exploring perceptual matters
a textile-based approach

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Abstract

This research takes a practice-based approach to exploring perceptual matters that often go unnoticed in the context of everyday lived experience. My approach focuses on the experiential possibilities of knowledge emerging through artistic enquiry, and uses a variety of modes (like textiles, sound, physical computing, programming, video and text) to be conducted and communicated. It examines scholarship in line with the ecological theory of perception, and is particularly informed by neurobiological research on sensory integration as well as by cultural theories that examine the role of sensory appreciation in perception.

Different processes contributing to our perceptual experience are examined through the development of a touch-sensitive, sound-generating rug and its application in an experimental context. Participants' interaction with the rug and its sonic output allows an insight into how they make sense of multisensory information via observation of how they physically respond to it. In creating possibilities for observing the two ends of the perceptual process (sensory input and behavioural output), the rug provides a platform for the study of what is intangible to the observer (perceptual activity) through what can actually be observed (physical activity).

My analysis focuses on video recordings of the experimental process and data reports obtained from the software used for the sound generating performance of the rug. Its findings suggest that attentional focus, active exploration, and past experience actively affect the ability to integrate multisensory information and are crucial parameters for the formation of a meaningful percept upon which to act. Although relational to the set experimental conditions and the specificities of the experimental group, these findings are in resonance with current cross-disciplinary discourse on perception, and indicate that art research can be incorporated into the wider arena of neurophysiological and behavioural research to expand its span of resources and methods.

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Visual material

Unless stated otherwise, all photography, illustration and tables are by the author

I declare that the work presented in this thesis is my own. During the period of registered study in which this thesis was prepared I have not been registered for any other academic award or qualification. The material included in this thesis has not been submitted wholly or in part for any academic award or qualification other than that for which it is now submitted.

Signature

Date

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Introduction

This thesis presents my practice-led study on how we perceive and make sense of different things and events we encounter. In other words, this thesis is an attempt to contextualise in a written format experiences and observations that have emerged through my research practice. The verbalisation of lived experience inherently involves processes of interpretation and hypothesising as well as the bias of describing what I understand to be a nonhierarchical process in a systematic way that complies with the stratified nature of written text. Inevitably, this entails the risk of 'variation, change, and, in particular, meaning' being lost in the process of making sense of and communicating the empirical material collected through my research (Kane 2001: 70). In a sense, the problematic nature of translating information generated through a certain mode into another represents the very problem posed by the subject of my research; that is, how can one study a process as obscure and internal as perception without falling into assumptions about the mechanisms underlying it? Moreover, how can one explore and communicate the multidimensional ways in which perception emerges through the linear path of linguistic communication?

By highlighting this problem at such an early point in this thesis, I wish to argue that it is perhaps unfortunate that research on perception is mainly taking place inside a laboratory and is almost invariably communicated through published papers and reports. This kind of dissemination of knowledge involves the use of a terminology that has become quite specialised in order to describe the highly complex methodological approaches employed (like, for example, different neuroimaging techniques). As such, in some cases it arguably reduces perceptual experience to a systematised account of recorded processes, and limits its potential audience to the academic and the researcher (for the reason that its accessibility to a non-expert requires extensive effort to familiarise with the specificities of the used language). Having said that, I wish to express the reasons for taking a practice-led, and for that matter an art-based, research approach to perception. I argue that artistic enquiry offers possibilities to challenge and possibly overcome limitations set by language in general, particularly so when examining and communicating a subject as nebulous as perception. Moreover, it provides possibilities of engagement with the subject to a wider and more diverse audience than the one reached by traditional theoretical and scientific enquiry. By making this argument, I do by no means want to underscore the importance of this thesis in the overall scope of my research. The following text not only presents the development, methodology and findings of my study (with all accounts of subjectivity they may entail); it also provides the theoretical framework upon which my research practice was made possible. Indeed, it is difficult to see how the threads of my art practice could be bound together outside the theories and practices examined in this thesis. Therefore, the textual and practical elements of my research should be considered in complement to one another, and should be understood as equally important parts of my research.

The theories I examine originate mainly in the fields of psychology, physiology and neurobiology, and resonate with what has been termed as 'ecological' approach to perception. The ecological approach understands perception as a process that occurs within a system comprising of an organism and its environment, where the two are inseparable from one another. Relocating the interest from the sphere of oneself to the sphere of oneself within the world, the ecological theory is in line with work conducted across different disciplines of the social sciences, like, for example, sensuous geography (Rodaway 1994), phenomenology (Merleau-Ponty 1945), social anthropology (Ingold 2000), cultural geography (Tuan 1977), sensuous anthropology (Howes 2005), sensory ethnography (Pink 2009), architecture (Pallasmaa 2005) and sensory design (Malnar and Vodvarka 2004). The line of thought of some of these thinkers will be discussed in relation to my own approach to the study of perception.

An exhaustive account of all relevant research on the subject falls outside the margins of this thesis. My interest centres on specific aspects of the perceptual domain and it is those areas that I examine in more detail in the text that follows. My study on perception begins with a brief account of how the physical world (the one encountered through its materiality) is differentiated to our perceptual world (the one experienced through our sensory modalities). Particular emphasis is given to the concept of the crossmodal: how does information received from different modalities combine to generate a final percept of what is experienced? How are our different modalities defined and classified? How do they integrate, interact, and inform one another? Different theories and examples of scientific research are presented to provide an insight into our perceptual mechanisms and the ways in which our sensory modalities are essentially crosslinked. Building on the ecological theory of perception, I address modalities as active perceptual systems differentiated to their common view as passive senses. I examine the role of culture in existing sensory hierarchisations, and attempt to unravel why some sensory modalities (like vision and hearing) are understood to be more important than others within what is broadly defined as western culture. Finally, I argue for the role of active exploration in the perceptual process, particularly in the context of a system in which the subject and their surroundings are both animate and latently affected by their interaction.

Ranging with regard to the diverse methodologies they employ and the specialised topics they examine, the scientific studies covered in this thesis share a common goal: to uncover the mechanisms of perception and to provide an explanatory frame for its function. My artistic enquiry is informed by the reviewed theories and methodological approaches, however, its scope and development differ significantly in that respect. The purpose of my research is not to explain the function of different processes contributing to perceptual experience, but rather to raise awareness of such processes and of the ways in which they interrelate and affect one another in the act of perception. This form of awareness is 'an adaptive process of human thinking and acting that is informed by our experiences and encounters' (Sullivan 2010: 96).

The starting point for my research is the creation of an artwork and its installation in an experimental setting. Although experimental approaches are often used to explore perceptual matters, the setting and methodology I propose are qualitatively different to those typically involved in the study of perception. My experiment takes place outside the context of the laboratory and its conduct relies greatly on the aesthetic experience of the artwork. In this sense, the artwork becomes an integral part of the investigative process: it creates possibilities for encountering and enhancing multisensory experiences, and provides a physical platform for studying how different sensory information integrates into a meaningful percept upon which to act by observation of enacted physical responses to the perceived information. In that regard, the artwork serves as a research tool that is used to examine the two ends of the perceptual chain: physical stimuli and physical response to it. I propose that the relation between these two ends can be telling of an intermediate process that is intangible to the observer (perceptual activity) through what can actually be observed (physical activity).

The artwork I have developed for the purposes of my research is a touch-sensitive, sound-generating rug. The use of the textile medium is not coincidental as regards my research methodology. Serres depicts 'tissue, textile and fabric' as 'excellent models of knowledge' whereby knowledge can be understood as perceptual experience (Serres 1998: 100). The textile material evokes sensations across the array of the senses, asking to be explored tactually and visually but also through sounds that come about by, for example, stroking its surface; its multisensory quality makes it a pertinent medium for the study of perception. However, its potentiality to become a research medium is only fulfilled when a set of design parameters are specifically determined to allow it to facilitate the investigative process. Within my research approach, the application of systematic design and utilisation principles is essential for the transformation of the rug from an artwork into an artistic research medium.

The element of responsivity plays a significant role in my research methodology in that respect. Combining traditional art practices with technological innovation offers methodological possibilities for maintaining an interactive relationship between the artwork and its audience. This form of participatory engagement engenders a dynamic system in which the actions of participants and the artwork as a responsive organism co-author the artistic outcomes. Experience of the emergent outcomes is integrally bound to the dynamic nature of the 'art system' that comprises of the artwork and the participants (Cornock and Edmonds 1973). The process by which artistic experience occurs in this sense is very similar to the manner by which perceptual experience is understood to occur (within a system comprising of an organism and its environment where the two are inseparable from one another) in the ecological theory of perception.

In my research practice, this form of interactive relationship between the artwork and its audience is facilitated by the touch-sensitive technology of the rug (the ability to sense people's movement on it) and its sound-generating performance (the ability to respond to people's movement by composing sonic output that is specific to the movement of each participant). I suggest that these design parameters set the basis for transforming the rug into an investigative tool: an artistic interface that can be used for studying how participants make sense of the multisensory stimulation they receive from interacting with it as manifested in the process of continuously informing their modes of interaction.

To evaluate the way in which participants' interaction with the rug evolves over time with respect to the sensory information they receive, I propose an experiment that is conducted in two stages with each stage involving a different task. My evaluation is built on analysis of how participants approach and perform the given tasks. My analysis examines material gathered from video recordings of the experiment as well as from data reports obtained from the software used for the sound generating performance of the rug. Combination of the collected qualitative and quantitative data provides a coherent overview of the different orientational and exploratory strategies employed by participants at each stage. Examination of correspondences and diversities in participants' strategies leads to some general observations regarding the perceptual process underlying the performances that occurred in the specific experimental setting. These observations point to the role of multisensory integration, attentional focus, exploratory behaviour and past experience in the shaping of perception. Moreover, they indicate that these factors are relational to one another and that the boundaries among them are difficult to define.

It should be noted that the proposed experiment has not been designed with the purpose of providing conclusive or objective evidence regarding the processes involved in the act of perception; this is a task beyond my expertise and one that is best served by researchers in a range of disciplines located mainly within the realm of natural sciences. The experiment has been designed as part of an artistic enquiry on perception that aims at providing an alternative, and hopefully complementary, approach to the scientific research that takes place on the subject. To this end, it serves as an example of how artistic research can contribute to the interdisciplinary discussion on perception in a creative but also informative manner.

The text that follows is structured in three parts that collectively present the process of my research as has evolved over the last five years: from the theories that have informed it to the development of a testable research concept; from the structuring of a design methodology to the making of an artwork that is used as an investigative medium; finally, from the application of the artwork in an experimental context to the findings generated through the experimental process. The first part of the thesis is an exploration of the theories that set the ground for my study. It presents a significant amount of discourse attending the subject of perception that ranges from neurobiology and psychophysiology to anthropology and sensory geography. At the focus of this theoretical framework are the concepts of the crossmodal and active exploration, as well as the influence of different models of sensory appreciation in the perceptual experience. The second part concerns my research practice and its development in relation to the examined theories. It considers the possibilities of responsive textiles as a research medium, and reviews a selection of large-scale, textile-based installation pieces upon which my practice is contextualised. It provides a detailed account of my design methodology and of the processes employed for the making of the practical element of my work. The third part essentially binds the first two (theory and practice) together. It presents the application of my practice in an experimental context, and discusses the experimental process, its analysis and findings in light of the theories that have informed the development of my research practice. The thesis closes with some reflections on my approach and with some thoughts on the possibilities it provides for future research and applications.

Part 1

On theory

> **The physical and the perceptual**

Before embarking on an inquiry regarding the mechanisms of perception it is important to underscore that what we perceive to be our physical world – that is, our perceptual or phenomenal world – is somehow different to our actual physical world. There is a complex relationship between these two domains that critically links the physical events we encounter and their corresponding psychophysical events which we experience and to which we react. As it is almost impossible to maintain a distinction between the two (the physical and the perceptual) in our everyday life, it is quite common to mistake one with the other and to consider them as one.

Our immediate awareness of the world is a matter of our access to it; and access depends on various different things like our current psychophysiological state, our drives and intentions, our previous experience, and our different cultural backgrounds. As such, perception cannot be confined to one 'universal', objective reality. That is not to say that perceptual worlds are mere personalised replicas of the physical world, in which case we would be 'trapped in a circle of subjectivism and diverted into futile speculations about private worlds' (Gibson 1959: 463). On the contrary, material objects and living organisms may differ in their accessibility to different people, yet there is remarkable agreement of people's corresponding percepts. Though not one and the same with the physical world, our perceptual worlds are veridical and this quality (with all accounts of subjectivity it may involve) forms the basis of shared experiences and social interaction. Metzger explains:

> Phenomenal worlds are not exact reflections of the physical world […] they have quite a number of essential characteristics that cannot be found in the physical world: the secondary and tertiary qualities of percepts and situations and the valences and tensions existing between them have no counterpart in the corresponding physical facts. But still they represent the physical facts so reliably […] that different subjects in spite of their different standpoints can consider their respective phenomenal worlds as identical, that is, as, for all purposes, one and the same objective reality (Metzger 1974: 58).

The perceptual world and its corresponding physical manifestation are related through a long chain of causation. Although the intermediate events are complicated to break down, a closer look at the two ends of the chain can suggest how they are differentiated. Let's consider an example of a sonic event, a beep, and examine how we make sense of it. The physical characteristics of the beeping sound are its wavelength (the sound's frequency of vibration), its intensity (the sound's amplitude) and its pureness. Yet, in place of these characteristics what we experience are the beep's pitch, loudness and timbre respectively. Grasping the beep relies on processing those combined sensory qualities which are essentially different to its actual physical characteristics (see Table 1). In a simplified manner, this example illustrates the way in which our phenomenal world comes about to help us make sense of and maintain contact with the physical world.

	Characteristics	*What we perceive*
Light:	Wavelength	Hue (colour)
	Intensity	Brightness
	Pureness	Saturation
Sound:	Wavelength	Pitch
	Intensity	Loudness
	Pureness	Timbre

Table 1. Distinction between the physical characteristics of light and sound, and what we experience (Kasschau 1985: 189; 197)

> An ecological approach to perception

The question of how we understand and relate to the world has been around since the ancient times. From the 18th century onwards it became a prominent subject of philosophical interest and scientific enquiry. Traditional studies on perception understood it to be a matter of subjective representations of the world; an inference of what surrounds us constructed on the basis of logic and reasoning. The epitome of this school of thought was formulated in the 1920s into what became known as the Gestalt theory. Developed by a group of German experimental psychologists, Gestalt saw perception as an inferential process during which sensory inputs are internally organised to provide us with mental representations of what we experience. The theory suggests a fundamental dualism between the perceiver and the physical world: in the Gestaltian view, it is not our environment that we are directly aware of; it is the subjective model of it created in the mind by means of complex, implicit rules of geometry and logic. In separating the self from the environment, Gestalt maintains a dichotomy between mind and body in which the latter is reduced to a passive receiver: the body is seen as a platform upon which sensory stimulation is imposed only to become veridical experience by means of mental processing.

In the 1960s, American psychologist J.J. Gibson started developing a perceptual theory that offered a truly new approach to the subject as established in previous discourses. His Ecological Theory of Perception deconstructed the dualism of an objective reality (the physical) and its subjective representation (the mental), and offered a radically new way of understanding perception. In place of such a dichotomy, Gibson's theory redefined psychophysical casualty as occurring in a system comprising of our environment and ourself, where the two are inseparably linked. In this context, perception is essentially of the self *and* of the world, emerging through the direct relation we share with the environment and relying not only on its physical characteristics but also on the sociocultural conditions it entails (see Heft 2001). Unlike traditional theories of perception which see the perceiver as a passive organism that forms internal representations of the external world, ecological theory renders the perceiver an active agent in the world. It proposes that 'the function of the brain is *not* to *organise* the sensory input'[1] and shifts attention from the study of structures – e.g., contours, contrasts, transitions, differences of intensities – to the subject matter of perception: how we position ourselves in the world and how we relate to it (Gibson 1966: 5; original emphasis, see also Gibson 1986).

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[1] Despite not rejecting forces of organisation, Gibson finds these forces to occur in the neural medium (Gibson 1966).

Perceptual experience, it argues, is not merely about what we see, smell or hear; rather, it is about what we make of what things afford us, their value, qualities, use and so on. Perception is essentially about awareness of affordances and the possibilities for action they involve.

Gibson's 'affordances' expand the relevance of physical objects and living organisms to the perceiver beyond the material substance, shape, size, rigidity and motion that characterises them. Affordances are not mere transitions experienced in the energy arrays available to our senses like, for example, 'differentials of colour, heat, motion, sound, pressure, direction' (Golledge and Stimson 1997: 189); they convey information pertinent to the perceiver through which meaningful responses, relations and eventually actions occur. To propose that affordances are relational to the perceiver does by no means suggest that they are subject to change with respect to the perceiver's needs. What an object, let's say, affords us is set. However, our current psychophysiological state alongside our drives and previous experiences determines our access to what the object affords and how we will relate to it (for example, a sofa affords sitting even when I choose to simply stand, or to lie down on it). The concept of affordances offers a new perspective on how perceptual meaning is made that transcends traditional binaries like physical reality and mental representations. Gibson explains:

> 'An affordance cuts across the dichotomy of subjective-objective and helps us to understand its inadequacies. It is equally a fact of the environment and a fact of behavior. It is both physical and psychological, yet neither' (Gibson 1986; 129).

At a physical level, affordances involve features that characterise the sameness of an object (or an organism, or a space) through time regardless of variation. Let us consider an example of a space, e.g. a gallery room. There are certain features that allow us to recognise it as the same room we visited a few months ago despite differentiations in its lighting (last time we visited the room on an evening but today is still noon), its differentiated acoustics (last time it was crowded but today the room is quite empty), and the fact that a different exhibition is now on display. The features of the gallery room that withstand variation and enable us to perceive it as one and the same through time are permanence, transgredience, and constancy. Let's take a closer look into what these features stand for. Permanence indicates identity, the knowledge that something is invariable in itself even when we experience changes in its properties. '*The experience of identity gives an object its unchangingness, its permanence, in spite of its partial or complete absence from the field of vision'*, where what is referred to as the field of vision can be expanded to involve all perceptual fields (Von Fieandt 1974: 80; original emphasis). Transgredience, a term coined by Kaila in 1962, involves those qualities that are perceived as 'essential' or 'substantial' in the existence, character or function of an object, organism or space. Transgredience associates the ephemeral qualities which, for example, an object presents to us with our empirical certainty about the given object:

> Every perceivable object, for example, a mirrored face, is transgredient in its relationship to its instantaneous appearance. […] Thus a perceivable object is never identical with any instantaneous appearance; such an object is not extant or present in its instantaneous appearance. But in practice we can ignore this logical condition because in normal cases we possess an empirical certainty about it, that particular implicit anticipations are confirmed (ibid: 81).

In other words, our anticipations of the given object contribute to its percept based on our integral experience of the object and not on its instantaneous individual manifestations. Finally, constancy involves our ability to perceive the unchanging nature of an object's, organism's or space's properties despite the variant changes they present us with regarding their experienced qualities such as colour, size, shape, pitch, timbre, smell, taste. For example, we recognise that a singer is shouting even if the sound on a recording is turned down, or a sound as being loud regardless of our proximity to the sound source, just as we recognise a person as being tall or not regardless of their relative proximity to us (see Leeuwen 1999).

Permanence, transgredience and constancy are closely interrelated phenomena; they form the basis for perceiving something as the same through temporal and spatial change by contributing to and complimenting each other. They characterise all affordances we encounter in the world, and create the conditions for us to understand events as spatiotemporal clusters. No individual physical feature of an event inherently generates perception; rather, it is the essential interrelation of different features that allows us to comprehensively experience the event as a whole.

Originated by Gibson and more recently developed by theorists and psychologists like Corello, Turvey, Heft, Noë, and Stoffregen, the ecological approach to perception puts forward some ideas that make artistic enquiry particularly relevant for their study. Grounded on the notion that it is impossible to disentangle our understanding of the world from our existence in it, ecological theory differentiates between imposed and acquired sensory stimulation, arguing that meaning is afforded when stimulation is actively and purposefully obtained. Perceptual meaning is, thus, relational to how we engage with our surroundings and emerges *as* we establish a relation with it. We are not mere observers but active agents of our perceptual experience; an experience that relies on our behaviour quite as much as it does on the sensuous materiality of what we experience through all of our senses.

These ideas highlight a problematic nature in perceptual studies conducted in laboratory settings, as still is the norm. The differences between looking at an image on a screen and looking around an environment are fundamental, as are also the differences between experiencing an object (or an organism, or a space) whilst sat on a chair with constrained body movement from being able to navigate around it. Gibson himself often criticised the lack of ecological relevance in scientific experimentation which reduces the perceiver to a passive receiver of sensory stimulation. My research takes a very different approach to that of traditional scientific enquiry – which centres on imposed sensory stimulation for the purposes of evaluating its effects on experimental subjects. Using installation art as an experimental medium, my research focuses on the possibilities offered by participatory art to explore perceptual matters as people physically engage with the artwork and as they go about to explore it with all their senses attuned. In this context, perceptual meaning emerges within a system that comprises of the artwork and its audience, where the latter obtain their own information as they freely interact with it. An important part of my methodology entails a number of elements typically found in an experimental approach: it involves a group of people that share certain common characteristics, it provides participants with some tasks they are asked to conduct, and it is filmed to provide observational material for analysis. Despite these procedural similarities, my methodology offers a new approach to problems encountered in traditional experimental research on perception by making the study of *active perceivers* possible. Part three of this thesis provides a detailed account of my experimental enquiry.

> **The role of culture in the history of perception**

> [d]ifferent cultures understand the same senses differently, privileging some characteristics over other, such as colour over line in the visual field, or temperature over texture in the field of touch. […] The meaning of senses is in their use, and perception is always mediated by the prevailing order of sensory values (Howes 2005: 143).

Through our active and fully embodied engagement with the world, we perceive things as interrelated events taking place within a system comprised of our environment and ourselves. This system is both dynamic and culturally sensitive. Therefore, what things within it afford us is not just a matter of physicality and availability to our senses but also of cultural appreciation. A study on the mechanisms of perception requires an understanding of how the senses are culturally attuned. It is therefore important to consider a number of factors that affect our understanding of the sensory modalities, bearing in mind that biology – and science in general – is itself a cultural product subject to social constructions that influence the representation and use of the senses within a given cultural setting.

The setting under study within the framework of my research is western culture. Of course, the term western culture is an ambivalent one actually embracing a vast variety of differentiated cultures and ideologies. For myself, coming from Greece (a western society that geographically and culturally shares many commonalities with the Middle East) and having lived for almost a decade in the UK, these differentiations have in many occasions become obvious. For the purposes of this thesis, I examine how senses have been conceptualised, appreciated and put into practice in what is believed to be the core environments of western culture, namely Central Europe, North America and the UK. However, reflecting on my own cultural background, my analysis will start with an etymological interconnection of the terms 'sense' and 'perception' as found in Greek, my mother language. Sense in Greek is translated as aesthesis/αίσθηση and derives from the verb aesthanomai/αισθάνομαι. Aesthanomai is an ambiguous term, which involves notions of feeling, sensing, grasping, and understanding. Perception, translated as antilepsis/αντίληψη, in turn derives from the verb antilamvanomai/αντιλαμβάνομαι whose meaning is also stretched to include a number of different concepts such as grasping, understanding, realising, and noticing. The concept of grasping and understanding in both 'sense' and 'perception' illustrate an underlying yet integral relation between the two terms. We directly experience our environment through our senses and perception is formed in parallel with the contextualisation of our experience. The process of contextualisation takes place at several levels and depends on a number of physiological and sociocultural factors. The concept of grasping suggests that this process is greatly dependant on notions of physicality such as the psychophysiological state and bodily memory of the perceiver as well as the materiality of the perceived. Also, its relation to the idea of feeling involves connotations of affect and emotional experience. From this point onwards, when referring to perception it will be with respect to these aspects, namely the physicality of the perceiver and the perceived, the cultural values of the perceiver's environment, and the psychological appeal the former two may have on the perceiver.

Dating back to Plato and Aristotle, the history of perception begins with the classification of our sensory system into five distinct senses. Unlike Aristotle who believed that of all the senses touch was the most critical because of its fundamental nature, for Plato touch, smell and taste were of the least value as he believed them to interfere with the acquisition of truth. Despite the different emphasis each school of thought put on different senses, perception was since ancient times considered to be our means of gaining knowledge of the world through our senses. The Enlightenment, followed by the Scientific and Industrial Revolutions of the eighteenth century brought forward a gradual change in the education of perception in Europe, particularly in England, France and Germany, which at the time comprised the hub of western culture. The establishment of perspective, precision scientific measurements, mathematical analysis, classification systems and technological standardisation urged a shift from a sensory-centred understanding of the world to a quantitative, systematised knowledge of the world. Investigative models of knowledge that were dependant on qualitative analysis of information obtained directly through the senses such as 'color change or turbidity, crackling sounds, and smells' became to be considered unreliable due to their essentially subjective nature (Roberts 2005: 117). The importance of sensory evidence was gradually downgraded as they were presenting substantial difficulties in being classified into the standardised systems favoured and promoted by the institutionalisation of the epoch. Information gathered through the body and the senses – and eventually the body and the senses as such – became subordinated by scientific instruments and the analysis of their measurements.

Of all the senses only vision was not deprived of its importance. Not only (as perspective demonstrated) vision could provide a model for representing in two dimensions the multidimensional experience of the world; it was also the medium through which scientific measurements could be read and made sense of. Thus, vision was granted a prevailing order in the array of the senses. However, it is important to note that the education of visual perception as established within the scientific revolution regime

> increased as regards the visual readings of the results produced by laboratory instruments (such as thermometers) but decreased with respect to the role of direct visual evidence (such as changes of color) (ibid.: 123).

Latour notes that with the detachment from the somatic sensations it includes, vision actually followed the fate of the other senses and became abstracted to 'sight' (Latour 1986). The reduction of pansensual experience to abstracted vision, described by Bachelard as 'geometrism' and by Ivins as 'optical consistency', ordered a rigid hierarchisation of the senses which cannot be solely justified through the scientific practices of the era (Bachelard 1994; Ivins 1973). The prioritisation of vision with respect to the other senses in fact served a greater context of social parameters after which science (a cultural product itself) was shaped. Sight, and to a certain degree hearing as well, were considered to be the most noble of the senses, associated to the upper classes of the societies under study. In contrast, the senses of smell and touch were associated to the working class whose surviving depended on physical labour and whose pleasures were considered to be solely of a corporeal nature (see Howes 2005; Williams 2001). Scientific knowledge, accessible at the time mainly to the wealthy, reflected this social division in discarding the value of the majority of the senses in favour of sight. Echoing the ideological orientation and social orders of the time, the scientific (and later on the industrial) revolution of modernity educated a sensory hierarchisation which undervalued the importance of all senses including that of vision (Vroon, van Amerongen and de Vries 1994).

Subject to the social constructions of each era, sensory representation and appreciation could not have remained unchallenged within the cultural challenges that followed the passage from the Industrial to the Information Society. The growing number of theoretical and scientific studies on the crossmodal nature of perception has come as a response to the changing social, political, technological, and theoretical perspectives that are shaping our times. Globalization, new technological and scientific advancements, the spread of new media and particularly of the Internet, paired with schools of thought like feminism, post-structuralism, psychoanalysis and theories of embodiment have challenged prevailing conceptions of acquiring knowledge and of relating to the world. The shift from a society in which knowledge was a privilege of the few to a society in which knowledge is produced and accessed by the masses has been facilitated by a number of factors that are characteristic of the Post-Industrial era. These, among others, include the turn towards interdisciplinarity and participatory practices – as opposed to the specialisation and division of labour dictated by the Industrial Age; the expansion of open sources, free information transferring and the social media; the breaking down of boundaries between local and global; the new possibilities offered by technological advances in our everyday life; and the impact of interactivity and virtuality across many domains, particularly within the fields of education, communication, and design (see

Jewitt 2009). These cultural changes have altered the ways in which we relate to the world, and in doing so they have created the ground for a gradual change in our appreciation of the senses and their interrelation.

Within this context, the huge progress science is witnessing from the twentieth century onwards has contributed significantly towards a reconsideration of traditional sensory hierarchies and perceptual theories. The dramatic advances in technology and emerging research methodologies brought forth during the last few decades (like, for example, functional neuroimaging and transcranial magnetic stimulation) have allowed us to get an actual glimpse into the ways in which the human brain works, and have highlighted the role of sensory communication in perceptual experience. The bank of knowledge generated by this explosion of research on human perception clearly points to multisensory integration as a fundamental aspect of the perceptual processes generating our lived experience. The idea that perceptual experience is essentialy multisensory in nature is not new. A number of philosophers (for example, Locke 1690, Berkeley 1709, Merleau-Ponty 1945) and psychologists (like E.J. Gibson 1969, J.J. Gibson 1966, Welch and Warren 1980, Werner 1973) have examined it before the advent of recent methodological advances in the field of neurobiology. However, it has been only in the last two to three decades that we are coming to realise and widely accept that multisensory integration is not an exception but rather the general rule. This gradual shift on our understanding of perception – from one that is being shaped by models of sensory hierarchisation to one that is essentially a process of sensory integration – is being reflected in the growing volumes of scholarship published on crossmodal activity, in the explosion of domains that aim to generate holistic sensory experiences, as well as in the increased interest for the design of multisensory systems for various applications such as virtual environments, e-commerce, training systems, and medical applications.

Before attempting to unravel the ways in which the senses combine and interact with one another, it is important to start with a question which might seem to have an obvious answer yet is quite challenged and challenging: how are our senses defined? Since the writings of Plato and Aristotle, the senses were classified with respect to what was identified as five distinct sense organs in the human body, a classification that still remains in effect in our days. As obvious as it is to associate sight with the eye, hearing with the ear, smell with the nose, and taste with the tongue, the sense of touch presents a difficulty in allocating a specific sense organ to it. This becomes apparent in various Renaissance studies on anatomy where the focal organ of touch is alternatively described as 'the entire body, the nerves, skin, fingertips, tongue, palms, the region about the heart' (Mazzio

2005: 88). A way to overcome the narrow boundaries set by a classification reliant on our sense organs would be to define our senses according to the energy arrays available to our organism ‘based on our sensitivity to light, sound, gas, liquids, solids, and body position and motion’ (Kasschau 1985: 187). Or, to classify the senses with respect to our receptors; this would result in about ten distinct modalities, namely vision, hearing, taste, smell, balance, kineasthesia, proprioeption, temperature, pressure and pain.

In 1966, J.J. Gibson provided an alternative manner of classification which examined not merely senses but sensory systems as a whole. In place of sight he introduced what he called the ‘visual system’, same as in hearing for which he introduced the ‘auditory system’. Gibson proceeded with merging the chemical senses into the ‘taste-smell system’, and expanded the sense of touch into the ‘haptic system’ to include the sensing of temperature, pain, pressure, proprioception, and kinaesthesia, where the latter involves body sensation and movement. Finally, he introduced a new sensory system, the ‘basic-orienting’, to address attentional response (Gibson 1966). Some years later, in his book The Ecological Approach to Visual Perception, Gibson explained the differences between a sensory system and a sense, noting that ‘a system has organs, whereas a sense has receptors, a system can orient, explore, investigate, adjust, optimize, resonate, extract, and come to an equilibrium, whereas a sense cannot’ (Gibson 1986: 245). Gibson’s sensory systems suggest an integral crosslinking between certain senses within certain systems – such as the chemical senses in the smell-taste system, and the skin-senses in the haptic system. He also proceeded to examine interrelations between different sensory systems, and produced a significant body of work on relations between the visual-and-haptic and the visual-and-auditory systems. Although restricted to bimodal cases with a primary focus on visual perception, his work set the basis for the study of intersensory communication in the act of perception.

> Notes on the crossmodal

> The sensible, in general, holds together all senses, all directions, like a knot or general intersection […] How could one see the compacted capacity of the senses if one separates them? (Serres 1998: 406).

The multisensory nature of perception has, over the last few decades, been extensively explored across the natural sciences (particularly in the fields of behavioural studies, neurobiology, and psychophysiology) as well as across many disciplines located in the social sciences. Gibson's ecological approach on perception has been highly influential in that respect, informing not only the bulk of scientific research on the topic but also the thought of many social scientists like Rodaway, Ingold and Serres. Reflecting a Gibsonian approach to perception, sensory geographer Paul Rodaway elaborates on the multisensuous character of our everyday experience, and emphasises the interrelation of the senses even in situations where a certain sense appears to be more dominant than the others (Rodaway 1994). At the same time, anthropologist Tim Ingold argues that the function of our perceptual systems is overlapping, and stresses that the eye and the ear (and all sense organs consequently)

> should not be understood as separate keyboards for the registration of sensation but as organs of the body as a whole, in whose movement, within an environment, the activity of perception consists' (Ingold 2000: 268).

His understanding of the sense organs not 'as separate keyboards' finds support in the work of neurobiologists Newell and Shams that challenges the historically prevalent idea of our modalities operating as modules that are independent of one another in the act of perception. Newell and Shams propose that

> our phenomenological experience is not of disjoint sensory sensations but is instead of a coherent multisensory world, where sounds, smells, tastes, lights, and touches amalgamate. What we perceive or where we perceive it to be located in space is a product of inputs from different sensory modalities that combine, substitute, or integrate (Newell and Shams 2007: 14; see also Shimojo and Shams 2001).

They add that the way in which these sensory inputs are combined into a final percept is further affected by our own experience and explain that, although integrative learning (and therefore cultural values) holds an important role in multisensory interaction, crossmodal activity already exists in the organism from its very early stages. This is resonant with earlier accounts on intermodal unity (see Bower in MacLeod and Pick 1974).

A large amount of scientific experiments originating mainly in the fields of neurobiology, neurophysiology and psychology have been conducted to shed light on the role of intersensory integration in perceptual activity. In these experiments, subjects are usually asked to participate in studies that examine communication between two modalities.

Whilst narrow in clearly demonstrating the full extent to which our modalities combine with and enrich one another, bimodal examples still provide an insight into crossmodal perception. For example, Macaluso and Driver's work on interactions between vision and touch in spatial attention indicates that stimulation in one modality can affect the activity of another modality as certain brain areas represent common regions for different modalities (Macaluso and Driver 2001). Their position resonates with Lacey's research on a particular cerebral cortical area known as the later occipital complex (LOC) which was shown to be activated by haptic exploration of shape despite being considered to be an exclusively visual area (Lacey et al. 2007). In 2001, a neurological study conducted by Calvert on the function of bi- or trisensory neurons located in the superior colliculus of the human brain showed that each bi- or trisensory neuron

> contains a map of sensory space, one for each sense (visual, auditory, tactile) to which it responds. The different maps overlap each other so that stimuli from different sensory modalities originating in the same spatial location activate the same region of the superior colliculus (Calvert 2001: 1111).

A recent study by neuroscientist Ross Deas on the perception of auditory space vividly illustrates relations between our haptic and auditory modalities. His findings show that the processing of vibrotactile input presents significant similarities to that of auditory information, and that there is a certain 'overlap between the frequency range of the sensitivity of the ear and skin' (Deas et al. 2010: 1). Deas's analysis asserts that auditory and tactile information is combined in the process of perceiving auditory space, a perspective that is in line with the work of pathologist Gonzalez-Crussi on interrelations between the hearing and haptic systems. Considering the ways in which sound penetrates the human body, Gonzales-Crussi argues that 'our whole body vibrates in unison with the stimulus' and concludes that 'hearing is, like all perception, a way of seizing reality with all our body, including our bones and viscera' (Gonzalez-Crussi 1989: 45). The close links between the haptic and auditory modalities have also been of interest to French philosopher Michel Serres who notes that the body is involved in the process of hearing through skin, bones, skull, feet, and muscles (Serres 1998). Expanding on the work of Serres, Connor argues for the close links between our auditory and haptic systems by drawing comparisons between the ear and the skin as perceptual organs: '[j]ust as the ear consists in part of a skin, so the skin itself is a kind of ear, which both excludes and transmits exterior vibrations' (Connor 2005: 324).

Research conducted within different fields indicates that the active correspondence of our sensory modalities not only strengthens the impressions we are afforded by the world we live in, but also – and most importantly – provides the possibilities for such impressions to be fully grasped and comprehended. However, crossmodal interaction is not a straightforward process but, rather, one that occurs in a number of different manners which can be generally summed under three broad cases[2]: firstly, one may obtain the exact same information from more than one sensory modality. In such instances of concordant information occurring from two or more modalities, differentiations can be recorded with respect to the accuracy or precision of information provided by the different modalities as well as regarding the time differences within which the different modalities receive the information. Alternatively, one may obtain discrepant information from two or more modalities. Finally, one may obtain differing yet complimentary information from more than one modality. Regardless of the various ways in which they combine, integration of the senses is essential for the formation of unitary percepts. Lalanne and Lorenceau assert that crossmodal integration is a crucial perceptual mechanism, which allows us to resolve perceptual ambiguities and provides us with a unitary grasping of our environment. This is true even in those cases where contrasting information is received from two or more different modalities. As they explain, grasping an event through information obtained from different sensory modalities is

> based on an adaptive combination of the contribution of each modality, according to the intrinsic reliability of sensory cue, which itself depends on the task at hand and the kind of perceptual cues involved in sensory processing' (Lalanne and Lorenceau 2004: 265).

This account echoes the Modality Appropriateness Hypothesis (MAH), which demonstrates particular interest in those cases where sensory information is not concordant. MAH suggests that when obtaining conflicting information form two or more modalities about the same spatio-temporal event, we allow for the more reliable or accurate information coming in from a certain modality to dominate the less indicative information coming in from the other(s). Lederman and Klatzky explain that in such cases of discordant multimodal information we 'weight the various modality inputs according to their relative unimodal performance capabilities' such as accuracy, response time, precision and variability 'with respect to the given task' (Lederman and Klatzky 2004:117). Hence, through unimodal compromise, multisensory experience is formed

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2 see MacLeod & Pick 1974, and Kasschau 1985.

into a meaningful and unified percept (see also Friedes 1974; O'Callaghan 2012; Welch and Warren 1980). Another perceptual model that agrees with the modality appropriateness hypothesis is that of Fuzzy Logic, developed by Massaro (Massaro 1999). Massaro's theory indicates that a certain modality may be given particular weight over another if it presents us with less variability and more predictability or more reliability. The general theoretical platform of Fuzzy Logic suggests that crossmodal integration, generated through 'convergence of separate information sources, with suitable weighting of each as they are combined', provides us with a round percept of the events we encounter in our environment (Driver and Spence 2000:731).

The theories presented above have been examined under the scope of multisensory communication in cases where the different modalities provide us either with concordant or discordant information about the same spatio-temporal event. Strikingly, crossmodal interactions where one modality is informed by another have been recorded even when the latter provides no information about the particular event. Such sensory interaction indicates a deeply grounded form of communication and integration across our different modalities. In 1970, Warren conducted an experiment in which participants were found to be more accurate in determining the position of a sound source in a dark room when not blindfolded despite the fact that the environment provided no visual information whatsoever with respect to the location of the sound source. Apparently, a single visual reference was enough to enhance their auditory localisation performance. More recent experiments with a focus that ranges from tactile to visual, auditory, and spatial perception point to the fact that one modality can be greatly informed by stimulation in another, grounding the position that perceptual mechanisms traditionally thought of as unimodal are drastically affected by crossmodal interaction (see Stein and Meredith 1993; Wallace, Wilkinson and Stein 1996; Driver and Spence 1998; Campbell and Brammer 2000; Kennett et al. 2000; Macaluso et al. 2000; Vroomen and de Gelder 2000; Calvert 2001; Lacey et al. 2007). In general, the recent literature on perception asserts that crossmodal integration is an integral part of our perceptual mechanism and that, in the case at least of adults, when presented with a plethora of sensory cues we are very flexible in dynamically weighting multisensory information to form a coherent perceptual estimate.

During the last few decades, a significant body of work has emerged by researchers focusing on multisensory development, a particular area of crossmodal perception that examines the ways in which the latter develops during the first months and, in many cases, during the early childhood of life. The question, of course, of how we learn to deal with the multisensory information that surrounds us as soon as we come into the world is not new (see James 1890; E.J. Gibson 1969). This relatively newly formed discipline has provided findings that shed light on the developmental processes of perception and, in doing so, it has provided compelling evidence of the essentially crossmodal nature of perception. The vast majority of studies on multisensory development conclude that crossmodal communication begins prior to birth (see Bradley and Mistretta 1975; Bremner, Lewkowicz, and Spence 2012; LeCanuet and Schaal 1996; Lewkowicz 2000; Lickliter and Bahrick 2000; Morrongiello et al. 1998; Walker-Andrews 1997). Indeed, multimodal processing begins during prenatal life; as soon as the sensory modalities begin to function[3], the fetus is faced with the challenge of starting to process the relations among them. Thus, when born, the infant already possesses certain elementary multisensory perceptual skills. As the infant grows, these basic skills are being further developed according to the neural growth and the gained perceptual experience. Lewkowicz explains that newborns

> start out life being able to perceive certain types of low-level multisensory relations (e.g. intensity, temporal synchrony) and that as they grow and gain increasing perceptual experience they gradually acquire the ability to respond to higher-level types of multisensory relations (e.g. rhythm, affect, gender) (Lewkowicz 2012: 164).

Infants seem to be able to process visual-tactile and visual-proprioceptive associations right from birth, and they quite quickly show signs of visual-auditory integrating activity when the combined sensory information they are presented with is synchronous (see Bremner et al. 2012; Morrongiello et al. 1998; Slater et al. 1999; Steri 2012).

Although developments in the literature of perception are ongoing and the area one has to cover to exhaust the topic is vast, the studies presented so far illustrate a fairly vivid picture of the integrally crossmodal nature of perceptual activity. They suggest that crossmodal integration is a crucial and sophisticated perceptual mechanism that takes place in various different ways and at various different stages in perceptual processing. Interaction among sensory systems enhances our perceptual ability when multisensory information is concordant, decreases perceptual mislead when information is conflicting, and allows us to build a round, accurate and meaningful percept. Unlike what has

[3] All sensory modalities –with the exception of the visual – begin to function after the first three months of gestation in a sequential order whereby the haptic is the first one to function, followed by the vestibular, the chemosensory, and the auditory respectively (Bremner, Lewkowicz, and Spence 2012).

traditionally been believed, crossmodal responses are considerably greater than unimodal ones; we are essentially attuned to perceiving the world in a multisensory manner. Crossmodal communication begins as soon as our sensory systems are formed while we are still carried in our mother's womb, and we perform some sort of rudimentary multisensory processing before we are even born. These scientific insights ask us to reconsider the prevailing notion of our senses as separate and hierarchised modules, and to address crossmodal interaction not as a matter of isolated cases but rather as a general perceptual rule.

> To perceive space

Historically, the majority of the many different theories of perception have been formulated around the perception of objects. The study of object perception presents an apparent advantage in relation to any other perceptual subject in the sense that it can be conducted in a laboratory – and, thus, in a controlled environment. Having control over the set of physical properties of the object(s) presented to experimental subjects, and being able to record subjects' responses to the object(s) involved in an experiment, allows researchers to have a clear overview of the two ends of the chain, and, as such, to focus on the processes that link them. For this reason, object perception has for many years been the primary research area of perceptual activity, and its principles – assumed to govern any individual case of perceptual processing – have provided the grounds upon which perception in general can be widely studied and understood. However, transferring principles of a very specific area of the perceptual field to the general field entails fundamental biases that undermine the holistic approach required for the study of perception. Developments in perceptual studies over the last decades have brought out the inadequacies of examining various aspects of perceptual activity – such as spatial perception – through explanatory systems derived from research on object perception. Spatial perception presents significant and fundamental differences to object perception; these differences lie in the simple fact that any attempt to understand the ways in which we relate to, make sense of and respond to our surroundings cannot be considered outside the context of our environment and our own role in it. In his 1973 essay 'Environmental perception and contemporary perceptual theory' Ittelson writes that

> [t]he distinction between object and environment is crucial. Objects require subjects –a truism whether one is concerned with the philosophical unity of the subject-object duo, or is thinking more naively of the object as a "thing" which

> becomes a matter for psychological study only when observed by a subject. In contrast, one cannot be a subject of an environment one can only be a participant. The very distinction between self and nonself breaks down: the environment surrounds, enfolds, engulfs, and no thing and no one can be isolated and identified as standing outside of, and apart from, it (Ittelson 1973: 149).

Ittelson's reflection on the distinction between our relationship to an object and our relationship to an environment raises two issues that are crucial in any attempt to understand the mechanisms of spatial perception: first, we are inseparable from our environment; second, our relationship to it is essentially bidirectional and fully participatory. Indeed, we – as entities – do not exist as separate and distant from our surroundings, rather, we are immersed in them. This quality of proximity and immersion renders us active agents in the perceptual experience of our environment. Unlike an object, the environment cannot be observed – it can only be explored – and the ways in which we go about exploring it become part of what we experience as being external to ourself and, hence, as constituting our environment. Spatial perception occurs through the active exploration of our surroundings, whereby what is defined as active exploration is a set of actions equally affected by the possibilities offered by a given environment as well as by our purposeful decision-making. The prospects of our potential actions – shaped by the possibilities offered by any set environment just as much as by our own needs and motivations – constitute the means of constructing our spatial experience. Spatial perception is both directive for and a result of purposeful action for the mere reason that we cannot act independently from what we are engulfed in nor can our engulfing environment be encountered independently from us.

The qualities of immersion and active exploration constitute two integral characteristics of spatial perception, and both of them are intimately bound to the essentially multisensory nature of space. If space is essentially multisensory then so is spatial perception by definition. It seems, of course, needless to argue that it is impossible to think of an environment which is not experienced through all of our senses. As Frances Anderton notes, a space is perceived

> not just by its impact on our visual cortex but by the way in which it sounds, it feels and smells. Some of these experiences elide, for instance our full understanding of wood is often achieved by a perception of its smell, its texture (which can be appreciated by both looking and feeling) and by the way in which it modulates the acoustics of the space (Anderton 1991: 27).

Reflecting on his studies of space, Edward Hall also asserts that we experience our surroundings through 'smells, tastes, textures, heats, sounds and muscular sensations' that render it 'round and deep' (Hall 1977: 177). The relative weighting and merging of all concurring information we gather through our senses when we actively engage with our surroundings provides us with a coherent and meaningful spatial percept. Environments are stages for actions, and the multisensory information they provide is not per se perceptually informative unless compared against the actions that generate our lived experience of them. As Bruner suggests, 'intended action, against which the feedback of the senses during action is compared' forms the basis of perception (Bruner 1970: 83). Indeed, crossmodal integration and action are always tied together in the act of spatial perception; the two do not operate in a sequential order, instead they are in constant and ongoing interaction with one another (see also Berthoz 2000; Noë 2004). Their intimate interconnection and their crucial role in spatial perception is evident in one particular way of spatial knowing: haptics, or what is otherwise known as active touch. Steri explains:

> The tactual perceptual field is limited to the zone of contact […] and has the exact dimensions of the surface of the skin in contact with the stimulus […] voluntary movements must be made in order to compensate for the smallness of the tactile perceptual field. The kinesthetic perceptions resulting from these movements are necessarily linked to the purely cutaneous perceptions generated by skin contact, and they form a whole (Steri 2012: 92).

The interrelation of the tactile senses – shaped on the fruitful ground of active exploration – can be thought of as a microcosmos of the ways in which crossmodal integration and action are intertwined in spatial perception. What we experience across the array of our senses, allows us to identify a complex set of interlinked environmental characteristics and to eventually make sense of our surroundings. Throughout this process we are always an active part of the space we encounter, shaping it through our actions and being able to explore the effects our performed actions have on it with respect to our drives. Action not only allows us to spatialise tactile, auditory, visual and olfactory information, but also to bind this multisensory information together with information we receive from mechanoreceptors in our muscles and joints, thus enabling us to form a unitary percept of both our environment and our bodily relation to it. In this context, spatial perception is 'an inherently interactive and wholly participatory process,' during which our different senses and purposeful actions work together in symphony (Malnar and Vodvarka 2004: 25).

If it has so far been thoroughly argued that crossmodal integration and action are intrinsic to spatial perception, the actual mechanism by which the latter is formed might still seem to be slightly blurred and obscure. It is not necessary to go into a lengthy discussion regarding the fact that our modalities provide us with qualitatively different information regarding the environment around us; we all have a relatively good understanding – based on our own lived experience – that 'vision is particularly good at transducing spatial information about near and far space from the visible light spectrum', 'audition is particularly good at encoding rapid temporal patterns of information arising from mechanical disturbances in both near and far space', and that 'information from the somatosensory channels (including information about touch from cutaneous receptors and about the arrangement and movement of our limbs from proprioceptors) helps us to perceive our body and the environment that is in direct contact with our body' (Bremner et al. 2012: 5). The question is how this qualitatively different information, which comes in from different sensory channels, is assembled and knit together into a unitary percept of the environment and its relation to our body. Recent studies clearly suggest this happens as a result of our ability to encode multisensory environmental input into a receptor-independent coordinate system (see Avillac et al. 2005; Cohen and Andersen 2004; Ma and Pouget 2008). But what does this mean? It is known that our sensory modalities encode spatial information in frames of reference that are specific to each modality. When we encounter an environment, different spatial reference-frames occur simultaneously to provide us with the necessary understanding of our surroundings – according to the sensory information available to us, as well as to our specific intentions and tasks at hand. These different spatial frames of reference are 'recoded' and integrated into a receptor-independent coordinate system that allows us to construct a unified spatial perceptual experience upon which we can act. Based on neuroimaging data, this kind of recoding is identified to be taking place in the posterior parietal cortex of the brain (Cohen and Andersen 2004). In their research on crossmodal integration for perception and action, Lalanne and Lorenceau conclude that

> '[a]ll the results highlight the multiple faces of crossmodal interactions and provide converging evidence that the brain takes advantages of spatial and temporal coincidence between spatial events in the crossmodal binding of spatial features gathered through different modalities' (Lalanne and Lorenceau 2004: 265).

Thus, by evaluating the spatio-temporal codes in which information is gathered through our senses, we integrate sensory inputs obtained directly from our body surface (e.g., through touch and proprioception) with that obtained from our enclosing environment (e.g., through vision, audition, and smell) into a receptor-independent, final multisensory estimate. This process, which we so comfortably perform in our everyday life, is a matter of highly complex computation, and crudely describes what underlies spatial perception.

Our perception of an environment consists of our sensing and understanding of all those features that characterize it and make it unique. Such features involve a wide variety of spatial properties like texture, form, temperature, humidity, colour, reflectance, density, smells, opacity, scale, continuity, resonance, echo and many more. Many of these properties can be grouped together under the umbrella of a single spatial attribute, namely that of texture. Texture is a microgeometric property and concerns the microstructure of spatial elements – as opposed to their macrostructure (e.g., form, shape and spatial layout). As a term, it is quite ambiguous as it can be used to describe properties that are experienced across many different sensory spectrums. For example, the texture of the air that fills a space includes resonances, humidity, clearness, smells, density and temperature, and these are experienced through our visual, hearing, chemical and skin senses. On the other hand, the texture of a spatial element (for example, a wall or a floor) confines properties like roughness, opacity, hardness, reflectance, rigidity, slipperiness, friction and thermal conductivity which are also experienced through various sensory channels like hearing, vision and touch – where touch is here expanded to include somatic sensations experienced through the whole of the body: the skin, the joints, the muscles and the tendons. On a review of selected studies on texture perception, Lederman and Klatzky conclude that the studies 'demonstrated that there is no fixed dominance hierarchy among modalities for the perception of textured surfaces, and with this observation underscored the multidimensional nature of texture perception' (Lederman and Klatzky 2004: 109). As will be extensively discussed in the third part of my thesis, the multisensory character of texture perception plays a central role in the development of my research practice.

In this first part, I tried to present some fundamental principles regarding perception and to draw attention to its essentially crossmodal nature. Moreover, I examined spatial perception as a particularly telling case of multisensory integration, and I raised the importance of active participation in the shaping of a round and meaningful understanding of our surroundings. These elements lay the theoretical framework upon which my artistic research unfolds.

Part 2

On practice

An artistic approach to multimodality
On textiles and the senses
Framing my research practice
On structure, function, and aesthetics
The rug as an experimental instrument

> **An artistic approach to multimodality**

The variety of disciplines involved in the study of different aspects of multimodality has led to significant differentiation in the use of the term multimodal. Through my own engagement with the subject for the purposes of my research, I found out that cross-disciplinary literature has paid little attention to clarify the different ways in which 'multimodal' is being used within different contexts. Of course, on a macroscopic scale the term is invariantly concerned with intersensory relations. However, two different approaches in its use can be noted in the bulk of literature on multimodality. The first has been extensively discussed in the first part of this thesis and specifically addresses different levels of interaction among our sensory modalities. This approach is found in disciplines like psychology, physiology, neurobiology, and in many of the social sciences like sensory geography and cultural ethnography. The second approach uses the term to express relations among different modes, whereby a mode can be understood as a form of communication like for example a text, a drawing, speech or music. The term is used widely in this sense in fields like semiotics, linguistics, communication, and design.

Having drawn a distinction between the two different uses of the term, I should stress that both play an equally important role in my research: if the study of crossmodal interaction is the very subject of my research, my practice-led enquiry essentially combines a variety of modes like sound, textiles, physical computing, software, video and text in order to be conducted and communicated. The starting point for my research practice is the creation of what can in short be described as a touch-sensitive, sound-generating rug. Within the context of my doctoral study, the rug is being used as a medium that creates both possibilities for multisensory encounters and the conditions through which aspects of crossmodal collaboration can be observed and explored as manifested in people's spatial behaviour. In a customised experimental setting, a group of people is asked to individually perform certain tasks on the rug. Their interaction with the rug is filmed and the film is in turn used as a medium for my research analysis. The rug itself, the videotaped material, and this thesis work in conjunction to cover the full spectrum of my research.

My decision to take a practice-led approach, and for that matter an art-based approach, to study a subject that is mainly located in the domain of scientific research is based on the notion that artistic research can help me address my research topic and gain an empirical insight into the processes of multisensory collaboration in ways that cannot be fully pursued through traditional theoretical and scientific enquiry. Art practices were first introduced to the realm of research in the late 1970s but it was not until the early 1990s that they started becoming acknowledged as an alternative mode of enquiry (Rust et al. 2007). This shift was – to a great extent – facilitated by the same socio-cultural conditions that nurtured the turn from a uni- to a multi-modal way of acquiring, understanding and transmitting knowledge[1], and created the grounds for art practices to become consolidated as a new form of research genre. When I first started thinking about the possibility of conducting a PhD on the subject of crossmodal perception, I was puzzled about how to explore the complexity of the subject through the form of a written thesis. I felt it would be difficult to explore as well as to express the multidimensional, dynamic and nonhierarchical nature of sensory experience solely through the linear channel of linguistic and, more so, written communication. I came to a gradual realisation that a practice-based approach could challenge and possibly overcome limitations set by language in examining and communicating instances of multisensory experience. As opposed to traditional research approaches, practice-led research allows audiences to engage with the research question at hand in a fully embodied, active, and emotional manner, and as such it can raise awareness and generate knowledge 'beyond the scope of explanatory systems […] where insight is not the consequence of causal, inferential, or predictive means' (Sullivan 2010: introduction xxiii).

My line of research practice is manifested as artistic enquiry yet follows systematic and observational principles in a similar vain to those followed in more traditional scientific approaches. McNiff argues on the importance of placing ideas in new relationships to one

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[1] See Part 1 of this thesis, p. 14

another for the advancement of knowledge, 'a process that typically requires crossing the boundaries of previously separated domains, such as those constructed between art and science' (McNiff 2008: 39). He stresses that within artistic research art and science complement each other, the first one contributing an insight on systematic methodologies and the other opening up the potentials of scientific discovery by generating diverse experiences that cannot be objectively measured or reduced to generalised rules. In my approach, the rug (an artefact that can otherwise stand as an artwork in its own right) fulfills the potentials of becoming an artistic research tool when a set of parameters involving its design and installation are determined in a way that allow it to facilitate a clearly defined investigative process. The application of systematic design and utilisation principles is essential for the transformation of the artwork into an artistic research medium in that respect.

At a design level this transformation is greatly aided by the merging of traditional artistic processes with soft technologies in the making of the rug. The incorporation of soft technologies in the rug interface creates the conditions for a dynamic and interactive relation between the rug and its potential audience. I argue that such a relation is important for the formation of holistic multisensory experiences. It is also essential in initiating fully embodied and participatory audience engagement, and therefore holds a key role in the layout of my research methodology. My research brings together techniques, processes and methodologies that span across the domains of artistic practice, scientific enquiry and technological innovation. Through this cross-disciplinary approach I attempt to explore theories of multisensory perception in a non-verbal, non-descriptive manner through the employment of an artwork as an investigational tool.

> On textiles and the senses

The textile material holds a prominent role within the bulk of literature on our senses, and is widely used as a metaphor to express the multisensory character of our lived experience. The use of textile vocabulary can be noticed in many writings within the field of social sciences that examine perception and draw attention to the intimate interrelation of the senses. Serres, for example, depicts 'tissue, textile and fabric' as 'excellent models of knowledge' whereby knowledge can be understood as perceptual experience, and argues that 'the sensible, in general, holds together all senses, all directions, like a *knot* or general intersection' (Serres 1998: 100; 406, my emphasis). The use of the word 'knot' in his argument generates a powerful image of sensory integration that is at the same time literal and poetic. David Howes also explores the idea of the knot as a symbolic element for representing the concept of multisensoriality in his book 'Empire of the senses'. Taking a critical approach towards still prevalent models of sensory hierarchisation, he writes that 'no matter how prominent or engrossing one strand of perception may appear, it is still *knotted into the fibers* of our multisensory experience' (Howes 2005: 12, my emphasis). Howes draws on the textile medium to provide a metaphor for the ways in which our percepts come into existence and are grasped through the integral cross-linking of our senses. He explains:

> to imagine the senses as knotted does not mean that sensations must be considered as simultaneous. *Just as in making a weaving the strands are woven together in sequence*, so in perception does one sensation often follow another to form different patterns of experience (ibid: 9, my emphasis).

Whether knitted, woven, or nonwoven, the structure of the textile medium exemplifies just how the senses intertwine in the formation of our perceptual experience. The parallels, however, between the textile material and processes of multisensory perception are more than just figurative; rather, the relation between the two is quite tangible, and is one grounded on the very materiality of textiles. The textile entails a multitude of qualities that are directly linked to its structure, like colour differentiations, roughness, resistance, reflectance, translucency, softness, friction, coldness and weight among many others. The textural richness of the textile material can be explored tactually and visually but also through the sounds that come about as a result of our interaction with it like, for example, rubbing or stroking its surface. The unique perceptual possibilities offered by the textile medium lie right in its power to evoke sensations across the array of our senses.

The interplay of the senses, triggered by and captured within the highly multisensory nature of the textile, is exposed in many expressions of traditional and contemporary textile art. The genre of textile installation presents a particularly captivating form of artistic expression in that respect. Not only does it expand the palette of materials available to the artist to involve space as an intrinsic element to the design, it also transmutes space into an arena of generated crossmodal experiences. The large scale of textile installation invites us to enter the space it occupies, and to explore it through all of our senses.

The way in which space – as captured, demarcated, or suggested by the textile medium – comes to life as a continuum of multisensory intensities is beautifully manifested in the works of Japanese textile artist Agano Machiko. Working with materials like silk, kozo, stainless steel wire, and fishing line, Machiko creates large, translucent sheets of mesh whose wave-like display and dim illumination produce fluid and almost ethereal spaces of shimmers, reflections, and shadows. As people move around Machiko's hung textiles, their movement creates a subtle breeze that animates the enclosed spaces into breathing organisms. With every movement the gleams and shadows of her pieces change and bring the space to life. People need to be in constant move, to open up their kinaesthetic and visual channels in order to capture the sensory richness of the produced space.

The manipulation of light and shadows for the creation of haptically and visually rich spaces is also central in the work of fellow Japanese textile artist Kyoko Kumai as well as in the works of American textile artist Piper Shepard and British textile artist Suzie MacMurray. Made of stainless steel, Kumai's textiles spread out in space creating flickering enclosures that change over time according to different angles of viewing. The contrast between the delicacy of her textiles and the roughness of the material she uses creates a tension that requires more than just a visual exploration of the enfolded space, it begs for tactile contact. The proximity required to experience her textile creations merges the different volumes of light reflections on their surface into a field of solid colour, creating a visual effect that is significantly different to what is experienced when the captured space is explored at a distance from its textile boundaries. The constant exchanges between tactile and visual impressions of Kumai's spaces on people evoke a circle of intersensory experiences.

The same is true for the room-scale textile works of Piper Shepard. Made of hand-cut cloth, her fragile, transparent laces create faint spatial enclosures. As the different layers mix with each other and with the shadows they cast, they blur the inside with the outside and produce illusive densities and opacities. One has to move around Shepard's enclosures and to feel them with the hand to grasp the indefinable space they suggest. Touch and sight fuse in symphony also in the work of Suzie MacMurray. Although very different materials are used in her pieces, her site-specific installations follow a similar approach to one another and create immersive, sensory enchanting spaces. MacMurray's spaces are not enveloped in textile, they are occupied by it. Whether composed of thousands of white feathers or of thousands of almost invisible shell-shaped hairnets, MacMurray's textile assemblages fill the space just like people do. As people mingle with them, touching them becomes inseparable from looking at them. The whole body is involved in the exploration of her textile spaces.

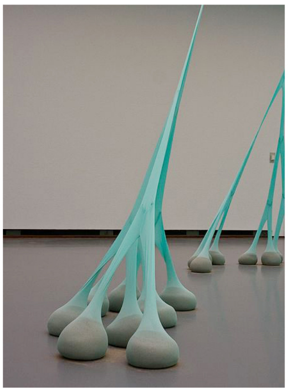
If, however, the work of one artist should be singled out as an extraordinary example of both physically representing and conceptually capturing the multisensory power of textile in the context of large-scale installation, that would, undoubtedly, be the work of Ernesto Neto. The starting point for Neto's work is the sensuous body itself and its movement in space which he sees as a way to connect to the world (Zuckerman-Jacobson 2001). His pieces spread out organically, allowing the textile to become wall, floor, and ceiling in a manner so radically different to the canonical, rigid construction of architectural space. His works 'deny the existence of an inner form or a single vector of forces that organise them, expressing a compositional structure devoid of hierarchies' (Dos Anjos et al. 2009: 71). The lack of structural hierarchisation in his pieces is reminiscent of the destratified sensory experience entailed in crossmodal perception. Indeed, Neto's work creates spatial atmospheres that capture most of our senses at once. His textile spaces seek to be explored through touch, vision, and the somatic senses, whereas the use of aromatic spices – like pepper, chili, clove, and coriander – in most of his early pieces adds a strong olfactory dimension to people's multisensory experience of the space. Neto's atmospheric enclosures bring the textural and structural qualities of the textile medium into play to challenge people's perception of boundaries and spatial continuity. Almost invariably composed of polyamide tulle, his spaces are literally shaped by the transparent material's diffusion of light and colour, while they are constantly being reshaped by people's interaction with the elasticity of the tulle. As curator Heidi Zuckerman-Jacobson notes in the online catalogue of his solo exhibition at the UC Berkeley Art Museum in 2001,

> [v]isitors experience a heightened sense of their environment while inside of the translucent installation[s]. The forms are altered as visitors step on the fabric, extending the form to meet the floor, and push out on the walls as a way of maintaining balance (Zuckerman-Jacobson 2001).

Neto's works facilitate the emergence of immersive spatial encounters where all senses integrate in the experience of the setting, and the whole body becomes part of the soft, fluid textile space just as the latter becomes a natural extension of the enveloped body.

Large-scale textile installation opens up a window to the multisensory qualities and possibilities offered by the textile medium. However, one sense in particular appears to have been poorly – if any at all – explored in the work of the artists discussed so far, and for that matter in the context of textile installation in general. It would be hard to imagine that, in such approaches where the artist so elaborately orchestrates striking spatial atmospheres to evoke multisensory relations, the sense of *hearing* has been

Figure 1. *Celula Nave*
Enesto Neto, 2004
Museum Boijmans Van Beuningen, Rotterdam



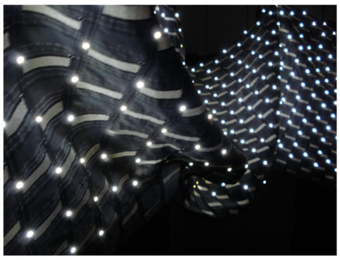
consistently neglected as a result of a conscious artistic decision. On the contrary, this apparent neglect can be explained as the limitation of the textile medium to emit sounds generated by people's interaction with it in a loud enough scale to be perceivable in an environmental context. One has to move their ear very close to the textile surface, and to focus their attention to listen to the sounds produced from scratching, stroking or rubbing it. Such a focus on the auditory certainly entails the risk of shifting attention from its relationship to the tactual, the visual and the kianesthetic, and, thus, of destabilising the multisensory experience. Until the recent fusion of textiles with soft technologies it was quite challenging to create textile-based pieces that actively engage the sense of hearing in a similar manner to how they engage the visual, tactile and somatic senses.

Emily DuBois' collaboration with pianist Michael Elinson in the early 1980s presents an attempt to investigate the sonic possibilities of the textile medium without the aid of technology. 'Woven Music', as is the title of their collaborative piece, is a bidirectional translation of piano rolls into weaving and of weaving patterns into music. Although DuBois and Elinson's approach was truly groundbreaking for its time, the links between the heard and felt qualities of the produced piece lie rather on the relationship between the two media (textile and sound) than on the actual perceptual experience of the combined work. Thirty years later, textile designer Ismini Samanidou and sound artist Scanner create 'Wave Weaves' (2013), a piece that also examines relations between weaving patterns and musical scores, only this time from a digital – as opposed to Woven Music's analogue – perspective. Wave Weaves looks at the visual and technical similarities between the software environments Scanner and Samanidou use respectively for the production of sound and the manufacture of woven textiles, and combines them into a single design language that informs both the textile and sonic structure. As with Woven Music, Samanidou and Scanner's work also results in separate mediums whose interrelation lies more on a conceptual than on a sensory level.

A different approach in combining the two media is taken in Ainsley Hillard's room-scale installation entitled 'Traces' (2008). Hillard conjoins sound and textiles in an attempt to create an immersive environment whose spatial experience is grounded on the intersection of aural, visual and haptic experience. The piece involves hung layers of transparent, mixed-media woven fabric, each of which features distorted images of different objects like chapel chairs, reading tables and books. Pre-recorded sounds, reminiscent of the objects depicted on the textile layers, are constantly emitted through speakers scattered in the room. As people move around the installation, the overlapping sounds merge with the fragmented images of the overlapping hung textiles, affording intense multisensory perceptual instances. Although, like Woven Music and Weave Waves, Traces is in reality a collage of two separate mediums, an audio and a textile installation, the two compliment one another so deeply that the piece is experienced as a unified perceptual whole.

Over the last few years an important number of textile-based works experiment with the creation of environments in which *all* sensory stimulation – visual, tactile, auditory and kinaesthetic – is directly afforded by the textile material itself. This shift has come not solely as a response to the, until recently, limited and sparse artistic attempts to explore relations between auditory and other forms of experience through the textile medium. The artistic potentials that have occurred as an outcome of recent developments in the fusion of textiles with soft technologies and smart materials – brought forward by research taking place mainly within the sports, fashion, medical and military industries – have contributed significantly towards this direction. New technologies have allowed artists to experiment with the enhancement of textile sensory attributes and, as such, to intensify the crossmodal relations entailed in the perception of textile installation. Works like Donneaud and Roudaut's XY Interaction (2005), Berzina and Tan's E-Static Shadows (2009), Karanika and Keenan's Strings (2009), Philip Beesley's Hylozoic Ground (2010), Anna Biró's Text in Textiles (2010), Luke Fischbeck's Center of Attention (2012), Kurbak and Posch's Drapery FM (2012), and Antinori and Pytlewska's Contours (2013) are examples of responsive textile interfaces or environments whose experience essentially involves collaboration of the visual, tactile, auditory and kinaesthetic senses. Although these works represent diverse artistic pursuits and seek to explore different aspects of everyday phenomena, they nonetheless illustrate a wider picture of how the merging of the textile medium with soft electronics affords possibilities for enhanced multisensory encounters.

Let us take a closer look at two of these works which encapsulate the multisensory potentials of responsive textiles in the context of spatial installation. Developed as a collaborative project between textile artist Zane Berzina and architect Jackson Tan, E-Static Shadows is a poetic exploration of the impact our physical presence has on an environment. The room-scale installation is composed of an electronic textile whose spatial display resembles irregular waveforms. Enriched with hundreds of seamlessly embedded LEDs and transistors, the fabric detects the presence of electrostatic fields emitted by the human body, and translates them into phenomena that can be visually and aurally perceived. As people interact with the fabric, their invisible bodily electrostatic charges cast evanescent shadows upon it, the size and duration of which is analogous to



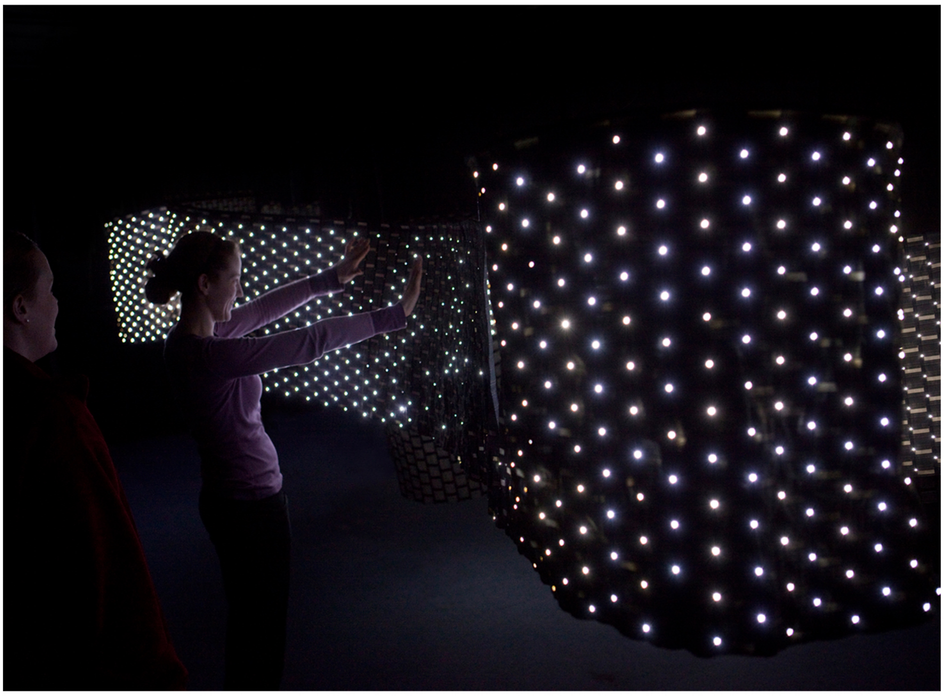


Figure 2. *E-Static Shadows*
Z. Berzina and J. Tan, 2009
Dana Centre, London

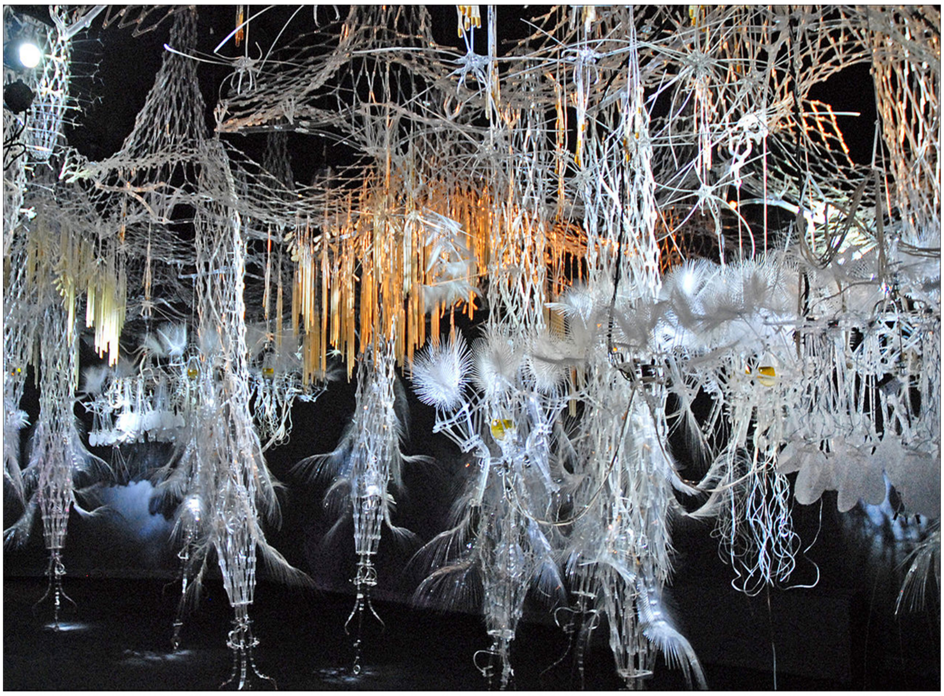


Figure 3. *Hylozoic Ground*
Philip Beesley, 2010
Canada Pavilion, Venice Biennale

Top: Images provided from Z. Berzina / Bottom: Images downloaded from the Internet, licensed for noncommercial reuse people's proximity to the responsive textile as well as to the intensity of each person's unique electrostatic emission. The faint, literally imperceptible sonic output of the generated electrostatic fields is captured through the technology of the fabric and is amplified thousand times to compose the soundscape of the installation in real time. The result is a beautiful ever-changing multisensory space whose audiovisual properties come to life through people's physical engagement with the textile.

In a similar vein, architect Philip Beesley's Hylozoic Ground also presents an immersive environment that explores bidirectional relations between spatial and bodily expressions. The installation is made of a network of microcontrollers, sensors, and shape-memory alloy tendrils that expand into an ethereal, acanonical mesh. The environment resembles a reversed coral reef microcosmos that comes to life as one walks through it, retracting, stirring and swaying in response to people's individual and collective presence and movement. As the hanging tendrils furl and unfurl, their wave-like motion affects the ambient, haunting soundscape of the installation, subtly linking people's presence to the differentiated acoustic textures of the piece. As people are lured into the enveloping textile space, a holistic interplay among their auditory, visual and proprioceptive experience unfolds. Hylozoic Ground fuses new technologies with textile practice to create a large-scale installation that blurs the boundaries between human and spatial organism and resurfaces the multisensory nature of spatial perception. Emerging from different research backgrounds and looking into different modes of engagement, both Hylozoic Ground and E-Static Shadows essentially ask one to combine their senses and somatic expressions to actuate and perceive a series of changes in the ambience of the installation spaces they occupy. In doing so, both works use responsive textiles as a creative medium for rethinking space as a continuum where 'material ends and sensation begins, tangibility arises' (Paterson 2007: 96).

> Framing my research practice

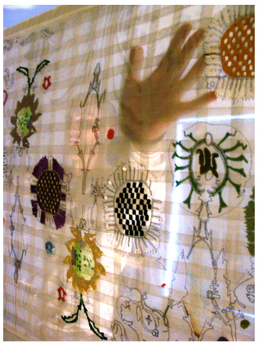
In this context, my practice-led research follows a non-verbal path of examining aspects of perceptual experience with an emphasis on its multisensory nature. Merging the disciplines of spatial design, responsive design, sonic art, and textile design, I seek to create a sensory-rich responsive textile interface whose spatial display demarcates and suggests a plateau for the study of crossmodal relations. I particularly focus on creating possibilities for encountering, enhancing, and observing perceptual relations among the senses of touch, hearing, vision, and kinesthesia as they are played out in people's spatial bahaviour. The multisensory character of the textile material holds an essential part in the layout of my research methodology. Responsiveness is also a critical starting point in my practice-based approach. Responsive design allows people to share bidirectional affective relations with the environment they occupy, a process that enhances and contributes to their perceptual experience of it. This direction is pointed out by a number of scholars like Berenson who argues that our bodily responses to textures highly depend on our understanding of their ability to affect and 'touch' us, and Williams who notes that this process occurs in an analogous manner to us physically touching and affecting textural qualities with our activity in a space (see Berenson in James 1987; Williams 2001). Architects Malnar and Vodvarka propose that perception is an 'inherently interactive and participatory process' during which 'the objects of perception are as animate as the perceiver', an argument supported also by Abram who notes that 'in the act of perception I enter into a sympathetic relation with the perceived' (Malnar & Vodvarka 2004: 25; Abram 1997: 64).

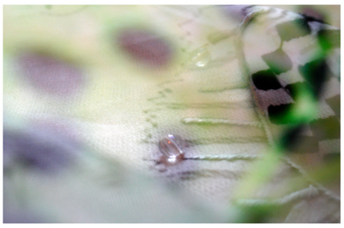
Approaching responsive textiles as a spatial medium, I aim at creating an installation piece that will allow me to observe integration of diverse sensory stimuli as expressed in the spatial behaviour of people during their engagement with the piece. The dynamics that facilitate the immersive quality of the installation equally depend on its potentiality of becoming an active, 'living' organism, as well as on people's physical interaction with it. My attempt to create the conditions for such dynamics evolves around the design of a touch-sensitive, sound-generating textile interface which is used as the main instrument for collecting my observational notes. The rich materiality of the proposed textile provides various levels of visual and haptic stimuli to evoke people's senses and somatic expressions, and its 'intelligent' nature enables it to sense, capture and respond to these expressions through subtle changes in the sonic output it generates. When spatially displayed, the textile interface brings to life an active architectural body that combines space, time, and sound: a spatial organism whose soundscape evolves over time in relation to people's engagement with it.

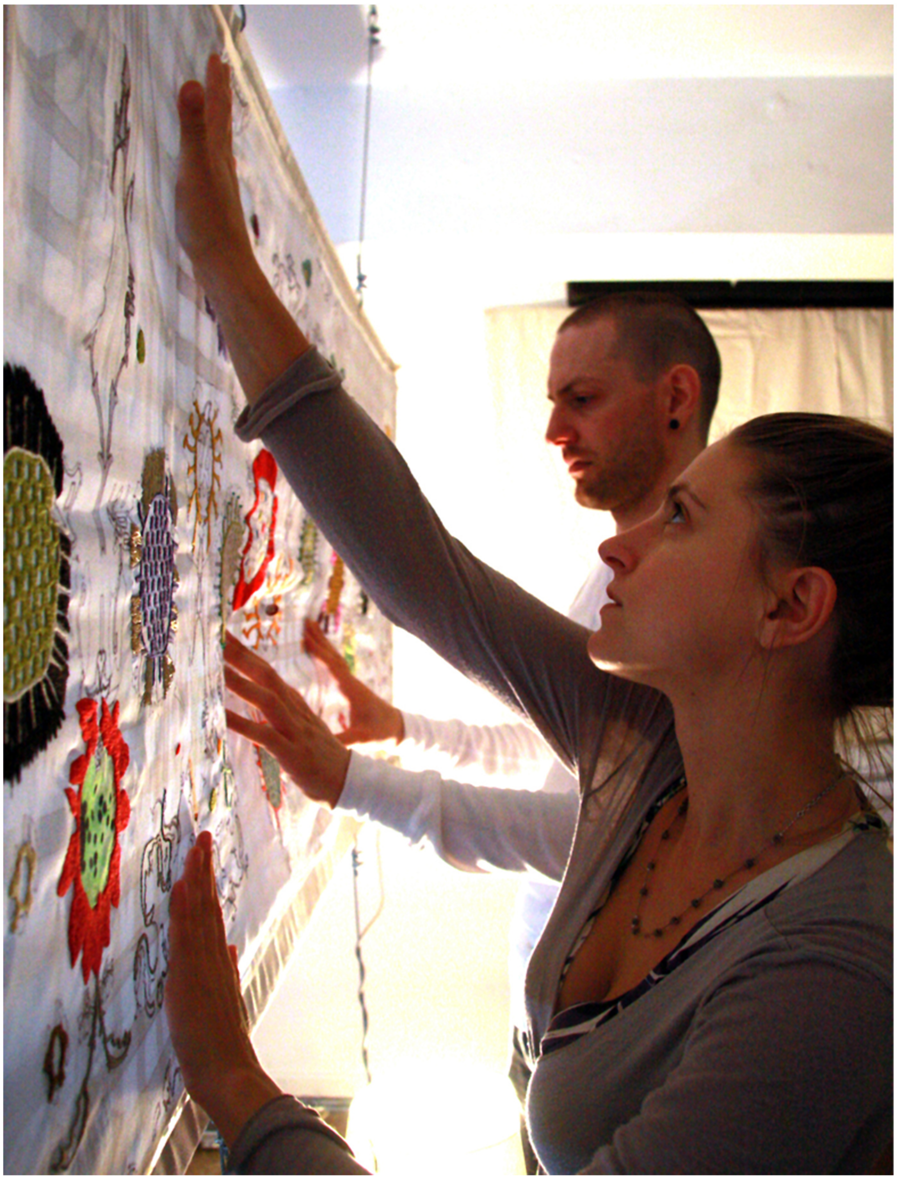
Following my training as an architect, my first experimentations with the overlap of textile, sound and electronics as a creative approach to rethinking the practice of spatial design started in 2007 when I was studying for a Masters in the Computing Department of Goldsmiths, University of London. My two-year long experimentations culminated in the creation of an audio-haptic textile installation entitled Strings (Figures 4 and 5). The piece was developed in collaboration with sound artist Jeremy Keenan as a means of investigating bi-directional relations between space and bodily expression through the

Figure 4. *Strings*
M. Karanika and J. Keenan, 2009
Battersea Arts Centre, London

Figure 5. *Strings*
M. Karanika and J. Keenan, 2010
SESI Gallery, Sao Paulo







combination of soft technologies and traditional art practices such as weaving, printmaking and embroidery. Made of hand-embroidered silk organza, cotton micro-tulle and various conductive and electronic components, Strings is a 70x160 cm double-faced hanging banner whose sheer structure allows one to see through the cloth and invites tactile engagement on both its sides. People's performed gestures on the textile compose an organic soundscape of string instruments, and initiate an on-going dialogue between the audio-haptic features of the installation and people's engagement with them. Strings has been exhibited widely in the UK and internationally in a variety of different contexts that ranges from galleries to museums, art festivals, and music venues. Its exposure to different settings and diverse audiences has given me the opportunity to observe and document different modes of interaction as well as matters of form and display that have significantly informed my current research approach.

Reflecting on these observations, two particular design questions stand out regarding the development of the textile interface I propose for the purposes of my research practice: the first one concerns the kind of tactile interaction people will share with the textile interface; the second is deeply bound to the first one and concerns the scale of the interface. One thing important I have learnt from my experience with Strings is that no matter how enthusiastic people are to creatively engage with a responsive piece, their physical interaction is nonetheless guided by the possibilities and limitations offered by the piece itself, both in terms of its micro- and macrostructure. For example, in the case of Strings, the display of the piece as a hanging banner restricts physical engagement to the surface of hands, while the density and microscopic detail of the embroidered parts of the textile invites small gestural strokes that allow the skin to explore the textural richness of the intricate stitching. This kind of physical interaction is significantly different to the one required for the purposes of my research subject, especially since kinaesthetic and proprioceptive information is as crucial as any other kind of sensory input in the process of spatial perception. My research practice requires the development of a textile interface that encourages a qualitatively different form of bodily engagement, one that involves the limbs just as much as the hands, and, for that matter, one that can potentially involve the whole of the body. This kind of bodily engagement suggests two important design features with regard to the textile form and its spatial display: first, the interface needs to extend across the horizontal plane (e.g., the floor); second, it needs to be of a large enough scale to both invite and afford whole body participation. Bearing in mind these two basic design characteristics in relation to the interaction requirements described above, I argue that a most appropriate form for the design and development of my research interface is that of a rug.

There are numerous contributing reasons for this decision. The rug as an artefact is so deeply grounded in our quotidian experience of the domestic interior and of 'home' that its presence invariably connotes a place of familiarity and comfortable care that invites tactile contact and encourages bodily engagement. One may slow down to walk on it and experience the sinking feeling underfoot, or they may choose to sit, or stretch out and rest flat on it to enjoy the comfort of its softness and warmth. Its haptic richness and proximity to the floor triggers sensory experiences that are embodied, or 'grounded', akin to lying down. A rug in a room generates what Pajaczkowska terms as 'ambient environment': an open creative space *inside* a determined space (Pajaczkowska 2010: 135). In this sense the rug acts as a territorial unit with many de-territorialising potentials (Delueze and Guattari 2004). Indeed, a rug not only physically defines space; it also renders space live in so many different ways. First created as a domestic product of practical necessity, it has over the centuries become a platform of social activity and a symbol of luxury and power, craftsmanship and beauty, religion and myth, and historical continuity. The tension created by this multifaceted nature and heavily loaded concept of the rug creates a 'transitional space' (Winnicott 2005: 65). This transitional quality of the rug can be observed in most primary schools in the UK from Nursery (4-year-old children) to Year 6 (10-year-old children). The classroom is arranged with tables and chairs in small groups, and with a rug or carpeted area on which children are asked to sit cross-legged for the National Curriculum's daily Literacy Hour. The contents of the Literacy Hour may vary from school to school but the children will, almost invariably, be sitting together on the rug facing the teacher for some time each day in order to listen to stories together. In this context, the rug symbolises a very unique space, one that is clearly demarcated from the rest of the classroom by the use of textile material. This special space signifies a kind of attention that is qualitatively different to that required from children during other parts of the school day. Much of the National Curriculum requires that pupils try hard to be disciplined, rational, and numerate, but the Literacy Hour invites children to enter into an imaginative space of make-believe, a space in which the teacher reading from storybooks is no longer being 'instructive'. The rug functions like a mythical 'flying carpet' well known from the Aladdin stories, on which the child can be transported to a space of interiority, playfulness, creativity and reverie.

The power of the rug to define and transform space, interwoven with the tactility and warmth of its materials, and enhanced by the visual impact of its patterns and colours, opens up our sensory channels and invites us to immerse ourselves in space through all of our senses. The rug combines all these 'ingredients' – both material and immaterial – that are so essential for the development of my research practice: it can extend across the floor and be of a relatively large scale; it is an everyday object that serves both functional and aesthetic purposes; moreover, it is an object of familiar comfort with which we quite naturally engage in many different ways – like walking, sitting, crawling, or simply lying down on it; its highly multisensory nature asks to be explored through the eyes, the hands, the limbs and the whole of the body; finally, its transitional quality can create space within space and signify a plateau for different types of activity and qualitative attention. As such, the rug can provide numerous spatial and sensory possibilities for exploring matters of crossmodal relations.

> On structure, function, and aesthetics

Considering contemporary examples of rug making, Farr notes that they are 'part of a long continuum' that not only joins the past with the present but also the present with the future (Farr et al. 2002: 11). He reviews a significant number of rug practitioners whose creations are sophisticated contemporary interpretations of traditional patterns and techniques[2], and, quoting carpet historian Cornelia Bateman Faraday, he stresses that contemporary rugs 'should above all "express absolutely the spirit of their times"' (ibid.: 11). My approach to creating a responsive spatial interface in the form of a rug offers a new reading of Farr's understanding of the rug as an artefact that both reflects its history and captures the spirit of its time. Balancing between novel technologies and traditional textile techniques, the proposed interface creates a sense of continuity that joins on-going developments in the field of interactive artistic production with the long history of rug making. For the purposes of my research practice, the rug is conceived as a living organism that affords intensified multisensory encounters, and is used as an investigative medium for the study of perceptual integration among the senses of touch, hearing, vision and kinaesthesia as expressed through people's spatial behaviour during their engagement with the rug.

Its design is inspired by the function of our haptic system, and involves three distinct yet closely interrelated layers: the 'skin', the 'deep tissue', and the 'brain areas'. The three layers are differentiated not only in terms of their function – as would their names imply –

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[2] Like Vincent Dane's Green Park (2000), Christofer Farr's Untitled rug (1992), Kaffe Fassett's Untitled series (1993-94), Sally Greaves Lord Untitled rug (1993), Gary Hume's Sky Carpet (1997), Bill Jacklin's Anemone (1993), Behrouz Kolahi's Microchip 5B (1998), Michael Rainsford's Untitled rug (1994), Agneta Svensk's Pomegranate (2001), Sian Tucker's Untitled rug (1991), and Madeline Weinrib's Bodi Tree (1998).

but also in terms of the materials they are made of and the techniques with which they are processed. Before proceeding with a detailed description of both the structure and the function of each layer, it is important that a basic account of their interrelation is given to allow the reader to fully grasp the logic behind the design. Starting from the outer layer, the rug skin is a texturally rich surface aimed at evoking people's senses and attracting their physical engagement with the rug. Tactile contact with the rug skin is captured through a network of nerves that runs across the deep tissue of the rug. The nerves transfer this information to a coding environment (Arduino) which, upon reception, forwards it to a sound software (SuperCollider) that processes the information and sonically responds to it. The Arduino and Supercollider software environments function as what can be understood as the brain areas of the rug that in sequence receive and respond to the electrical signals generated by people's physical interaction with the rug.

The skin

The skin of the rug is 240x160 cm in size, and is made of felt. Reflecting the textile references I grew up with, the pattern is a contemporary take on motifs one frequently comes across in traditional neo-Hellenic or post-Byzantine textile craft. Hellenic culture has been inextricably interlaced with that of the Islamic world for centuries (Gutas 1998; Leaman 2004). The influence of the Middle East, particularly Asia Minor, is very evident in the themes and spiritual values underpinning Greek folk art as expressed through the use of bright, bold colours and the depiction of floral and faunal elements that bear a symbolic significance. The rug skin features a peacock and an arrangement of pomegranates, flowers, and birds. These elements are typically found in Greek tradition, and, although their meaning may no longer be as widely recognised in modern Greek culture as it once used to, they carry strong symbolisms which point back to their oriental roots. In this context, the peacock is a symbol of immortality, and the pomegranate a symbol of fertility. Birds also symbolise fertility as well as faith, while flowers embrace many different concepts such as spirituality, regeneration, serenity, rebirth, prosperity, innocence, purity, and liberty (Ford 1992). Within my work, the use of the pomegranate and the peacock offers an additional symbolic layer, though the symbolism rests more on a visual than on a conceptual level; the spatial organisation of eye-feathers when spread out in the peacock train and the seeds of the pomegranate seem to bare a striking resemblance to neuroimaging data of neural clusters (Figure 6). This visual relation makes a subtle reference to the very subject of my research.

The skin of the rug is approached as a kind of canvas across which these traditional elements are drawn with a modern twist of sensibility and childlike quality that creates a bridge between their past and present use in artistic expression. The process is quite

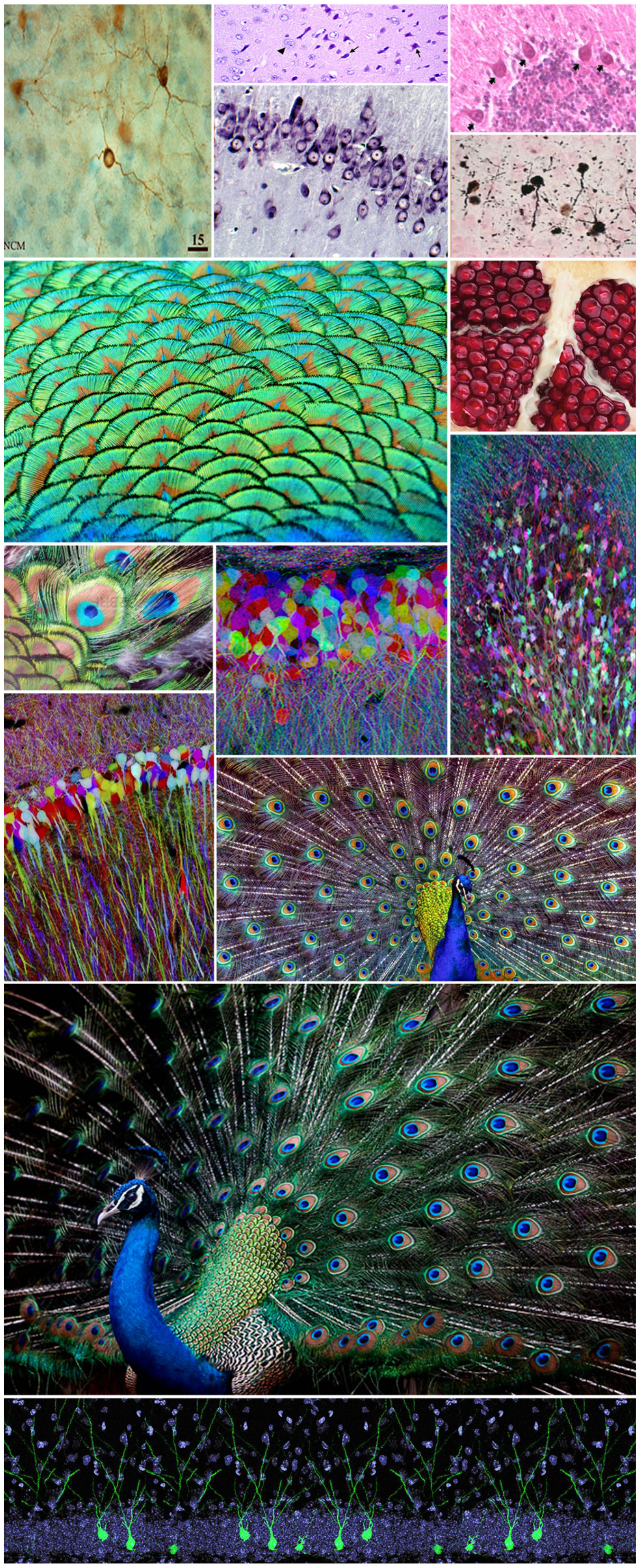

Figure 6. Visual study on the spatial organisation of seeds in the pomegranate fruit, eye-feathers in the peacock train, and neural clusters as depicted by different neuroimaging techniques.

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Figure 7. Embroidery detail of motifs on the rug 'skin'

organic at the first stage, sketching all motifs in ink on separate sheets of paper, and then importing them in the Photoshop software, where layer upon layer the final pattern comes to life. Although the motifs appear to be freely scattered on the background, their spatial arrangement follows an organisational order that is essential for the qualities of balance and tranquility typically found in traditional rug designs. Each motif is individually processed in Photoshop with vivid colours to combine with the others in a harmonious synthesis that creates a strong contrast on the dark background. The pattern is digitally printed on the felt surface and then elaborately hand-embroidered with a variety of stitches that creates an embossing effect of intricate textures (Figure 7). The rug skin is produced through radically different processes to those typically found in the history of hand-made rugs; hand-weaving techniques are here replaced with digital printing and hand-embroidery. The use of these unusual rug-making techniques contextualises my attempt to create a surface of an aesthetic quality deeply rooted in the folk tradition of my culture through contemporary artistic processes. The warmth of the felt, the bright colours of the print and the threads, and the tactility of the embroidered forms create a sensuous interface that emits a 'strengthened sense of materiality and hapticity, texture and weight' (Pallasmaa 2005:37). The exploration of the skin's visual and tactile richness invites different forms of interaction with the rug. As different relations between people's activities form and dissolve over time, they are sonically communicated through an evolving soundscape whose composition relies on the technology underlying the deep tissue and brain areas of the rug.

The deep tissue & brain areas

The deep tissue serves as an underlay to the rug skin, and features the technology that allows the rug to effectuate a touch-sensitive performance that is integral for its responsive behaviour. The layer is made of spacer fabric and sustains a combination of conductive elements and circuitry that form what can be described as 'a grid of nerves' spreading across the deep tissue. Different samples of spacer fabrics were considered for the making of the deep tissue layer. The one selected to proceed with is a multichannelled three-dimensional surface which is made of 100% polyester. The gauge of the channels is 4mm in width and 2mm in height. A number of parameters were taken into account for this decision with the most contributing ones being the highly robust and resilient nature of the particular fabric, its manufacturing dimensions, and its unique multichannelled structure. As will be later explained, this structure is crucial for the function of the layer's nerves. The nerves running through the deep tissue are spatially organised into a grid. The scale of the grid is determined through an approximate calculation of the relative relation between the size of the rug and different foot sizes that inclusively represent the diversity of a potential audience in terms of age and sex.

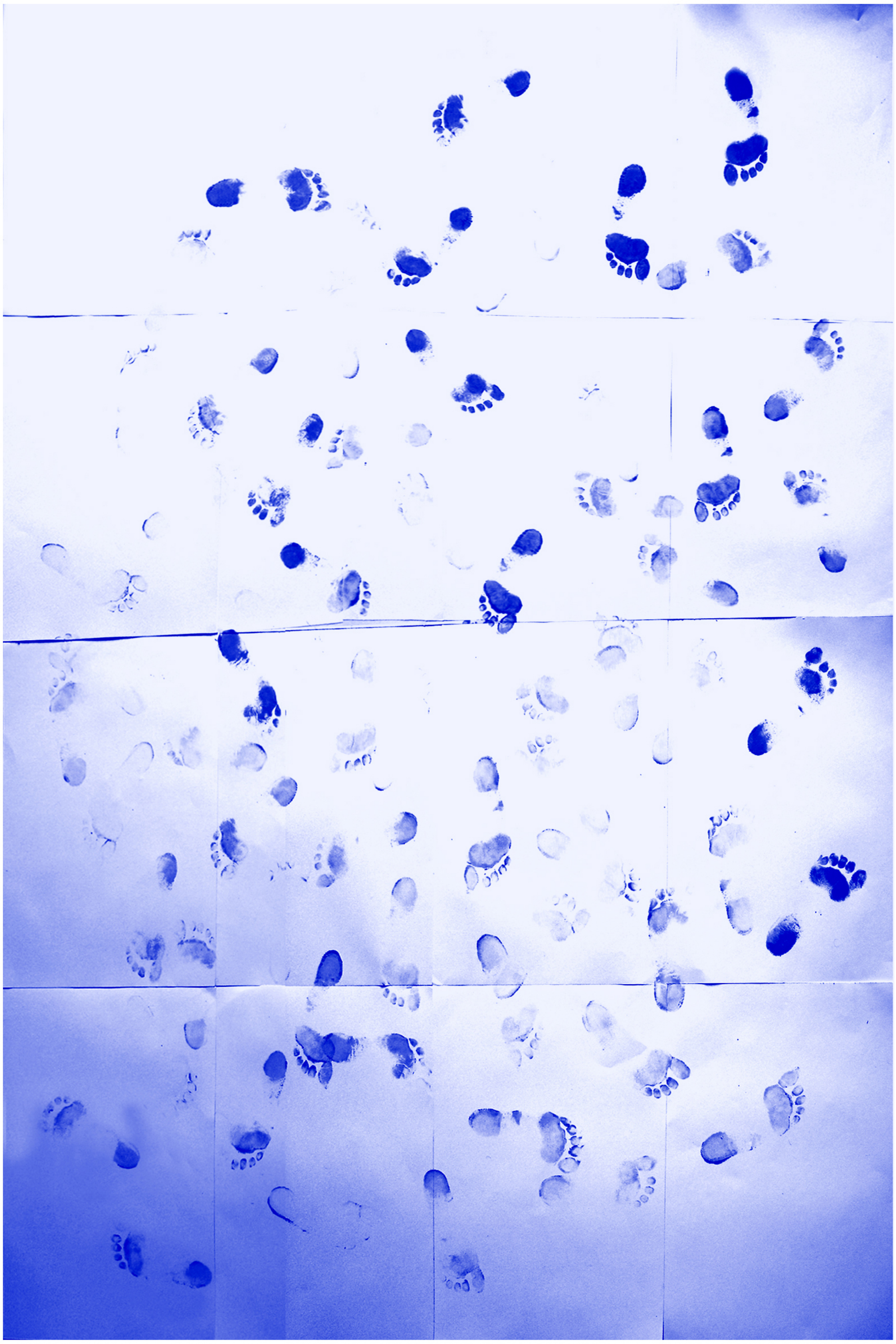

Figure 8. Visual study for determining the size of the grid. UK size 3 footprints on a paper layer the size of the rug.

To gather the data required to help me come to a conclusion about the density of the grid, six people were asked to take part in a series of pre-tests. The participants involved two adult males (one age 32, UK size 11; one age 37, UK size 8.5), two adult females (one age 31, UK size 3; one age 28, UK size 5), one young girl (age 8, UK size 2), and one young boy (age 6, UK kids size 12). The preparation involved taping large pieces of white paper together until they formed a layer the size of the rug, and providing participants with footprint paint. Each participant was asked to remove their shoes, step on the paint, and then individually walk around the paper layer for one minute. The distinct pattern of each participant's footprints was then studied in relation to the foot size, the average distance between successive footmarks, and the overall area occupied by footmarks (Figure 8). This fairly simple yet painstaking form of visual investigation allowed me to make some significant observations. First, the areas near the margins of all six layers – each individually bearing the imprints of a single participant – displayed no footmarks at all. This indicated that people's activity on the layer was unfolding inside an imaginary frame that is offset by about 10 to 15cm inwards the layer edges. Second, a distance of 10cm or less between the rows and columns of the grid is an effective spacing for even the youngest of the participants to activate a significant number of cross-sections during their one minute wandering on the layer.

These observations were considered in relation to the multichannelled structure of the spacer fabric and the quantity of conductive band I had available for the development of the deep tissue surface[3]. The results pointed to a 19x20 grid that spreads across 345cm² of the total 384cm² of the fabric surface. Dividing the suggested area by the number of rows and columns provided the final spatial display of the grid on the fabric. Twenty conductive bands, made of 0.10mm stainless steel wire knitted mesh, were hand-stitched on every sixth and seventh channel of the spacer fabric across its length at a distance of 6cm from each other. Nineteen conductive bands were then hand-stitched along the width of the fabric in regular spatial intervals of 10cm. The first set of bands intersects with the second at right angle, but the two are separated by the height of the fabric's channels. The conductive bands form in this manner a three-dimensional grid whose conductive rows cannot make contact with the conductive columns unless they are compressed by touch (Figure 9, bottom). This particular design attribute of the grid offers the foundation upon which the touch-sensitive technology of the deep tissue layer is

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[3] The conductive mesh band was kindly offered as support in kind for my research project by KnitMesh Technologies Ltd.

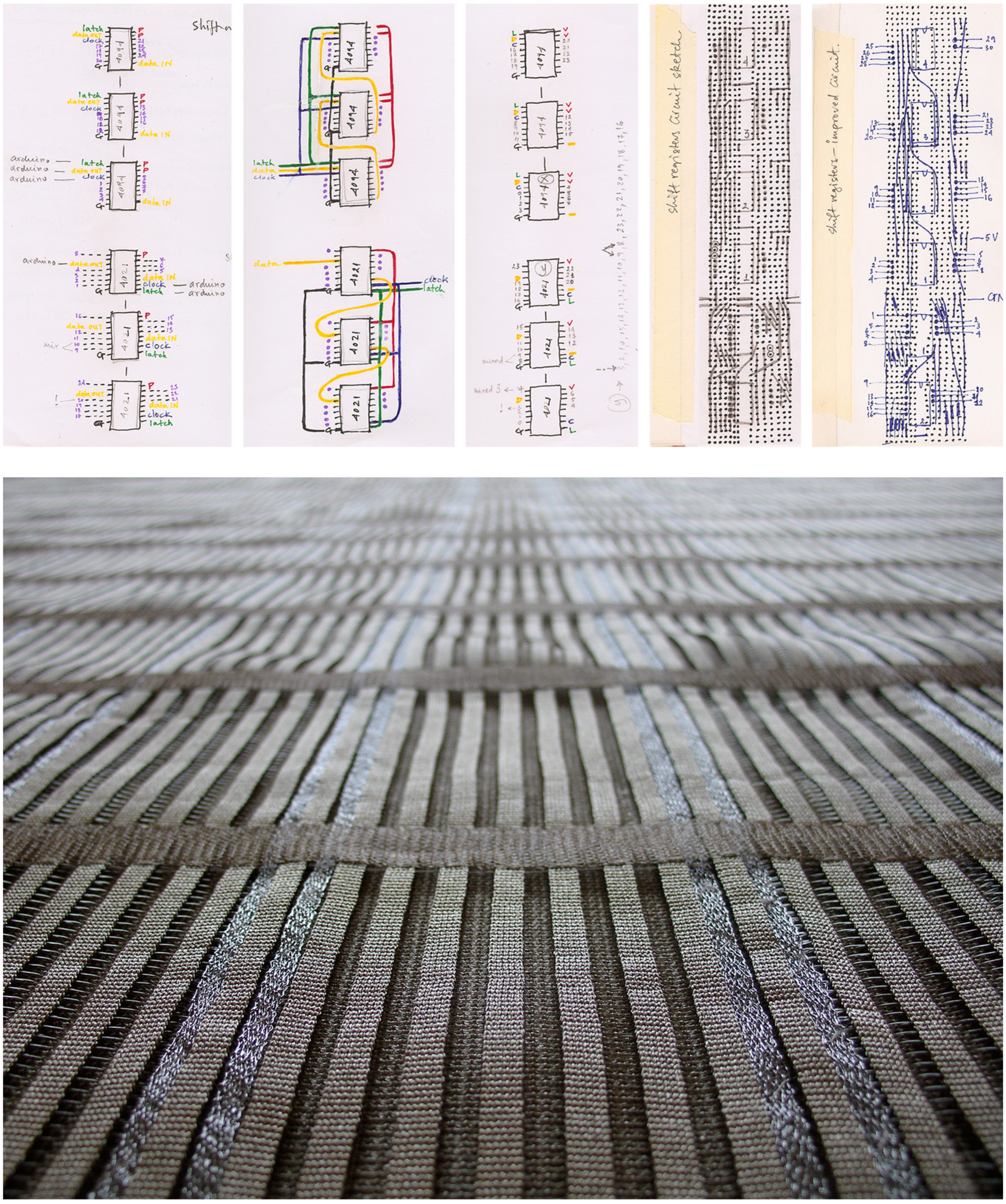

Figure 9. Top: Skethes for the circuit design
Bottom: Detail of the 3D grid on the 'deep tissue'

the foundation upon which the touch-sensitive technology of the deep tissue layer is based.

All conductive bands embedded in the spacer fabric are wired and connected to a complex of shift registers (Figure 9, top). The circuit is in turn connected to an Arduino microcontroller. When compressed by touch, each physical cross-section of the grid on the deep tissue is perceived within the Arduino programming environment as a unique element of a virtual matrix whose rows and columns are respectively equivalent to the horizontally and vertically embedded bands in the spacer fabric. People's interaction with the rug is, thus, captured as a series of physically triggered conductive cross-sections, and eventually as a series of coordinates that respond to the matrix elements. The deep tissue simulates in this way a soft, tactile, numerical interface that is activated by pressure and whose resolution depends on the density of the conductive grid.

Soundscape

The flow of data generated by the physical interaction of people with the rug is passed to the SuperCollider sound software. The software uses the stream of generated data to compose an ambient, evolving soundscape in response to people's performed activities. As the rug is being walked on, touched, stroked, and pressed, the sound software encodes these gestures on different spatial and temporal scales, continuously generating sonic output that ranges from short, staccato bursts to expansive, harmonic sound fields. The rigid, predefined, striated form of the grid of nerves running through the deep tissue engenders and dissolves into an open-ended, non-predetermined, smooth soundscape. Deleuze and Guattari beautifully explain how the striated and the smooth invaginate one another, and how the two 'exist only in mixture: smooth space is constantly being translated, transversed into a striated space; striated space is constantly being reversed, returned to a smooth space' (Deleuze and Guattari 2004:524).

Given the significant role sound holds in the design of my research project and the limited practical experience I have on the subject, sound artist Jeremy Keenan was invited to contribute his expertise in the production of sound art in installation contexts and to lead the sound design process. Over a period of nine months, Jeremy and I worked together to determine the ways in which distinct elements of a person's physical interaction with the rug will be mapped to specific synthesis destinations in the SuperCollider sound software. One key issue in defining the structure of the interaction scheme from a sonic perspective was striking a satisfactory balance between immediate response to touch and emerging interactions that arise from longer-term patterns of interactivity. From initial observations garnered during our former piece Strings, it became clear that some form of direct temporal association between touch and sound was necessary. While the evolving sound of Strings captured participants' attention in the short term, and over time they became aware of their agency within the production of it, a common thread was expressed in the question, "how am I effecting the changes in the sound?" Conversely, we were also aware of the need to avoid falling into more conventional paradigms of activity, such as digital gaming as well as that of the traditional musical instrument. These modalities, the former engendering concern with a specific goal, or 'winning', the latter inviting notions of mastery and composition, discourage the kind of engagement that the rug is intended to enable.

With these concerns in mind, we worked on developing a scheme of interaction that allows both short-term, immediate response and long-term, evolutive response to interactive behaviours to coexist. Given that the essence of the rug's physical interface is comprised of an array of binary nodes, the design of expressive modes for the sonic output (like pitchbend or volume) centred on the spatiotemporal characteristics of pressure differentiations attributed to people's movement and not on criteria such as variables in audience body weight. As such, interaction data focused on the following analyses of input data: distance between node presses, the length of time pressed, the number of nodes pressed, time between node presses. Different synthesis destinations – such as wave levels, chord notes, individual note octaves, chord type, grain speed and size, timbre, and spatial position between speakers – were related to distinct or combined physical interactions like destination and duration of touch, spatial and temporal distance between successive touched points, overall or site-specific average activity over time, and non-activity intervals to name a few. Set within a range of values and timescale parameters that are programmed to ramp over time, the above data are tracked from the time the textile is initialised to produce continually changing mean average values that reflect trends and patterns of behaviour.

The primary, immediate response is a linear mapping of node presses to pitches along a musical scale. With repeated interaction however, the nature of this mapping transforms and new relationships between the nodes and resultant pitches become apparent. The scale type changes between major and minor, with the root moving between tonic, dominant, subdominant, and submediant, giving the impression of cadential movement. A secondary, evolutive response emerges from a continuous chordal background, following the harmonic movement of the direct interaction. Additionally, the interaction data above, both immediate and averaged, are applied to different components of the synthesised sound. Texture density, amplitude modulation (type, depth, speed) and the collective amplitude of the tones produced are all affected. This results in an evolving soundscape that is constantly nuanced by the collaborative input of people's physical responses to the tactile and aesthetic properties of the rug. In this way, the sound interaction design fulfils the criteria of both immediate audition and long term evolution: it promotes a form of engagement that avoids goal orientated behaviour while achieving a satisfactory level of user agency and, at the same time, it rewards continuous play in a musical context free of conventional instrumental metaphors. In its immateriality, the produced soundscape becomes a physical material which together with the textile material define a highly multi-textural, responsive organism. Thus, the rug provides an open, physical platform on which bidirectional affective relations between multisensory stimulation and bodily responses can be studied as they emerge.

> The rug as an experimental instrument

Within my artistic research, the sound-generating rug has been conceived and realised as an artefact that facilitates two purposes: affording a range of sensory stimuli it represents the very subject of the crossmodal; most importantly, it can be used as a physical platform for observing aspects of perceptual meaning as it emerges. I argue that people's interaction with the rug (and its sonic output) allows an insight into how they make sense of the various stimuli they concurrently experience via observation of how they physically respond to it. The relation between the two types of activity – perceptual and physical – is of course dynamic and complex. However, its study can be telling of a process that is intangible to the observer (perceptual activity) through what can actually be observed (physical activity). In this sense, the rug can serve as an experimental medium for examining aspects of people's spatial behaviour and how the latter is informed by the various sensory affordances of the rug.

The term 'spatial behaviour' is used across many and diverse disciplines – e.g., sociology, behavioural geography, urban planning, psychology, neuropsychology, and so on. As such, its meaning varies significantly from field to field. Within my research, spatial behaviour resonates with the neuropsychological use of the term, and is introduced to describe the human mechanism that enables us to direct ourselves 'towards (or away from) significant objects and locations in the environment' (Nardini and Cowie 2012: 142). It is a mechanism built up on a number of spatial tasks that we learn to perform as we grow older such as balance, locomotion, orientation, and navigation. Presenting differentiated levels of difficulty, these tasks are achieved at different stages of our early childhood, and perfected throughout our childhood and adult life. Balance and locomotion form the basis of our spatial behaviour, and are the cornerstones for the development of our ability to efficiently orient and navigate ourselves in an environment. Orientation and navigation are the most advanced tasks of spatial behaviour we perform.

A significant number of recent scholarly studies suggest that spatial behaviour and crossmodal perception are closely interlinked. Multisensory integration is deeply rooted in, and underlying the ways in which our bodies move in space (see Nardini and Cowie 2012; Sarko et al. 2012; Sheynikhovich et al. 2012). As we move about, we perceive information about both the environment and our movement in it through many different sensory inputs – visual, auditory, tactile, proprioceptive, kinaesthetic, vestibular, and olfactory. These inputs are integrated into 'a final multisensory estimate, which can then be acted upon' (Nardini and Cowie 2012:12). Our spatial behaviour is informed by the integration of the multisensory information we experience into a single reference frame, and performed in response to it. This becomes clearer in the study of isolated spatial tasks. Examples of how such tasks (e.g., spatial localisation of a sound or light source) not only demonstrate crossmodal processing, but are also enhanced when multisensory inputs are introduced to the experimental subjects, have already been presented in the first part of this thesis. However, I would like to present one more telling example of the links between crossmodal perception and spatial behaviour as found in the work of neuropsychologist Karen E. Adolph. Focusing on the spatial task of locomotion, Adolph conducted a series of experiments with children of different ages to draw comparisons between their perception of ability and their actual ability to walk on slopes (Adolph 1995). Her study showed that the children combined visual and haptic information for their decision-making, indicating that locomotion is crucially informed by integrated feedback coming from a variety of sensory inputs such as visual, tactile, proprioceptive, and vestibular. The same can be said to be true for all spatial tasks we perform; spatial behaviour is informed by, and responds to, the multisensory inputs we are afforded as the latter are integrated into a coherent, unified perceptual frame of reference.

Grounded in this notion, I propose that the study of spatial behaviour in a set environment can reveal aspects of crossmodal processing by close observation of the relationship between sensory inputs afforded by the environment and motor outputs performed by the people that explore it. As it is easier to define, identify, and analyse distinct spatial tasks comprising spatial behaviour (as opposed to looking at spatial behaviour as a whole) my research will focus on the task of orientation and the exploratory actions entailed in one's movement. In this context, the responsive rug presented earlier in this chapter will be used as an investigative medium within an experiment context. Video documentation and movement tracking within the SuperCollider software will be used to collect information on participants' orientational decision-making with respect to the visual, auditory, and tactile feedback they receive from their interaction with the rug. Analysis of the collected information is hoped to highlight co-relational patterns between the rug's sensory outputs and participants' movement. This material will be used to evaluate how participants create perceptual meaning with which they inform and guide their movement across the rug.

Part 3

Theory through practice

> **Theory through practice**

The last part of this thesis is concerned with the application of my research practice in an experimental setting under the light of the theories that have inspired and informed its development. These theories are grounded on the idea that perception is constructed upon *ecological knowledge*, which asserts that perceptual meaning does not derive straight from the physical characteristics of what we encounter, but rather from our current relation to and past experience of these characteristics. My artistic enquiry seeks to create possibilities for exploring aspects of crossmodal processing involved in the act of perception, as well as how the latter comes about through interaction with our surroundings by comparison of sensory feedback to performed actions. In this context, eight people are invited to interact with the rug and to conduct certain tasks that require some understanding of the relation between its touch-sensitive function and sound-generating performance. People's activity on the rug offers an empirical insight on how they make sense of its responsive behaviour by combining different sensory information into a unified percept upon which to act with regard to the tasks they are given.

Particular focus is given on the reciprocal relation of the tactile textures of the rug to the produced sonic ones. The exact nature of this relation will be discussed shortly in detail; however, it is important to take a moment to expand on the role of this pairing.
As Steri argues, touch is limited to the dimensions of the skin surface in contact with a

stimulus source, therefore the perceiver greatly relies on performing voluntary movements to allow an expansion of the tactual perceptual field (Steri 2012). This acknowledgement points to two significant remarks: that tactile perception is integrally bound to a process of active exploration, and that tactile texture is perceived as an integrated whole of cutaneous stimulation generated by skin contact and kinaesthetic stimulation generated by muscle and joint movements. In this sense, tactile perception encapsulates the essence of theories reviewed in this thesis, which argue that perception entails sensory integration and is only possible through active exploration. The same can be said to be true for auditory perception. We hear through the ear as well as through all of our body[1]. Moreover, sound perception relies on body movements for locating and attending to a sonic event, as much as it relies on our kinaesthetic experience of bodily gestures and how we know them to relate to the generation of a particular sound based on our 'ecological knowledge' (see Clarke 2005; Cook 1998; Noë 2004).

Being able to relate different tactual textures of the rug to distinct sonic textures in the generated soundscape requires that the people involved in my study actively engage with their whole body in an exploratory process. This way they acquire valuable kinaesthetic feedback against which they can forge links between different stimuli – visual (print), tactual (embroidery), and auditory (sonic output) –, and to experience them as a fused event. Within this exploratory process, action and multisensory integration do not operate in a sequential order, instead they are in constant and ongoing interaction with one another. The proposed approach offers possibilities to observe people *as* they build an understanding of correspondences between the rug's sonic responses and visual/tactile attributes, and to evaluate how they make use of this understanding when performing certain tasks. The rug provides a platform for exploring an obscure mental process as manifested in certain aspects of people's spatial behaviour, especially in their orientational decision-making.

Participatory action research has previously been used on occasions to study how we perceive attributes related to the textile field. For example, Moody et al. have carried a study on textile perception and how we discriminate different fabrics, Homlong has examined how we perceive and communicate the aesthetic qualities of textile patterns, and Bang has researched on the emotional value of applied fabrics with respect to their visual and tactual qualities (Moody et al. 2001; Homlong 2006; Bang 2010). All three

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[1] Gonzalez-Crussi argues that 'hearing is […] a way of seizing reality with all our body, including our bones and viscera' a view supported by a number of other theorists, see Part 1 of the thesis (Gonzalez-Crussi 1989: 45).

studies incorporate the Repertory Grid as a methodological tool to allow participants to verbalise their sensory experiences in a manner that is as open-ended and unbiased as possible within the channel of verbal communication. The Repertory Grid works well within the particular studies as they all involve a range of small textile samples to facilitate the necessary triading stage that the method entails. My research is quite different in that respect as perceptual meaning is explored through interaction with a single large textile interface. Acknowledging the difficulties entailed in asking people to express the multidimensionality of sensed experience through the linear structure of verbal communication, and being aware of the inherent risk of asking questions that may unwillingly lead people towards certain directions, I decided to exclude verbal communication (such as interviews and questionnaires) from my research methodology.

My methodology focuses on observational notes on people's interaction with the rug, and on analysis of their distinct and sequential body movements. This is a unique approach within the textile design field; it allows people to avert the bias of describing something as obscure as perceptual experience through the stratified nature of spoken or written language, yet presents the researcher with the challenge of interpreting and essentially hypothesising over something as nebulous as bodily expression. To restrain such a challenge within reasonable margins, my analysis focuses on two specific aspects of people's physical interaction with the rug: their exploratory behaviour (the set of actions and strategies carried out in response to the sensory stimulation afforded by the rug, and with respect to the tasks at hand); and their orientational decision-making (how knowledge acquired through the different exploratory techniques employed appears to be informing movement on the rug with respect to the tasks at hand). The material used in the analysis process is collected from video recordings and software reports produced for each individual participant in my study. This material sets the basis for examining consistencies and differentiations in people's performances, as well as for reflecting on emergent behavioural patterns. My approach does not aim at producing new evidence in support of the theories examined in this thesis. Rather, its intention is to look at how crossmodal processing and active exploration mutually shape perceptual meaning by studying them within an artistic context.

> Coding the rug

Within an experimental setting, the rug cannot fulfill the potentials of becoming an artistic research tool unless a set of parameters involving its design, installation, and application are specifically determined to allow it to facilitate the investigative process. The application of systematic design and utilisation principles is essential for the transformation of the rug from an artwork into an artistic research medium in that respect. To give a clear idea of how the rug is incorporated within my research methodology, it is important to cover certain technical features contributing to its responsive behaviour.

As has already been discussed in the second part of the thesis, the rug comprises three layers: two physical, the 'deep tissue' and the 'skin', and one virtual which involves the processing of digital information within the Arduino and SuperCollider software environments. The rug skin is made of felt that has been digitally printed and hand-embroidered, while the deep tissue is made of a 4mm gauge spacer fabric that bears a hand-stitched 3D grid of conductive mesh band (60x100x4 mm). The deep tissue serves, and will be onwards referred to, as the rug underlay. Separated by the gauge of the spacer fabric, the conductive rows and columns of the underlay grid cannot make contact within the same plane unless they are compressed by touch.

The grid embedded on the rug underlay consists of 20 columns (x) and 19 rows (y), presenting a total of 380 nodes. These are perceived within the software environments – Arduino and SuperCollider – as pairs of coordinates (x, y) of a 20x19 virtual grid. Each pair of coordinates is assigned a Unique Identifier (UI) according to the following formula: UI = [(x*24) + y – 25]. This allows the software to perceive nodes both as sets of coordinates and as unique matrix elements (Figure 10). These two sorts of data – (x, y) and UI – are the primary sources upon which the responsive behaviour of the rug evolves with respect to people's physical interaction with the skin. As people walk on the rug, the nodes compressed by body weight are registered in SuperCollider as input for the generation of sonic output that relates to people's followed paths.

All physical grid nodes on the rug underlay are assigned within SuperCollider a further variable that allows the software to classify them into two distinct categories. The classification is made with respect to the variable of texture, and discriminates between the areas on the skin that have been processed with embroidery and those areas that have not. Taking into account each node's unique set of coordinates and its spatial correspondence to the overlaying rug skin, nodes overlapping with embroidered areas on the skin are classified as EA (Embroidered Areas). The rest of the nodes are classified as NEA (Non-Embroidered Areas) (Figure 11). The analogy between the two categories is approximately 0.75:1 (43% EA – 57% NEA).

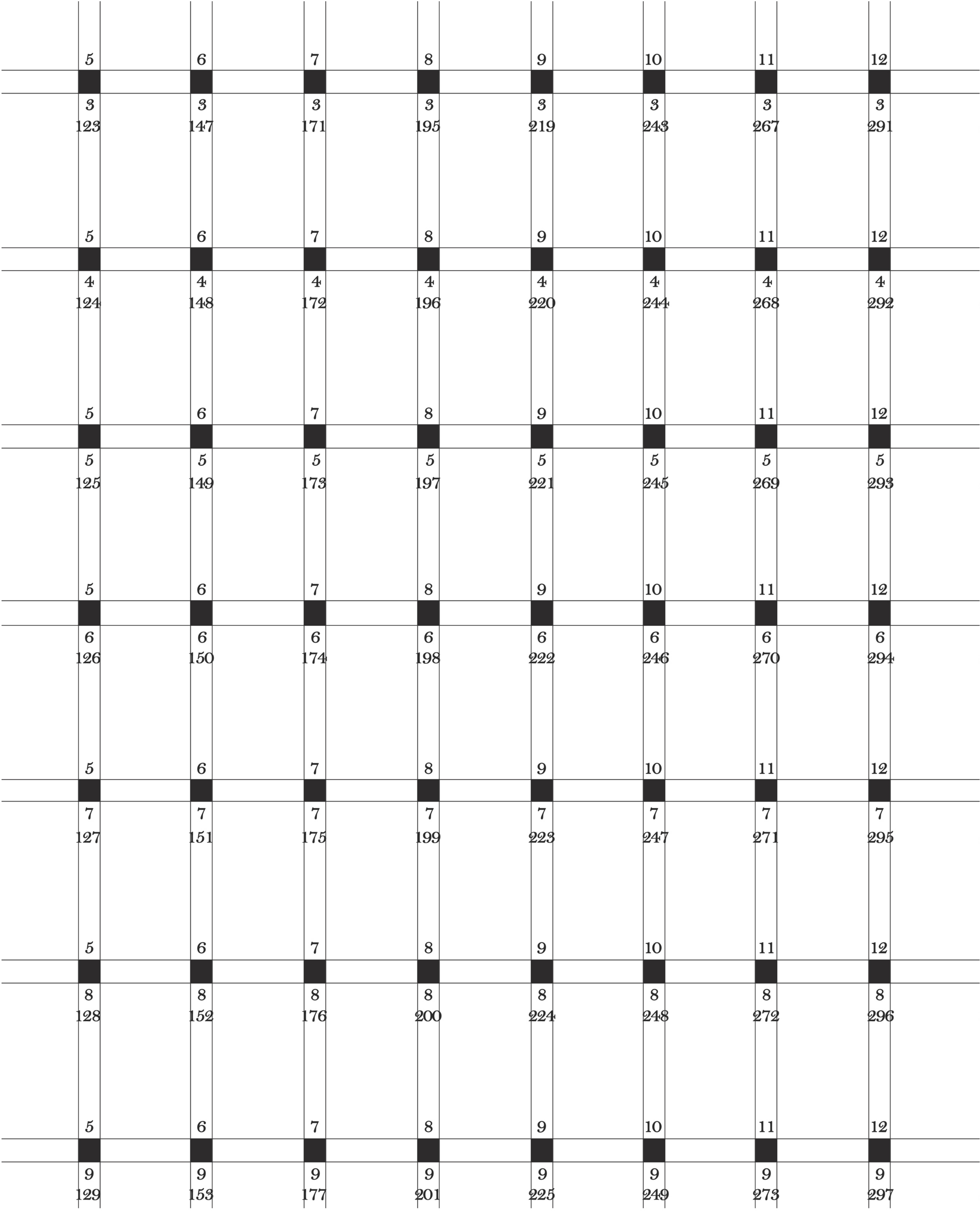
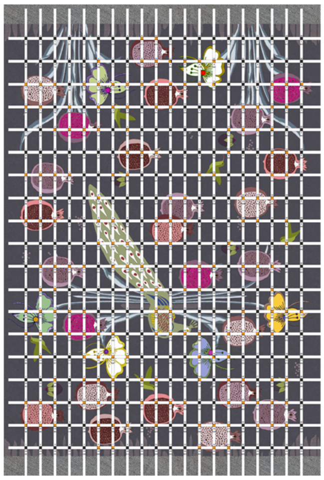
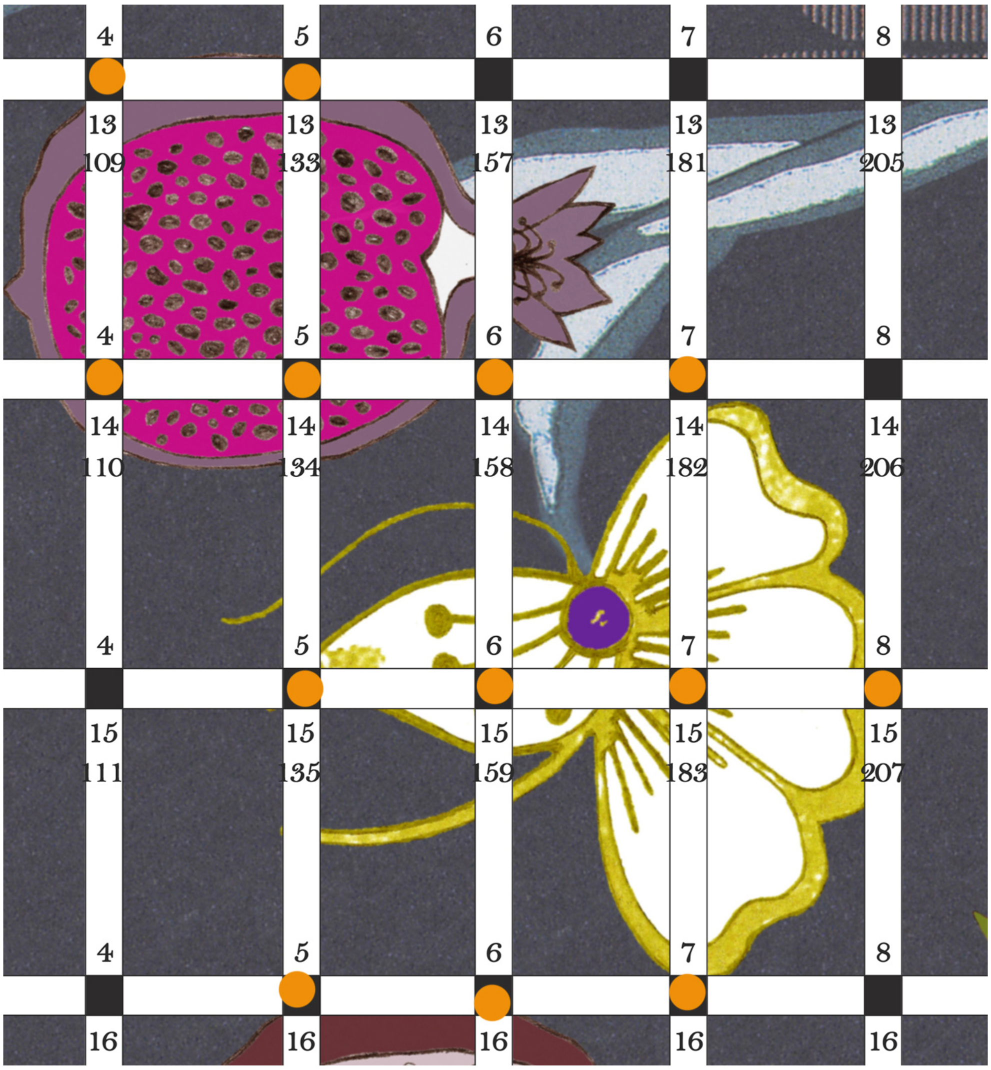


Figure 10. Sketch detail of the grid on the deep tissue. Cross-sections are classified as sets of coordinates (x,y) and as unique matrix elements (UI).

Figure 11. Mapping the grid of the deep tissue to different textures on the skin. Orange cross-sections are perceived within SuperCollider as EA while black cross-sections are perceived as NEA.





This sort of classification is central to my methodology because embroidered texture can be perceived both haptically and visually. Indeed, a number of recent experiments provide empirical evidence that support the idea that this type of textural information is not only gathered by but also bidirectionally exchanged between our visual and haptic modalities from as early as the first weeks of our life (see Merabet et al. 2004; Molina and Jouen 1998; 2001; Saan and Steri 2007). To avoid a straightforward relation between the visual and tactile information afforded by the rug – which could potentially lead to dominance of the first over the other or vice versa – most patterns on the skin have been partially embroidered whilst others have not been embroidered at all.

When people are asked to step on and explore the rug, the SuperCollider sound software composes an organic soundscape that evolves in real time with respect to people's unique movement. The soundscape is composed through calculation of complex spatiotemporal relations between triggered nodes using various synthetic sounds and one natural sound, a sound recording of cicadas. The cicadas' sound recording occurs in the emergent sonic composition only when someone walks on an embroidered area on the rug (EA). Association of EA to the cicadas' sound in the generated sonic composition creates the conditions for the otherwise predominantly tactile and visual property of embroidered texture to be further perceptible through the sense of hearing. This kind of interplay between the tactile, visual and auditory experience of a single material property and its relation to people's kinaesthetic experience is a crucial parameter of my methodology.

> Introduction to the experimental process

The experimental process took place and was recorded over the course of two days in the living room of my family house in Athens, Greece. Using an actual, though carefully arranged, setting of a living room was an integral part of the experimental design. Although many of the original furniture was removed for the installation of the rug as well as for filming purposes, the room kept its strong character of a homely interior into which the rug smoothly integrated as an everyday domestic object. Moreover the setting provided a safe, familiar environment for the people involved in my study, a factor which they acknowledged to have significantly contributed to reducing their feeling of nervousness about being filmed throughout the process. The final setting comprised of the rug, various furniture invariably found in a living room, and various equipment such as a computer, two active speakers, speaker stands, a 2-channelled audio interface, two cameras, one tripod, and one pole (Figure 12, top).

A number of reasons contributed to using video for collecting my empirical data. The most important one was minimising my presence in the room to prevent obtrusive interference in people's attention and performance. Other decisive factors included: the potential of the video medium to capture spatio-temporal sequences and non-verbal interactions as they unfold in a manner that would be difficult to be described by a single observer taking notes; the benefit of being able to later revisit the recorded material and to manipulate it – for example by means of slowing it down, speeding it up, freezing it, rewinding it etc. – as many times needed for analysing and interpreting the recorded events; and, finally, the possibility recordings offer to people who would not have been able to be present at the experimental process to access the events independently from the reports I have produced for the purposes of this thesis.

Following some experimentation with different camera angles and positions in the room, I concluded on the use of two fixed cameras for the filming process: a high quality DV-camera (Camera A) was positioned on a tripod at one side of the room in equal distance from and at the same height with the two speakers – approximately 1.5 meters high from the floor. Camera A captured the full width and length of the rug as well as the audio environment in a stereophonic manner. A camcorder (Camera B) was positioned on a pole at the other side of the room at approximately 3 meters high from the floor providing a planar view of the rug (Figure 12, bottom).

The process involved a total of eight participants that were randomly divided into two groups of four, with each group occupying one of the two set experimental days. Participants are members of the Athens Youth Symphonic Orchestra, and their selection was made on the basis of their music education background with no other parameters (gender, ethnic or physical characteristics) affecting the selection process. Musicians were chosen to take part in my study on the assumption that over years of musical training they have developed an aural sensibility that is important in performing tasks which rely on attuning to differentiated sonic textures like those involved in the proposed experimental context.

Participants were gathered in the garden of my family house and were given a brief overview of my research practice. This involved basic information about the responsive nature of the rug, as well as information on the purpose, structure, and duration of the

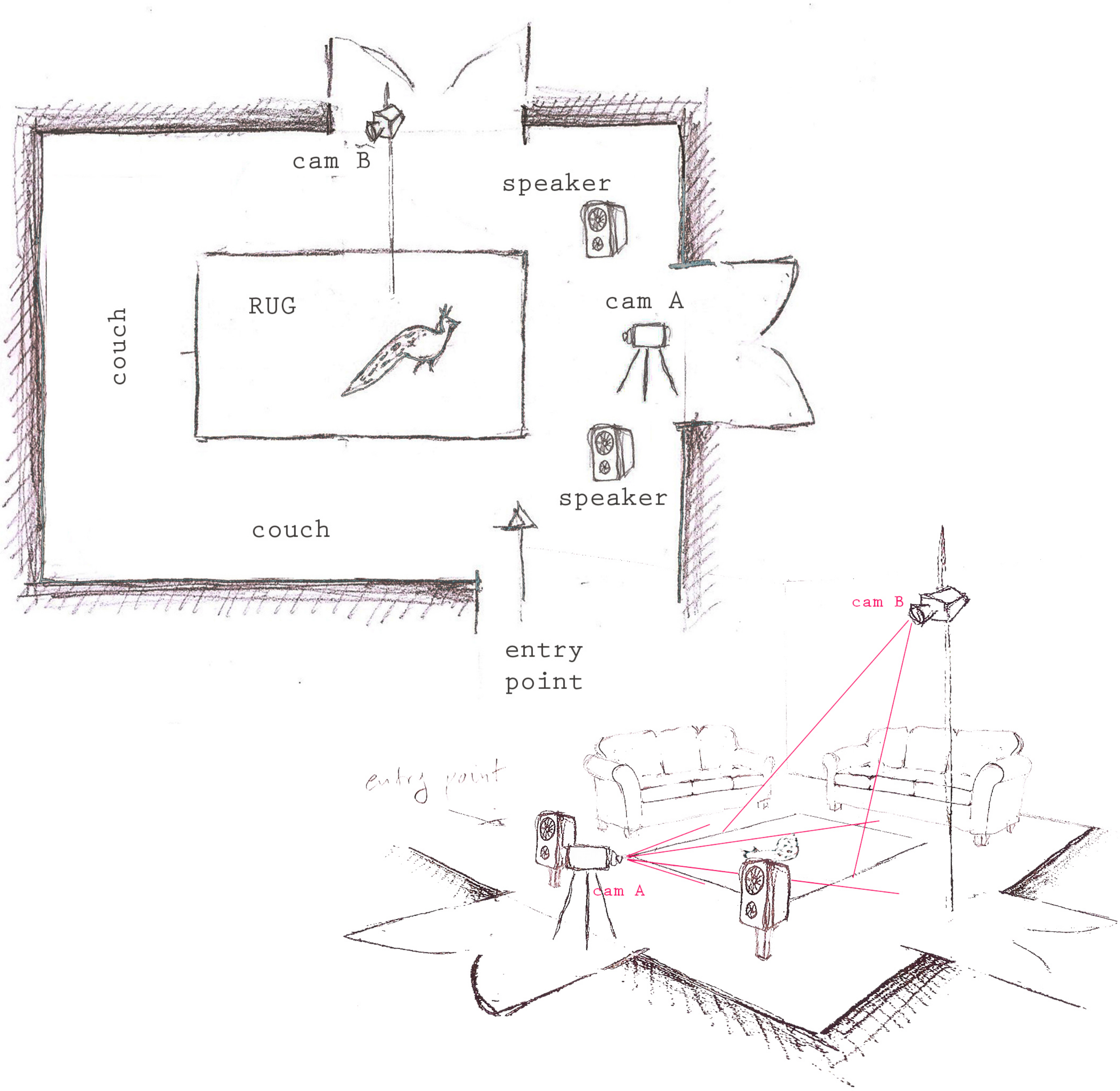


Figure 12. Top: experimental setting plan
Bottom: camera view angles

experimental process[2]. They were then led to the rug installation one-by-one to perform the experiment without other participants watching. The process consisted of two stages, and the duration of each stage varied from 5 to 7 minutes. At the start of each stage, participants were given a set of instructions and were asked to wait for me to leave the room before they carry it out. Instructions to the experimental stages can be found in Appendix B.

> **Methodology for analysis**

My analysis takes into consideration two different sets of data. The first one concerns quantitative data generated within the SuperCollider sound software that provide important spatio-temporal information on each individual participant's movement on the rug. They involve streams of sets of coordinates that spatially map the exact paths followed by a participant. They also provide a record of the overall duration between successive steps in a followed path as well as of the amount of time spent on any given area on the rug at any given point of time throughout the course of the experimental process. The second set of data provides qualitative information on participants' movement on the rug and is obtained from observation of the collected video material. This ranges from generic information characterising a participant's movement – like, for example, whether it appears to be developing randomly or to be purposefully directed towards specific rug textures, whether it is static, slow, continuous etc. – to particular actions performed by a participant like toe walking, walking backwards, or performing repetitive steps on a spot. Video recordings are carefully studied and notes are taken detailing participants' activity on the rug. Emerging themes are crammed into categories that outline different types of actions and processes, and categories are broken down into distinct variables with each variable being clearly defined by a descriptor (see Table 2). This way of organising qualitative information allows consistencies in participants' responses to be detected and diversities to be revealed.

Combining this type of observational material with data obtained from the sound engine, I examine each individual participant's interaction with the rug in relation to the tasks at hand. Particular focus is given on how they go about to explore the visual, tactile and sonic textures afforded by the rug, and on how they integrate this multisensory information to guide their movement on the rug. Analysis of participants' performances is

2 Participants were informed that they will be filmed and were asked to complete a consent form for the use of the videotaped material for the purposes of my research (Appendix D).

Category	Variable	Abbr	Descriptor
Steps	Average	A	Walk pace
	Small	S	Smaller than walk pace
	Big	B	Bigger than walk pace
	Walk rhythm	R	Walk rhythm
	Fast	F	Faster than walk rhythm
	Slow	SL	Slower than walk rhythm
Actions	Continuous movement	C	In constant move
	Discontinuous movement	D	Sometimes moving and sometimes standing still
	Static on one foot	SF	Standing still on one foot
	Static on both feet	SBF	Standing still on both feet
	One foot fixed, one foot free	OFF	Standing still on one foot, other foot explores surrounding areas
	Repetitive steps on the spot	RES	Standing still, shifting body weight from one foot to another
	Backwards	BKW	Performing backward steps
Use of foot	Toes	T	Walking on toes
	Whole	W	Walking on the whole foot
Direction	Free	FR)	Walking freely across the rug
	Constrained	COD	Constrained movement on the rug, e.g. circular, diagonal
	Targeting EA	TEA	Purposefully walking on EA
	Targeting NEA	TNEA	Purposefully walking on NEA
	No particular targeting	NT	Non EA or NEA focused movement
	Changes in direction	CD	Abruptly changing the direction of movement
Type	Exploratory	EX	
	Non-exploratory	NEX	
	Confident	CON	
	Hesitant	HES	
	Purposeful	PUR	
	Random	RAN	

Table 2. Analysis of movement characteristics

followed by discussion on behavioural patterns observed in my study, and what they reveal about the role of active exploration and crossmodal processing in the formation of a unified percept upon which we can act.

> Notes on individual performances

Stella

Stage 1

Table 3. Stella's movement characteristics in Stage 1

Tags	(A), (S), (B), (TEA), (TNEA), (NT), (RES), (SL), (TNEA), (SF), (SBF), (BKW), (CD), (T), (W), (D), (FR), (EX), (PUR)
Rhythm	39 steps/min
Triggered EA	58.7%

She starts by walking in a regular pace primarily targeting EA. Gradually, her pace grows slower as she performs small repetitive steps on different rug patterns. Focusing mainly on EA, she does follow strictly NEA paths from time to time. Her movement is composed of small, carefully placed steps and presents a variety of elements such as resting on one foot, standing still on both feet, weight transfer from one foot to another, performing backward and forward steps, frequent changes in direction, and toe walking. Over time her temporal pace is increased and her spatial pace fluctuates between small steps on the spot and significantly larger steps from one spot to another. Walking in a non-organised manner – non-linear, non-circular – she covers most of the rug surface. By the end of the first stage she has identified the sound of natural origin as one being produced by cicadas.

Stage 2

Table 4. Stella's movement characteristics in Stage 2

Tags	(F), (A), (S), (B), (TEA), (TNEA), (SF), (SBF), (CD), (T), (W), (D), (C), (FR), (EX), (PUR), (CON)
Rhythm	53 steps/min
Triggered EA	22.1%

For the first 30 seconds of this stage, she is performing relatively fast steps of regular distances that are specifically targeted on EA. Keeping the same tempo, she then shifts her movement towards NEA. Her steps become larger and more confident. Her NEA route is interrupted for 3 seconds, during which she purposefully targets embroidered patterns with small steps, before continuing to walk only on NEA. The exact same process is repeated for yet another 3 seconds half a minute and two minutes later. From this point onwards and for the remaining time of this stage (2'21'') she walks only on NEA. Her movement combines elements performed in Stage 1 (like toe walking or resting on one foot) with what can be described as dancing moves – abrupt changes in direction, two-and-single-footed jumps, demi-plies, turns on one foot, adages. Same as in Stage 1, her movement covers most of the rug surface.

Analysis The SuperCollider data report of her Stage 2 interaction with the rug illustrates a significant decrease (62%) in the amount of triggered EA nodes in relation to her Stage 1 performance. Her second stage recording shows that the first 30 seconds of her performance are approached as a trial period during which her understanding of the relation between the rug's multisensory textures (as developed through her Stage 1 experience) is reaffirmed and consolidated. Upon completion of this 'trial period', her movement starts unfolding specifically on non-embroidered rug areas. Moreover, the incorporation of complex step combinations, such as basic dance manoeuvres, suggests that she is confident about how to move across the rug with respect to her given task. This indicates that the highly exploratory spatial behaviour she demonstrated in Stage 1 has provided her with enough clues to forge meaningful links between the rug's tactile and sonic textures before entering Stage 2. This is an interesting observation that suggests she was able to forge those links prior to being hinted to do so for conducting Stage 2.

Rallia

Stage 1

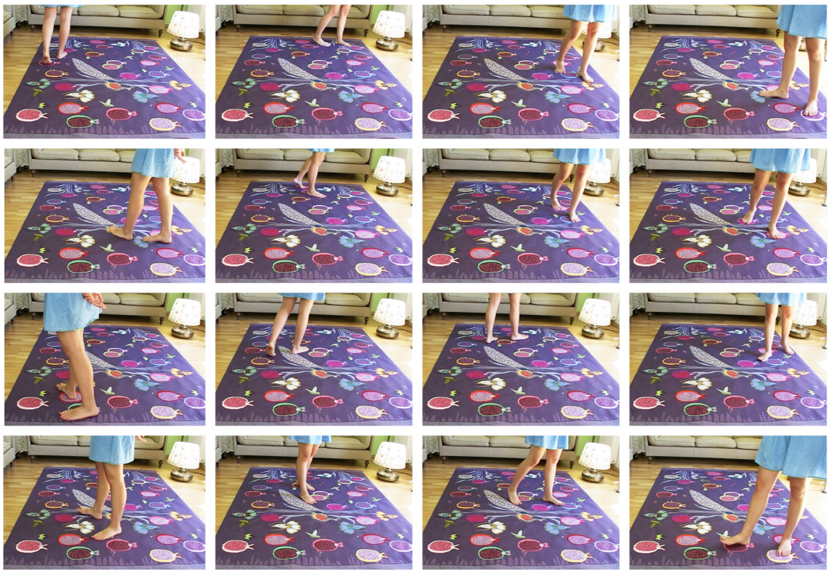


Table 5. Rallia's movement characteristics in Stage 1

Tags	(A), (SL), (CD), (COD), (NT), (C), (RES), (W), (EX), (PUR), (RAN)
Rhythm	31 steps/min
Triggered EA	54%

She walks across the rug in a slow, steady pace, in an almost ritualistic manner. Her movement on the rug is very homogenous and unravels into mostly circular and linear paths with few changes in direction. Her steps do not particularly target EA or NEA, however the placement of her feet is very slow and controlled, starting from the heels and gently covering all the way to the toes. Her pace is steady both temporally and spatially for the duration of the stage with the exception of some reoccurring smaller steps backwards and forwards which result from transferring her body weight from front foot to the back and vice versa. Her movement covers most of the rug surface. By the end of Stage 1 she has identified the sound of natural origin as being produced by wind chimes.

Stage 2

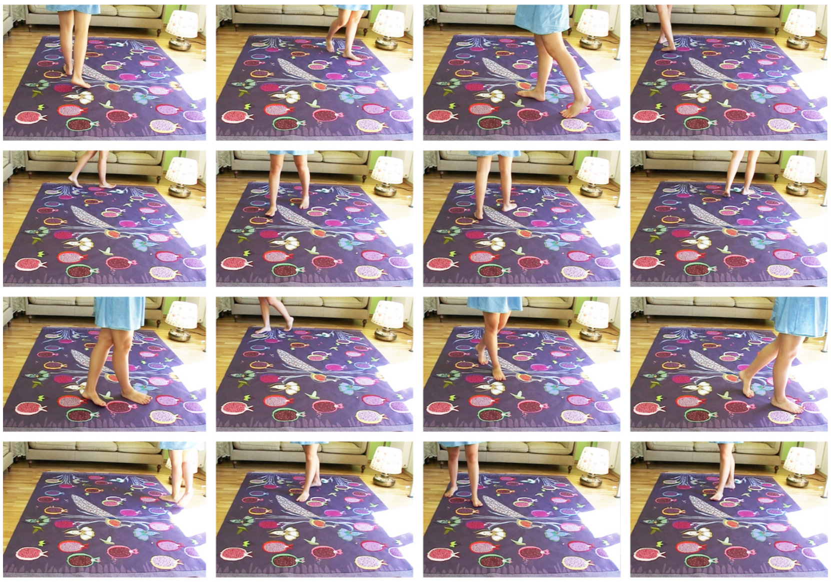


Table 6. Rallia's movement characteristics in Stage 2

Tags	(A), (B), (SL), (CD), (COD), (TNE A), (C), (W), (CON), (PUR
Rhythm	30 steps/min
Triggered EA	14.5%

Her movement is quite similar to that of Stage 1 in that it is characterised by a slow, steady pace and a mainly circular development. One important difference from her first performance, which unfolded randomly onto both EA and NEA, is that in Stage 2 her movement is consistently focused on NEA. Her targeting of NEA results in relatively bigger steps and more frequent changes in direction which can be explained as an attempt to avoid stepping on embroidered patterns. She spends all Stage 2 walking on NEA with the exception of 2 seconds during which she experimentally steps on EA. Her movement is homogenous and confident and expands across most of the rug surface.

Analysis

The video recording of her first stage interaction with the rug depicts an overall slack movement that presents little variation in the performed steps and their spatiotemporal relation. However, it seems that the consistently slow steps she performs in Stage 1 are aimed at exploring different rug textures through careful and controlled placement of the foot (each step slowly expanding from heel to toes). It seems that this form of attentive walking allows her to haptically explore the textural differences between EA and NEA as well as the relation of each category to the various sonic textures it generates. This observation is supported by data produced within SuperCollider for her second stage interaction with rug. The data show an activity of merely 14.5% on EA, a figure that illustrates a dramatic 73% drop in relation to her Stage 1 performance. Her

SuperCollider report and video recording suggest that she enters the second stage with an understanding of which areas to direct her movement towards and which to avoid with respect to her task at hand. This is an important point in my analysis because it indicates that she was able to form an integrated percept of the multisensory stimuli afforded by the rug from as early as Stage 1 – before having to do so for conducting Stage 2.

Irene

Stage 1

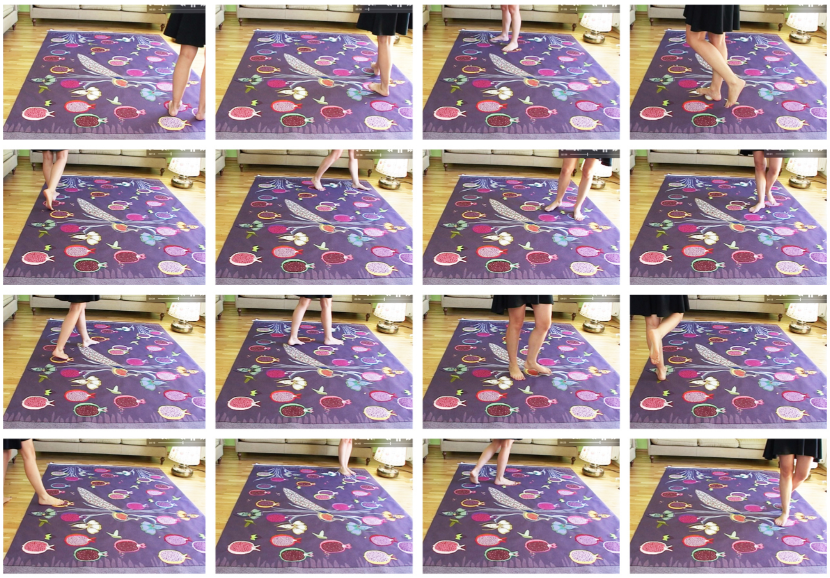


Table 7. Irene's movement characteristics in Stage 1

Tags	(SL), (TEA), (RES), (S), (CD), (FR), (COD), (D), (SF), (SBF), (W), (EX), (PUR)
Rhythm	24 steps/min
Triggered EA	58.6%

She walks slowly on the rug targeting different embroidered patterns (EA). Her pace is steady in terms of rhythm and length with the exception of frequent small, repetitive steps that occur by shifting her body weight from one foot to the other. She gradually engages with non-embroidered areas on the rug (NEA) mostly as a means of facilitating her next step onto an embroidered pattern. She steps off the rug to take some time to listen to the sonic differences between the sounds generated by the rug when she is not interacting with it. Her steps are smaller than average walking pace, and her movement is consistently slow, almost ritualistic, and involves a variety of changes in direction. Her movement unfolds across the rug in random routes and circular or linear paths. By the end of Stage 1 she has identified the sound of natural origin as that of cicadas.

Stage 2

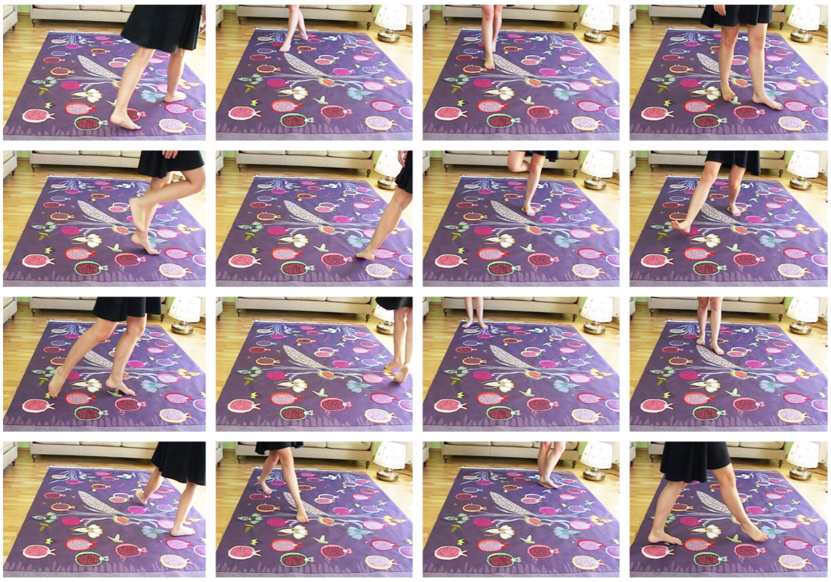


Table 8. Irene's movement characteristics in Stage 2

Tags	(SL), (TNEA), (TEA), (S), (B), (CD), (FR), (D), (SF), (SBF), (W), (T), (EX), (HES), (PUR)
Rhythm	29 steps/min
Triggered EA	41.4%

She walks slowly on the rug in a similar rhythm to that of her Stage 1 performance. This time, however, she starts by following a strictly NEA route that lasts for approximately 45 seconds. Progressively she shifts her attention towards some embroidered patterns. She returns to walking mainly on NEA whilst sporadically stepping on EA. In an attempt to trigger as little of the cicadas sound she walks on her toes, her steps however are targeted on both EA and NEA. She occasionally takes time to stand still on one foot as well as on both feet. Frequently changing direction, her steps seem less decisive over time and her overall movement on the rug becomes less confident progressively. She interchangeably performs NEA-and-EA-targeted steps before finally focusing on a NEA-only path.

Analysis

Her Stage 1 SuperCollider data report indicates a moderate difference between triggered EA and NEA coordinates (17.2% in favour of the first). However, a closer look at the video recording of her first performance reveals that this numerical difference does not accurately illustrate her movement on the rug. Throughout Stage 1, her movement is mainly directed towards EA; this suggests that many of the NEA coordinates registered in SuperCollider were likely triggered when, within an EA-targeted step, her foot occupied an area larger than the targeted embroidered pattern. This is an important observation in deciphering her second stage performance. Her second video recording depicts her demonstrating a highly exploratory spatial behaviour quite similarly to how she performed Stage 1. Having spent most of the first stage walking onto EA, she has easily identified the recurring sound recording of cicadas; however, the lack of successive NEA steps in this stage has resulted in an almost constant emission of cicadas sounds whose temporal blending between EA and NEA steps has not allowed her to explore the parallels between different rug textures and their corresponding sonic output. As a result, she spends most of the second stage trying to figure out the relationship between the visual-haptic stimuli afforded by the rug and their respective sonic output generated by her movement. With both stages being equally characterised by an element of active exploration, it is interesting to look at the ways in which her second stage spatial behavior appears to be informed by her experience of Stage 1. Building on her first stage experience, she introduces new exploratory techniques (like, for example walking on toes to target areas in a more focused manner) and processes (e.g. following strictly NEA paths), and she combines them with movement variations she has previously explored. Over time these behavioural novelties seem to allow her to link the generated cicadas' sound to the embroidered textures as its source, something that is also reflected in the numerical data gathered from SuperCollider – the data reports indicate a 39% decrease in the amount of triggered EA coordinates during Stage 2 in relation to that of Stage 1.

Dimitris

Stage 1

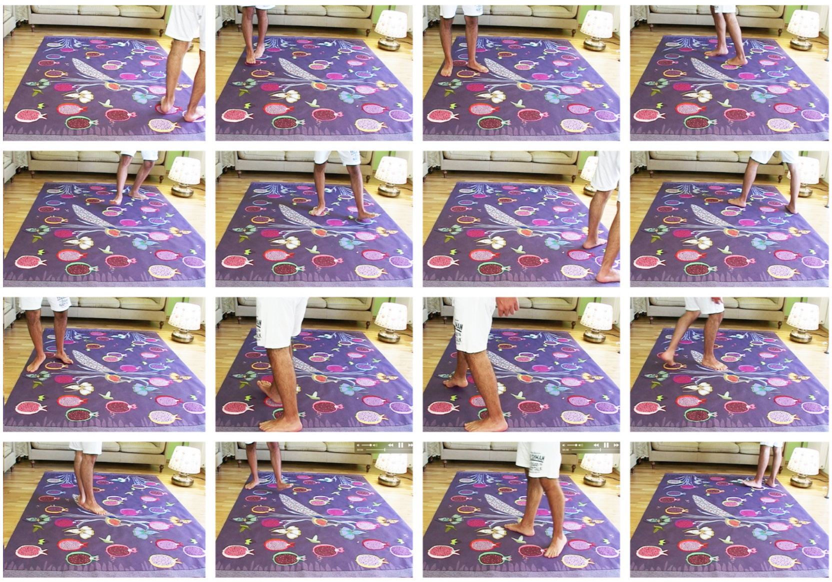


Table 9. Dimitris' movement characteristics in Stage 1

Tags	(S), (B), (R), (F), (SL), (NT), (TEA), (TNEA), (T), (EX) (W), (SBF), (OFF), (CD), (COD), (C), (PUR), (RAN)
Rhythm	41 steps/min
Triggered EA	54.9%

His tempo is close to his average walking pace while his steps vary in length. He starts by randomly walking across the rug without particularly focusing his attention to EA or NEA. Gradually, he starts targeting different embroidered patterns on the rug and for a significant amount of time follows an EA-only path which is in turn succeeded by a NEA-only one. He frequently uses the toes of his feet to target different areas he seeks to explore as well as other exploratory techniques such as standing still with both feet fixed on the rug (both feet on EA or both feet on NEA), or standing still with one foot fixed on NEA and the other foot extending to step on surrounding embroidered patterns. Eventually he returns to walking freely on the rug without a particular focus on where he steps along his route. His overall movement presents differentiations in terms of his spatial and temporal pace. It involves frequent changes in direction and many pauses to stand still. His followed routes are mostly linear and cover most of the rug area. By the end of Stage 2 he has identified the sound of natural origin as one being produced by cicadas.

Stage 2

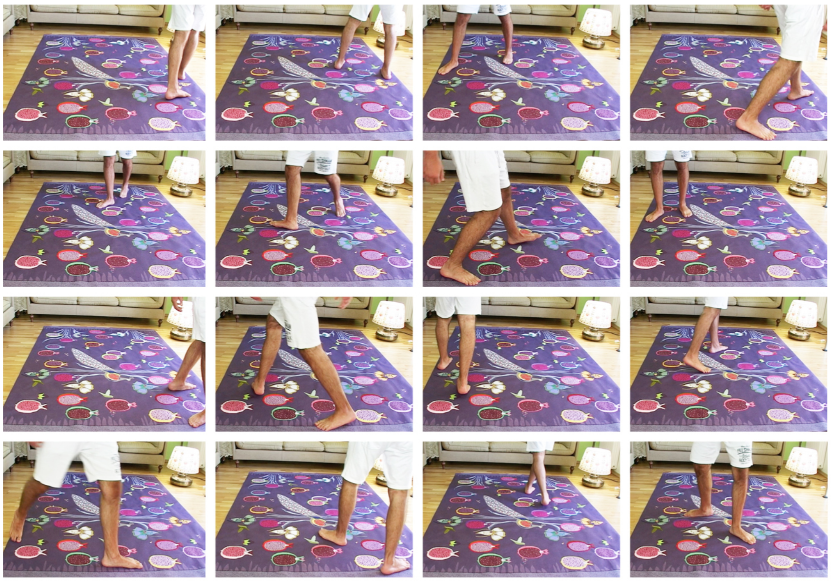


Table 10. Dimitris' movement characteristics in Stage 2

Tags	(F), (S), (B), (TNEA), (C), (CD), (FR), (T), (W), (PUR), (CON)
Rhythm	43 steps/min
Triggered EA	11.3%

Throughout Stage 2 he walks only on NEA. His pace is confident and much faster than in the previous stage and involves very frequent changes in direction and significant differentiation in the size of his steps. This clearly demonstrates an understanding of EA as 'obstacles' that need to be avoided. His movement unfolds across most of the NEA on the rug in a much freer, non-linear manner than the one performed in Stage 1.

Analysis

His video recordings illustrate conspicuous differences between his Stage 1 and Stage 2 performances both in terms of the performed moves and their spatial relation to the rug patterns. The latter is further evident in the data gathered from SuperCollider which depict a noteworthy 83% drop in stepped-on EA between the two stages (54.9% for Stage 1, 9.4% for Stage 2). His second video recording shows that, as soon as he enters Stage 2, he is consistently oriented towards non-embroidered areas on the rug. This NEA-focused movement seems to be the outcome of a multisensory-relations understanding that was developed in Stage 1 as a result of his highly explorative approach. Apart from employing various exploratory techniques – like standing on one foot or toe walking – he also experimented with alternately following distinct EA and NEA paths as well as random paths of mixed textural elements. I believe that this multi-targeted movement on the rug in Stage 1 allowed him to develop a round understanding of the haptic-sonic relation among the different rug textures and their corresponding aural textures. The videotaped material of his second engagement with rug supports this hypothesis. From as early as the beginning of his second film, he gives the impression that he has worked out an 'action plan' for which areas to walk on and which to avoid with respect to the task he is given. This impression becomes stronger in the remaining time of his second stage performance.

Nikos

Stage 1

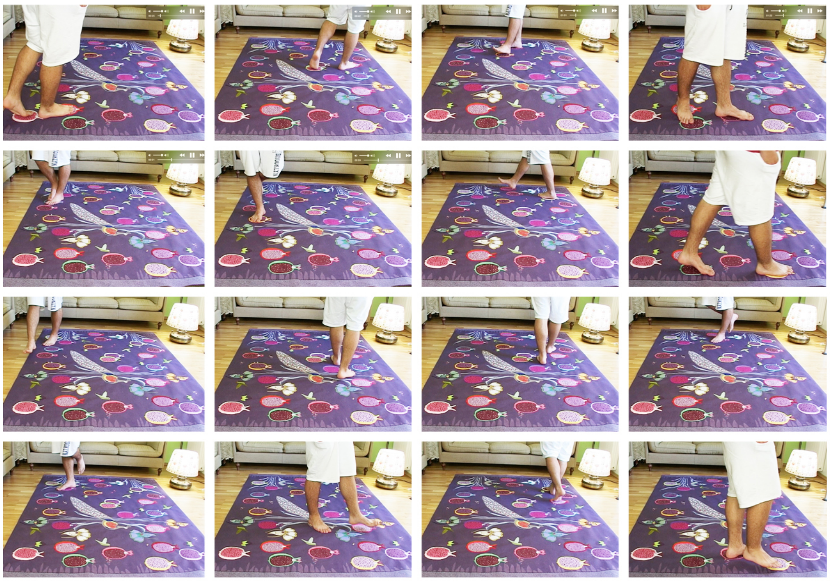


Table 11. Nikos' movement characteristics in Stage 1

Tags	(SL), (S), (A), (D), (SF), (RES), (W), (CD), (COD), (TEA), (EX), (PUR)
Rhythm	17 steps/min
Triggered EA	58.1%

His movement is consistently slow, and it mainly develops in a circular manner despite presenting many recurring changes in direction. He frequently performs repetitive steps on various spots by transferring his body weight from one foot to the other, and, quite regularly, he stands still on one foot paying attention to the sounds generated by the particular spots he targets on the rug. His steps are in majority small although some bigger steps are also performed to allow him to reach selected embroidered patterns. Overall, his movement is mainly oriented towards EA. He does sparsely perform successive steps on non-embroidered areas, however most of his steps onto NEA occur as random intervals within his EA-focused paths. By the end of the first stage he reports he has identified the sound of natural origin which he describes as a 'shushing' or 'chirping' sound.

Stage 2

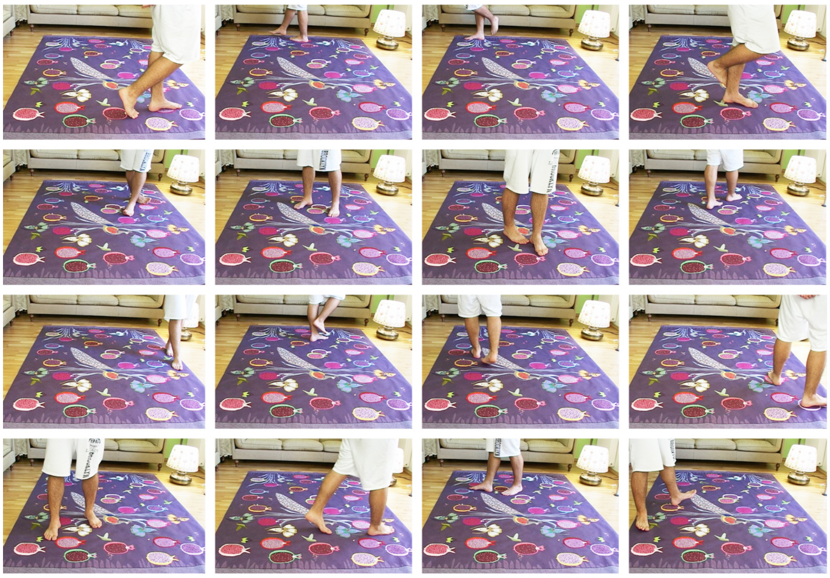


Table 12. Nikos' movement characteristics in Stage 2

Tags	(SL), (S), (A), (B), (D), (CD), (W), (SF), (SBF), (RES), (BKW), (TEA), (TNEA), (NT), (FR), (EX), (HES), (PUR)
Rhythm	21 steps/min
Triggered EA	27.9%

Moving slowly on the rug, he starts the second stage by spending 20 seconds walking solely on EA and then a further 10 seconds walking only on NEA. His movement gradually becomes less restrained by rug textures, carefully stepping on both EA and NEA. This free wandering across the rug lasts for about one and a half minutes. He spends the remaining time of the stage following a strictly NEA-path. His overall movement is extremely slow and fragmented: he frequently changes direction and stands still on one foot, and occasionally reverses some of his steps in a backwards manner.

Analysis

SuperCollider data show a 52% decrease in triggered EA from Stage 1 to Stage 2. Although the figure looks high, his second stage video recording reveals that a significant part of Stage 2 is spent for exploration of the relation between the tactile stimuli afforded by the rug and their corresponding sonic output. The reason for this can be traced back to his Stage 1 performance, and more specifically to the orientational characteristics of his movement throughout this stage. His first video recording indicates that his attention is primarily shifted towards exploration of the different embroidered patterns on the rug. Although – some times accidentally and other times intentionally – he does trigger a considerable number of NEA nodes (about 42% of all triggered nodes), his overall movement remains oriented towards the visual/tactile elements on the rug. As such, his auditory attention is primarily attuned to picking up the sonic textures that relate to the embroidered patterns but not to processing the sonic differences between EA and NEA. After completion of Stage 1, he has identified the sound of natural origin as requested but he has not been able to disassociate it from the non-embroidered areas. Entering Stage 2 with the task of generating as little of the natural sound as possible, he has to spend more than one third of the overall stage duration figuring out the relation between EA and the natural sound recording before confidently orienting his movement solely on NEA.

Despina

Stage 1

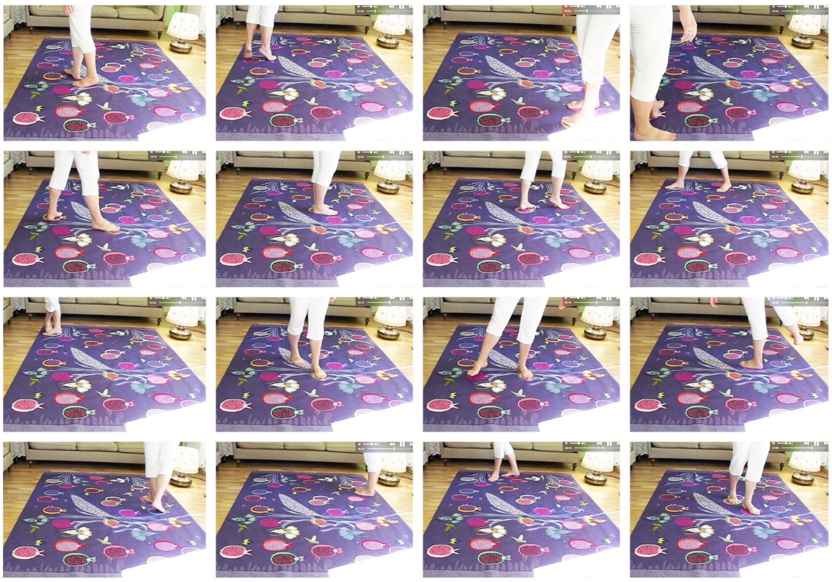


Table 13. Despina's movement characteristics in Stage 1

Tags	(S), (B), (F), (SL), (D), (SF), (SBF), (OFF), (RES), (T), (W), (FR), (TE), (TNEA), (CD), (EX), (PUR)
Rhythm	20 steps/min
Triggered EA	61.3 %

Walking slowly across the rug, her movement is focused towards the embroidered parts of the rug. However, her movement interchangeably involves EA-to-EA and EA-to-NEA steps. Her pace varies notably in terms of tempo and length; this spatiotemporal variability is furthered by frequent changes in her movement direction. Her movement is highly exploratory combining different elements such as standing still on one or both feet, standing still on one foot while extending the other to reach selected surrounding areas, performing repetitive small steps on the same spot, shifting her weight from foot to the other, and frequent use of toes to focus on specific spots on the rug. Her movement covers most of the rug and is characterized by many pauses and a non-linear development. By the end of the first stage she has identified the sound of natural origin as crickets.

Stage 2

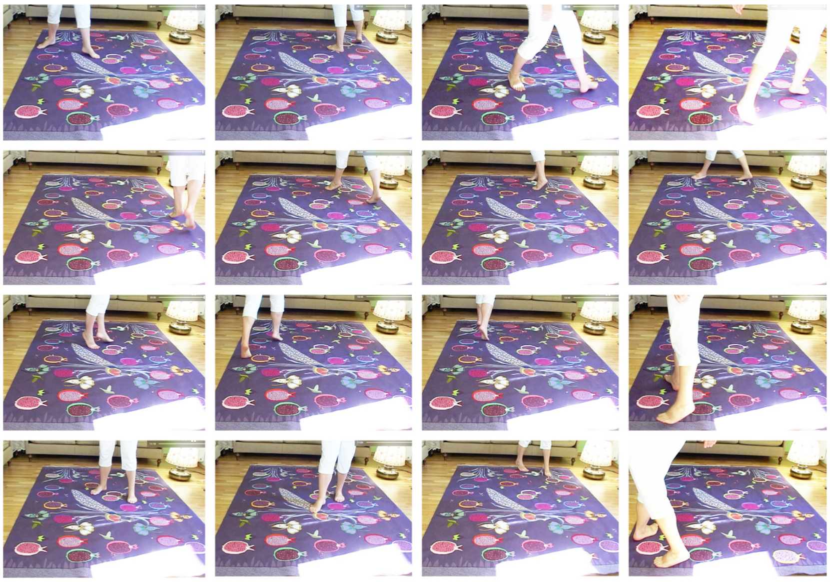


Table 14. Movement characteristics of Despina in Stage 2

Tags	(A), (S), (B), (F), (R), (SL), (D), (SF), (SBF), (OFF), (T), (W), (FR), (TNEA), (TEA), (CD), (CON), (PUR)
Rhythm	45 steps/min
Triggered EA	14.3%

Moving slowly, she starts by following various NEA paths. She occasionally interrupts her strictly-NEA paths by keeping one foot fixed on a non-embroidered spot on the rug and extending the other foot towards embroidered patterns. She spends the last 6'13'' of the stage (over 2/3 of the overall duration) stepping only on NEA. Her steps seem to be confident and well controlled, ranging from small, rapid jumps to big, smooth moves. Her pace is temporally fluctuating from stillness to swift movement: she combines frequent changes in direction, a significant amount of toe walking, as well as frequent pauses. Her movement unfolds across the rug into arbitrary, non-linear NEA paths.

Analysis

Over two thirds of her Stage 1 movement takes place onto embroidered areas, a number higher than for any other participant. However, careful observation of her first video recording reveals that, in between her EA-focused paths, she repeatedly performs carefully placed steps alternately from EA to NEA and vice versa. It seems that this kind of reoccurring reciprocal steps has allowed her to build an understanding of the relation between different tactile textures and their correlated sonic output at some point in Stage 1. Indeed, her second video recording depicts her focusing her movement towards NEA from a very early point in Stage 2. With the exception of some sparse steps onto EA at the beginning of the second stage that seem to serve as a means of re-evaluating audio-haptic connections she made in Stage 1, she spends the remaining time walking smoothly along the non-embroidered areas of the rug. This is also illustrated in the SuperCollider data report of her second stage interaction which presents a dramatic drop (by almost 80%) in the amount of triggered EA in relation to her Stage 1 performance.

Elisavet

Stage 1

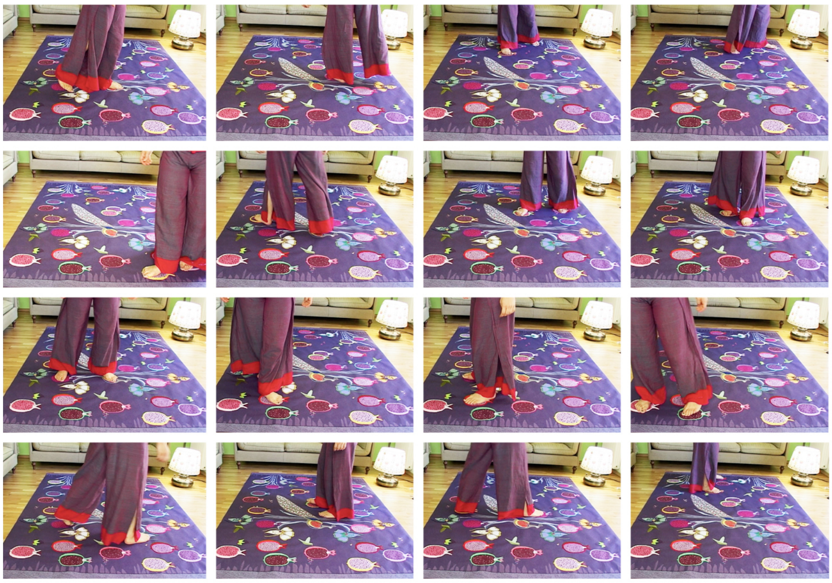


Table 15. Elisavet‘s movement characteristics in Stage 1

Tags	(S), (B), (SL), (D), (SF), (SBF), (RES), (W), (T), (FR), (TEA), (CD), (EX), (PUR)
Rhythm	36 steps/min
Triggered EA	57.6%

Her pace varies significantly in its temporal and spatial dimensions. Her movement is consistently targeted towards embroidered patterns and ranges from big steps that emerge from abrupt changes in direction to small, sudden, repetitive steps. She meticulously explores targeted embroidered areas by frequently transferring her body weight from one foot to the other, standing still on one or on both feet, and performing repetitive steps on the spot over a significant amount of time. Her overall movement on the rug is slow, non-continuous, and develops in a non-hierarchical, non-linear manner. As she walks across the rug she steps on both EA and NEA, however, her movement is focused towards systematically exploring EA throughout the whole stage. By the end of the stage she reports she has identified the sound of natural origin as one being produced by cicadas.

Stage 2

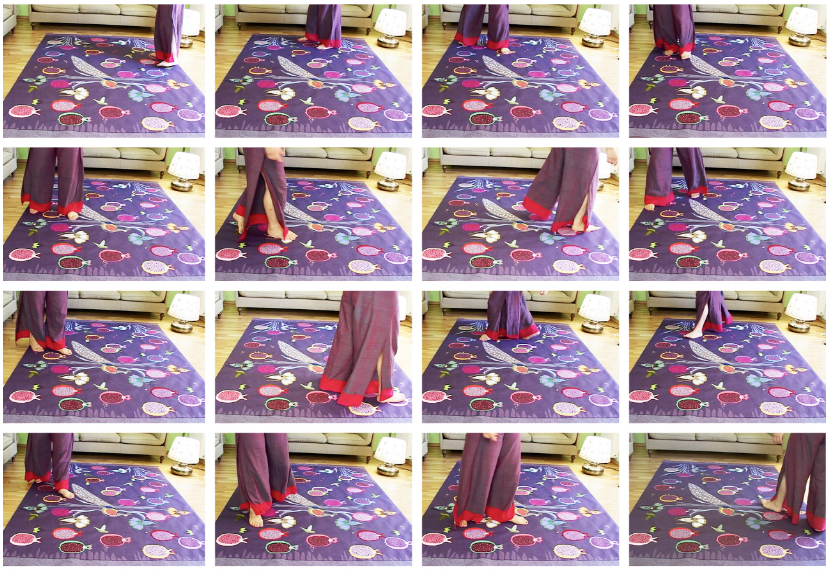


Table 16. Elisavet's movement characteristics in Stage 2

Tags	(S), (B), (R), (SL), (D), (SF), (SBF), (OFF), (RES), (W), (T), (FR), (TEA), (TNEA), (NT), (CD), (EX), (HES), (CON), (PUR)
Rhythm	45 steps/min
Triggered EA	37.8%

Similarly to Stage 1, she performs small, slow steps onto embroidered patterns. She spends almost 2 minutes (over one third of the overall duration of this stage) walking only on EA, before shifting her attention to non-embroidered areas on the rug. Her NEA-only paths are interrupted two times over the remaining time of Stage 2, once by a half-minute interval of stepping on EA and once by a half-minute interval of performing random steps on both EA and NEA. Her movement presents multiple changes in direction and significant variations on the performed steps –small and big steps, repetitive steps on one spot, toe walking, standing still on one foot and extending the other to reach neighbouring spots, body weight transfer from one foot to the other. Gradually, as she grows more confident about focusing on NEA paths, these variations dissolve into a more uniform and continuous movement that is characterised by big steps and no pauses.

Analysis SuperCollider data show that the relation between triggered EA and NEA in her first performance is relatively balanced (57% to 42%). Although this suggests that her movement has unfolded in a manner that is not particularly directed towards EA or NEA, a closer look at her first stage video recording suggests otherwise. The film reveals that, throughout Stage 1, her attention is focused on exploring EA with the majority of NEA triggering occuring through steps that facilitate movement from one EA spot to another. Her EA-oriented movement has allowed her to quickly grasp the source of natural sound as instructed, but has also contributed to a constant generation of the natural sound that seems to have obscured her ability to associate it to a particular tactile texture. As such, relations between different rug textures and their corresponding sonic output need to be explored from scratch in the second stage. This becomes evident in her second video recording which depicts her performing a complex combination of exploratory moves in an attempt to figure out how to perform the task she is given. Building on her first stage experience, in Stage 2 she introduces new exploratory techniques that over time seem to allow her to form an understanding of the cause-and-effect relation between embroidered areas of the rug and the generation of the natural sound. This is clearly reflected in the last part of her second stage performance, during which her movement is consistently oriented towards NEA.

Paris

Stage 1a

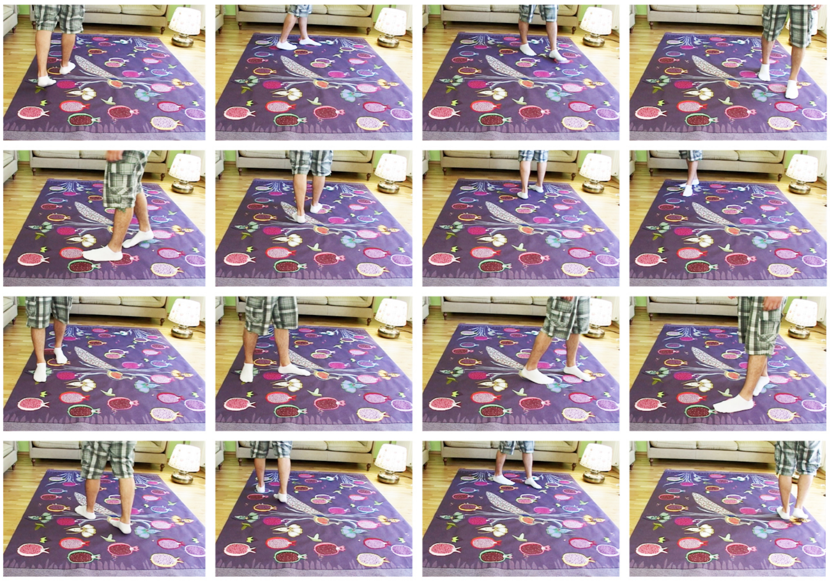


Table 17. Paris' movement characteristics in Stage 1a

Tags	(A), (R), (C), (W), (COD), (NT), (NEX), (RAN)
Rhythm	52 steps/min
Triggered EA	42.5 %

Performing steps at regular distances and a steady rhythm, he walks across the rug in a circular and diagonal manner. He demonstrates no particular focus towards EA or NEA. His movement is continuous with few changes in direction. It is composed of almost invariant steps and presents no exploratory elements such as repetitive steps on the spot, pauses (standing still), or toe walking. Following the same pattern of movement throughout the duration of the stage, his pace gradually grows faster. By the end of his first interaction with the rug he has not been able to identify a sound of natural origin. He is advised that the soundscape he creates as he moves around the rug is composed of various synthetic sounds as well as a sound recording of cicadas. He is asked to repeat Stage 1 paying attention to these sonic elements and their relation to the paths he takes as he walks across the rug.

Stage 1b

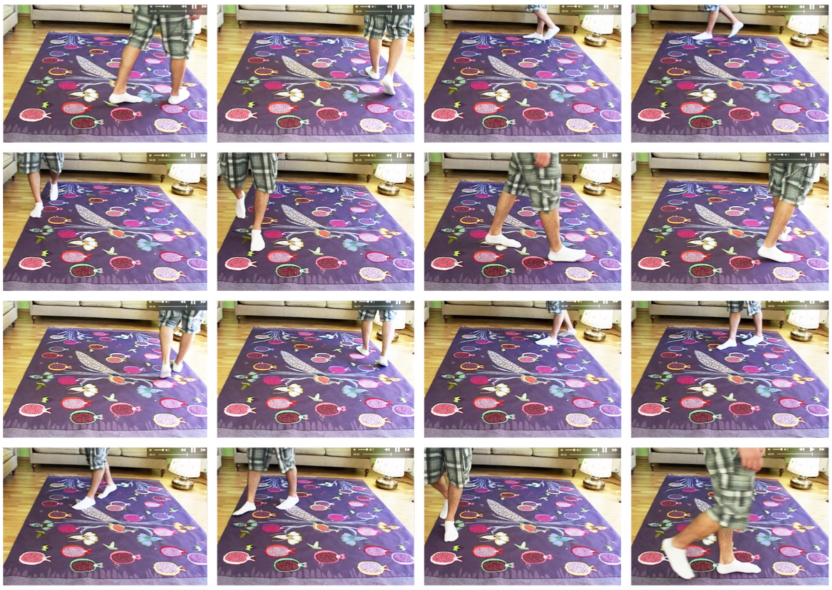


Table 18. Paris' movement characteristics in Stage 2

Tags	(A), (R), (F), (C), (W), (COD), (NT), (NEX), (RAN)
Rhythm	61 steps/min
Triggered EA	42.4%

Throughout the second round of the first stage, his performance is almost identical to that of the first round – one noticeable difference being a slight increase in his walking tempo. He moves hastily across the rug, mainly in a circular manner, performing uniform steps that seem to be arbitrary in relation to the visual/haptic stimuli presented by the rug. His movement does not present any particular exploratory elements and could be described as a kind of mechanical wandering.

Stage 2

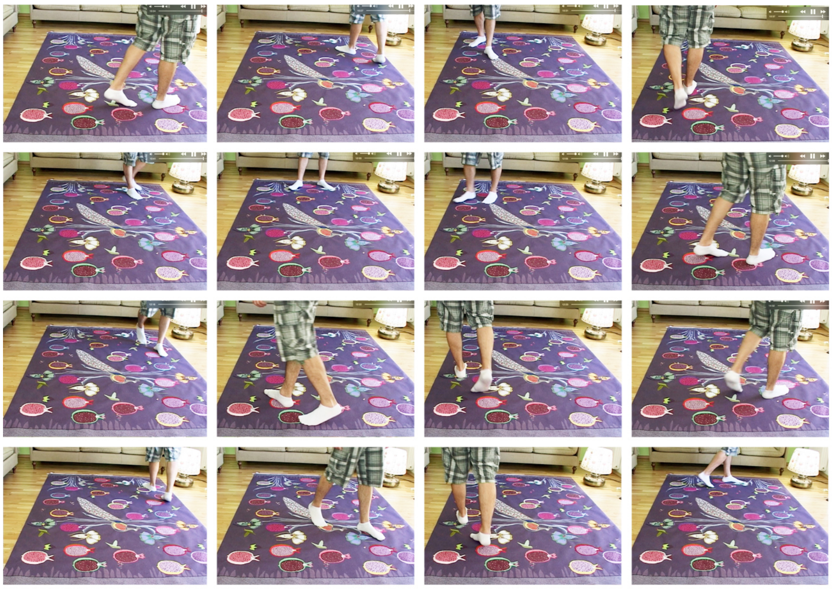


Table 19. Paris' movement characteristics in Stage 2

Tags	(A), (R), (F), (C), (W), (COD), (NT), (NEX), (RAN)
Rhythm	61 steps/min
Triggered EA	42.4%

Same as with Stages 1a and 1b, his movement unfolds in a circular manner with few changes in direction. He performs fast, steady steps that do not appear to be targeting any particular elements or textures of the rug, neither to be particularly informed by the sonic output they trigger. Overall, he introduces no new combinations of steps, spatiotemporal variations in his pace, or occasional pauses in his movement.

Analysis The video and SuperCollider recordings of his three performances (Stages 1a and 1b, and Stage 2) present minor differentiations to one another. This is an interesting observation if we consider that: a) by repeating Stage 1 he has more time to explore relations between the generated sounds and the textural elements on the rug; and b) the natural sound source (cicadas) was revealed to him before re-conducting the first stage, providing him with an important clue with which to forge links between the different sonic and the tactile textures afforded by the rug. A question arises as to why these additional resources (extra time, knowledge of the natural sound source) do not seem to have informed his second stage performance. A possible explanation to that can be found in the video material of his Stage 1 performances. In both phases of Stage 1, his orientation on the rug appears to be informed by the overall rug surface – which he covers by moving almost invariantly in a circular and occasionally diagonal manner – rather than by specific elements on the rug (tactile and/or visual patterns). This indicates to me that he understands the rug as an abstract surface rather than as a composition of various patterns that could be individually or collectively explored. As his movement across the rug seems to be developing randomly instead of with respect to the afforded visual-tactile stimuli, it is difficult for him to built an understanding of the relation of the latter to the sonic output it generates when triggered by his steps. As such, when he enters Stage 2 he has developed no particular points of reference to help him guide his movement according to the task he is given. This is an important point in evaluating why his second stage performance presents no substantial differentiations to his first two. His relative disengagement with particular patterns and textures of the rug seem to have limited the different exploratory techniques he could employ to plain pacing. A difference I was able to identify among his three performances is a slight increase in his walking rhythm as he moves from one stage to the next. This can be interpreted in many ways like, for example, that he is gradually familiarising himself with the rug interface, or that he is feeling more comfortable within the experimental setting over time. My personal impression is that this temporal increase in his pace reveals a progressive lack of enthusiasm and an anxiety to complete the experiment. Such lack of enthusiasm can be justified if we take into consideration that, for over a quarter of an hour, he is walking around a confined area which doesn't seem to be providing him with informative cues to which to shift his attention. In evaluating his three performances, it is important to take into account that he is the only participant who did not conduct the stages barefoot. A series of pre-tests that were conducted the week prior to the actual experiment variably involved bare-foot and non-barefoot (socks on) subjects, and no notable differences were observed between the two categories. However, it should be considered that Paris might have experienced a significantly reduced tactile experience of the embroidered patterns which could have contributed to his random wandering around the rug throughout all three stages he conducted.

> Notes on performances as a whole

Building on my analysis of participants' individual interactions with the rug, in what follows I examine the performances collectively as they evolved in each experimental stage as well from one stage to the next. Particular focus is given on how participants approached the tasks they were given at each stage respectively by examining two key parameters involving their movement: orientation and the scale of exploratory actions performed.

In Stage 1, most participants (five out of eight) developed their movement in a manner that mainly focused at exploring different elements comprising the rug pattern and spent a significant amount of time exploring EA. Among them, of course, can be noted differentiated levels of activity on EA. The video and SuperCollider recordings show that all five participants performed steps on non-embroidered areas; however, out of the five, only two participants repeatedly performed consecutive steps on NEA while, for the other three, most NEA steps occurred either accidentally or as a means of reaching to an embroidered pattern. Of the total group of eight, one participant oriented his movement both towards EA and NEA. Finally, two participants moved freely across the rug without a particular focus on EA or NEA. At the same time, the vast majority of participants (seven out of eight) performed complex combinations of actions to explore the rug and its corresponding sonic output in an attempt to identify the natural sound recording as requested. The videos show that each of them followed a unique set of actions among which common 'exploratory techniques' can be observed – like, for example, toe walking, standing still on one foot, or performing repetitive steps on a spot. All seven identified the natural sound recording by the end of the stage. The eighth participant limited his exploratory options to pacing. He was not able to identify the natural sound in the composed soundscape. Table 20 presents an overview of participants' performance in Stage 1 with regard to orientation and performed actions.

In stage 2, four out of the eight participants oriented their movement consistently towards NEA for the duration of the stage, although they all occasionally performed some sparse steps on EA. This indicates that half of the participants entered the second stage with some basic understanding of the relation between the different rug textures (EA / NEA) and their corresponding sonic output, and that this understanding was developed at some point in Stage 1. These participants did not introduce new exploratory techniques when conducting Stage 2, although some performed new moves (e.g. dance moves) which can be interpreted as a result of feeling confident on how to move across the rug with respect to the task at hand. The other four participants entered the stage without a clear understanding of how the tactile textures relate to the generated sonic ones. Three of them spent most of the second stage moving along EA before finally shifting their attention to NEA. All three expanded the array of exploratory actions they performed in Stage 1 by introducing new techniques and taking alternative paths on the rug (variably EA only, NEA only, and mixed paths). This process gradually allowed them to make a connection between the embroidered elements and the emission of the natural sound in the produced soundscape. Finally, one participant moved freely across the rug throughout

Orientation focus	Exploratory actions performed	Identification of natural sound recording	Number of participants
Mainly EA	Variety	Yes	5
Both EA and NEA	Variety	Yes	1
Neither EA nor NEA	Variety	Yes	1
Neither EA nor NEA	Pacing	No	1

Table 20. Overview of participants' performance characteristics in Stage 1

Understanding correspondences between EA and the natural sound before entering Stage 2	Orientation focus	Introduction of new exploratory actions	Number of participants
Yes	NEA	No	4
No	EA then shifting to NEA	Yes	3
No	Neither EA nor NEA	No	1

Table 21. Overview of participants' performance characteristics in Stage 2

Orientation focus in Stage 1	Exploratory actions in Stage 1	Understanding correspondences between EA and the natural sound before entering Stage 2	Orientation focus in Stage 2	Introduction of new exploratory actions	Number of participants
Mainly EA	Variety	Yes	NEA	No	2
Mainly EA	Variety	No	EA then shifting to NEA	Yes	3
Both EA and NEA	Variety	Yes	NEA	No	1
Neither EA nor NEA	Variety	Yes	NEA	No	1
Neither EA nor NEA	Pacing	No	Neither EA nor NEA	No	1

Table 22. Comparison of performance characteristics between the first and second stage

the stage. His movement was not particularly oriented towards EA or NEA, and did not entail diversity of exploratory actions (see Table 21).

It is interesting to take a closer look at how participants' movement in Stage 2 relates to that of Stage 1 with respect to the reviewed characteristics (orientation, exploratory actions, see Table 22). Participants who followed strictly NEA paths in Stage 2 present significant differentiations as to how they oriented themselves across the rug in the first stage; two of them oriented their movement mainly towards EA, one moved freely without a particular focus on EA or NEA, and one alternately followed EA and NEA paths. They all, however, performed a variety of exploratory actions in Stage 1. On the other hand, participants who spent most of the second stage moving on EA before shifting their movement towards NEA share significant similarities in how they performed Stage 1. All of them directed their movement towards EA and they all experimented with many different exploratory techniques. Finally, one participant performed both stages in a very similar way; he constrained his exploratory options to pacing and unfolded his movement freely across the rug without a particular orientational focus towards EA or NEA. conducted.

> Discussion of findings

Analysis of the performances points to four factors that (in the context at least of this experiment) seem to have played a decisive role in participants' ability to build a meaningful percept upon which to act. These are multisensory integration, attentional focus, active exploration, and previous experience. My findings suggest that these factors are closely interconnected, and that their relational character affects both their individual and collaborative performance in the perceptual process.

I would like to begin this discussion with a general observation on *attention* and how it is more likely to attune to multimodal than unimodal information. The vast majority of participants spent most of the first stage exploring distinct patterns on the rug, particularly those processed with embroidery. On the contrary, 'blank' areas of the rug received significantly lesser activity. It seems that participants were drawn to explore those rug areas that combined the richest visual information (vividly coloured motifs on the dark felt) with the highest tactual stimulation. This suggests that multisensory information creates a stronger impression in the human brain than information received from a single modality, and that it attracts attention more effectively than unimodal stimuli (see also

Lacey et al. 2007; Macaluso and Driver 2001; Newell and Shams 2007). This idea is resonant with neuroimaging studies which illustrate enhanced neuronal stimulation when a subject is presented with information received through more than one modality. Figure 13 presents such an example of differentiated levels of neuronal activation resulting from processing visual, sonic and combined audiovisual information.

Analysis of the video recordings shows that participants who, in the first stage, mainly focused their attention on exploring the distinct motifs comprising the overall rug pattern (EA) were all able to identify the recurring natural sound recording as instructed. However, the constant generation of the natural sound in the produced soundscape (a result of their substantially EA-oriented movement) obscured the ability of many of them to associate it to a particular rug variable – embroidered texture. Those who failed to forge meaningful links between the rug's tactile and sonic correspondences in the first stage introduced new exploratory techniques in the second one. This points to the role of *active exploration* in the formation of a unitary percept with which to guide activity. In the context of the specific experimental process, the above crudely translates into perceiving embroidered motifs as the generating source of the natural sound recording in the produced sonic output, and avoiding movement on EA in the second stage. The scale of active exploration (diversity of distinct and combined actions performed by participants) played a crucial role in grasping the emission of the natural sound and the tactile stimulation experienced from stepping on an embroidered motif as a fused spatiotemporal event. It seems that comparison of each action against the multisensory feedback it provided allowed participants to over time build a frame of reference with which to evaluate the relation of the emergent soundscape to the different rug textures. This impression is enhanced by the fact that participants who formed an understanding of the relation between embroidered patterns and the cicadas recording at some point in the first stage did not enrich their range of exploratory activities in the second. On the contrary, participants who entered the second stage without a clear understanding of this relation experimented with new movement techniques. The results indicate that this process of experimentation, paired with the experience gained from their first interaction with the rug, eventually allowed them to combine multisensory information afforded by the rug into a single frame of reference with which to conduct the second stage task.

It is important to note that, in the context of the followed experimental process, active exploration alone was not a sufficient condition for the formation of what I defined above as a unitary percept upon which to act. My analysis shows that participants who mainly focused their performance on exploring EA in both stages were less likely to link

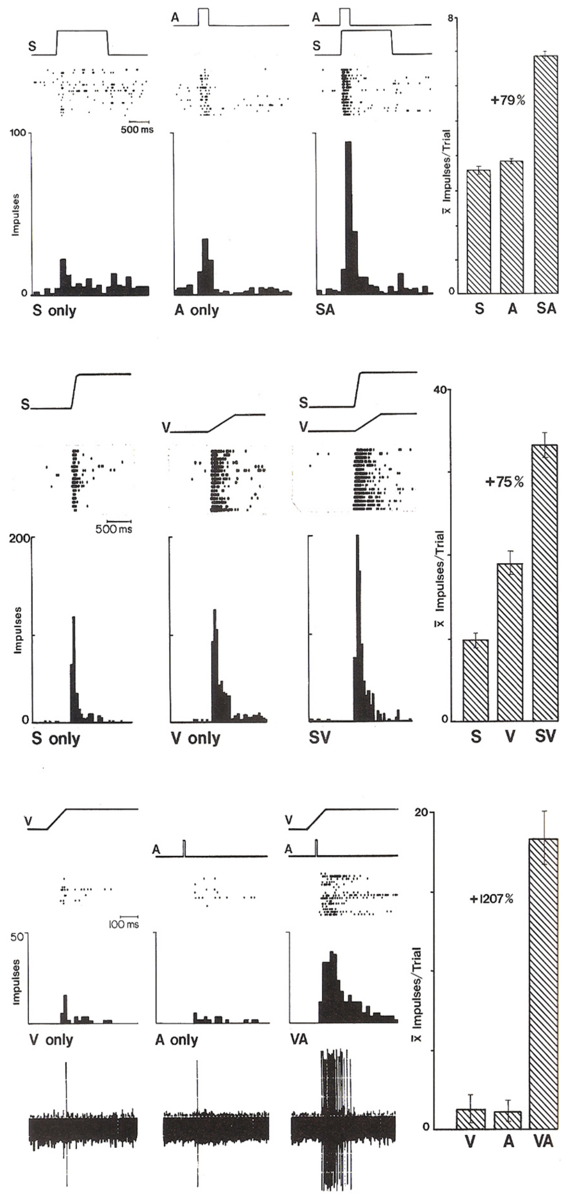


Figure 13. Illustration of neuronal response to uni- and bi-modal stimulation. Response is shown to be enhanced when processing multisensory information (Stein & Meredith 1993: 124; 126).

Cases of unimodal stimulation examined: audio (A), visual (V), and somatosensory (S)

Cases of bimodal stimulation examined: audio-visual (AV), somatosensory-audio (SA), and somatosensory-visual (VS) embroidered texture to the generation of the natural sound in the sonic composition despite performing a complex set of exploratory actions to aid their understanding. This indicates that *what* we choose to attune our attention to can significantly affect how we evaluate sensory feedback from our performed actions. A question worth posing here is whether some participants' EA-oriented movement in the second stage was motivated by the ease with which they performed the first task (identifying the natural sound recording) by specifically focusing on EA in Stage 1. Although there is no way to tell, there is a possibility that some participants may have entered the second stage with a lasting impression of how they conducted the first task which may have prevailed over the overall experience of their first interaction with the rug. This raises another question regarding the design of my experimental methodology as to whether participants should be given a time break after completing Stage 1 (and before moving to Stage 2) that would allow them to perceive the two stages as related but not as a continuity. This is a point that deserves further investigation and indicates future steps that could be followed in a similar context.

Another recurring theme in my analysis concerns the role of *past experience* in the perceptual process (see Gibson 1966; 1986). The fact that perceptual experience (for example of an event) relies on our previous experience of encountering similar events is of course an obvious point to make; however, it is worth looking at how it is manifested in the context of my experimental approach. I have already discussed how participants who did not enter the second stage with some basic understanding of the multisensory relations afforded by the rug informed their second stage performance by building upon their first stage experience. This was done by introducing new exploratory actions and/or by re-shifting their attention to different sensory information in order to expand their perceptual spectrum. Interestingly, participants who entered Stage 2 with some pre-built understanding of the sonic-tactile relations also felt the need to corroborate their first stage experience by cross-checking against it. This is evident in the way in which they all occasionally performed steps on EA as a means of reconfirming embroidered patterns as the source of the natural sound in the generated soundscape. In both cases, participants' final estimate of how to conduct the second stage task was developed on the basis of the experience they acquired from their first encounter with the rug and the produced soundscape in relation to what they were experiencing in real time in the second stage.

It becomes apparent that the above observations are relational to one another and that the boundaries among them are blurry. It is difficult to distinguish between the ways in which attention affects the exploratory process and vice versa, and how the two are constantly informed by real time multisensory feedback and past sensory experience. Their relational character is evident in the performances of all participants in the experimental group. It would perhaps make sense to take a closer look at this interrelation through the performances of participants that most 'efficiently' figured out an action plan for conducting the tasks they were given. However, I believe it is more interesting to examine it through the performances of a participant who was not able to do so even when provided with additional clues that could potentially inform the way he approached his tasks.

The given participant performed both stages in a very similar manner, moving freely across the rug without a particular focus towards EA or NEA and without a considerable range of actions incorporated in his movement. As argued in my analysis, I believe that his homogenous approach throughout the two stages was facilitated by his understanding of the rug as an abstract interface. The inability to identify specific points of reference on the rug surface (like, for example, distinct printed and/or embroidered motifs) to which he could shift his attention to affected the exploratory dimension of his interaction with the rug. By limiting his movement to pacing and by unfolding it arbitrarily across the rug, he narrowed the possibilities of developing a frame of reference with which to evaluate the multisensory stimulation he was receiving. Put simply, the absence of attentional focus affected the scale of his exploratory behavior, which consequently narrowed down the wealth of information resulting from his performed actions. This constrained his possibilities of relating emergent information to performed actions, which in turn maintained his attentional focus to low levels. Moreover, by conducting the stages in an almost invariable manner, comparison of his second stage ongoing experience against that of the first stage yielded no new information that could be used to guide his movement with respect to the task at hand. Altogether, these factors obscured his ability to perceive the different sensory stimuli he experienced as related spatiotemporal events and to perform his tasks upon this understanding.

In perspective, the multidirectional manner in which attention, active exploration, and previous experience affect spatial behaviour in the case of the participant described above illustrates the wider picture of how closely these processes interrelate in perceptual activity. Within the context of my experiment, these processes were identified to form the basis for integrating the multisensory information afforded by the rug into a meaningful percept upon which to act; their relational nature created the essential conditions for participants to progressively understand how to guide their movement on the rug with regard to the different tasks they were given.

Conclusion

The primary objective of this thesis has been to provide an account of my practice-led study on different perceptual processes (and on the ways in which they shape how we make sense of and relate to events we encounter). At the same time, this thesis has set out to provide the theoretical framework upon which the threads of my research and practice were bound together. Perception is a vast area of enquiry and an overview of all relevant discourse on the subject turned out to be an ambitious task to undertake. The scholarship on which I focused my study is in line with the ecological theory of perception, and crosses disciplinary boundaries between various natural and social sciences. Particular focus was given to neurobiological research on sensory integration as well as to cultural theories that examine the role of sensory appreciation in the perceptual experience. The intention was to highlight important aspects pertaining our mechanisms of perception that often go unnoticed in the context of our everyday lived experience.

The idea of the five senses as five distinct modules through which we gain knowledge of the world is so deeply rooted in the history of western culture that we often forget to question how our senses were defined and classified in the first place. We have become so accustomed to relying on vision that we rarely question why it is considered to hold a prominent role across the array of our sensory channels, or how what it conveys is affected by what we experience through our other senses. These questions illustrate some of the early thoughts that motivated me to conduct this study, and have played an important part in the shaping of my research.

The studies reviewed in this thesis understand our senses as active systems which interact with and inform one another. Rudimentary exchanges among them have been shown to take place from as early as the first months of being carried in the mother's womb and to gradually develop as we grow and learn to interact with our environment. We are attuned to perceiving the world in a multisensory manner; even in cases where one sense appears to be more reliable than others in a given context, processes of crossmodal integration still play an integral part in the overall perceptual experience. These findings challenge traditional models of sensory hierarchisation and ask us to consider that the emphasis placed on certain sensory modalities is a cultural product and not a matter of universal principles governing our perceptual system. Through my theoretical study, I presented perception as an adjustable process that relies on a complex set of closely interrelated parameters. These involve aspects of cultural appreciation, our current psychophysiological condition, drives and intentions, as well as knowledge gained through our past experience. With respect to these parameters, perception occurs as a process of evaluating different sensory feedback we receive across our senses against different actions we perform. In this sense, crossmodal integration and action are essentially intertwined in the act of perception. The two do not operate in a sequential order, instead they are in constant and ongoing interaction with one another; it is their relation that forms the basis of our perceptual experience.

My research practice presents a case of exploring these theoretical views in a non-verbal way through the use of an artwork as an investigative medium. The decision to take an art-based approach to my study was grounded on the experiential possibilities of emerging knowledge entailed in such an approach. It was also encouraged by an understanding of the inherent difficulties involved in examining and communicating a subject as obscure as perception solely through the channel of a written format. To this end, my research practice combined a variety of modes (like sound, textiles, physical computing, software, video and text) in order to be conducted and communicated. Its focal point was the development of a touch-sensitive, sound-generating rug and its application in an experimental context. The rug was designed with the purpose of providing a physical platform for observing how people integrate diverse sensory information into a meaningful percept upon which they can act. Its ability to sense movement and to aurally respond to it by composing real-time sonic output that is specific to the captured movement was an integral part of my research methodology in that regard. These qualities created the grounds for the development of an interactive relation between the rug and its audience that allowed me to study processes of crossmodal integration as manifested through the different facets of the interaction.

For the purposes of my study, the rug was installed in the living room of my family house and was used in an experiment that was conducted over two days and involved eight participants with a substantial record of music training. Certain attributes of the sonic behaviour of the rug were specifically programmed to meet the requirements of the experimental design. In particular, activation (through touch) of the embroidered areas of the rug was programmed to trigger a natural sound recording in the generated soundscape. The experiment consisted of two stages: in the first stage participants were asked to identify the natural sound. In the second, they were asked to engage with the rug in a manner that would emit as little of the natural sound recording as possible. Simply put, the second stage task involved participants avoiding to walk on the embroidered areas of the rug. Altogether, the two stages were designed to provide a context for observing the ways in which participants' interaction with the rug evolved over time with respect to the sensory information they received and the tasks they were given.

It is important to stress that the purpose of the given experiment was not to generate new knowledge on the mechanisms of perception; rather, its objective was to create possibilities for observing the two ends of the perceptual process (sensory input and behavioural output), and to generate empirical material that could be used to study the relation between the two. The findings of this study are based on analysis of participants' engagement with the rug and its sonic output, and in particular on analysis of certain parameters that characterised participants' movement on the rug, like orientation and performed exploratory actions. These parameters were evaluated according to the tasks introduced in each experimental stage. My study took into consideration qualitative data gathered from the videotaped material as well as quantitative data obtained from the SuperCollider sound engine. These two sets of data provided a basic overview of the different orientational and exploratory strategies employed by participants at each stage, which in turn highlighted common patterns and diversities in how they approached and performed their tasks. Analysis of correspondences and differences in the examined performances led to some general observations regarding the factors that influenced their spatial behaviour (and the perceptual processes generating this behaviour) in the specific experimental setting.

My findings indicate that attentional focus, active exploration, and past experience actively affected participants' ability to integrate multisensory information, and proved to be crucial parameters for the formation of a meaningful percept upon which they could act. More specifically, analysis of the performances showed that participants' attention was generally enhanced by crossmodal (as opposed to unimodal) stimulation and that active exploration provided their means for making sense of the multisensory information to which they attuned. This suggests that participants' attention and their exploratory behaviour were in ongoing dialogue with one another. Indeed, analysis of participants' performances revealed that their scope of attentional focus had a direct effect on their scale of exploratory behaviour and that, reciprocally, the variety of actions they performed was reshaping the spectrum of their attentional focus. Moreover, the relation between the two in the second stage seemed to be further affected by experience gained from participants' first interaction with the rug and was constantly re-established by real-time information they received across their senses as feedback to their performed actions (see Gibson 1986). The findings of my analysis are in resonance with the theoretical framework presented in the first part of this thesis, and point to the relational character of action, attention, past experience, and sensory integration in the overall perceptual process.

> Some thoughts on my approach

Some of the main challenges I was faced with throughout the process of my research involved arguments dating back to the first years of my study which, upon hindsight, had to be critically re-examined and progressively changed. One of the first propositions made at the very early stages of examining possible ways for developing my research practice was to address responsive textiles as a potential 'spatial medium'. By this I suggested that installation of an interactive textile interface in an environment could provide possibilities for bringing an 'active architectural body' to life; a body that combines space and time and whose responses (sonic output) to other bodies (people) would render it a live spatial organism. Upon reflection, this seems like a rather bold initial hypothesis, and one that entails a significant amount of 'creative' ambiguity. If in the context of early brainstorming that is something welcome, its problematics became apparent as I moved deeper into my research practice. Certain questions emerged regarding the conception of an artwork as a living, let alone spatial, organism.

First, what makes an organism a *living* organism? At a basic level one can argue that the qualities constituting an entity 'live' are its ability to sense and its ability to respond to what sensed. In terms of design, I tried to address this issue by drawing parallels between the function of the produced artwork and that of our sensing mechanism. To this end, the design of the artwork was developed on the basis of the structure of our haptic system; the rug consists of skin, a cluster of nerves running through its deep tissue, and a virtual environment processing all information received through the nerves in a similar fashion to how the brain does. The simplifications of this approach, however, are hard to overlook. They lie not so much on the focus placed on the function of one particular sensory system (as correspondences between the function of different sensory systems provide grounds for overcoming such a critique at a design level), but rather on the very nature of processing and responding to the received information. The technology of the rug allows it to perceive stimulation from people's movement on it like pressure, speed and trajectory. However, other aspects of the haptic experience (like, for example, force of pressure or heat emission) go undetected; the haptic is reduced to tactile in that regard. Having said so, I should stress that incorporation of such aspects in the sensing capacity of the rug was not pivotal for the particular purposes of my experimental approach; however, the additional data it would generate could possibly expand the scope of my research and, therefore, presents a design challenge that deserves further investigation in the future.

Another issue concerns the extent to which the responsive nature of the rug can be truly compared to that of a living organism. As discussed in the second part of this thesis, the sonic behaviour of the rug evolves in an organic, non-linear manner and involves a complex set of immediate and intermediate responses to people's engagement. Unique real-time responses occur in that respect; their relationship evolves over time into a non-predetermined soundscape on the basis of current and previous interactions. This entails processes of autonomy and 'learning' that are integral characteristics of a living organism. However, these processes are the outcome of programming specifications and, therefore, subject to the artist not the artwork itself. In that regard, the transformation of the artwork into a living organism is always trapped in the process of *becoming*. This poses questions of both a philosophical and a designerly interest that also ask to be further explored in a future research project.

Finally, the last question concerns my approach to the artwork as a spatial entity. To start with, a definition of 'spatial entity' is quite obscure if not impossible to make. Space is an entity in its wholeness, through its flow in time, and without set barriers; it is a continuum and cannot be extracted from itself. Over time, my approach shifted from thinking the artwork as a spatial organism to understanding it as a medium for defining and transmuting space. I focused on the 'transitional' power of the artwork to create space within space by signifying a plateau for different types of activity and qualitative attention (Winnicott 2009). In this sense, it was not responsive textiles that provided a spatial medium, but rather space that provided a design tool for my research practice. The presence of the rug in a room defined an arena for encountering, enhancing and observing relations among the senses of touch, hearing, vision, and kinesthesia as played out in people's spatial bahaviour. To combine these two elements (space and textiles) into a design methodology for the study of crossmodal relations, I examined a series of large-scale textile installations. Works like Neto's Celula Nave (2004), Berzina and Tan's E-Static Shadows (2009), Beesley's Hylozoic Ground (2010), and Machiko's Untitled (2001) manifest how textile space comes to life as a continuum of multisensory intensities. I also examined literature on spatial perception and how it differs to object perception. My methodology considered aspects of both perceptual types, and relied on experiencing the artwork both in terms of its aesthetic/sensory qualities and its spatial dimension (entailed in the form of interaction the artwork invites).

Having laid out the main theoretical and design-based challenges of my research approach, I would also like to discuss difficulties and limitations of a more practical nature that were encountered during the experimental process of my practice and the evaluation of its empirical material. As noted, the experiment involved a relatively small group of participants (eight in total) and, although participants presented differentiations as regards their age (with the youngest being 18 the oldest 31 years old and), in general, the experimental group covered a somewhat narrow age range that was limited to young adults. In addition, all participants had an extensive background of music training which further narrowed down the group to young adults with a possible degree of advanced aural sensibility. As such, the findings of my research should be understood to be of a limited scope that is particular to the aforementioned specificities. Another issue that should be considered with respect to my analysis involves the qualitative data examined, and in particular the context in which they were generated. As explained, the experiment was conducted in the living room of my family house in Athens. This means that it was conducted in a setting that is qualitatively different to laboratory environments typically used to conduct research on perceptual matters. Although the context of a homely interior allowed both the rug to integrate naturally in the setting and participants to experience a comfort of familiarity that admittedly reduced their nervousness about the experimental and filming processes, it presented certain difficulties that had not been foreseen during the planning of the experiment. To start with, the living room was not completely soundproof to street noise. The experiment took place over a summer weekend when outdoors activity is high, and the video recordings occasionally depict outside sounds (like passers-by voices or car alarms) being fused with the room's soundscape. They also depict a very subtle screech of cicadas (that is one of the most widespread sonic experiences of summertime Athens) coming from outside the room. This is particularly important, as the quite distinctive screech resembles the natural sound recording used in the soundscape composition. Undoubtedly, these external to the soundscape noises may have affected the sonic experience, and consequently the performance, of some participants. Moreover, the lighting conditions of the living room were gradually changing over time with respect to the natural light coming from outside. This is evident in some of the video recordings. Although this factor is not thought to have affected participants' experience to a degree of influencing their overall performance, it has affected the quality of some of the films examined for my analysis. Such sound and lighting differentiations raise an issue regarding the fact that the experimental conditions were not exactly the same for all participants. Moreover, the group of participants presents numerical, background and age-related characteristics that constitute its study insufficient for generating conclusive results. Arguably, the followed experimental process and its findings entail an element of deduction and are open to debate from a scientific perspective. In that regard, they illustrate the wider picture of possibilities entailed in this approach and provide a basis for alternative variables that could be considered in relation to it.

> Contribution to my fields of study and practice

My research practice is part of the technological development textile research has seen over the last few decades. Raw industrial materials processed with conductive or smart elements and electronics are constantly reinventing traditional textile functions and are presenting a range of new textiles; these among others include light or heat emitting fabrics, touch-sensitive fabrics, interactive digital textile displays, colour-changing fabrics, and muscle textiles (Colchester 2007). Emerging from the fusion of textile design with different areas of science such as communications technology, nanotechnology and biomimetics, fabrics like Lawrence's Printed Water Conducting Material, Yoel Fink's Spectrometric Fabric, Crawford and Berwin's Concrete Canvas and Oxford Biomaterials' Spidrex are examples of how contemporary textiles present a range of innovations to meet current and future demands within an array of disciplines. Some general directions can be noted in the ever increasing research involving smart textiles: textiles as means of protecting the body (human or built) from its environment; textiles as data communicators of environmental or biological information; and smart textiles as products of luxury for the fields of fashion and interior design.

The above directions typically produce responsive textiles as *end products* designed to provide *solutions* to different needs that emerge through different investigative processes and focuses. My research approach is quite different in that regard. The rug is not an end product of a followed research process, but rather an essential medium for facilitating the research process itself. The rug exemplifies the expressive qualities of the physical and non-physical materials involved in its making (textiles, embroidery, custom electronics, software) to *generate* (as opposed to simply collect or display) data that provide important insights into the perceptual process in a manner that has not been previously explored. Although visual art (drawings, images, collage) has been widely incorporated in the field of psychology of perception, to my knowledge, no documented studies involve large-scale installation art as a means of generating knowledge on the subject. The novel methodological approach of my artistic enquiry lies in the creation of an artwork that provides opportunities for fully bodily participation and multisensory stimulation upon which one can reflect on different perceptual aspects such as multisensory integration and active exploration. In this context, the sensory qualities of the rug are as essential as the responsive nature of its textile technology.

As innovation in the field of textile technology is largely an outcome of research initiated by industries with a particular focus on the functional properties of textiles (such as the military, medical, sport, and product design industries), there often is a noticeable imbalance between the feel and performance of responsive textiles. In the process of exploring the endless possibilities offered by new technologies and materials, we artists/designers/researchers often forget that what we make should also be meaningful to audiences/users/people by connecting to their subjectivity through collective memory and emotional affect. Over the last two years of conducting this research project, I had the chance to exhibit the rug in a variety of different contexts and scales that include an experimental setting (Greece), a gallery (W3, UK), the Biennial Smart Textiles Salon (Belgium), and the Kaunas Textile Biennale (Lithuania). Each of the above attracted audiences of different backgrounds, interests and ages – respectively music students, local art lovers, industry professionals, textile practitioners and general audience – with many of which I had the chance to engage in short or lengthy conversations about my work. A common thread emerged throughout these conversations regarding people's experience and appreciation of the rug: they were drawn to revisit the rug and spend time on it, trying to grasp an ambiguous feeling it brought out to them which they found difficult to articulate. They were using words like 'magical', 'overwhelming', 'beautiful', 'mesmerising' to describe how they felt about the fact that what they understood to be an elaborate piece of craftsmanship could also respond to them by producing sound. They were not so much mystified by the fact that a *'craft object'* could exhibit a responsive behavior, as they were by the handicrafted effort and attention put into the making of a *'smart object'*. Their connection to the rug was not generated merely by nostalgia about the handmade in an age of technological design and mass production; it was more about innovation being able to incorporate and express values that transcend spatial and temporal boundaries by keeping close with tradition.

The rug combines elements of art, craft, design and technology in a manner that makes boundaries between those areas indistinct. It is a hybrid artefact whose meaning is made tangible through the loss of clear-cut definitions between its form and function; an artefact that blends the technological innovation necessary to serve the purposes of the research context in which it emerged with human aesthetic values that are often neglected in research, particularly so in technology-driven research. Exposure of the practical element of my research to different publics has highlighted that such a merging is not only felt to be widely missing from current research in the field of responsive design, but is also an essential part of relating to and appreciating creativity and innovation. My research emphasises that the affective qualities of the handicraft in a society whose design aesthetics are substantially directed by technology is an important condition for establishing closer connections between research and the audiences it aims to reach. Understanding the need to shift attention towards the creation of artefacts/objects/products in which technological innovation and historical continuity do not necessarily constitute distinct areas can have profound implications across a wide spectrum of research fields and practices.

In this sense, the contribution of my research practice to new knowledge lies not specifically on the actual findings it has produced but essentially on the novel methodological approach it takes both within its field of study (perception) and field of practice (responsive textiles). My practice sets an example of how large-scale, participatory art offers alternative yet informative enquiry routes into the cross-disciplinary discourse on perception by allowing multisensory experiences and purposeful action to become part of the investigational process. Expanding the array of artistic practices involved in the study of perception beyond the limits of visual art opens up the experiential possibilities of generating knowledge on the subject. At the same time, it opens up the possibilities of engagement with a wider, more diverse audience, and becomes relevant to a variety of practices that touch upon processes of cognition and lived experience. My research practice takes a unique approach to responsive textile design as a medium for developing and testing new forms of knowledge. Merging elements of art, craft and technological innovation, I propose a design methodology that attends to the materiality and long tradition of textile craftsmanship with the same care it attends to the functional possibilities offered by soft technologies. Reinstating human aesthetic values within technological innovation is crucial to understanding novel functions as meaningful experiences to which we (users and makers) can connect at a deeper level. In a growing demand for new uses and functions, responsive textiles research is more often than not found to compromise aesthetic and affective qualities over performance. My research offers a new perspective on responsive textiles as a research medium whose potentiality to generate new knowledge lies in its very power to embrace current innovation with values carried in the textile material that transcend our times.

> Future directions

My practice-based approach to the interdisciplinary discussion that takes place on perception shows how art research can be incorporated into the wider arena of neurophysiological and behavioural research in a way that expands its span of resources and methods. I would argue that not only does it point to similar routes that can be followed to study the subject in a creative yet informative manner; it also indicates future avenues for the application of such studies in a variety of contexts that directly (or not) relate to the realm of perception. For example, my approach to create conditions for encountering and enhancing possibilities for multisensory integration and action is particularly relevant to empowering strategies aimed at improving the quality of life of people experiencing certain physical or psychological difficulties. The latter may involve different degrees of sensory deprivation in one or more modalities, partial loss of basic motor skills (early to middle stages of Parkinson disease), age or stress related memory loss (early to middle stages of Alzheimer disease or dementia), or experiencing certain sensory sensitivities (autism).

To this end, the practical element of my research could be incorporated in schemes designed to help people experiencing such types of psychophysiological dysfunctions to cope with difficulties related to performing everyday activities. Research on dementia suggests that enhancing the sensory capacity of patients increases their propensity to act independently, as well as that mild forms of exercise (like walking) can contribute to the patient's overall functional capabilities (National Collaborating Centre for Mental Health 2007). Moreover, the benefits of these individual processes are shown to be strengthened when combined. Similar results are also shown for patients suffering from Parkinson or Alzheimer disease (Calvert et al. 2004; Larsen 2006; Murray and Wallace 2012). People suffering from dementia or other forms of neurological damage, like for example people recovering from stroke or brain trauma, often present significant difficulty in perceiving the boundaries of their own body as well as its relation to their environment. As a result of the disturbance of their bodily and spatial awareness, people presenting loss of basic motor skills typically experience increased levels of unrest and insecurity. Research has shown that, when combined with different forms of medical treatment, targeted sensory stimulation promotes the process of recovering different degrees of spatial awareness of the limits of the body and its surroundings (Söderback 2009).

In this context, the rug could be seen as part of different occupational therapy approaches that aim to empower patients suffering from early stages of motor skills loss through multisensory stimulation and integration. The rug invites a combination of mild forms of activities like walking, crawling, rolling over, and lying down. When performed at a regular rate, such activities have been shown to be crucial in stimulating motor and mental responses as well as in restoring confidence in coordinating different movements. Moreover, they have been shown to have soothing effects on restlessness and to promote tranquility. The multi-textural surface of the rug presents an exceptional physical platform for the generation of continuous yet differentiated levels of tactile stimulation which is pivotal in regaining awareness of the body and its relation to the environment. Continuous change in the tactile stimuli in contact with the skin strengthens the ability to perceive skin as a bodily border, and gradually enhances awareness of what is one's body, what lies outsides one's body (environment), and how the first is positioned within the latter. The process of recovering awareness between one's body and one's environment through alternating tactile sensations can be further enhanced through auditory stimulation generated by physical contact with the rug.

The use of the rug in occupational settings aimed at people suffering from a range of clinical conditions that result to partial loss of basic motor skills, memory or sensory disorders presents a number of benefits for the improvement of patients' everyday life. The rug provides an aesthetically pleasant platform upon which to perform different activities that is deeply routed in our experience of everyday domestic life. This sense of familiarity can have a comforting effect on patients, particularly when installed in environments that often generate feelings of uneasiness such as hospitals or other rehabilitation spaces. Patients can perform a routine of mild exercises on the rug aimed at gradually improving their motor or retention responses and empowering their feeling of confidence and independence. When combined with movement, the tactile and sonic attributes of the rug provide constant sensory stimulation which can significantly increase patients' awareness of their body and its position in space. Increased sensation of the body, its borders, and its relation to the environment is crucial for creating a sense of security to people that exhibit partial loss of motor and/or memory functions.

Occupational therapists and carers can make use of the rug to help patients gain a sense of empowerment through a combination of sensory stimulation, sensory integration, and movement. In this sense, the rug can provide a mobile, cost-effective, and patient-tailored alternative to the 'Snoezelen room' or what is otherwise known as controlled multisensory environment (MSE). Snoezelen rooms offer a range of sensory stimuli (materials with different textures, lighting, sounds, aromas) that are aimed at enhancing the therapeutic and learning process of people with cognitive, behavioural, or physical difficulties. Patients have the opportunity to interact with different materials and equipment within the room, and to feel a sense of control over their sensory experiences. This enhances responses to sensory stimulation, improves patient performance of different tasks, and contributes to the overall functionality of the patient. Depending on size, Snoezelen rooms can accommodate up to 10 people, and can be booked for a single person or a small group of people. As such, the rooms are tailored to cover a wide spectrum of sensory stimulation that can meet the needs of users of different ages and abilities. The rug presents a significant advantage in that respect: its visual, textural and sonic qualities can be customised to the specific sensory requirements of one person; moreover, it can be installed in any patient's home allowing them to experience multisensory stimulation on a daily basis.

In this sense, installation of the rug in a care or a patient's home could become part of a therapeutic methodology which combines movement with multisensory stimulation to enhance patients' functional abilities and possibilities for autonomy. In a different context, the rug could become part of a wider strategy for encouraging social interaction or other daily activities for people that present symptoms of autism. For example, adjusting the rug's visual, tactile and aural stimuli with respect to a person's specific sensory sensitivities could provide friendlier, customised environments that could affect the person's motivation to perform certain types of activities (Gaudion 2013). These examples indicate some of the future directions my research practice could take and illustrate its potential implications to a diverse array of health practices that are related but not specific to my subject of enquiry.

Appendices

Conversion of nodes on the 'deep tissue' grid to UI, EA, and NEA

Instructions to experimental stages

Summary of quantitative data for participants' individual performances

Participants' consent forms

Appendix A

Conversion of nodes on the 'deep tissue' grid to UI, mapping UI to EA and NEA

X,Y	UI	EA	NEA	X,Y	UI	EA	NEA	X,Y	UI	EA	NEA
1,1	0		x	3,4	51	x		5,7	102	x	
1,2	1	x		3,5	52	x		5,8	103	x	
1,3	2	x		3,6	53	x		5,9	104		x
1,4	3		x	3,7	54	x		5,10	105	x	
1,5	4		x	3,8	55	x		5,11	106		x
1,6	5		x	3,9	56	x		5,12	107	x	
1,7	6		x	3,10	57	x		5,13	108		x
1,8	7		x	3,11	58		x	5,14	109		x
1,9	8		x	3,12	59	x		5,15	110		x
1,10	9		x	3,13	60	x		5,16	111	x	
1,11	10		x	3,14	61	x		5,17	112		x
1,12	11	x		3,15	62		x	5,18	113		x
1,13	12		x	3,16	63		x	5,19	114		x
1,14	13		x	3,17	64		x	6,1	115		x
1,15	14		x	3,18	65		x	6,2	121	x	
1,16	15		x	3,19	66	x		6,3	122	x	
1,17	16		x	4,1	67		x	6,4	123	x	
1,18	17		x	4,2	73		x	6,5	124	x	
1,19	18	x		4,3	74		x	6,6	125	x	
2,1	19		x	4,4	75		x	6,7	126	x	
2,2	25		x	4,5	76		x	6,8	127		x
2,3	26	x		4,6	77		x	6,9	128		x
2,4	27	x		4,7	78	x		6,10	129		x
2,5	28		x	4,8	79	x		6,11	130		x
2,6	29	x		4,9	80	x		6,12	131	x	
2,7	30	x		4,10	81	x		6,13	132	x	
2,8	31	x		4,11	82		x	6,14	133	x	
2,9	32		x	4,12	83		x	6,15	134		x
2,10	33		x	4,13	84		x	6,16	135		x
2,11	34		x	4,14	85	x		6,17	136	x	
2,12	35	x		4,15	86		x	6,18	137	x	
2,13	36		x	4,16	87	x		6,19	138	x	
2,14	37	x		4,17	88		x	7,1	139		x
2,15	38		x	4,18	89		x	7,2	145	x	
2,16	39		x	4,19	90		x	7,3	146	x	
2,17	40		x	5,1	91		x	7,4	147	x	
2,18	41		x	5,2	97		x	7,5	148	x	
2,19	42	x		5,3	98		x	7,6	149	x	
3,1	43		x	5,4	99	x		7,7	150	x	
3,2	49		x	5,5	100	x		7,8	151		x
3,3	50	x		5,6	101	x		7,9	152		x

Conversion of nodes on the 'deep tissue' grid to UI, mapping UI to EA and NEA

X,Y	UI	EA	NEA	X,Y	UI	EA	NEA	X,Y	UI	EA	NEA
13,19	306	x		16,3	362		x	18,6	413		x
14,1	307		x	16,4	363	x		18,7	414	x	
14,2	313	x		16,5	364	x		18,8	415	x	
14,3	314	x		16,6	365		x	18,9	416		x
14,4	315		x	16,7	366	x		18,10	417	x	
14,5	316	x		16,8	367	x		18,11	418		x
14,6	317	x		16,9	368		x	18,12	419		x
14,7	318		x	16,10	369	x		18,13	420	x	
14,8	319		x	16,11	370		x	18,14	421	x	
14,9	320		x	16,12	371	x		18,15	422	x	
14,10	321	x		16,13	372	x		18,16	423	x	
14,11	322		x	16,14	373		x	18,17	424		x
14,12	323		x	16,15	374		x	18,18	425		x
14,13	324		x	16,16	375	x		18,19	426	x	
14,14	325	x		16,17	376	x		19,1	427		x
14,15	326		x	16,18	377		x	19,2	433		x
14,16	327		x	16,19	378		x	19,3	434	x	
14,17	328		x	17,1	379		x	19,4	435		x
14,18	329	x		17,2	385		x	19,5	436	x	
14,19	330	x		17,3	386	x		19,6	437		x
15,1	331		x	17,4	387	x		19,7	438		x
15,2	337	x		17,5	388		x	19,8	439	x	
15,3	338	x		17,6	389		x	19,9	440		x
15,4	339	x		17,7	390	x		19,10	441		x
15,5	340	x		17,8	391		x	19,11	442		x
15,6	341	x		17,9	392	x		19,12	443		x
15,7	342	x		17,10	393	x		19,13	444		x
15,8	343		x	17,11	394		x	19,14	445	x	
15,9	344		x	17,12	395	x		19,15	446	x	
15,10	345		x	17,13	396	x		19,16	447		x
15,11	346	x		17,14	397		x	19,17	448	x	
15,12	347		x	17,15	398		x	19,18	449		x
15,13	348		x	17,16	399	x		19,19	450	x	
15,14	349		x	17,17	400	x		20,1	451		x
15,15	350	x		17,18	401		x	20,2	457		x
15,16	351	x		17,19	402		x	20,3	458		x
15,17	352		x	18,1	403		x	20,4	459		x
15,18	353		x	18,2	409		x	20,5	460		x
15,19	354		x	18,3	410	x		20,6	461		x
16,1	355		x	18,4	411	x					
16,2	361		x	18,5	412		x	13,18	305	x	

Conversion of nodes on the ‘deep tissue’ grid to UI, mapping UI to EA and NEA

X,Y	UI	EA	NEA
20,9	464		x
20,10	465		x
20,11	466		x
20,12	467		x
20,13	468		x
20,14	469		x
20,15	470		x
20,16	471		x
20,17	472		x
20,18	473		x
20,19	474	x	
		164	216
		43%	57%

Appendix B

Instructions to experimental stages

Stage 1:
Spend some time walking around on the rug. Pay attention to the soundscape you create as you move around, and its relation to the paths you take as you walk across the rug. The soundscape is composed in real-time using various synthetic sounds, as well as one sound recording of natural origin. Can you identify the natural sound?

(Participants that haven't identified a sound of natural origin during their first interaction with the rug are asked to repeat Stage 1)

Stage 1 (Round 2):
Spend some more time walking around on the rug. The soundscape you create as you move around is composed of various synthetic sounds and a sound recording of cicadas. Pay attention to these sonic elements and their relation to the paths you take as you walk across the rug.

Stage 2:
Walk around on the rug while attempting to compose a soundscape using as little as possible of the natural sound that you identified in Stage 1 of the experiment.

Appendix C

Summary of quantitave data for participants' individual performances

Participant	Stage	Stage Duration	Performed Steps (s) *	Average s/min	Triggered EA	Triggered NEA	EA/NEA analogy
Stella	1	6'10"	240	39 s/min	58.7/100	41.3/100	1.421
	2	4'30"	235	53 s/min	22.1/100	77.9/100	0.283
					decrease by 62%		
Rallia	1	5'41"	177	31 s/min	54/100	46/100	1.173
	2	5'54"	136	30 s/min	14.5/100	85.5/100	0.169
					decrease by 73%		
Paris	1a	5'40"	297	52 s/min	42.5/100	57.5/100	0.739
	1b	3'43"	201	54 s/min	44.3/100	55.7/100	0.795
	2	6'27"	395	61 s/min	42.4/100	57.6/100	0.736
					decrease by 2%		
Nikos	1	5'45"	96	17 s/min	58.1/100	41.9/100	1.386
	2	5'40"	120	21 s/min	27.9/100	70.1/100	0.398
					decrease by 52%		
Elisavet	1	5'50"	211	36 s/min	57.6/100	42.4/100	1.358
	2	5'40"	258	45 s/min	37.8/100	62.2/100	0.607
					decrease by 34%		
Irene	1	5'50"	139	24 s/min	58.6/100	41.4/100	1.415
	2	5'51"	167	29 s/min	35.8/100	64.2/100	0.557
					decrease by 39%		
Dimitris	1	5'29"	223	41 s/min	54.9/100	45.1/100	1.217
	2	5'40"	243	43 s/min	9.4/100	90.6/100	0.103
					decrease by 83%		
Despina	1	7'03"	142	20 s/min	61.3/100	38.7/100	1.583
	2	8'47"	396	45 s/min	14.3/100	85.7/100	0.166
					decrease by 77%		

* Steps are normalised / converted to number of occurances per minute

Appendix D

Participants' consent forms

Royal College of Art
RESEARCHRCA

For further information
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0208 348 6853
claire.pajaczkowska@rca.ac.uk

09/07/2014

Body and space through textile media: a practice-led study on the crossmodal
Survey Consent Form

I ..Nikos....Kargopoulos.....................have read the information on the research project Body and space through textile media: a practice-led study on the crossmodal which is to be conducted by Myrto Karanika from the Royal College of Art, and all queries have been answered to my satisfaction.

I agree to voluntarily participate in this research and give my consent freely. I understand that the project will be conducted in accordance with the Information Sheet, a copy of which I have retained.

I understand that I can withdraw from the project at any time, without penalty, and do not have to give any reason for withdrawing.

I consent to:

- Participate in an experiment that involves walking on a touch-sensitive, sound-generating rug (approximate length of time 30mins)
- Be filmed during the experiment
- Give personal information if required

I understand that all information gathered from the survey will be stored securely, my opinions will be accurately represented. Any images in which I can be clearly identified will be used in the public domain only with my consent.

Print Name:.Nikos.....Kargopoulos.......................................

Signature....NK...

Date: ......13/7/2014...

This project will be conducted in compliance with the Research Ethics Code of the Royal College of Art.

Royal College of Art

RESEARCHRCA

For further information
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claire.pajaczkowska@rca.ac.uk

09/07/2014

Body and space through textile media: a practice-led study on the crossmodal
Survey Consent Form

I ...Despina.....Spai......................have read the information on the research project Body and space through textile media: a practice-led study on the crossmodal which is to be conducted by Myrto Karanika from the Royal College of Art, and all queries have been answered to my satisfaction.

I agree to voluntarily participate in this research and give my consent freely. I understand that the project will be conducted in accordance with the Information Sheet, a copy of which I have retained.

I understand that I can withdraw from the project at any time, without penalty, and do not have to give any reason for withdrawing.

I consent to:

- Participate in an experiment that involves walking on a touch-sensitive, sound-generating rug (approximate length of time 30mins)
- Be filmed during the experiment
- Give personal information if required

I understand that all information gathered from the survey will be stored securely, my opinions will be accurately represented. Any images in which I can be clearly identified will be used in the public domain only with my consent.

Print Name:......Despina.......Spai....................................

Signature.....[signature]..

Date: ....13.7..2014..

This project will be conducted in compliance with the Research Ethics Code of the Royal College of Art.

Royal College of Art

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09/07/2014

Body and space through textile media: a practice-led study on the crossmodal
Survey Consent Form

I RALLIA FAFALIOS............have read the information on the research project Body and space through textile media: a practice-led study on the crossmodal which is to be conducted by Myrto Karanika from the Royal College of Art, and all queries have been answered to my satisfaction.

I agree to voluntarily participate in this research and give my consent freely. I understand that the project will be conducted in accordance with the Information Sheet, a copy of which I have retained.

I understand that I can withdraw from the project at any time, without penalty, and do not have to give any reason for withdrawing.

I consent to:

- Participate in an experiment that involves walking on a touch-sensitive, sound-generating rug (approximate length of time 30mins)
- Be filmed during the experiment
- Give personal information if required

I understand that all information gathered from the survey will be stored securely, my opinions will be accurately represented. Any images in which I can be clearly identified will be used in the public domain only with my consent.

Print Name: RALLIA FAFALIOS.......................

Signature: RMFafalios.......................

Date: 13/7/2014.......................

This project will be conducted in compliance with the Research Ethics Code of the Royal College of Art.

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09/07/2014

Body and space through textile media: a practice-led study on the crossmodal
Survey Consent Form

I ..Karagkiouloglou..Dimitris........have read the information on the research project Body and space through textile media: a practice-led study on the crossmodal which is to be conducted by Myrto Karanika from the Royal College of Art, and all queries have been answered to my satisfaction.

I agree to voluntarily participate in this research and give my consent freely. I understand that the project will be conducted in accordance with the Information Sheet, a copy of which I have retained.

I understand that I can withdraw from the project at any time, without penalty, and do not have to give any reason for withdrawing.

I consent to:

- Participate in an experiment that involves walking on a touch-sensitive, sound-generating rug (approximate length of time 30mins)
- Be filmed during the experiment
- Give personal information if required

I understand that all information gathered from the survey will be stored securely, my opinions will be accurately represented. Any images in which I can be clearly identified will be used in the public domain only with my consent.

Print Name:...Karagkiouloglou...Dimitris........................

Signature.....[signature]..

Date: ...13/07/2014..

This project will be conducted in compliance with the Research Ethics Code of the Royal College of Art.

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09/07/2014

Body and space through textile media: a practice-led study on the crossmodal
Survey Consent Form

I ....Stella Miopoulou....have read the information on the research project Body and space through textile media: a practice-led study on the crossmodal which is to be conducted by Myrto Karanika from the Royal College of Art, and all queries have been answered to my satisfaction.

I agree to voluntarily participate in this research and give my consent freely. I understand that the project will be conducted in accordance with the Information Sheet, a copy of which I have retained.

I understand that I can withdraw from the project at any time, without penalty, and do not have to give any reason for withdrawing.

I consent to:

- Participate in an experiment that involves walking on a touch-sensitive, sound-generating rug (approximate length of time 30mins)
- Be filmed during the experiment
- Give personal information if required

I understand that all information gathered from the survey will be stored securely, my opinions will be accurately represented. Any images in which I can be clearly identified will be used in the public domain only with my consent.

Print Name:....Stella Miopoulou....

Signature....[signature]....

Date: ....12/7/2014....

This project will be conducted in compliance with the Research Ethics Code of the Royal College of Art.

Royal College of Art

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For further information
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09/07/2014

Body and space through textile media: a practice-led study on the crossmodal
Survey Consent Form

I ......Paris.....Rozakis.............have read the information on the research project Body and space through textile media: a practice-led study on the crossmodal which is to be conducted by Myrto Karanika from the Royal College of Art, and all queries have been answered to my satisfaction.

I agree to voluntarily participate in this research and give my consent freely. I understand that the project will be conducted in accordance with the Information Sheet, a copy of which I have retained.

I understand that I can withdraw from the project at any time, without penalty, and do not have to give any reason for withdrawing.

I consent to:

- Participate in an experiment that involves walking on a touch-sensitive, sound-generating rug (approximate length of time 30mins)
- Be filmed during the experiment
- Give personal information if required

I understand that all information gathered from the survey will be stored securely, my opinions will be accurately represented. Any images in which I can be clearly identified will be used in the public domain only with my consent.

Print Name:...Paris....Rozakis....................................

Signature...PR...

Date: ....12/7/2014...

This project will be conducted in compliance with the Research Ethics Code of the Royal College of Art.

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09/07/2014

Body and space through textile media: a practice-led study on the crossmodal
Survey Consent Form

I ..Elisavet Anagnostou............have read the information on the research project Body and space through textile media: a practice-led study on the crossmodal which is to be conducted by Myrto Karanika from the Royal College of Art, and all queries have been answered to my satisfaction.

I agree to voluntarily participate in this research and give my consent freely. I understand that the project will be conducted in accordance with the Information Sheet, a copy of which I have retained.

I understand that I can withdraw from the project at any time, without penalty, and do not have to give any reason for withdrawing.

I consent to:

- Participate in an experiment that involves walking on a touch-sensitive, sound-generating rug (approximate length of time 30mins)
- Be filmed during the experiment
- Give personal information if required

I understand that all information gathered from the survey will be stored securely, my opinions will be accurately represented. Any images in which I can be clearly identified will be used in the public domain only with my consent.

Print Name:...Elisavet Anagnostou.......................................

Signature....EA...

Date: ......12/7/2014..

This project will be conducted in compliance with the Research Ethics Code of the Royal College of Art.

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09/07/2014

Body and space through textile media: a practice-led study on the crossmodal
Survey Consent Form

I ....Irene Valaoritou............have read the information on the research project Body and space through textile media: a practice-led study on the crossmodal which is to be conducted by Myrto Karanika from the Royal College of Art, and all queries have been answered to my satisfaction.

I agree to voluntarily participate in this research and give my consent freely. I understand that the project will be conducted in accordance with the Information Sheet, a copy of which I have retained.

I understand that I can withdraw from the project at any time, without penalty, and do not have to give any reason for withdrawing.

I consent to:

- Participate in an experiment that involves walking on a touch-sensitive, sound-generating rug (approximate length of time 30mins)
- Be filmed during the experiment
- Give personal information if required

I understand that all information gathered from the survey will be stored securely, my opinions will be accurately represented. Any images in which I can be clearly identified will be used in the public domain only with my consent.

Print Name:...Irene Valaoritou.................................

Signature.......[signature]..

Date: ....12/7/2014..

This project will be conducted in compliance with the Research Ethics Code of the Royal College of Art.

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