M. Merleau-Ponty, *The phenomenology of perception*, Routledge, 1958, p. 256]. The knowing, perceptive subject, shot through with a fundamental emotional dimension, acting and suffering in their way of being in the world.
2. With support from the French Federation for the Blind.
3. According to the tactile properties of temperature, hygrometry, weight, shape, size, texture and vibration.
4. *Perception* designates all of the psycho-bodily, social and cultural processes that go into the formation of percepts or sensitive forms felt by the subject as phenomena. In terms of meaning here, the percept as the partial and always relative result of perception is distinct from *stimulus*.
5. The linguist É. Benveniste gave *sign* a precise definition using the model of the *linguistic sign* as separate from *signal* [Benveniste, 1966, 1974]. However, the definition given by semiotician Umberto Eco from Pierce's conception of *sign* seems to us to be the best adapted to our experiment: the *sign* is something that has a link to representation with an end to practical use. The *sign* is an element of communication and signification due to a shared, even imprecise, fragmentary and provisional code. [Eco, 1988, p. 33-34, 40-41].
6. <http://www.deaf.elemedu.upatras.gr/images/Proceedings/THE%20PALLOPHONE.pdf>.
7. The *Pallophone* is a portable vibrotactile instrument [Genevois, 2015].
8. <http://www.agence-nationale-recherche.fr/Projet-ANR-12-CORD-0005>.
9. Dayton Audio 13 mm 8 ohms NXT transducer.
10. To identify groups and sequences.
11. Apple *Garage Band* sound bank.
12. Physics, psychology, ergonomics, engineering, musicology, art history.
13. Communication through hearing aids, lip-reading and/or sign language (LSF).
14. As a support, the pulsation was *audible* thanks to a signal transmitted through headphones and *visible* thanks to a signal on a screen, in the software interface.
15. A third party filled out the form for the vision impaired and blind.
16. On signal morphology, for example.
17. Like personal pronouns such as "I" and "you".
18. Only two cases overall.
19. The x-axis shows temporal data and the y-axis the amplitude, are on the same scale for each figure.
20. In the case where two signals (AB) were identified as identical.
21. In its relationship to visual, auditive and tactile channels.
22. This continuity is encouraged by the fact that the four signals used in the last phase of the experiment came from the signals used in the previous phases.
23. In particular due to the fact that our everyday life does not necessarily incite us to carry out this task.

24. As for the preparation, start, alert, warning, or “preparation for another action” signals (“pole vaulting”, “*bâton de théâtre*”, “phone call”, “alarm”, “boat starting”, “machine gun”, “water pump”, “phone vibrating”, “pneumatic drill”, “woodpecker”, “cricket”, “mosquito warning”).

25. The conscious categorisation of vibrotactile sensations is not a usual everyday practice for the non-disabled.

ABSTRACTS

An essential modality in apprehending the environment, the perception of vibrations can provide innovative solutions in the renewal of complex instrumental practices, socially shared and adapted to different perceptual conditions (sighted, blind, hearing, non-hearing public) . This article presents the results of an exploratory experiment conducted on the perception of vibrotactile stimuli transmitted through a vibrating device. The originality of this study lies in that it aims to articulate a subjective approach to sensory experience with the scientific and technological advances identified in the fields of vibroacoustics, electroacoustics and music. Vibrotactile perception has been explored with a view to its application to the interpretation of a complex instrumental practice, musical play. This artistic practice is exemplary in nature and can be generalized in certain aspects to any demanding daily activity, in an individual or collective situation.

INDEX

Keywords: musical interpretation, digital violin making, perception, sensory feedback, semiotics, vibrations

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