WIRELESS SPECTRES

Space and the re-enchantment of invisible technologies

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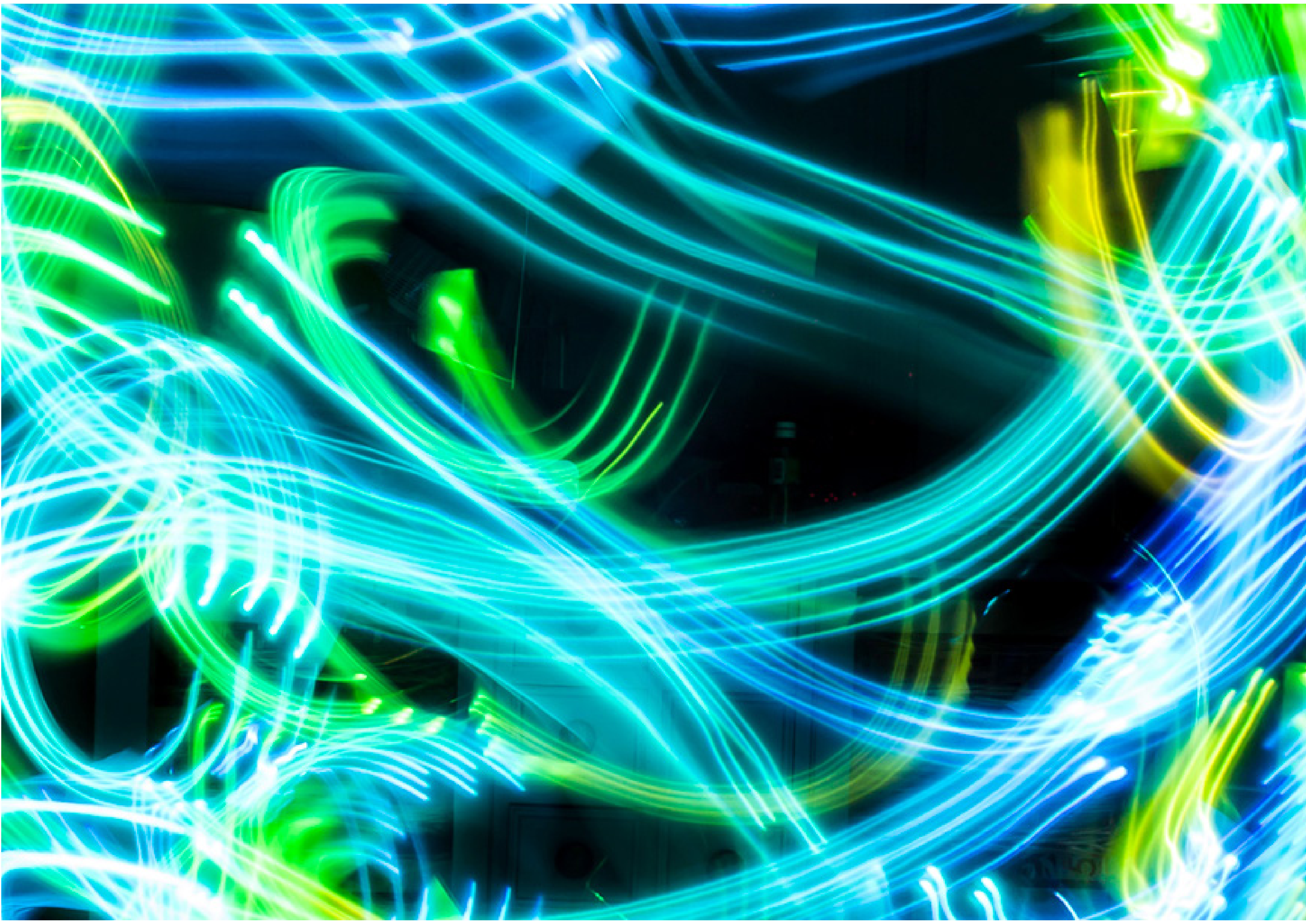
PRESENTED FOR THE QUALIFICATION OF DOCTOR OF PHILOSOPHY

SCHOOL OF ARCHITECTURE, PLANNING AND LANDSCAPE

PHD BY CREATIVE PRACTICE

JUNE 2017



ABSTRACT

This thesis examines wireless technologies, and the way they are integrated in architecture to produce new spatial experiences.

The thesis draws from the school of New Materialism in suggesting that the materiality of wireless infrastructure is not a fixed property that can be captured and revealed, but that is rather contingent on transactions with other materials and through human interaction. Measuring and representing wireless involves a series of transactions — the construction of a probe to measure signal strength, logical processes involved in the transformation of values into visible patterns, and a choreography of movement as the probe is deployed in space. Following notions of agential realism and digital materiality, I propose that these transactions construct the materiality of wireless, and aim to position the process of representation as a form of speculative design which deals with the emergent materialities of wireless. In this context, representations do not increase literacy, but rather enable us to think of wireless infrastructure in ways which go beyond the convenient transfer of information to think of them as ways of creating new spatial experiences.

The thesis develops a creative practice approach that adapts tools and techniques developed in explorations by others to engage with the material transactions in representing wireless. I introduce the strategy of *material conceit* to draw on historical precedents that saw wireless technologies as spectres.

The exploration results in a body of work comprising instruments, photographs and installations which constitute allusive images aimed at contributing renewed notions of how wireless can be integrated in the design of artefacts and spaces

To Nina

ACKNOWLEDGEMENTS

Writing a doctoral thesis is a funny thing. One spends countless early mornings and late nights staring, peeled eyes, at a blinking cursor on a computer screen. Reading reference upon reference, wondering in cold sweat where does one's contribution fits in. Sending draft chapters which come back with comments such as '*Great notes, when are you sending the draft chapter?*'. There is then the descent to that Dantean place some insist on calling 'write-up year' — *Lasciate ogne speranza, voi ch'intrate* — where one descends concentric circles that repeat the agony over and over again. Draft, redraft, rework the argument, include more references, great notes, when will you have the draft ready? Dante had Virgil to guide him, and I am eternally grateful for the thick matrix of people, things and institutions which were there for me when I needed them.

I would like to begin by thanking Carolina, who was brave and embarked on her own doctorate at the same time as I did, and lived and worked with me throughout the process. Not only did she endure the emotional hurricanes that are part and parcel of being foolish enough to embark on a PhD, but was also instrumental in developing and refining the ideas and the creative exploration in this thesis. Without her, this thesis wouldn´t had been completed, and the design projects would be considerably less interesting.

To my supervisors. To Dr, Martyn Dade-Robertson, who offered me a studentship to carry out my PhD. To Professor Adam Sharr, who introduced me to Object Oriented Ontology and to the work of Graham Harman.

To my examiners, Professor Chris Speed and Dr. Steve Parnell, who were incredibly nurturing during the VIVA and helped me see the possibilities of this thesis.

To my family. It is not easy leaving your home country to embark in a masters and doctorate despite the cultural and linguistic differences. And even more so when pitted against a bureaucracy hell bent on making Kafka´s The Castle come across as just too generous on those creatures that come from foreign, strange lands. I can only thank my mother and siblings for having been there at the darker times to support me.

To all my friends in Newcastle. To Nikoletta, Tim, Christian, Caroline, Bettina who were there at different points for coffee, dinners, talks and laughs.

To all my friends elsewhere. To Ricardo, who came over to the Toon the week we arrive to show us 'the ropes', and who kept on coming back at key moments, and who offered a sympathetic ear to the moaning of a fellow PhD candidate.

Sincere thanks also go to my students from Interaction Design, Programming for Design and Stage 6, who took part in some of the projects and sessions included in this thesis. In particular, I am grateful to Vanessa and Khaushik whose work is included in the peripheral essays of this chapter.

I also thank all the staff at the School of Architecture who were hugely helpful during the development of this research, especially to Sean, Bill, Richard and Nathan at the workshop.

Thanks also go to all the people in Culture/Open Lab, who offered support and equipment for this project. Thanks to Patrick Olivier, who was kind enough to gather enough Android phones to construct the first version of the Chandelier, and who provided generous access to their installations.

I would also like to thank the different people and institutions who have contributed to the development and dissemination of this work. Thanks go to Eleni Blechinger, Katja Gunkel and all the curatorial team at the Angewandte Kunst museum in Frankfurt for inviting me to participate in Hamster, Hipster, Handy.

This thesis is specially indebted to the reviewers of the Digital Creativity paper published as this thesis was being finished. Blind peer review means that I will never know who they are, but I would like to sincerely thank Reviewer 1 and Reviewer 2 for all their comments, and for steering me in the direction of feminist theories on materiality.

[A sort of] Instructions to the reader

I must have been in high school, an aspirant to bohemian, when I first read Cortazar's Hopscotch, and was transfixed by the idea that a book could be read in more than one way and, more importantly, that said book could be open with a list of instructions to the game. Since then, I've always wanted to write something that would be prefaced by instructions, and flirted with non-linear versions of this thesis. Sanity won the argument and decided against it.

The closest I can get to provide the reader with some instructions is to suggest that are alternative readings of this work by recreating some of the conditions of writing it. Most of this thesis has been written to different jazz songs which, I am convinced, can be felt through in the rhythms and flow of the prose. If a reader has some time to spare and is willing to indulge, I might advise to read what follows to Salt Peanuts as performed by Charlie Parker, Dizzy Gillespie, Bud Powell, Max Roach & Charles Mingus in The Quintet.

Other pieces of the soundtrack of this thesis include: All Res, by GoGo Penguin, The Hunt by The Greg Foat Group and Haitian Fight Song by Charles Mingus.

PART

I

INVISIBILITY AND ANALOGY

PART

II

CREATIVE EXPLORATION

And, as the fragile substance thickened and took shape, that of my firiends thinned until the bricks of the cemetary walls showed through their bodies

Carlos Gamerro in The Islands

I

INTRODUCTION

In 1894, Sir Oliver Lodge delivered a lecture at the Royal Institution on the work of Heinrich Hertz, the physicist who was first successful in detecting and producing the waves put forth by Maxwell's theory of Electromagnetism. Underlying Lodge's lecture was a conviction that the work of Hertz had profoundly changed Physics' understanding of the world. It had, for instance, encouraged the development of the theory of Ether, which tried to reconcile Newtonian Physics with magnetic and electric phenomena. Lodge, however, also believed that so-called *Hertz waves* had a profound technological significance. In the second part of the lecture, Lodge prepared the stage with a table lined with the latest instruments to produce and detect Hertz waves. These, he argued, represented a major technological leap. Fifty years before, Morse had introduced the telegraph, itself a revolutionary technology that enabled transmitting information over long distances. The instruments in Lodge's lecture amplified the changes brought about by the telegraph, providing the means to broadcast information over the air, without the need for expensive laying out of wired infrastructure.

Lodge proceeded by demonstrating the succession of Hertz wave detectors, each smaller in size and more sophisticated than the previous. Once he had reached the last, he ventured a speculation:

> *It is just conceivable that at some distant date, say by dint of inserting gold wires or powder in the retina, we may be enabled to see waves which at present we are blind to (Lodge 1908, p.34)*

The projection is interesting in that it imagines a seamless fusion between technological and human and, in some respects, prefiguring the techno-utopian and trans-humanist discourses of the late 20th and early 21st century. It also hints to a deeper conviction that electromagnetism would change radically the way we understand ourselves as humans. Lodge would invest his time and reputation in exploring earnestly the supernatural dimension of Hertz waves, investigating how they were the basis of telekinesis and communication with the spiritual world.

Lodge's musing is, however, even more relevant to this thesis for a simpler, implicit premise. Although electromagnetism had the potential to radically transform science and technology, its full potential to redefine everyday life could only be achieved until the human body could be extended to directly perceive them, revealing their influence.

1 INVISIBLE TECHNOLOGIES

More than 120 years later, the vision of an extended human eye remains unrealised. Regardless, electromagnetic waves form part of a host of invisible technologies which are increasingly relevant to every-day life, and to architecture and design. They constitute the technical basis of *wireless infrastructure*: a collection of digital communication protocols which underpin ubiquitous technologies. Contemporary discourses in human computer interaction highlight the embedded nature of digital technology in the built environment, suggesting the former has become 'ubiquitous' and 'pervasive'. Through ubiquity, it is proposed that digital technologies become invisible, in the terms of Michael Weiser, to "*…weave themselves into the fabric of everyday life until they are indistinguishable from it* " (Weiser 1999).

The vision of ubiquity constitutes a profoundly architectural challenge, as embodied experience of spaces need to be reframed to respond to a changing brief of requirements and interactions mediated by digital devices. In this context, wireless infrastructure has become an increasingly prominent piece of ubiquity. Not only because they constitute an invisible mesh that connects a multitude of digital artefacts, but also because they have prompted a transformation in the way some people use space. This is attested by the countless stories of the pervasive influence of wireless signals on the social use of space, from coffee shops which become communications hubs because they have free Wi-Fi (Sevtsuk et al. 2009), or the huddles of laptop users in previously unused corners of the library because wireless signal strength is strongest (Hill 2009; Hill 2012). Coyne (2010) places wireless exchange protocols in the same terms as Mumford did for the technologies of time-keeping. Mumford argued that time related technologies such as clocks and timetables, more than being designed to merely keep track of passing time are, in reality, technologies of synchronisation and coordination—they enable humanity to work to the same mechanical beat. Similarly, Coyne interprets digital devices as the means through which people tune their activities with one another. Wireless infrastructure can be said to constitute a technology of alignment of social activities.

The interpretation of wireless infrastructure as a synchronisation technology, and their consequent implication for the construction and habitation of space, is also elaborated by Mitchell (1996) and extended to also shape the physical infrastructure and supply chains of whole cities. His thesis is based on what can be called the *materialization* of digital information, or as Weiser (1999) would call it *embodied virtuality*, where material and information are no longer separated. The key point in this evolution, Mitchell argues, is the development of ubiquitous wireless connections, which enable distant parts in the physical realm to be, at least theoretically, networked. This revolution in materiality of digital information makes for cities where the patterning of wireless infrastructure is just as important as patterning of physical walls and built structures.

Despite their relevance, it has been problematic to integrate wireless infrastructure in design contexts. One strategy has been to regard them as materials, in the sense that they can be manipulated to produce specific effects, and the fact that they interact with other tangible resources in shaping the experience of products and spaces (Arnall 2013a; Martinussen 2012; Nordby 2010; Nordby 2011; Vallgårda & Sokoler 2010; Vallgårda & Sokoler 2009). This process, however, is at odds with a perceived lack of technical proficiency within traditional design disciplines, such as product design and architecture. Despite the increasing relevance of digital technologies to everyday life, traditional design disciplines, such as architecture and product design, possess few tools and frameworks to understand them and interrogate how their disciplines and practices should adapt.

One answer to this challenge has been in documenting the technical complexity of invisible technologies, providing designers with the knowledge to understand them. The last decade has seen the emergence of a number of design and creative explorations, which set out to tackle this by developing visualisations intended to document the technical complexities of wireless infrastructure, revealing their materiality (Anon 2008; Husbands 2013; British Council 2014; Chan 2013; De Vicente et al. 2012). These projects deal in the language of mimetic representation, realising Lodge's aspiration to actually *see* the electromagnetic underpinning of wireless infrastructure. For instance, Arnall describes the process followed in *Immaterials* as follows: '*The project set out to expose some of the phenomena and mechanisms of technological infrastructures*' (Arnall 2013b). In describing the same project, Martinussen talks of '*instruments and techniques that can reveal qualities of wireless networks that we cannot normally see*' (Martinussen 2012, p.235). Another project representing Wi-Fi is described by their authors as taking '*"pictures" of spaces illuminated by wireless radio signals, in much the same way that a traditional camera takes pictures through visible light* (Haque et al. 2007). These practices are often located in a politically charged discourse. In developing tools and methods that illuminate the technical obscurity of digital technologies, it is argued, designers and the general public are provided with the means to participate in the future development of such technologies and, as a consequence, to have greater control on the pervasive effect in their lives. Bridle considers: '*Those who cannot perceive the network cannot act effectively within it, and are powerless. The job, then, is to make such things visible*'.

This thesis presents an alternative approach. I will argue that measuring and representing wireless involves a series of transactions — the construction of a probe to measure signal strength, logical processes to transform values into a visible pattern, a choreography to move the probe in space. Drawing from notions of New Materialism, I will propose that these transactions *construct* the materiality of wireless, in the sense that it is not inherent to the object, but that it emerges of the set of relationships in which it is located. Instead of using representation to document technical complexity, I will propose it as a form of creative re-appropriation. The thesis will argue that representations of wireless technologies not only capture specific, technical aspects of their electromagnetic components, but that they also *produce* new materialities: ways in which they can interact with other materials, and be integrated in design contexts.

2 ALTERNATIVE MATERIALITIES

Lakoff and Johnson have argued that metaphors play a crucial role in the development of the human conceptual system. Metaphors '*govern our everyday functioning, down to the most mundane details [they] structure how we get around in the world, and how we relate to other people*' (Lakoff & Johnson 1980, p.3). The authors argue that language is a good way to trace how metaphors shape conceptual structures. In a classic example, they analyse how arguing is often talked of in terms of war. We often say that arguments are lost or won, for example, or that we need to prepare our defence in preparation for a debate. The influence, however, is not constrained to the linguistic, rather '*many of the things we do in arguing are partially structured by the concept of war. Though there is no physical battle, there is a verbal battle, and the structure of an argument — attack, defense, counterattack, etc. — reflect this*' (Idem, p.4). The implication of this, Lakoff and Johnson go on to argue, is that cultural practices can be radically changed by shifting their underlying metaphor. For instance, a culture that sees argument as a dance, would have very different practices which might involve imagining participants as performers, and would contribute in developing arguments in an aesthetically pleasant manner:

> *In such a culture, people would view arguments differently, experience them differently, carry them out differently, and talk about them dif-*

> *ferently. But we would probably not view them as arguing at all: they would simply be doing something different (Idem, p.5).*

Similarly, this thesis will propose that metaphors and analogies play a crucial role in the way that we represent invisible technologies and, as a consequence, of the way we assign materiality to invisible technologies. Instead of tracing how metaphors are evident in language, I will analyse how they manifest in the design decisions to produce instruments to make wireless infrastructure visible.

A metaphor that has proved widely influential in this context is that of the electronic terrain of cities, eloquently articulated by Mitchell as: '*every point on the surface of the earth is now part of the Hertzian landscape(…) The electromagnetic terrain that we have constructed (…) is an intricate, invisible landscape*' (Mitchell 2003, p.55). In this thesis, I will document a creative practice approach that adapts tools and techniques developed by others to engage with the material transactions in representing wireless. I shape the exploration through the historical guiding metaphor of wireless as spectre, a notion which emerged in the 19th century as a result of the introduction of the first generation of wireless technologies for telegraphy and radio broadcast. The process involves analysing the layers through which materiality is constructed. The materiality of wireless infrastructure is constructed through the interaction between electromagnetic signals, the device, the access point and the specific user. Likewise, the materiality represented is constructed by the configuration of the probe, the algorithm used to interpret data, and the metaphor used to translate data into a visible pattern. Recognising these layers of materiality enables thinking of the process of representation not as a way of documenting the operational parameters of wireless infrastructure, but as a way of speculating on alternative materialities. Consciously tuning different elements of the representation process allows us to produce new materialities of wireless, which invite us to think of potential '*poetic and multi-layered coupling of electromagnetic and material elements*' (Dunne 2006, p.121).

3

STRUCTURE

The thesis is structured in three parts, bookended by an introduction and conclusion. Part I is developed in the traditional structure of a PhD thesis, providing the context of the research, the literature review and detailing the methodology. This provides the groundwork for Part II, which develops the argument further by documenting a creative practice structured around the design of three instruments to record wireless infrastructure. Part III presents peripheral aspects of the exploration that are relevant to the insertion of wireless infrastructure in design contexts, but which are not directly related to the exploration of their materialities.

Part I is divided in three chapters. In **chapter one**, I will review the relevance of wireless infrastructure to the notion of ubiquity, analyse contemporary practices that set out to increase their legibility, and contest the language of indexicality they trade in. Moreover, I will suggest that representation can be used not only as a form of documenting technical complexity, but also of exploring alternative materialities. I will begin by reviewing the influence of digital technologies in contemporary ways of understanding and inhabiting architectural spaces. In this context, wireless infrastructure plays a crucial role in providing the invisible meshwork that enables the notion of ubiquity. I will describe how, inspired by discourses critical of invisibility as requirement for ubiquity, a number of practitioners have developed projects which aspire to provide legibility to wireless networks. These projects are generally described as developing surveying instruments which reveal material, spatial and contextual aspects of wireless technologies. Moreover, they are contextualised in a perceived lack of technological literacy which, it is argued, prevent designers and the wider public to engage fully with the way digital technologies are developed, and how they affect everyday life. I will argue that the language of indexicality used in describing these explorations is problematic, and that there are several complexities in the production of representations of the invisible which need to be taken into account, and that have a bearing in the sense of materiality they communicate. I will draw from the notion of elongation of the indexical link to suggest that, in the context of wireless infrastructure, representations can be thought of as design exercises to explore alternative materialities.

Chapter two lays the groundwork for the notion of materiality used in this thesis. It begins by exploring different authors and design philosophies which look to expand the notion of materiality beyond the tangible and enduring, and proposes a definition which alludes to the intuitive understanding of how materials can be used. The argument will draw from contemporary design discourses that engage with non-tangible materialities such as *digital tectonics*, which involves developing digital systems of representation that allow to constrain digital manipulation to measured properties of materials; and *digital materiality*, often used in the context of software design, and that proposes materiality as an emergent property of the contexts of operation and use of technologies. I will go on to outline the creative exploration methodology. The methodology draws inspiration from *Alien Phenomenology*, a philosophical enquiry that traces the material exchanges to draw *metaphorisms*: enhanced forms of metaphor aimed at describing how it is to perceive the world as the specific object does. Similarly, I will propose the use of *material conceits* as a strategy to speculate on alternative materialities for wireless. Conceits are a form of extended metaphor intended to introduce ingenious images that enable thinking of a subject in different or more sophisticated ways. I will suggest that, in the context of this research, they enable explorations which might suggest a poetic coupling of electromagnetic and material elements. They do so by bypassing the limitations of prevalent analogies around electronic terrain, which condition to think of wireless in specific contexts.

Chapter three will examine prevalent metaphors in describing wireless, and will propose a *material conceit*. The first part of the chapter, entitled *Electronic Landscapes* will review how contemporary discourses in technology are deeply influenced by the work of William J. Mitchell, who proposed the image of invisible infrastructure as extensions of the physical landscape of cities. I will trace the way in which the techno-utopian discourse of Mitchell is connected to a wider tradition of seeing technology as prosthetic extensions of the human body, starting in 19^{th} century philosophy of technology, and developing in the 20^{th} century through the work of McLuhan and Fuller. I will propose that this evolution goes to explain how the analogy shapes the materiality developed by the host of projects and practitioners reviewed in chapter one, often placed in the context of urban environments. In the second part, *Wireless Spectres*, I propose the conceit of *wireless spectralities*. I will review how its emergence in the 19th century inspired an understanding of wireless technology as infused with a spectral character. I will argue that the idea of wireless spectralities is creatively useful as it invites three new materialities of wireless. One, it enables thinking of wireless as a substance that *thickens* space, as alluded by physical and spiritual theories of ether. Two, notions of mesmerism and mediumistic trance suggest an interaction of the human body and invisible forces, made visible through violent, bodily spasms and ectoplasm. Third, the figure of medium as an instrument of the spiritual telegraph invite different ways in which the coupling of body and instrument can be used in representing wireless infrastructure. These themes will inform the design of three instruments, documented in the second part of this thesis.

Part II of this thesis is structured in three chapters, and documents *Digital Ethereal*, a creative practice which revolves around the relationship between body, instrument and wireless infrastructure as material. As described above, if follows a methodology which explores prevalent analogies used in representing wireless infrastructure, and uses material conceits: ingenious metaphors that enable new ways of understanding the invisible. **Chapter four** will document the development of the *Space Reader*, an instrument developed to register signal strength dispersion and that was modelled after instruments used by the Touch Research Group in their *Immaterials* project; and by the Mediated Matter group in *Immaterial Fabrication*. The exploration enables reflecting on the different design decisions taken in representing wireless infrastructure, the way these are informed by different metaphors, and how the process determines the resulting materiality. I will propose the alternative figure of ether, as a fluid that saturates physical space and affects the experience of its inhabitants, to imagine wireless signals. This enables, I will suggest, highlighting the interaction between signals and the body of the performer, an argument which is developed through a photographic exploration carried out with an early prototype of the *Reader*

Chapter five and six will document the design of two further instruments, inspired by the *Space Reader*, and that revolve around the connection between tool, performer and material. Both chapters are structured around *material engagements*, understood as specific alignments of materialities, instruments, practices and contexts of use; which reveal different ways of thinking about wireless infrastructure, and how they can be integrated in a design context.

Chapter five will document the development of the *Kirlian Device*, a redesign of the Space Reader that enabled the photographic exploration *Spirit Photographs*. The first *engagement*, *Body as instrument*, documents how the *Kirlian Device* was designed by assigning a different status to the instrument compared to the *Space Reader*, as it understands the combination of body-instrument as an apparatus to detect wireless signal. The *material engagement* of *Trance* explores the way bodily movements can be used to represent signal dispersion, as well as the technical complexities of recording. It does so by drawing from analogies to creative mediumship, a form of artistic creation predicated on the use of mediumistic trance to inscribe the invisible. The figure of trance enables an unstructured exploration, wherein the performer is subject to external forces which influence their decisions. I will argue that such a method also alludes to concepts of design materialities explored in the previous chapters: namely, that knowledge of materials is constructed by systematic encounters with the material, and that contribute in creating an intuitive knowledge of how materials can be manipulated and acted upon.

The *engagement* of *layers* reflects on the imprint of the photographic process on the images. The analysis begins by describing how the contracted sensitivity range of digital sensors conditions long-exposure photography, which is produced through layering: the blending of individual images into one, which mimics capture in low sensitivity materials. The techniques used in layering create further levels of interpretation and mediation between process and image. I will argue that post-processing can also be understood as a form of asynchronous feedback, which enables the performer to understand the relationship between body movements, signal dispersion and technical process. The fourth *engagement*, *Feedback*, will continue the thread of *layers* and reflects on the different mechanisms of connection between signal dispersion and performer afforded by the process. I will analyse how the notion of feedback alludes to that of materiality, and argue that it is central in developing an intuitive understanding of the material.

Chapter six will document the development of the Kirlian Device Mobile (KDm), an Android application which builds on notions of feedback and calibration developed in the previous chapter. The redesign instrument enabled a number of design explorations, the *Wireless Séance*, a prototype running in Google Glass, and the installation *The Chandelier*. These contribute in reflecting around four *material engagements*: *calibration*, *séance*, *immersion* and *atmospheres*. The first will analyse the improved calibration format afforded by mobile phones, expanded by the use of a Graphic User Interface, and that enabled tuning to local, instead of global, signal strength limits. *Séance* will reflect on how the app enabled distributing the instrument to a wider audience, eliciting others to produce their own rendition of the Spirit Photograph. It also enabled *wireless séances*, social gatherings which provide the context to discuss wireless and its materiality. This is implemented in the context of an Interaction Design module, where architecture students are asked to engage in a format reminiscent of the séances used in 19th century spiritualism.

The Android platform also enables experimentation on Google Glass, a set of augmented reality glasses, as described in *Immersion*. The KDm was ported to the Glass platform, and a prototype deployed during the *Invisible Body of Wireless* exhibition. The section will argue that the experiment suggests a new model of immersion in which the wearer can explore how signal dispersion shifts as they walk through physical spaces. Notions of immersion are further explored in *Atmospheres*, which details the development of The Chandelier, an installation designed as the central piece of the Invisible Body installation and that integrates a number of Android devices running the KDm. I will suggest that the configuration of the Chandelier provides fixed reference points to understand the dispersion of signal strength, creating an unmediated experience of wireless. More importantly, it enables exploration on atmospheres: intangible areas of influence which connect to humans, and disturb their sense of time and space. I will draw from research in affective atmospheres to analyse how the installation produces forms of immersion that also allude to space thickening.

The **third part** of this thesis constitutes peripheral design exercises which, although connected to the use of wireless infrastructure in design, do not follow in the same route of exploration set out in Part I and II. They are included in this thesis, however, as they reveal relevant aspects to the manipulation of wireless infrastructure from a design perspective, or in the exercise of research through design itself. Part III is structured by three short essays. The first essay, entitled *Pedagogies*, documents the design of an Interaction Design module, part of the Masters in Design and Emergence, and that was structured using the same methodology used in Part II. In this context, analogy is used to structure students' exploration on the role of wireless and digital technologies in architecture. This is used as part of a design exercise that asked students to develop an interactive intervention for Newcastle's Railway Station. The second essay, *Research through design and intellectual property*, analyses an online controversy initiated by the researchers of the Touch Research group. Following the media coverage, members of the research group contacted me through Twitter, claiming breach of intellectual property. Their position was that the Spirit Photograph series constituted a form of plagiarism, as it made use of a technique which they considered their intellectual property and, as a result, should be treated as copyright protected. The third essay, *Wet-collodion Spectres*, explores the way long-exposure photography resonates and amplifies the material conceit of spectral technologies, reviewing the long-established relationship between photography, long-exposure and supernatural narratives.

4 PUBLICATIONS

The argument presented here has been published, in an abridged format, in *Atmospheres of digital technology: Wireless Spectres and ghosts outside the machine*, included in the October 2016 number of the Digital Creativity journal. The timing of the publication was helpful in developing the final manuscript of the thesis. The comments provided by both reviewers were invaluable, specially in shaping the section on materiality and representation. The design work, and an early narrative connecting it to prevalent metaphors, was published in *Of wireless and bodies: atmospheres in the smart city,* included the proceedings of the *MEDIACITY 5 Social Smart Cities* conference at Plymouth.

Leonard Bilsiter was one of those people who have failed to find this world attractive or interesting, and who have sought compensation in an "unseen world" of their own experience or imagination - or invention. Children do that sort of thing successfully, but children are content to convince themselves, and do not vulgarise their beliefs by trying to convince other people. Leonard Bilsiter's beliefs were for "the few," that is to say, anyone who would listen to him.

Hector Hugh Monro 'Saki' in The She-Wolf

CHAPTER 1

1

MAKING VISIBLE THE INVISIBLE

MAKING VISIBLE THE INVISIBLE

1

INTRODUCTION

In this chapter, I will set out the context for representations of wireless infrastructure and the way they are understood in design contexts to produce notions of materiality. In doing this, I will lay down the groundwork for the creative exploration in this thesis which explores how materiality of wireless infrastructure is constructed. I will begin by giving an account of the pervasive influence of digital technologies in contemporary spaces, and reviewing different authors who argue that digital technologies have an agency to transform space, demanding new ways to approach them in design. However, one of the challenges in understanding and approaching wireless is their double invisibility. On the one hand, wireless employ communication protocols which depend on a slice of the electromagnetic spectrum which is beyond human sensory experience. On the other, wireless is designed around the notion of invisible tool, a concept central to the vision of ubiquity as originally conceived by Marc Weiser. I will trace the root of the invisible tool in the thought of Martin Heidegger, and will contrast it with authors who critique invisibility as a pragmatic strategy to minimise early technology rejection.

I will also review *seamfulness*, a discourse which promotes deliberately exposing technological complexity and that has inspired a number of design explorations that aspire to increase legibility of wireless networks. This is contextualised in a perceived lack of technological literacy which, it is argued, prevented designers and the wider public from engaging fully with the way digital technologies are developed, how they affect everyday life and to propose alternative routes for their future development. In doing so, these projects are described as developing instruments and techniques which reveal material, spatial and contextual aspects of wireless technologies. The way in which these projects are presented suggest an aspiration to indexicality, which refers to the degree of accuracy in representations achieved by contiguity to phenomena. I will argue that the notion of indexicality in this context is problematic as it implies that materiality is a quality inherent to wireless infrastructure. This is at odds with the process by which representations are produced, wherein a number of instruments, techniques and metaphors come together, each contributing their own qualities to the image produced and, as a consequence, to the materiality of wireless infrastructure.

I will review the work of Wolf, who has put forward the notion of elongation of the indexical link to refer to representations that are partly modelled by its conditions of production, whilst still keeping a link to the represented. Wolf suggests that this points to the possibility of understanding representation not only as a way of recording and documenting, but also as a way of generating new knowledge. I will extend this argument to suggest that in the context of wireless infrastructure, representations can be thought of as a way of exploring speculative new materialities. This has implications for the argument linking representation to technological literacy. It has been said that revealing the mechanisms of technologies will make evident their materiality, which will encourage their use as design resources (Arnall 2014; Martinussen 2012; Jones 2009; Nordby 2010; Bridle 2012). In a variation of this argument, I will suggest that in order to move beyond current models of development and use of digital technologies, it is necessary to develop ways of exploring potential materialities of wireless which alter fundamentally current models in which they are integrated in the built environment.

2

WIRELESS INFRASTRUCTURE

Writing in 2003, William J. Mitchell predicted that the 21st century would see a drastic increase in the role digital technologies played in the construction of cities and spaces. In *Me++ the cyborg self and the networked city,* he argues that digital networking technologies hold the potential to blur the difference between atom and bit, metonymies for the physical and the digital, transforming with this the instruments by which societies are constructed and organised. He goes on to propose that wireless technologies constitute invisible and intricate landscapes and topographies that are just as relevant to the construction of cities and cultures as the physical terrain (Mitchell 2003, pp.55–59). The argument is similar to that of Bryant (2012), who reflects on the instrumentality of mediums of communication in constructing identity and culture. The size, complexity and articulation of societies, Bryant argues, are contingent on the nature of the technology used to propagate messages. Plato, for instance, imagined an ideal, compact city which enabled verbal communication to flow between citizens, thus creating conditions of stability and identity. However, speech and writing allows a slower rate of communication, and yields more compact cities as compared to electronic media—such as radio broadcasts, satellite and internet—which allows contemporary cities to expand geographically whilst keeping common elements of identity.

The work of Mitchell is located in a wider context of authors who have studied how different aspects of wireless infrastructure influence social practices, transforming with this traditional understandings of space and place (Hampton et al. 2010; Sanusi & Palen 2008; Forlano 2009; Sevtsuk et al. 2009; Sant 2006; Greenfield & Shepard 2007; Buliung 2011). In the context of this thesis, the term wireless infrastructure refers to the collection of protocols which use some form of electromagnetic signals to exchange digital information, including for instance GPS, Wi-Fi, Bluetooth, Cellular networks, and RFID. Mackenzie, for instance, argues that contemporary social practices are increasingly dependent on wireless infrastructure, in a way which suggests that their technical operation and conditions of use shape notions of human experience and identity. This allows to think of *wirelessness*, defined as a '*contemporary mode of inhabiting places, relating to others, and indeed, having a body*' (Mackenzie 2008; Mackenzie 2010).

Wirelessness as bodily experience is evidenced, for instance, in the graphic essay by Hill, which shows users of Queensland public library pacing reading rooms, arms outstretched holding laptops and mobile devices to locate spots where WiFi signal is stronger. (Hill 2009; Hill n.d.). This is complemented by a graphic dictionary of gestures associated to the use of wireless infrastructure. Included is the *pass hip-bump*, which involves angling the hip to raise a satchel just enough to expose id cards to electronic gates (Hill 2012). Similarly, other practices suggest a change in understanding of space and place. A recent trend has seen WiFi station names used to exchange messages between neighbours. One Wi-Fi station's name is set to *'You're music is annoying!'*, with a nearby one responding *'Your grammar is more annoying!'*' (Heyden n.d.). The practice exploits ambivalence of space ownership and signal propagation. Although base stations are located inside someone's home, their signals propagate beyond the property. This allows delivering messages to people who live nearby, but also allows to remain relatively anonymous. Sanusi and Palen (2008) have also observed how wireless infrastructure allows new strategies to validate legitimacy of space usage. Coffee shops, for instance, use so-called free WiFi networks to lure people in, sharing security details only to costumers. Similarly, wireless networks are also used in promoting public spaces. Public engagement programmes, especially in the United States, regularly involve deployment of Wi-Fi infrastructure in parks and squares, as a way of promoting new uses and attracting a younger demographic.

2.1 WIRELESS AS MATERIAL

The growing relevance of wireless infrastructure has prompted a number of explorations which look to understand them as materials in design contexts (Arnall 2013a; Martinussen 2012; Jones 2009; Shepard 2009b). An early and highly influential example is *Hertzian Tales,* a book collecting critical essays and design objects engaging with different aspects of electronic objects. In it, Dunne and Raby propose the notion of *Hertzian Space* to refer to the spread of electromagnetic signals which become increasingly relevant to design. They write:

> *We are experiencing a new kind of connection to our artifactual environment. The electronic object is spread over many frequencies of the electromagnetic spectrum, partly visible, partly not. Sense organs function as transducers, converting environmental energy into neural signals. Our sense organs cannot transduce radio waves or other wavelengths outside the narrow bandwidth of invisible lights (and infrared energy through the skin as warmth). Electronic objects are disembodied machines with extended invisible skins everywhere. They couple and decouple with our body without us knowing (Dunne 2006, p.107).*

In describing Hertzian Space, Dunne aspires to encourage a '*poetic and multi-layered coupling of electromagnetic and material elements to produce new levels of cultural complexity*' (2006, p.121). Illustrating this notion is the *Faraday Chair,* a plastic chamber coated in electromagnetic shielding paint, designed to produce a radiation free shelter from its potentially harmful effects.

The notion of Hertzian Space has influenced a number of practitioners. In *Hertzian Rain,* for instance, Mark Shepard develops an installation which allows participants to actively shape electromagnetic fields. It consists of a number of wireless transmitters which broadcast different sound signals. Participants use a customised umbrella lined with electromagnetic shielding fabric. The umbrella enables picking up signals from different streams by pointing towards them. It also reflects signals, changing the distribution of audio streams across space. In describing the project, Shepard contextualises his approach as an exploration of mechanisms to shape infrastructure, and as a result, the experience of the urban environment:

> *I'm interested in how these dataclouds shape how we move through and interact within urban space, particularly in relation to conditions of interference, interruption and drop-out of wireless signals. Given these conditions, how might we begin to think about how we can shape these environments? How are they (already) shaping us?(Shepard 2009a)*

Similarly in *Sky Ear,* Usman Haque produces a floating installation that responds to wireless infrastructure, and provides means to interact with it. It consists of a fibre structure which bundles together a number of helium balloons. These house electromagnetic wave detectors connected to light emitting diodes (LED), which change colour in response to signal fluctuation. The piece is conceived within a larger exploration theme of *softspace*, which Haque conceptualises as non-tangible resources which shapes the experience of space. *Sky Ear* also allows spectators to participate by placing calls and texts on their mobile phones, collectively shaping the electromagnetic signal to which the structure responds (Perron 2005; Bullivant 2005). The work of these practitioners follows a wealth of earlier artistic projects which explore electromagnetic phenomena as material (Milutis 1996; Heivly & Reed 1992; Lee & Dawes n.d.; Montague 1991; Theremin 1996). Example of this is the work of Robert Barry in *88mc Carrier Wave (FM)* and *1600kc Carrier Wave (AM),* which uses carrier waves, defined as sinusoidal waves that are used as the basis to modulate audio signals. Both pieces were installed in 1968 in a gallery space at the Museum of Modern Art New York by fitting small radio transmitters behind the gallery's wall (Lovat 2012). To experience the piece, visitors are required to tune a transistor radio to the specified FM frequency. When moving about the gallery space, sound tone would modulate depending on the received signal strength, which allows intuiting a changing distribution of the electromagnetic field.

Understanding wireless as material, nonetheless, poses several challenges. A common practice in traditional design disciplines, like architecture and product design, involves gaining knowledge of materials through systematic encounters, which allows understanding of how they interact with tools, other materials and in different contexts of use. Wireless infrastructure, in contrast, exchange information over air by using a section of the electromagnetic spectrum which is imperceptible. This means that knowledge of them often depends on technical representations, in the form of simulations and specifications sheets, that describe their behaviour as captured by instruments. In this context, designers often lack the literacy to translate technical representations into design possibilities, as they would if dealing with, for instance, wood or plastics. For this reason, visual representations of wireless infrastructure are important to provide a sense of their materiality, understood broadly as the way in which they relate to tangible and other invisible matter. These require a process of transduction, which involves interpreting some of its aspects and presenting them in a visible or tangible form. The complexity of this process is compounded by their context of operation. Wireless infrastructure constitutes a central component of ubiquitous computing systems, which are designed to be invisible to cognition. Another way to describe this is to say that wireless infrastructure are the seams of a system intended to appear seamless. In the next section, I will explain the notion of ubiquitous computing, and how wireless infrastructure can constitute technological seams. I will then present discourses which have sought to provide alternative models to understand seams in ubiquitous systems, and how these have resulted in a number of creative explorations visualising wireless.

2.2 UBIQUITY AND SEAMS

Ubiquity refers to a highly influential principle in contemporary development of digital technologies. Initially proposed by Weiser (1999; 1994a; 1994b), ubiquity refers to a stage where computers are embedded in the physical context. In previous models the form factor of computers, requiring initially whole rooms to house them, and later a desk as work station, limits the possibilities of interaction with the user, who is forced to *enter* the space of the computer. However, as computational resources reduce in size and production cost, it is possible to embed them in everyday spaces and contexts, creating dense meshes of devices. In this context, computers enter the space of the user instead. This, Weiser proposes, requires a new interaction paradigm that enables humans to interface an ever-growing wealth of information. Weiser writes:

> *There is more information available at our fingertips during a walk in the woods than in any computer system, yet people find a walk among trees relaxing and computers frustrating. Machines that fit the human environment instead of forcing humans to enter theirs will make using a computer as refreshing as taking a walk in the woods. (Weiser 1999, p.11)*

Achieving an intuitive interaction with computers, he goes on to propose, involves creating *calm technologies,* which present digital information at the periphery of consciousness, rather than demanding undivided attention. The model for this, Weiser argues, is to render digital technologies figuratively and literally invisible to consciousness. This results in computational systems which are *'literally visible, effectively invisible because their design, along with one's experience and understanding of them, lets one focus on interaction through the whole instead of on the parts'* (Chalmers & MacColl 2003, p.1).

Weiser references Heidegger's model of the *invisible tool* as basis of ubiquity. Central to Heidegger's thought is the notion that human consciousness is articulated by an interplay of elements which transition between core and context of attention. Heidegger proposes that humans are not continuously aware of everything in their surroundings. Instead, they perceive things in terms of their usefulness or handiness, a *zuhandenheit* in the original German which translates roughly as *something-in-order-to*. A carpenter, for instance, is able to work on wood without a conscious focus on the hammer. Yet, Heidegger elaborates, when the handiness of things is not evident, they become explicitly manifest (Harman 2002). As we are not able to use things anymore, we deliberately pay attention to its individual, objective presence which renders them *visible* to consciousness (Dreyfus 1991, p.72). Weiser uses this notion to argue that computational devices should aspire to become effectively invisible to consciousness, succinctly formulating that '*the most profound technologies are those that disappear*' (Weiser 1999, p.3).

Chalmers and McColl (2003) analyse how the aspiration to invisibility in cognition has often been interpreted as a requirement for seamless integration of computational components. They reference the vision of pervasive computing formulated by the Institute of Electrical and Electronics Engineers to illustrate this: '*many key building blocks needed for [Weiser's] vision are now viable commercial technologies. The challenge is to combine these technologies into a seamless whole*' (IEEE quoted by Chalmers and MacColl 2003, 1). In this context, the notion of *seams* alludes to the points and mechanisms that allow devices to come together and operate in synchrony as a whole. The technical operation of seams, moreover, is expected to remain hidden from the user, imposing as little additional complexity into the system as possible. This seems to be captured in IBM's vision of pervasive computing: '*We expect devices—personal digital assistants, mobile phones, office PCs and home entertainment systems—to access that information and work together in one seamless, integrated system*' (IBM quoted by Chalmers & MacColl 2003, p.1).

Wireless infrastructure constitutes one of the seams of ubiquitous systems, in that they allow a convenient way to exchange information, a crucial requirement to present users with a consistent experience across devices. As such, its technical operation is expected to remain hidden within the system. This includes, for instance, connection protocols, mechanics of information transfer, or signal propagation and quality. Often, this creates a number of issues which make interaction more problematic rather than easier. An example of this, Chalmers and McColl propose, is the way connection is transferred between towers in cellular networks. Mobile phones operate through a grid of radio stations, each serving a limited geographical area. When users move between them, the network transfers their connection automatically through a technical process called handover. However, when users are close to the edges between two coverage areas, they can experience a drop in received signal strength, which in turn causes fluctuations in the quality of calls and data transmission. This is due, in part, to the changing signal distribution of each tower, which shifts over time creating temporary interference between tower signals. As a consequence, phones erratically establish and break connection with both stations. Designing the system according to the requirement for seamlessness involve hiding connection details from the user, which makes them unaware of the boundary clash, and of the tower their device is currently connected to.

Chalmers and McColl advance *seamlfulness* as an alternative approach, exposing internal workings as a deliberate design strategy to enrich interaction. The authors argue that the model of invisible tool has been wrongly interpreted as a requirement for seamless integration, which involves integrating the variegated components of ubiquitous systems by hiding their points of connection. Instead, seamfulness advocates exposing seams, using their complexity and operation to increase richness of the system (Chalmers & MacColl 2003; Chalmers & Galani 2004). In the example above, a seamful approach would involve displaying which radio tower the phone is currently connected to. This would allow users to notice the erratic handover, and decide to physically move to force connection to one of the towers, improving signal quality and their experience of the system.

Another good example of seamful approaches to wireless infrastructure is the mixed reality game *Can You See Me Now* (CYSMN) (Benford et al. 2006). In CYSMN, a group of online players are chased and hunted by a group of real-world players. Online players are provided with a 3D representation of the city, which allows them to run through the streets and find shelter. Hunters are equipped with a backpack containing GPS and WiFi transmitters, which allows a user to represent their position in the online interface. To hunt their prey, they have to run across the city to the corresponding coordinate of the online player. Although designed to study virtual-real world adjacency, deployment of the game revealed complexities of wireless infrastructure which created uncertainty and ambiguity. GPS units would tend to behave inaccurately when in proximity to buildings, with specific areas within the game's scenario where signal was altogether blocked. Similarly, patchy Wi-Fi coverage meant real world players often disappeared in the virtual interface. These problems were leveraged by players, who developed different strategies to cope and take advantage. For instance, hunters would identify areas unseen by GPS to hide and ambush virtual players.

In analysing the outcomes of CYSMN, the authors propose that infrastructure should be taken into account in the design of interactive systems. They argue that designers often regard interactivity as a problem of interfacing virtual content with physical location. Wireless infrastructure, however, is capable of introducing elements of uncertainty and ambiguity which destabilise the delivery of information and the representation of physical spaces. In this context, infrastructure and its operation need to be accounted for in early design phases. They go on to conclude: *´the main implication of such arguments for the formal modelling of ubiquitous computing system is that seams—the operational characteristics of the infrastructure—will also often need to be explicitly modelled*' (Benford et al. 2006, p.5). This might include, for instance, building aspects of the game around unreliability of GPS and Wi-Fi such as rewarding hunters that find poor connectivity areas, or by penalising time spent outside coverage.

3 MAKING VISIBLE THE INVISIBLE

Inspired by the argument of seamfulness, a number of artists and designers have engaged in efforts to increase legibility of wireless infrastructure. This process is often described with the notion of *making the invisible visible* (De Vicente et al. 2012). Nickolay Lamm, for instance, has developed a series of illustrations (figure 1) showing hypothetical signal dispersion overlaid on photographs of public squares in Washington D.C. The images were produced in collaboration with

Browning Vogel, an astrobiologist who provided technical advice on the operation of electromagnetic fields.

Revealing wireless infrastructure is often connected with efforts to identify aspects relevant to design contexts, which requires developing instruments for their recording. Somlai-Fischer, Sjölen and Haque, for instance, developed the WiFi camera, an instrument consisting of a directional antenna coupled to a photographic sensor. Using this instrument, the designers are able to produce images (see Figure 2) which show Wireless Networks as a haze of variable density (Somlai-Fischer et al. 2007). Similarly, Anthony DeVincenzi developed *Invisible Forces,* a series of visualisations which depict EM fields, composed of electromagnetic signals generated by electrically charged objects, as a cloud of light points hovering above electric appliances, as seen in figure 3 (De Vicente et al. 2012). To achieve this, DeVicenzi developed what he calls a *wireless electromagnetic field sensor*: a hand-held probe fitted with a 1mH coil custom circuit. The instrument sends EM data wirelessly to a computer, which combines it with tracking data from a Kinetic camera to represent intensity values on top of a photograph of the surveyed object.

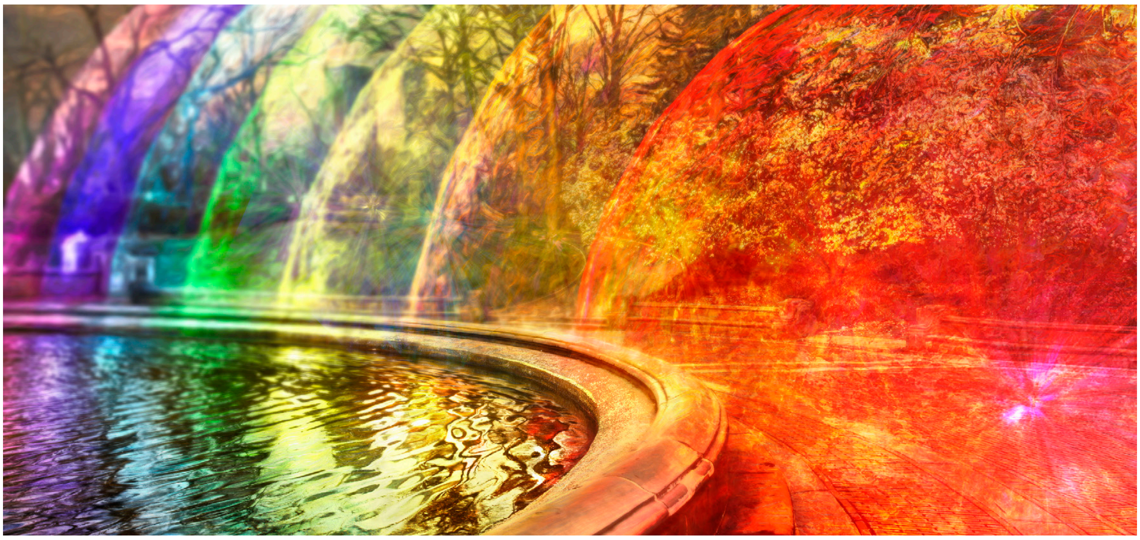
Other projects develop similar techniques and instruments, but frame wireless infrastructure as a design resource which interacts with and has properties similar to tangible materials. For instance, in *Immaterials: Ghost in the Field*, Martinussen, Arnall, Nordby and Knutsen, researchers from the Touch research project, employ a technique which combines bespoke probes with long-exposure photography to register signal dispersion of RFID antennas. *Radio Frequency Identification* refers to a set of protocols that use electromagnetic signals to exchange tracking information by using circuitry powered by the signals themselves. The handheld probe developed for *Immaterials* houses a RFID sensor and a Light Emitting Diode, which is turned on when signals are detected. This is registered in long exposure photography, producing a cloud of light points delineating the edges of signal dispersion (See Figure 4). The authors use the resulting images to argue for conceptualising RFID signals as materials in interaction design contexts. In discussing the image in figure 4, Nordby proposes that '*By seeing RFID interactions as physical 'immaterials' we could adjust and control its material relationships, to significantly alter the interactional experience of RFID interfaces* ' (Nordby 2010, p.109).

The techniques developed in *Ghost in the Field* are also extended to visualising the shape and reach of Wi-Fi in a second project called *Immaterials: Wi-Fi Lightpainting.* The project uses a 10m wooden mast fitted with 60 blue LED light points and a sensor which registers Received Signal Strength (RSSI). Strength information is remapped in a manner akin to a bar graph: the stronger the signal reported by the sensor, the more LED points are lit, resulting in higher stacks of illuminated LED. The probe is carried by an operator, who walks holding the probe vertically and pausing every number of steps. This is registered using long-exposure photography, which enables the creation of images as the one included in Figure 5, overlaying a bar-graph like representation of Wi-Fi on top of a picture of the surveyed area.

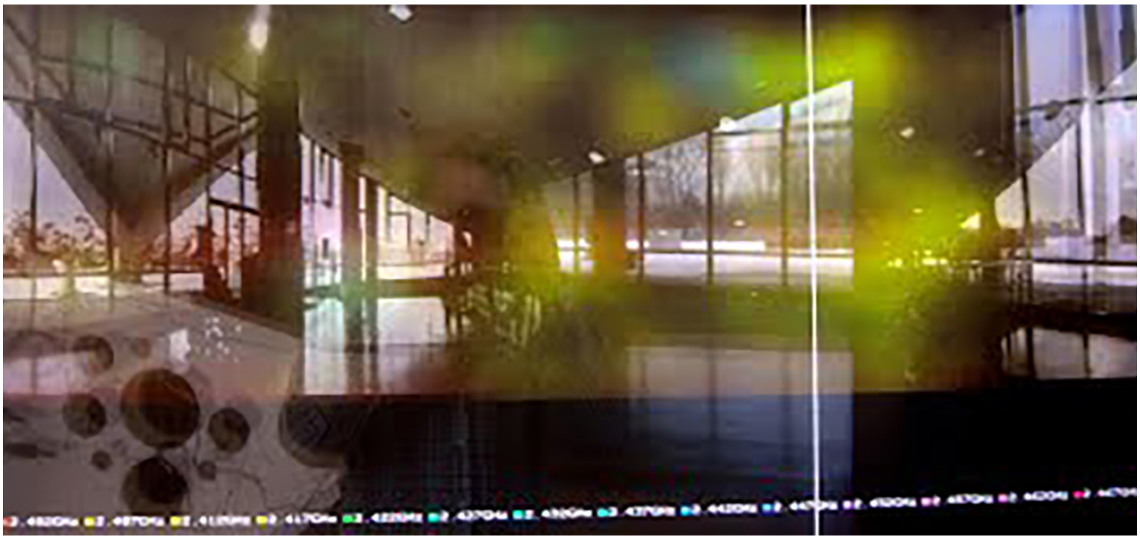
In analysing the development of instruments used, the authors make reference to the materiality of wireless infrastructure, suggesting a connection to the physical terrain of cities. Martinussen writes:

> *The measuring rod is reminiscent of the poles used by traditional land surveyors to map and describe the topography of physical landscape. Similarly, our equipment and technique allows us to survey and visualise the immaterial landscapes that surround out interactions with mobile devices (Martinussen 2012, p.237).*

Immaterial Fabrication, developed by MIT's Mediated Matter group, also makes reference to the notion of materiality in approaching wireless infrastructure. The project consists of a number of photographs showing electromagnetic fields emitted by electronic objects. Images are produced with a custom made probe, consisting of a sensor coupled to a microcontroller and colour LED. The sensor scans for a specific signal frequency, and passes

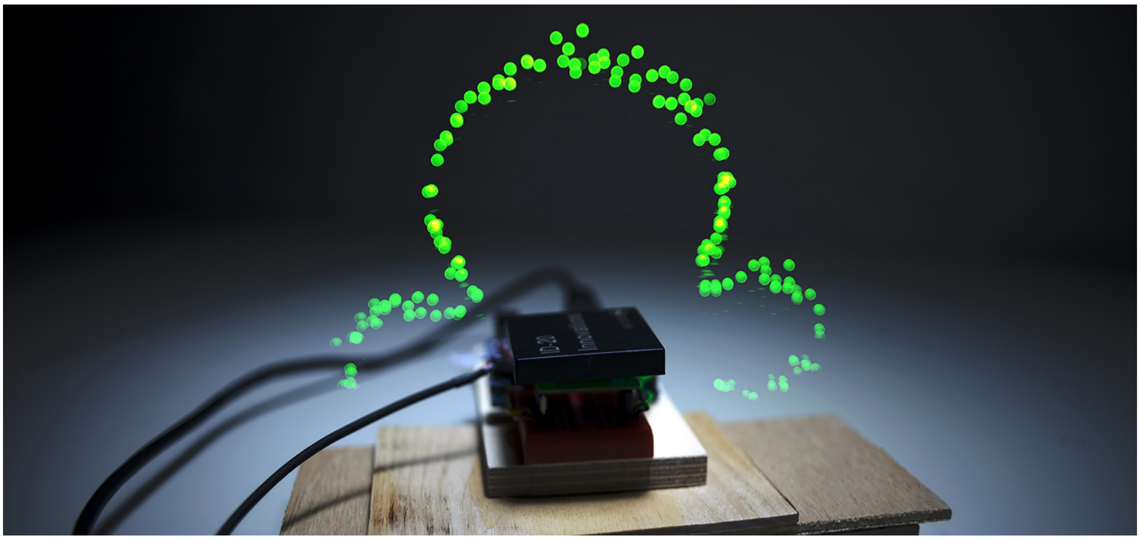


1 Nickolay Lamm

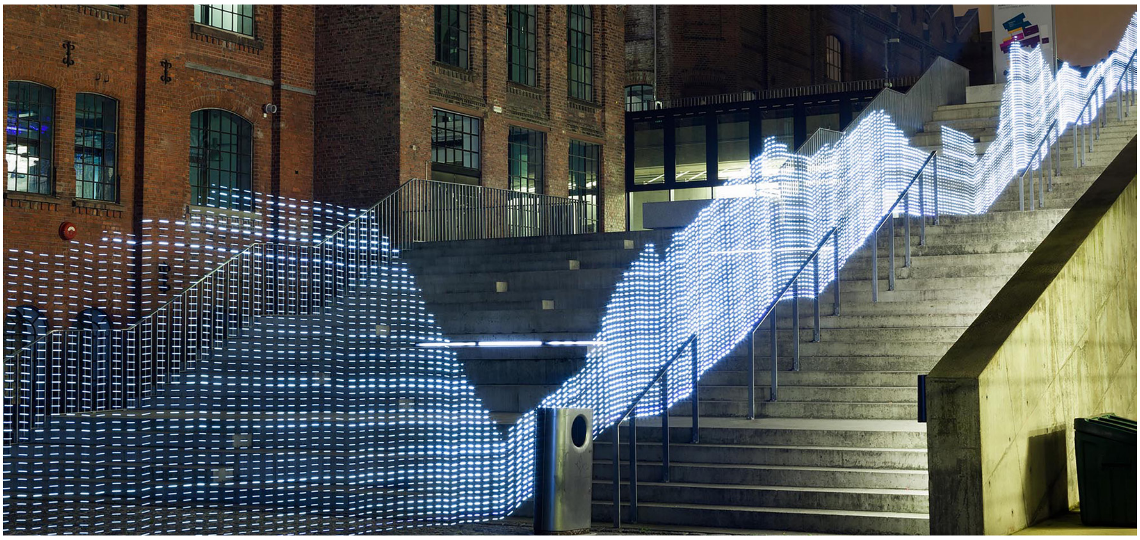


2 Part of the WiFi Camera project, by Bengt Sjölén and Adam Somlai Fischer with Usman Haque

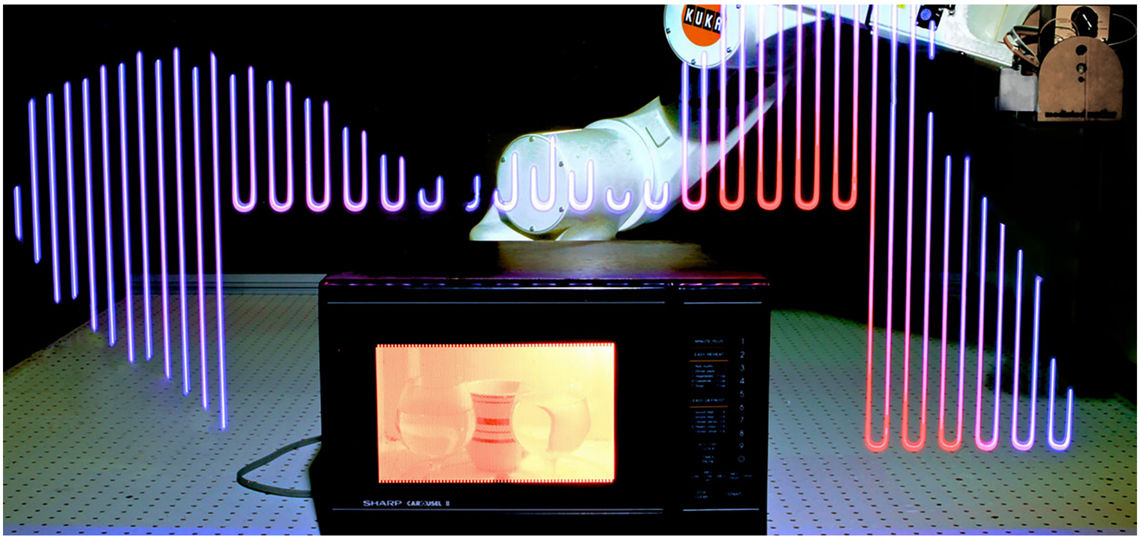
3 *Visualisation of electromagnetic field leaked by a microwave, Immaterial fabrication project*



4 Still from film created for Invisible Forces project, by Anthony DeVincenzi



5 *Field range of RFID reader produced by the Touch Research project*



6 Wi-FI Lightpainting project

on intensity values to the microcontroller. Data is parsed into colour values which are rendered using the colour LED. The probe is attached to a robotic arm, which moves it in predefined, regular patterns around the object. The process is captured using long-exposure photography, which allows to produce a volumetric display representing electromagnetic field intensity.

The exploration is contextualised as preparatory work to explore the use of electromagnetic fields to influence the formation of functionally graded materials. Keating and Oxman write:

> *Immaterial fabrication processes are based on non-mechanical forces and fields, such as electromagnetic, thermal, radioactive, and acoustic fields. In the case of annealing (…) electromagnetic forces (radiative energy transfer) are used to affect the material and create the designed structure (…) the use of immaterial fabrication may promote and contribute to industrial purposes such as localized heat treatments, specific curing designs, or magnetic patterning. Instead of outputting light, an effector can produce complex heat treatments, electromagnetic fields, and magnetic designs for target structures (Keating and Oxman 2013,3).*

The description of the project is interesting in the way it equates wireless infrastructure to physical materials, in the sense that both can be manipulated in concert to produce artefacts.

3.1 LITERACY AND TRUTHFULNESS

In conceptualising wireless infrastructure as material, the projects analysed in the previous section participate in wider discussions on technology. They engage more specifically in debates on a perceived lack of literacy which prevents designers and the wider public to debate on the effects of technology, and to imagine alternative routes for their future development. Arnall (2013b) analyses the significance of *Immaterials* by referencing contemporary discourses which argue the relevance of understanding the mechanisms of operation of technology. In this context, Greenfield writes:

> *the complex technologies the networked city relies upon to produce its effects remain distressingly opaque, even to those exposed to them on a daily basis. […] it's hard to be appropriately critical and to make sound choices in a world where we don't understand the objects around us (Greenfield 2009).*

Similarly, Bridle discusses the relevance of visualising invisible technologies by observing the political consequences of technological illiteracy. In societies where digital technologies are increasingly relevant, not understanding the mechanisms of operation can result in the impossibility to act against harmful effects. He succinctly concludes:

> *Those who cannot perceive the network cannot act effectively within it, and are powerless. The job, then, is to make such things visible (Bridle 2012).*

Creating representations of wireless infrastructure, Arnall suggests, contributes by increasing their legibility not only actually, but also figuratively by exposing '*some of the phenomena and mechanisms of technological infrastructures through visual, photographic, narrative, animated and cinematic techniques*' (Arnall 2013b). Doing so, he suggest, allows to integrate wireless infrastructure as part of the material repertoire of design disciplines (Arnall 2014).

The *WiFi camera* is placed within a similar discourse of technological literacy and political action. When exhibited in the art festival *Transmediale,* the project was included in the *hacktivism* section. The term refers to a set of practices which make use of critical thinking and technological skills to act upon issues relating to '*expressive politics, free speech, human rights, or information ethics*' (Krapp 2005, p.73). The curatorial decision to place the *WiFi Camera* in this category suggests that it increase awareness of how much contemporary social, cultural, and technological practices rely on wireless

infrastructure.
Descriptions of these projects, and the discourse they are contextualised in, trade in the language of indexicality. Indexicality refers to a concept used in semiotics and art history to characterise how representations relate to represented phenomena. It references the theory of signs developed by Charles Sanders Peirce, who proposed a three tier system to categorise signs depending on their distance to the thing they represent. Icons, for instance, represent by direct resemblance. Symbols operate on a more abstract level wherein cultural links and habits connect it to the represented. Indices represent by contiguity: they rely on physical traces and imprints left by phenomena on them to validate a connection. One of Pierce's original examples for indices is that of a footprint left on sand, which depends on the physical presence of a foot on soft soil to generate an index of presence. In the projects described above, the techniques and instruments used are described as revealing material properties of wireless, which in turn enable the production of representations that work as index of them.

Notions of indexicality are embedded, for instance, in the development of the WiFi Camera, which relies on different levels of metaphor to connect to the indexicality of traditional cameras. An early prototype of the instrument, identified as *WiFi Camera Oscura,* is described as a room that would act analogously to a camera obscura, an early room-sized photographic device in which a small hole was used to project an inverted image onto an interior wall. Similarly, the authors propose a camera that captures electromagnetic waves as they *illuminate* physical objects, conveying with this a correspondence to the way the visible spectrum of light behaves. A smaller prototype was later constructed at the *Transmediale*. In the catalogue, the work is described as taking:

> *(…) 'pictures' of spaces illuminated by wireless radio signals, in much the same way that a traditional camera takes pictures through visible light. In effect, it is a camera which captures the invisible. Wireless radio networks are increasingly part of our daily lives throughout the developed world. The camera reveals the topology of this electromagnetic ecology,*

> *or 'Hertzian space', showing that even our own bodies cast their 'shadows' (Haque et al. 2007).*

The language above alludes to indexicality. The term *capturing* conveys an unmediated process that certifies its truthfulness by establishing a parallel between the behaviour of visible light and electromagnetic fields, and between the photographic and Wi-Fi camera. A similar principle is employed by Lamm, who describes his illustrations as showing how the world would *look like* if Wi-Fi were visible (Chan 2013; Lamm 2013). This implies the invisible can be translated into visual form, to be perceived without loss or interference in the process.

The authors of *Immaterials* also allude to the processes and instruments followed in producing their visualisation to validate a high level of accuracy. Martinussen describes their project as developing:

> *instruments and techniques that can reveal qualities of wireless networks that we cannot normally see. This allows us to get closer to some of the spatial, contextual and material aspects of everyday networked technologies, and how these can be used to unpack, communicate and discuss our interactions with devices and networks in the city (Martinussen 2012, 235–236, Italics not in the original)*

The term *reveal* suggests an unmediated process which allows to record, as opposed to interpreting, the materiality of wireless infrastructure. Martinussen goes on to strengthen this by suggesting a further level of accuracy by linking their instruments to land surveying tools, and by drawing on the language of cartography. He writes:

> *The measuring rod is reminiscent of the poles used by traditional land surveyors to map and describe the topography of physical landscape. Similarly, our equipment and technique allows us to survey and visualise the immaterial landscapes that surround out interactions with mobile devices (Martinussen 2012, p.237 Italics not in the orignal).*

Parallels to cartography are similarly used in describing *Invisible Forces.* In *Invisible Fields, Geographies of Radio Waves*, a compilation of design explorations on infrastructure and digital technologies, the project is described as providing '*a framework for the measurement and spatial mapping of radiation. It is a tool that measures stray electronic fields emitted by common electrically charged objects*' (De Vicente et al. 2012, p.35). The language is deployed to describe an indexical process, in which instruments certify representations remain true to the materiality of the represented.

Describing these representations as indexical to the materiality of wireless, however, ignores the fact that they also operate as indices of the material process by which they were created, which include a number of instruments and techniques that leave an imprint of their material qualities as well. This argument is analogous to the way indexicality has been approached and critique in other fields. In art theory, for instance, indexicality has been used to account for the way in which different representations and mediums claim and leverage on a sense of truthfulness, understood as how accurately they record reality. Schofield, Dörk and Dade-Robertson, for instance, analyse how chemical processes involved in photography allow it to trade on a sense of accuracy and reality:

> *One obvious significance of the advent of photography was that it constituted the apogee of mimesis (accurate representation of the real world) (…) Photography's claim to indexicality is firstly drawn from the physical continuity from light reflecting from the physical world to the photosensitive crystals on photographic film and thence, through an enlarger, on to paper. Photography's appeal was partly in presenting an indubitable record of the real world (Schofield et al. 2013, p.2).*

The authors go on to argue how art discourses in the 1970s challenged the claim of truthfulness by analysing the way in which photographs were not only an index of the scene in front of a camera, but were imprinted as well by the instruments used in the process of capturing and post-processing the image. This means that, for instance, decisions taken in post-production, such as framing, fundamentally alter the perceived contiguity of photographic representation. Despite this, photography is culturally understood to be a guarantor of reality. This assumption is often leveraged in cinematography, for instance, to suspend audience's disbelief when introducing fantastical elements into the narrative.

3.2 ELONGATING INDEXICALITY

The way in which representations operate as index not only to the thing represented, but also to its conditions of production, have important consequences to the argument of technological literacy. The sense of how wireless infrastructure can be used as design materials is contingent on its representations. However, these representations will vary, providing variations of its materiality. A good way to frame this problematic is to refer to the way in which Wolf analyses the elongation of indexicality. He uses colours schemes and their translation to data to formulate his argument. In the context of medical and astronomical imaging techniques, different colour schemes are used to transduce invisible sets of data into the visible portion of the light spectrum. Doing so, he analyses, constitutes a departure from accurate, objective representations as it involves a degree of subjective interpretation:

> *The rendering of these transduced waves into the visible spectrum means tones or colors must be assigned to various frequencies to make them visible. The false coloring making up the image, however, is a step into the subjunctive, because the image is not a record of how the subject appears to the observer, but rather how it might appear, if such frequencies were substituted for frequencies (light waves) within the visible spectrum. Thus it is the differences between frequencies that are being documented, not the frequencies themselves (Wolf 1999, p.277).*

This analysis is relevant also to the projects analysed in the previous section. To represent the edges of Bluetooth signal dispersion, for instance, the authors of *Immaterials* chose to fit their probe with a green LED, which resulted in green dotted bubbles representing the signals emitted by different antennas. In their exploration on Wi-Fi signals, they switched to a pole fitted with 80 ultra-bright LED points, which generates images of blue bar-like landscapes of Wi-Fi networks. The selection, they reflect, was in part pragmatic as ultra-bright LEDs are the cheaper source of light points. However blue LED are ubiquitous in electronic objects, which helped them to create an image of WiFi networks that felt coherent with digital technologies and networks (Martinussen 2012). In contrast, the images in *Immaterial fabrication* employ a heat map colour scheme which allows to communicate a graded dispersion of electromagnetic fields. This is done by fitting the measuring probe with a RGB LED, which enables the representation of signal strength with different colours. DeVicenzi departs from coloured light altogether, and developed the probe used in *Invisible Forces* with a white LED, manipulating its brightness to indicate fluctuations in signal strength.

Colour schemes are among a number of design decisions which impact the sense of materiality that can be derived from the resulting images. For instance, the authors of Immaterials developed their probing instruments for *Wi-Fi lightpainting* around a wooden stick, which allowed them to establish parallels with land-surveying instruments (Martinussen 2011), and to generate the abstraction of signal strength as a physical line graph moving across space (Arnall 2011). An unintended imprint of the wooden stick, however, is the possibility of interpreting the images as fences and vertical boundaries produced by Wi-Fi networks. In a comment left at one of the early blog posts documenting the project, a reader identified as Brent observed:

> *Since vertical height is a meaningful component of terrain in an everyday sense, there's a little bit of a visual metaphor mismatch, with higher signal strengths looking like virtual "walls", and thus appearing to be wifi network boundaries, when in fact the lower signal strengths are more the boundaries (Martinussen 2011).*

The comment suggests the image has created a possibility where wireless networks exist as boundaries, as walls overlaid on the physical city. Similarly, in an editorial reviewing its significance as a piece of data visualisation, the project is introduced as: '*Is it a new form of sheet lightning, is it an alien force field, is it a neon-lit security fence? No. It is a graph. It is a graph in real time. And in real space as well*' (Arnall 2011, p.38).

The interplay between representation and phenomena invite an understanding of representation beyond strict recording. In the context of computer visualisation, Wolf proposes that attending to the traces left by decisions, instruments and techniques enables a new form of representation, where recording is combined with speculation and extrapolation. Wolf writes:

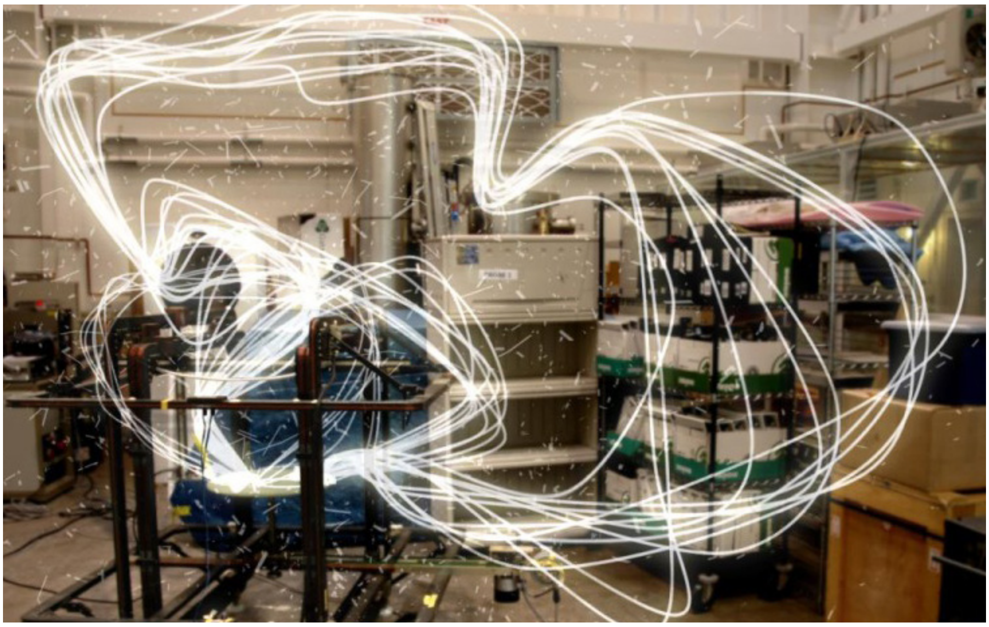
> *Whereas most documentaries are concerned with documenting events that have happened in the past, and attempt to make photographic records of them, computer imaging and simulation are concerned with what could be, would be or might have been (…) By translating invisible entities (beyond the range of human vision) or mathematical ideas into visible analogues, computer simulation (…) has created new ways in which an image can be linked to an actual object or event (…) By narrowing and elongating the indexical link and combining it with extrapolation or speculation, computer imaging and simulation (….) can document what could be, would be, or might have been (…) [it] documents possibilities or probabilities instead of actualities. (Wolf 1999, p.274)*

This, he goes on to propose, allows new forms of knowledge that are impossible to access when approaching representations as means of validating empirical knowledge. That is, a documentary form of representation enables to understand things as they are. In contrast, an elongation of the indexical link enables imagining how things might be, it allows to create possibilities instead of actualities. Such possibilities are explored by Husbands in the context of the artistic exploration of *Semiconductor*. An artistic duo formed by Ruth Jarman and Jow Gerhardt, *Superconductor* have engaged in a number of projects which develop different experimental representations of invisible, physical phenomena. In the short film, *Magnetic,* the duo explores electromagnetism in the context of astrophysics. Husbands described the work as:

> *hybrid experimental artworks that engage with their subject matter on*

a number of different levels, with varying degrees and manifestations of scientific 'truth' (…) [they] embody a philosophy of science that is engaged with technological investigation and its ability to expressively reveal the material nature of our universe (Husbands 2013, p.199).

Magnetic engages in a philosophical exploration, Husband proposes, of the process of translatability and how this is compounded in the case of invisible phenomena. In doing this, *Superconductor* refuses to comply to strictly indexical representations. Instead, they rely on animations which allow them to allude to different aspects of scientific knowledge. A similar approach is taken by Alison Sant (2006), who develop a series of maps that represent the experience of using wireless infrastructure. Sant operates from the intuition that, given the increasing relevance of wireless networks to everyday life, they should be considered as part of the urban landscape. However, instead of recording wireless infrastructure itself, Sant borrows from the conventions of topography to examine 'the interplay of wireless networks with the corporeal experience of the urban landscape'. In this, she aspires to produce maps that are closer to the ancient Greek tradition of maps that represent a system of relations, rather than as a physical inventory.



7 Still from *Magnetic Movie,* by artistic duo Superconductor

4

MATERIALITY OF WIRELESS

In this thesis, I will propose that the materiality of wireless infrastructure is constructed through representation, rather than revealed in mimetic, indexical representation. Accounting for this process involves an analysis of the different *engagements* by which materiality is formed, which involve the instruments used in recording them, the protocols used, the base metaphors employed in contextualising, and the way in which representations interact with others and are inscribed in wider contexts of design. To achieve this, I will propose a design-based methodology that enables me to trace the material interactions involved in representations, and how they can be modified to speculate on new materialities. This argument relies heavily on New Materialism, a contemporary philosophical school which understands materiality as a description of how objects relate, transform and are transformed by others. In this context, the problem of technological literacy can be reformulated. Not understanding the technical operation of wireless technologies prevent discussing their effects. In this context, representations can be useful in allowing designers and the wider public to understand their complexity and consequences. But it is also useful in speculating on new materialities. That is, in imagining in what new ways they can operate with other materials, other than as a convenient way of transferring information. In chapter two I will explore the concept of materiality at depth, and will relate how it connects to the notion of representation as a method to produce speculative materialities.

Following this approach has implications for the argument of digital literacy. In this chapter, I have reviewed a number of creative practices and discourses that make visible the invisible. These engage in revealing the mechanisms of wireless infrastructure, which are expected to make evident their materiality and encourage their use as design resources. This is based in a discourse which argues that traditional design disciplines are ill-equipped to understand and participate in the development of digital technologies, and that, in order to redress the situation, efforts are required to increase their legibility. I have reviewed the elongation of indexicality referred by Wolf, which suggest that representations which involve a large degree of interpretation modify the accurate link of traditional documentary representations. In doing this, they provide what the represented *might be,* which allows accessing new forms of knowledge otherwise unavailable. Schofield, Dork and Dade-Robertson (2013) remind us of how media studies, especially in the work of Huhtamo (2004) and Kittler (1999), argue that our capacity to imagine is dependent on the technologies used to assist and expand what can be seen. This suggests that representations are crucial in creating the ways in which wireless infrastructure can be imagined.

In their description of *Hertzian Space*, Dunne and Raby declared an aspiration to produce poetic integrations of the material and the invisible. The projects analysed above have often resulted in pragmatic integrations of wireless infrastructure and tangible material. *Immaterials: Ghost in the field* is presented in the context of explorations which enable product designers to think, for instance, of the gestures which can be used to interact with RFID systems. For example, in how approaching a mobile phone to a reader from different angles can be used to codify specific actions in the system. Similarly, *Immaterials* aims to use electromagnetic fields as a way of influencing material formation. These projects are highly relevant in integrating design and digital technologies, and have generated a context where it is possible to further the exploration into how wireless infrastructure generate more fundamental changes to, for instance, understandings of space. In Dunne and Raby terms, what poetic integrations are possible. In a variation of the original argument, I suggest that representations of wireless infrastructure are powerful, not only because they contribute to a better understanding of technology, but also because they inspire radical new ways of thinking about and shaping invisible infrastructures. New representations provide the possibility of imagining new materialities for wireless infrastructure: in what ways they can interact with the tangible. This involves engaging with the processes which accrue their materiality through representations, which in turn will inspire different possibilities for their integration and interaction with the physical environment.

5 CONCLUSIONS

In this chapter, I have set down the context for a creative exploration that engages with representing wireless infrastructure. I began by reviewing the growing relevance of digital technologies to everyday life and to the constitution and understanding of architectural space. Central to this is a mesh of electromagnetic signals, referred to as wireless infrastructure, which provide the means to connect different computational devices that can be embedded into the fabric of the everyday. Despite its importance, wireless infrastructure presents a challenge in design terms due to its double invisibility, a term which alludes to the suprasensible nature of electromagnetic signals, and to the requirement of invisibility embedded in the framework of ubiquitous computing. First advanced by Weiser, ubiquity is generally connected to the notion of invisible tool, which proposes that the best technologies are those that disappear from conscious attention and recede into cognitive periphery. Achieving this often involves hiding away mechanisms of operation, which is expected to provide a natural and intuitive interaction with technology.

In this context, I have referenced a growing discourse which argue against invisibility in design terms, and call for a framework which deliberately reveals the seams and technical operation of systems. Inspired by this, a number of practitioners have engaged in different projects to increase the legibility of wireless infrastructure. These practices are interesting in that they conceptualise wireless infrastructure as material, and propose a number of instruments and techniques that allow to reveal their qualities and interaction with other tangible materials. This is inscribed in a discourse which highlights a lack of technological literacy which, it is argued, prevent designers and the wider public to engage fully with the way digital technologies are developed, and how they affect everyday life.

I have proposed that the approach of the practices explored in this chapter is problematic in that it allude to truthfulness and accuracy. This prevents analysing how representations also index their conditions of production. I have referenced Wolf, who uses the notion of elongation of the indexical link to describe representations which, due to the level of interpolation and speculation involved, depart from traditional models of documentary representation and allow new forms of knowledge. I have used this context to propose that the materiality of wireless infrastructure is not an actuality that can be measured, revealed and recorded in accurate representations. Instead, materiality is accrued by the material transactions involved in detecting and representing wireless infrastructure. In this thesis, I will develop a creative exploration that engages with this notion to account for the different registries in which materiality is constructed. In the following chapter, I will dissect the notion of materiality, how it relates to wireless infrastructure and the way in which the framework of Speculative Realism can be used to trace the construction of materiality in the transactions of the objects involved.

Against the positivism which halts at phenomena — 'there are only facts' — I would say: no, facts are just what there aren't, there are only interpretations. We cannot determine any fact 'in itself': perhaps it's nonsensical to want to do such a thing. 'Everything is subjective,' you say: but that itself is an interpretation, for the 'subject' is not something given but a fiction added on, tucked behind. —It is even necessary to posit the interpreter behind the interpretation? Even that is fiction, hypothesis.

Inasmuch as the word 'knowledge' has any meaning at all, the world is knowable: but it is variously interpretable; it has no meaning behind it, but countless meanings. 'Perspectivism'

It is our needs which interpret the world: our drives and their for and against. Every drive is a kind of lust for domination; each has its perspective, which it would like to impose as a norm on all other drives

Friedrich Nietzsche (2003), Writings from the late notebooks, 7[60]

CHAPTER 2

2

MATERIALITY

MATERIALITY

1

INTRODUCTION

In the previous chapter I described how wireless infrastructure is often treated as a type of material in design contexts, in the sense that it can be manipulated and integrated with other tangible resources in the creation of artefacts and spaces. I also floated a definition of materiality, which referred to the way in which an entity engages with others, is affected and transformed. I alluded to the way materiality is central to the exercise of design, as it enables designers to develop an intuitive understanding of how materials can be used. In the context of wireless, this notion is complicated as it is impossible to gain a direct experience of the material. In this section I will explore the concept of materiality at length, and argue how representation constructs materiality.

I will begin by reviewing how the last decade has seen a growing interest in the concept of materiality, generally framed by a discussion of rapid technological advances and their relevance to design. I will describe how Manzini approaches the problem of specification materials, and proposes developing a language that substitutes for direct engagement, helping to gain an understanding of performance and aesthetic qualities. The work of Manzini alludes to the complexity in gaining knowledge of materials in a context where rapid technological advance multiplies their possibilities. The argument laid down by Manzini has been used in the context of digital technologies, as described in notions such as digital tectonics and digital materiality. The argument connecting rapid technological change with materiality is also explored in the philosophical schools of New Materialism. I will use the framework of Object Oriented Ontology to define materiality, where it is used to describe the way in which objects interact with each other and is connected to notions of representation and analogy.

I will propose that an OOO conceptualization of materiality is of particular relevance, as it describes materiality as something which is constructed, rather than revealed. Karen Barad has talked of materiality as a feature which emerges of the interaction between objects, instead of preceding and shaping interaction. I will suggest that this understanding of materiality invites us to explore the emergent materialities of wireless, and to speculate on it. By the end of this chapter I will have proposed a methodology which uses analogy as a guiding principle to explore materiality, and that operates through *material conceit*: an imaginative extended metaphor which allows for alternative understandings of a subject matter. In representing wireless, *material conceits* enable thinking outside the prevalent *electronic terrain* analogy, opening up new materialities that speak to a poetic coupling of electromagnetism and spaces.

2 DESIGN MATERIALITIES

The concept of materiality has traditionally been used in design contexts to describe the relationship between designer and material. Through their sensorial experience, designers are said to gain knowledge of the possibilities of materials: of how they can be manipulated and transformed, what forms are natural to them, and of how they can be integrated in producing artefacts and spaces (Manzini 1995). Donald Schön described design knowledge as a form of tacit understanding: designers are often ill at ease when asked to articulate, formally, their working method and techniques, as they rely on embodied experience which translates to material skill. Schön elaborates:

> *designers know more than they can say, tend to give inaccurate descriptions of what they know, and can best (or only) gain access to their knowing-in-action by putting themselves into the mode of doing (Schön 1992, 2).*

Crawford links the notion of tacit knowledge to craft practices. Himself a philosopher and motorbike mechanic, Crawford proposes that making and sensual experience are central to thought processes. In reflecting on the practices of car mechanics, and the way they rely on experience rather than formalised knowledge to make decisions, he writes: '*when a mechanic makes this kind of judgement, he is relying on a tacit integration of sensual knowledge, by which he subconsciously refers what he sees to patterns built up in his mind through long experience*' (Crawford 2010).

The image of the carpenter is a good example of the way materiality connects with tacit knowledge: systematic encounters with the material provide the craftsman with the knowledge of how tools and wood interact. For example, how different species of wood yield more easily, or resist movements in one particular direction, and how different tools create different effects in its surface. In so doing, the artisan develops a sense of materiality of the wood — an innate knowledge of how wood *unfolds* in the material realm: of the series of interactions and transformations that allow for the material to be used in specific ways. Lillegard describes how these encounters constitute a material repertoire, and influence a work methodology based on unstructured experimentation: *'Artists and designers rely upon a vast reservoir of expert skills, knowledge and techniques, but they work in experimental, intuitive ways that embody tacit knowledge, a degree of unstructured "mess" and risk-taking'* (Lillegerd 2007, 1). The reservoir of material knowledge, however, is not constrained to an understanding of material in the process of fabrication. It also constitutes a mode of understanding that extends to contexts of use: how the material will integrate with others in specific artefacts and spaces, and how it is likely to be perceived by users. In addition, materiality constitutes a design strategy. She elaborates:

> *Very often I start out with a vague idea, a concept or a theme. At other times a project can be triggered by a specific material or technique. I often examine how far I can push a technique or a material. Testing and manipulating the materials shows me how much they can stand, and the technical manipulations and abuse I put them through tell me if they are capable of evoking associations, emotions, memories and/or expressions of any kind (Idem, 2).*

Technological advances in the last fifty years, however, have prompted a revaluation of materiality and its role in the design process. The material revolution of the 1960s poised a radical challenge to theories and practices of design. The emergence of material science brought about a new set of designed materials, such as PVC, fiberglass or plywood, which could be specified to the molecular scale to specific requirements (Bergström et al. 2010). This presented a challenge for designers, as their material possibilities expanded significantly. Ezio Manizini (1995) approached this problem in his influential *The material of invention*. In it, he argued that design was tightly interlinked with material possibility: '*Every object made by man is the embodiment of what is at once thinkable and possible. Something that someone was able to both think of it and physically create*' (Manzini 1995, 17). His theory hinged around the way that matter becomes material, referring with this to the way matter is integrated in design to become part of its outcomes. This, Manzini proposed, was enacted by a series of cognitive tools and cultural references.

Manzini observes how, historically, designers engaged directly with materials to understand its possibilities. Manipulating material directly revealed its functionality and allowed designers to develop mental models of how it would behave in fabrication, and of its aesthetic qualities in different contexts of use. Material science afforded the possibility of a significantly larger range of materials, with minute difference of performance and appearance between each other. This hampered the possibility of traditional craft-like, direct engagement. He argues that:

> *The 'material' of which objects are made therefore appears increasingly difficult to define in simple categories that we can say have been acquired once and for all. The only way to describe the materials[sic] is to consider it as a system capable of performance: thus we shall speak of a 'material,' not by defining 'what it is,' but by describing 'what it does (Manzini 1995, 32).*

This triggered a revaluation of the design methods to acquire material knowledge. In the absence of direct material engagement, Manzini argues, it is language that provides designers with the allusive images to navigate the possibilities of an expanded material catalogue.

Similar arguments have been developed in contemporary design discourses, where notions of materiality have served to explored new relationships between design and material. *Digital tectonics*, for instance, aims to develop systems of representation that afford a more direct relationship of designers with digital form-finding and robotic fabrication. Central to this is the notion of *digital materiality,* which is used to describe representations of materials structured to constrain or enable transformations in digital environments. Oxman defines it as:

> *Digital tectonics is the way in which the material elements of architecture are digitally represented, generated and modulated in processes of morphogenesis. This representation constitutes its digital materiality (Oxman 2013, 12).*

The notion of digital materiality has also been used to develop a framework in which materiality is not linked to fixed properties of matter, but is rather contingent on interactions between elements. Leonardi, for instance, reflects on a growing relevance of the term of materiality in the study of software. He points out that in media and communication studies, the notion of digital materiality has been useful in approaching how software influences people behaviour, and to argue for new design frameworks that look into the contextual use of digital artefacts. Leonardi distinguishes between two concepts of materiality. The traditional tends to link material to tangible substance, where materiality is understood as a set of fixed properties that transcend time and space. A second definition assigns material to any entity, abstract or physical, that affords or constraints action. Digital artefacts can be said to be material under the second definition as: '*they have effects on the way people interact only when they are incorporated into people's action. Consequently, perhaps what matters most about an artifact begins to matter only as one utilizes it to achieve a particular goal*' (Leonardi 2010). In this context, materiality is contingent upon context of use. An example of this, he proposes, is the way tools of the Adobe Photoshop software can be considered more or less material for different users. The blur feature is more significant to someone editing high-school yearbooks as it allows them to retouch blemishes. The sharpen tool, however, might appear more material to law enforcement officials who use it to bring up license plate details. As a result, he proposes a notion of materiality which is tied to how technology is enacted in use:

> *although technologies are material artifacts, their materiality can only bring change if people recurrently enact them as technologies–in–use. Therefore (…)it is the technologies–in–practice, not the technological artifacts, that 'are the set of rules and resources that are (re)constituted in people's recurrent engagement with the technologies at hand (Leonardi 2010)*

A notion of *digital materiality*, Leonardi goes on to propose, allows a nuanced design approach, where the same features have a range of *materialities,* which are defined by the way in which different users perceive them. As a consequence, designers are required to engage in the different ways a tool can be used by different users, rather than conceptualising it as having equal relevance for all.

The design debates and exploration reviewed in this section echo contemporary philosophical discourses, which have set out to redefine notions of materiality as a way of developing frameworks more adept in dealing with an increasingly complex material landscape. The next section will introduce the school of new materialism, an emergent philosophical discourse which looks to provide new frameworks to approach matter, and that provide relevant concepts and tools to approach the materiality of wireless infrastructure.

2.1 NEW MATERIALISM

Design discussions on the nature of materiality in the last fifty years are analogous to philosophical debates on the status of matter. New materialisms, a term first used in the context of design by Manuel DeLanda (2004) and Rosi Braidotti (2006), has been used to encompass a number of discourses with a common project of a revaluation of matter. This involves a critique of understandings of matter which represents it as an inert substance which is shaped by human activity. Instead, New Materialism proposes that matter has agency and influences human behaviour, and proposing a definition of materiality based on a gradient of vibrancies.

Coole and Frost reflect on the term of new materialism, which makes reference to the 19th century materialistic tradition of Marx, Freud and Niezsche, but that also respond to an increasingly complex material landscape. Among others, they point to an increasing '*saturation of our intimate and physical life by digital, wireless and virtual technologies*' (Coole et al. 2010, 5–6). In approaching the challenges brought about by a shifting notion of the material world, they argue, it is necessary to shift attention to matter and to speculate on new ways of understanding it:

> *we are finding our environment materially and conceptually reconstituted in ways that pose profound and unprecedented normative questions. In addressing them, we unavoidably find ourselves having to think in new ways about the nature of matter and the matter of nature (Ibid).*

The project of New Materialisms is influenced by the critique of knowledge by feminist studies. In this context, enquiry in social sciences is described as predicating on principles of abstraction, which discourage direct engagement with the observed world. Feminist studies oppose this by *tuning* into the intricacies of the material dimension, which involves using the living experience as a starting point to produce a *situated knowledge* (Wood and Cox 1993).

Central to the discourse of new materialism is the redefinition of matter to include different degrees of animation and agency. Bennett (2009) for instance proposes the notion of *vitality* of matter, which alludes to a spectrum of possibilities in which matter can act and make things happen independent of a sentient subject. In this, Bennet aspires to challenge a philosophical tradition which structures the world as divided between the 'dull' matter, and vibrant life, commonly attributed to sentient agents. A framework which recognises different degrees of agency and vitality, she argues, is more relevant to deal with contemporary debates about the relationship between humans and the material world, especially those which concern the ecological effect of human activity.

One of the consequences of assigning agency to matter is that materiality is no longer a fixed feature which transcend time and space, but is rather in constant change:

> *Conceiving matter as possessing its own modes of self-transformation, self-organization, and directedness, and thus no longer as simply passive or inert, disturbs the conventional sense (…) Matter is no longer imagined here as massive, opaque plenitude but is recognized instead as indeterminate, constantly forming and reforming in unexpected ways (Coole et al. 2010, 10).*

A good example of this shift is *agential realism,* which challenges the notion that material entities precede interactions. Barad (2006) proposes the notion of intra-action to refer to the way in which individual entities do not have an immutable, transcendent substance. Rather, they are constructed by the set of material transactions. An example of this would be to talk of the flexibility of wood. In a traditional understanding of materiality, different types of wood have specific mechanical properties. This feature, however, can only be assessed through direct interaction — a craftsmen yielding the wood, or an engineer performing load testing to determine its flexibility instrumentally. Agential realism posits than the materiality of wood, as seen through its feature of flexibility, only exist when it is acted upon (Barad 2006; Kleinman 2013). Materiality is therefore an emergent feature, which is contingent on transactions with other materials and through human interaction.

2.2 WIRELESS MATERIALITIES

The range of contemporary notions of materiality suggest an alternative approach to representation of wireless. The work of Manzini deals with the relationship between designer and material, where technological complexity becomes an obstacle for direct engagement. He proposes that in the absence of sensorial experience, design should develop a representation system that allows to gain knowledge of the material and its possibilities. A traditional understanding of materiality would allow a documentary approach to this. Material entities are thought to precede interaction, and materiality to be immutable properties which determine how objects can transform and be transformed. As such, representations are required to reveal these qualities, providing designers with enough information about how the material can be integrated in design. This is the approach taken by the explorations reviewed in the previous chapter. I analysed how their descriptions trade in the language of mimetic, indexical representation to validate the link between representation and represented; projects are described as revealing the materiality of wireless through carefully designed instruments and techniques. In this context, representations are contextualised as providing the means to increase technical literacy, which provides the necessary basis to debate and understand the impact of wireless infrastructure in everyday life and in design.

A notion of emergent materiality provides an alternative interpretation to traditional understandings, where matter is indexed to tangibility. Leonardi and Barad propose an understanding of materiality as an emergent feature dependent on the interactions in which the material is invested. This means, for instance, that the materiality of wireless is not a fixed property which can be simply recorded and revealed in representations. Leonardi traces this understanding of materiality in the range of meanings admitted by the adjective *material*, one of which involves having significance or relevance. Leonardi writes: '*the adjective "material" seems to refer to some property of the technology (…) that provides users with the capability to perform some action*'. Applied to wireless infrastructure, its materiality can be said to be constructed by the interaction between electromagnetic signals, the device, the access point and the specific user. Moreover, wireless will appear *more material* to a laptop user, often equipped with larger antennas and better reception, than to a smartphone. In representing wireless, materiality is constructed by the configuration of the instruments, the algorithm used to interpret data, and the metaphor used to translate data into a visible pattern. Recognising these layers of materiality allows us to think of the process of representation not as a way of documenting the operational parameters of wireless infrastructure, but as a way of speculating on alternative materialities. Consciously tuning different elements of the representation process allows us to produce new materialities of wireless, which invite us to think of potential '*poetic and multi-layered coupling of electromagnetic and material elements*' (A Dunne 2006, 121).

A good framework to approach representation as a speculative tool of materialities is Object Oriented Ontology, a philosophical school identified with the principles of new materialism. OOO links representation directly to materiality, and allows for an ideal tool to understand the material transactions involved in them. The next section offers an overview of the principles behind OOO which will form the core of the creative exploration in the next part of this thesis.

3

MATERIALITY, REPRESENTATION AND ANALOGY

Object Oriented Ontology (OOO hereafter) refers to a philosophical school which develops a system of flat ontology around the notion of *objects*. Flat ontology refers to a framework in which all elements are considered of equal importance, and of equal relevance to philosophical study. It derives from the work of Manuel DeLanda, who defines it in opposition to hierarchical ontologies:

> *while an ontology based on relations between general types and particular instances is hierarchical, each level representing a different ontological category (organism, species, genera), an approach in terms of interacting parts and emergent wholes leads to a flat ontology, one made exclusively of unique, singular individuals, differing in spatio-temporal scale but not in ontological status (DeLanda 2013, 47).*

In OOO, O*bjects* are understood as coherent, unified entities that cannot be explained through their constituent parts, nor by their appearances and effects (G Harman 2011). The name of objects is problematic, as it tends to relate instinctively to tangible matter. However, the concept is meant to encompass tangible entities, as well as abstract and notional things such as metaphors and ideas. To address this issue, Bogost (2012) has suggests *thing* and *unit* as synonym and alternative for objects. Example of objects include:

> *cinder-blocks, bendy straws, iron fillings; a storm, a rat, a rock, a lake, a lion, a child, a worker, a gene, a slave, the unconscious, a virus ; Elections, mass demonstrations, books, miracles, viscera laid open on the altar, viscera laid out on the operating table, figures, diagrams and plans, cries, monsters, exhibitions at the pillory; the locusts that devour the crops, the cancer that beats others at its own game; the mullahs who dissolve the Persian empire, the Zionists who loosen the hold of the mullahs, the concrete in the power station that cracks, the acrylic blue that consumes other pigments, the lion that does not follow the predictions of the oracle (Bogost 2012, 23; Latour 1993, 192, 196, 198).*

A foundational element of OOO is flat ontology, which makes reference to a theory of existence in which all entities are given the same ontological status, even when they differ in their spatial and temporal scales. The opposite to flat ontology is, for instance, phenomenology, which reject the possibility of knowledge of the material world outside human thought and perception. In doing so, human perception is granted primacy over other objects. Object Oriented Ontology seeks to transcend this by assigning the same importance to all objects, sentient or inanimate. Following in the movement of new materialism, OOO critiques the insufficiency of contemporary philosophical systems to deal with increasingly complex matter in contemporary human activities. This is, it is argued (Meillassoux 2010), due to *correlationism*, defined as the principle that humans only have access to the correlation between matter and thought, and that as a consequence '*philosophy cannot speak of human or world in isolation, but only of a primal correlation or rapport between the two*' (Graham Harman 2011, 171). As a consequence, it is impossible to separate matter from thought, since perceiving matter involves a thinking process. Correlationism has influenced a number of philosophical schools which argue the impossibility of talking about reality, instead shifting their attention to subjectivity: the correlate of human perception and material reality. However, OOO contends that correlationism is inadequate in the face of an increasingly complex material landscape (Coole et al. 2010). In this context, OOO provides a platform for speculative realism: a project to theorise closer to the material by speculating of what it means to perceive the world as specific objects. Doing so requires *tuning* into the materiality of objects, as described in the next section.

3.1 MATERIALITY AND REPRESENTATION

Materiality is a key notion in understanding objects independent of human perception. For OOO, materiality describes the way in which objects affect and are affected by one another; the way in which they unfold in the material realm (Bryant 2012). As such, materiality is contingent on the interaction of objects. There is not, for instance, a materiality of cotton. Rather, there is a materiality of cotton as it encounters, for example, fire. Harman elaborates:

> *When fire burns cotton, it makes contact only with the flammability of this material. Presumably fire does not interact at all with the cotton's odor or color, which are relevant only to creatures equipped with the organs of sense. Though it is true that the fire can change or destroy these properties that lie outside its grasp, it does so indirectly: through the detour of some additional feature of the cotton that color, odor and fire are all able to touch (G Harman 2011, 44).*

The passage hints at the relative nature of materiality. As in Barad's notion of agential realism or in the concept of digital materiality, Harman points to the way in which materiality is dependant on the specific associations an object enters. To the fire, only a portion of the cotton is material, in the sense that only its flammability is relevant to its own configuration. That is, the materiality of objects is defined by the way they perceive, transform and can be transformed by others. Moreover, materiality is linked to notions of representation and analogy. Perception of objects is limited and structured by its internal configuration: they perceive the world in their own terms (Morton 2013). The consequences of this are that all relations between objects are, in effect, based on a form of representation—every entity perceives each other through deformed, analogical images indexed to an original. That is to say, '*objects try to make sense of each other through the qualities and logics they possess (…) a rendering that captures some aspects of something else at the cost of other aspects*' (Bogost 2012, 66). Harman (2005) has described this process as following the structure of metaphor, a form of analogy characterised by the imperfect transfer of meaning from one domain to another. Although the term of metaphor is often used in the context of human perception, here it is used more broadly to describe the way all objects *perceive:* how they are transformed by other objects. In the example above, fire does not interact with all the properties of cotton: it interacts with a version of the cotton which is relevant to the internal configuration of fire. In doing so, we can say that it is creating a *metaphorical* representation of cotton: it engages only with some of the properties of fire which are relevant to its own configuration. This process, Harman argues, involves an imperfect transfer from one domain to the other — from all the properties of fire to a smaller subsection that is relevant to cotton — and can be therefore described as metaphors.

Doing philosophical work on the perception of objects requires a careful tracing of the metaphors at play in the interaction between objects, which define their materiality. Tuning into these metaphors is not only useful in philosophical enquiry, but is also relevant to design research. For instance, Ian Bogost (2012) has used *Alien phenomenology* to explore the creative opportunities of new technologies. The methodology involves carefully tracing the material exchanges of objects to draw *metaphorisms*: enhanced forms of metaphor aimed at describing how it *feels* to perceive the world as the specific object does. Bogost has applied *Alien Phenomenology* to explore the aesthetic potential of the *Foveon*, a new type of digital photographic sensor that was first incorporated by Sigma in 2010. The Foveon has created some debate in photographic circles due to its untypical performance at high light sensitivity settings. In *Bayer* arrangement, the predominant sensor typology, higher sensitivity settings are associated to a higher degree of noise, manifested as grain in the image. This has often been assimilated in the photographic aesthetic repertoire, as it operates analogously to the grain distribution of photographic film: higher sensitivity in film requires bigger silver halide crystals, which result in a more noticeable grain distribution in the image. High resolution settings in the *Foveon* sensor, however, result in chromatic aberrations: red hues shift towards yellow, with an almost total desaturation of green.

Bogost follows alien phenomenology to propose that the perception of foveon sensors is analogous to mesopic vision. Mesopic vision describes human vision in terms of threshold levels of light characterised by muted images with an overall blue cast. This is caused by a continuous shift between cones and rode cells. The human eye is composed of an array of photoreceptors, rods and cones, which transduce light into an electrical impulse. Rods react to the amplitude of the electromagnetic wave, transducing their response into grayscale intensity. Cones, on the other hand are sensitive to one of three possible frequencies, which correspond to red, green and blue colours. In low conditions of light, the human vision relies mostly on rods, which deliver a black and white image. In bright light, this is combined with information from cones, resulting in full-colour images. Mesopic vision refers to threshold lighting zones, where the brain switches between both modes, resulting in a desaturated image with a blue cast. This is analogical to the colour aberrations of foveon sensor. Alien phenomenology of the foveon sensor, Bogost concludes, provides a metaphor aimed at inspiring a creative response to what would otherwise be regarded as a technical limitation:

> *I'm sure both Foveon and Sigma are looking for ways to improve performance in the hardware and software. And one part of me looks forward to a firmware or RAW converter update. But part of me wonders why technical evolution must always represent fault, rather than opportunity. It is not everyday that a creative constraint of a whole new order emerges in an art form. The Sigma DP1 along with its DSLR cousins offer just such a thing: a coupling between light sensitivity and selective color rendering (Bogost 2008).*

The work of Bogost provides an important precedent in how the framework of OOO may be deployed connecting representation, analysis and analogy. This involves a notion that materiality depends on the exchanges of objects, which are characterised by concatenated processes of analogical transformation and representation. Moreover, analogy provides a methodology to explore the materiality of new technologies, and to integrate them meaningfully in a creative context. Analogies, however, are not only useful in understanding how objects relate to each other. They are also relevant in conditioning human cognition, and in producing frameworks through which we can understand invisible phenomena, such as wireless. I will analyse these connections in the following section, suggesting that we think through analogies in understanding the unknown.

3.2 ANALOGY

Analogy can be understood as '*a comparison between two objects, or systems of objects, that highlights respects in which they are thought to be similar*' (Bartha 2013, para. 1). One way of understanding analogy is to look at their speech instantiation in metaphors, similes and allegories. These devices are similar in that they all follow the structure of analogy, mapping elements from one domain to another, but do so in different contexts and to different extents. Metaphors, for instance, are considered to be expressions in which meaning is transferred from one element, the *vehicle*, to another, the *tenor*. The etymology is descriptive: the root *metapherein* is the ancient Greek word for *transfer*. The Russian poet Andrei Voznesensky (2011) uses metaphor to great effect when he writes: '*they sell the blood of God here on tap*'. Combining the image of divinity with that of blood and tap creates a powerful image that denounces a perceived transformation of religious sentiment in commodity. Similes are related, generally characterised by the use of the word like: '*life is like a game of cards*' (Schopenhauer 2007, 85).

In speech, analogy is often described as an extended metaphor that draw more formal links, and is aimed at understanding the workings of one unknown event in terms of a familiar one. When the character Jaques says *'All the world's is a stage/And all the men and women merely players/They have their exits, and their entrances/And one man in his time plays many parts*' (Shakespeare 1848, 32), he is establishing a classic case of analogy. First a comparison is drawn between stage and life at large. Then, the similarities are used to understand life through theatre: *'(…)last scene of all,/That ends this strange eventful history,/Is second childishness, and mere oblivion; Sans teeth, sans eyes, sans taste, sans everything*' (Idem, 33).

Analogy is not only helpful in speech. Hofstadter, for instance, places it at the core of human cognition:

> *(…) every concept we have is essentially nothing but a tightly packaged bundle of analogies, (…) all we do when we think is to move fluidly from*

concept to concept — in other words, to leap from one analogy-bundle to another — and (…) such concept-to-concept leaps are themselves made via analogical connection, to boot (Hofstadter 2001, 499).

The argument is premised on the notion of *chunking*. Throughout cognitive development, small children increasingly attain the capacity to *chunk* individual stimuli into higher-level categories. Sense perceptions—the colour red seen under halogen light, the smell of flowers—are clustered into bigger and more abstract concepts. Red is no longer an optical stimulus, but corresponds to a category or red hues, which in turn correspond to an abstract category of colours, which in turn associates to other categories such as warmth or danger. When we encounter different shades of red however, we are forced to fit perception imperfectly on previous experiences. Categories are in constant flux, morphing to accommodate new incoming sense perception. This process, Hofstadter argues, is analogy:

categories are quintessentially fluid entities: they adapt to a set of incoming stimuli and try to align themselves with it. The process of inexact matching between prior categories and new things being perceived (whether those things are physical objects or bite-size events or grand sagas) is analogy-making par excellence (…) the mental mapping onto each other of two entities (Hofstadter 2001, 504).

Lakoff and Johnson have made a similar argument, exploring the process of slippage between *vehicle* and *tenor*. They argue that human cognition is always bound to an oblique access of reality, based on indirect connection made through conceptual metaphors. The consequence of metaphor as conceptual system, Lakoff and Johnson (1980) go on to advance, is that metaphors condition the way in which we understand and construct reality. Example of this are the expressions '*He attacked every weak point in my argument*' or '*I've never won an argument with him*', which point at conceptual links between war and debate. These, they reflect, condition the way we produce and present arguments. Metaphors to dance, in contrast, would shape these around aesthetic performance and balance, resulting in radically different practices. Slippage in analogy also provides the basis for creative thought (Casakin 2007; R A Finke 1990; Ronald A Finke 1995; Ronald A Finke, Ward, and Smith 1992; Gentner 1981; Hesse 1966; Holyoak and Thagard 1989; Koestler 2014; Perkins 1994). The imperfect fit between one domain and the other often leads to cues that might reveal previously overlooked potentialities. Indurkhya has described how:

> *Whenever we notice that two objects or situations are similar, we can do so only with respect to their existing ontologies and descriptions. However, in analogy (…) a new ontology and a new level of description is created for the target object (Indurkhya 1989, 217–18).*

It is not uncommon, for instance, to use visual, verbal of spatial analogues in architectural education, which assist in solving under-defined design problems. For example, looking at how other designers have designed similar typologies, such as houses or schools. (Çubukçu and Dündar, n.d.; Casakin 2007). Also, analogy fares high in the development of science, especially in the emergence of new paradigms. In using the image of a tree as analogous to genetic evolution, for instance, Darwin inaugurated a new model for understanding nature. And although the image of tree as the structure of genetics comes natural in the modern framework: '*it is not immediately obvious why a tree is suited to represent evolutionary history – woodland trees do not have their buds in the present and their trunks in the past, for a start – the reason why trees make sense to us is historically and culturally, not scientifically, predicated*' (Hellström 2012, 234). The metaphor is effective in transmitting the central organising principle of shared descent: the notion that all species are related and have evolved from a common ancestor in the ancient past. At the same time, the metaphor is limiting. Sonia Stephens has observed how the tree of life is often depicted as an oak, with a thick, central truck. This structure, however, is inaccurate in describing early evolution. Stephens writes:

> *This thick, woody trunk doesn't map well to what we know about early evolution- for example, we now know that there were probably many instances of gene transfer among different groups of organisms early in*

the history of life. Some biologists have suggested replacing the traditional oak tree with an image of a mangrove, with many interconnected branches and roots near its base, in recognition of this early complexity in the history of life (Stephens 2011, para. 5).

Gruber (1988) has analysed how the analogy of the tree of life was highly influential in formulating the theory of evolution of species, and useful in formulating an eloquent discourse to disseminate it. It does, however, also constrains how we can think of evolution and, as described by Stephens above, potentially flattens the richness and complexity of its subject. Bartha (2013) reminds us that analogies are heuristic tools: they assist, but also constraint discovery by conditioning the way we can think of certain subjects.

4 MATERIAL REVERIES

In the previous section, I have provided a model of Object Oriented Ontology that connects materiality and representation through the structure of analogy. I have explained how OOO centres around the notion of objects, which refer to unified entities which cannot be reduced to their parts or to their effects. In this context, materiality is understood as emergent, contingent to the association of objects. Moreover, objects perceive each other through a process of representation: they interact through caricatures of each other. This process follows the structure of analogy: the imperfect translation of one domain to another. I have also mentioned how analogy is used by Bogost (2012) as a method to attune into the perception of objects. In a creative context, Bogost applies *alien phenomenology* to build *metaphorisms*, allusive images which inspire aesthetic potential for new technologies. I have also analysed the role of analogy in structuring human cognition. Central to this is slippage, the notion that *vehicle* and *tenor* become so intertwined through analogy, that they often become undistinguishable from each other. As such, we often tend to regard things in the terms of the analogies initially used to understand them.

In this thesis, I propose the use of analogy as a method to speculate on alternative materialities of wireless. Measuring and representing wireless involves a series of transactions — the construction of a probe to measure signal strength, logical processes to transform values into a visible pattern, a choreography to move the probe in space. Following notions of agential realism and digital materiality, I propose that these transactions *construct* the materiality of wireless. I propose to develop a creative practice approach that adapts tools and techniques developed in explorations by others to engage with the material transactions in representing wireless. This will be done by following a structure similar of *alien phenomenology* in tracing the materiality of the object. As such, it will explore the *material engagements* of wireless: the instrumental, the choreography, and the photographic. The term of *engagement* is inspired by the work of Thrift (2005), who argues that the exchanges between the registers of human body, software and screens, result in a new, emerging sense of materiality. The term highlights the concatenated nature of the process of producing materiality: each engagement is produced by a series of material transactions structured by analogy. In addition, engagements interact between themselves also in analogy.

Gaston Bachelard described the *reveries of matter*, which posits a deep connection between imagination and matter, evidenced in the material causes for poetic language: images of fluidity, reflection and depth are inextricably connected to water for instance. In this thesis, I am interested in exploring an inverse material reverie. Inspired by the project of New Materialism, I propose that poetic imagery can assist in exploring new materialities. In the previous chapter, I reviewed how representations of wireless infrastructure are often contextualized as providing means of increasing technical literacy, providing the means to integrate wireless in design. This against a backdrop where digital technologies are perceived as integrating poorly to the spheres of action of traditional design disciplines, as designers have little means of understanding their significance to everyday life. I suggest an alternative approach and use representation as an exploratory tool for new materialities: of placing wireless in new contexts that might inspire new poetic integrations of electromagnetic and tangible materials that go beyond the banal, convenient transfer of information. In this, I propose to borrow the poetic device of conceit to use representation as a tool to explore alternative materialities of matter. The work of metaphysical poets, a term coined by Samuel Johnson to describe a movement within 17th century English lyric poetry, is characterised by the use of *conceits,* which refer to ingenious forms of metaphors that are drawn more for their effect rather that for precision between *vehicle* and *tenor*. It works by manipulating images and ideas in often outlandish ways to invite new or more sophisticated understandings of the subject at hand (Gardner 1985; Eliot 2014). Similarly, I propose a form of *material slippage*, in which a conceit is introduced to place wireless technologies in unprecedented contexts, deriving new materialities from the exercise. This involves shaping the exploration in material engagements through the *material conceit of spectralities:* the analogy of understanding wireless through notions of spectres and ghosts that emerged in the 19th century as a result of the introduction of the first generation of wireless technologies for telegraphy and radio broadcast.

In the context of wireless infrastructure, an analogy often used is to compare electromagnetic signals to physical terrain. The analogy was most influentially developed by William J. Mitchell in *Me++*:

> *Every point on the surface of the earth is now part of the Hertzian landscape(…) The electromagnetic terrain that we have constructed (…) consists of hotspots and deadspots, exposed areas and shielded areas, cells that get you through and overloaded cells that don't, signals (encoded in many different ways) that interfere with one another and signals that are cleverly multiplexed so that they don't interfere, jammed zones and Faraday cages, and the endless buzzes and bursts of electromagnetic noise. It is an intricate, invisible landscape (Mitchell 2003, 55 Italics not in the original).*

The analogy has proved deeply influential in developing a materiality of wireless infrastructure in the sense that it has conditioned the way we think of its substance, how it can be manipulated and integrated in spaces and artefacts. Dunne and Raby, for instance, use it to create an allusive image of how wireless operates as an '*'electroclimate' defined by wavelength, frequency and field strength. Interaction with the natural and artificial landscape creates a hybrid landscape of shadows, reflections, and hot points*' (1998, 78). The analogy has also influenced the design of instruments to measure and represent it. I analysed in the previous chapter how the authors of *Immaterials* conceptualise their instruments by drawing direct parallels to cartography, suggesting that their instruments survey the immaterial landscape of wireless infrastructure.

The use of the conceit of *spectralities* looks to provide possibilities which would be otherwise impossible operating within the tools and practices established by the metaphor of electronic landscape. I will describe both analogies in detail in the next chapter, delineating aspects of spectralities which will be useful and reflecting on the limitations of the electronic terrain metaphor.

5 CONCLUSIONS

In this chapter, I have defined the notion of materiality, and derived a creative practice methodology by exploring its connections to representation and analogy. I began by reviewing the concept of materiality in design, where it is used to refer to the intuitive knowledge which hint at how materials can be manipulated. Technological advances in the last fifty years have prompted a revaluation of materiality. Example of this is the theory of Manzini, who argued that in the absence of direct engagement with the material, it is allusive language that substitutes to navigate through an expanded material catalogue. Of interest is the way these arguments have been developed further to contemporary concerns of the integration of digital technologies in traditional design disciplines. Digital tectonics, for instance, aims to integrate physical properties of materials in digital simulations. Notions of digital materiality have also been used in the study of software, proposing that materiality is an emergent property of technologies in use. These contemporary discourses suggest an understanding of materiality as emergent of their contexts of operation and use.

In the second section of this chapter, I have suggested that New materialism offers a useful framework to structure a design exploration of materiality. I reviewed how the emergence of new materialist schools of thought have run parallel to discussions in design, especially in a drive to address the increasingly complex material landscape. Object Oriented Ontology offers a structure which allows to link materiality with notions of representation developed in the last chapter. OOO hinges around a system of flat ontology with objects at its core. Objects are understood as unified entities which cannot be reduced nor explained entirely to their constituent parts, nor to the effects. Moreover, a flat ontology allows us to consider any object, animate or inanimate, on a par. This provide a framework to tune into their materiality, understood as the way in which objects unfold in the material realm: the way they *perceive* other objects, are transformed and affect each other. Perception in this context operates on a model of analogy: objects translate and reduce each other to caricatures that are relevant to their own configuration.

Placing analogy at the core of object interaction and perception suggest its use as a methodology to tune into their materialities. This is developed in alien phenomenology, a critical method for characterising object perception. It involves tracing the material exchanges between objects, which are used to draw a metaphorism, an enhanced form of metaphor aimed at describing how it *feels* to perceive the world as the specific object does. I have also argued that analogy is not only relevant in understanding the materiality of objects, but also allows structuring our own perception of them. This is based on theories which suggest analogy as the structure of human cognition. Of particular relevance to the representation of the invisible is the slippage of analogies: the tendency for *tenor* and *vehicle* to blur in cognition, to a point where one is indistinguishable from the other. Based on this analysis of analogy, I have proposed the use of material conceits as a strategy to speculate on alternative materialities for wireless. Conceits are a form of extended metaphor intended to introduce ingenious images to allow thinking of a subject in different or more sophisticated ways. In representing wireless infrastructure, an analogy often used is wireless as and invisible electronic terrain . Although this analogy has been deeply influential and useful in thinking through the consequences of the use of digital technologies in contemporary cities, it also constrains understanding of how they change space in an architecturally relevant way. I propose material conceits as a way of structuring an exploration of other materialities possible for wireless, which might suggest the poetic coupling of electromagnetic and material elements described by Dunne. In the next section, I will review the analogy of electronic terrain at more depth, and provide elements of the *wireless as spectre* conceit which will become relevant in the creative exploration in the second part of this thesis.

Materiality

I believe on the contrary that the future belongs to ghosts, and that modern image technology, cinema, telecommunications, etc., are only increasing the power of ghosts

Jacques Derrida in Ghost Dance

CHAPTER 3

3

LANDSCAPES AND SPECTRES

LANDSCAPES AND SPECTRES

1

INTRODUCTION

The last chapter proposed a creative exploration inspired by the use of conceits in 17th century poetry, where unusual metaphors were introduced to explore topics that had been overly examined, and for which there were well established analogies that constrained ways of thinking about them. This is proposed in a context wherein wireless infrastructures are often depicted as landscapes, which has conditioned practices of representation to allegories to cartography and map-making. As an alternative to this, I suggested *wireless spectralities*, an analogy often used in the 19th century to describe incipient wireless technologies.

In this chapter I examine both, original metaphor and conceit. In the first part, entitled *Electronic Landscapes*, I will analyse the analogy of wireless as electronic terrain of cities. Used by William J. Mitchell in his highly influential *Me++*, the analogy participates in a wider tradition of understanding technology as an extension of the body, which dates back to the work of 19th century German philosopher Ernst Kapp. Buckminster Fuller evolved this into a modern understanding of mechanical technology as physical extension of the body, inspiring Marshall McLuhan to formulate this theory on electronic media as extensions of the nervous system. These authors come together in the *Delos* events, which introduce their work to a number of architects and urban planners influencing the emergence of *Ekistics*. The discipline prefigures contemporary interest in the way that technology change understanding of the urban environment, and serves as direct influence to the work of Mitchell and his understanding of wireless as electronic terrain. I propose that in this context, the analogy of electronic landscape helps in highlighting the relevance of wireless infrastructure in the organization of cities. Moreover, it actualises the objectives of Ekistics, in bringing the technological within the area of concern for architects and urban planners. This mission is carried out by the host of projects and practitioners reviewed in chapter one, creating visualisations which deal with the materiality of wireless as placed in the context of urban environments.

In the second part, *Wireless Spectres*, I propose an alternative metaphor of *wireless spectralities* as as inspiration to explore new materialities of wireless. I will review how its emergence in the 19th century inspired an understanding of wireless technology as infused with a spectral character. This is illustrated, for instance, in the parallel emergence of wireless and the movement of New Spiritualism, which combined elements of ghosts and spectres from the 18th and 17th century with the mechanisms of operation of the new technology. The idea of wireless spectralities is creatively useful as it invites three new materialities of wireless. One, it enables to think of wireless as a substance that *thickens* space, in the way that notions of ether suggest. Two, notions of mesmerism and mediumistic trance suggest an interaction of the human body and invisible forces, made visible through violent spasms and ectoplasm. Third, the figure of medium as an instrument of the spiritual telegraph predates explorations on the idea of the human body as an instrument to detect electromagnetic fields. These new aspects will help in informing the exploration of the *engagements* of wireless in the next chapter.

PART 1. *ELECTRONIC LANDSCAPES*

1

INTRODUCTION

In 2003, William J. Mitchell published *Me++ The cyborg self and the network city*, a book thought to culminate a trilogy delineating the effects of digital technologies on urban environments. Kinsley describes it as '*playfully grandiose and hopefully dystopian*' (Kinsley 2013, 1520) in reflecting on the style used by Mitchell to point at the impeding merge of *bits* and *atoms*, of the digital and the physical, and of the profound consequences of this in the understanding of the city. Central to Mitchell's discourse is the notion of the 'spatially extended cyborg', an emerging human being intimately connected to technology '*in a mutually recursive process that continually engages ... fluid, permeable boundaries and my endlessly ramifying networks*' (Mitchell 2003, 39). Here the *networked city* is the human body, technologically '*extended with connective urban architectures and infrastructures*', conceptualising the city as a '*prosthesis to the recursively connected body*' (Kinsley 2013, 1521).
In bringing together figures of city, technology, the body and prosthetics, Mitchell engages in a metaphorical play, which is intended to provide new ways of thinking of digital technology, and of how it can be designed to create specific experiences of the urban space. Specifically, he connects wireless with the figure of terrain, inviting a conceptual interchange between the two:

> *Every point on the surface of the earth is now part of the Hertzian landscape(…) The electromagnetic terrain that we have constructed (…) consists of hotspots and deadspots, exposed areas and shielded areas, cells that get you through and overloaded cells that don't, signals (encoded in many different ways) that interfere with one another and signals that are cleverly multiplexed so that they don't interfere, jammed zones and Faraday cages, and the endless buzzes and bursts of electromagnetic noise. It is an intricate, invisible landscape (Mitchell 2003, 55).*

The mission of Mitchell is to bring the technological into the range of action of design: to think integrally of how technology produces spatial effect in the city, providing poetic images connects them. Moreover, in understanding the city as the prosthetics of the human body, Mitchell participates in a tradition inaugurated by *Delos,* a series of events which saw the emergence of Ekistics, a new discipline to study urban environments with an emphasis on the impact and use of electronic technologies. The events bring together the work of Marshall McLuhan and Buckminster Fuller, who had developed the notion of technology as prosthetic extensions of the human body, a framework first proposed by German philosopher Ernst Kapp. The following section will review the Delos events, and the image it developed of technology as prosthetic extension of the human body.

2 DELOS AND THE CITY OF THE FUTURE

In the summer of 1964, Constantino Doxiadis organised the first *Delos symposion*, an eight-day event held on board of the *New Hellas* while sailing the Cyclades archipelago, and discussing the evolution of human settlements. The event was modelled on the *Congrès International d'Architecture Moderne* (CIAM), a series of events that disseminated modern architecture, and especially in its fourth meeting, held in a ship travelling from Marseilles to Athens. The description of the event as a *symposion*, after the Greek word instead of its Latin counterpart of symposium, was intended to signal '*a radical mixing of intellectual activity and sensual pleasure as the boat travelled from island to island*' (Wigley 2001, 84). Doxiadis, an architect and urban planner, held the theory that industrialisation had introduced changes to the urban environment which were unprecedented in their speed and scale. Traditional methods of analysing the problem, as well of designing cities, had therefore to be reinvented as to keep pace with the increasing complexity. In this context, the *Delos symposion* was also intended as a platform for *Ekistics*, a discipline instituted by Doxiadis in the mid 1950s and that can be described by modern standards as a field that conflates urbanism with data mining and visualisation. Wigley elaborates:

> *The idea was to think at the largest possible scale by domesticating vast*

amounts of global information. If the data could be controlled, cities could be controlled. Courses in statistical analysis became "indispensable" for architectural training. Spatial patterns would follow from detecting patterns in the flow of information. Design would begin with precisely calibrated charts rather than artistic sketches (Wigley 2001, 87).

2.1 EXTENSIONS OF MAN

Central to Delos are the ideas of Buckminster Fuller and Marshal McLuhan. Wigley (2001) for instance characterises the first Delos event, and its subsequent ten editions, as a reverberating chamber for McLuhan's theory of electronics prosthetics of man. McLuhan argued that media fundamentally changes the way in which humans are capable of relating to the world, and informing new ways in which it can effect change upon it—that is, technology creates humans inasmuch as humans first create technology. By the time of the Delos conference, McLuhan had developed his argument in *Gutenberg Galax*y (2011), in which he argued that the invention of the printing press had affected the interrelation between human and world. Before the printing press, people would rely on an interplay of senses to make sense of their surroundings. The rapid reproduction and mass availability of books shifted this to institute a tyranny of the visual, pre-empting contemporary, visually-oriented culture.

By the time of the Delos event, McLuhan had been developing his argument further in the draft for his *Understanding Media: The extensions of man*. On board he presented the issue of electronic media as one of urban settlement. He argued that electronic technologies had effectively extended the human body by providing new ways of sensing and acting upon distance. The result, he advanced, was that the world was to shrink in apparent size, potentially becoming a global village. To think of evolution of technology is, to some extent, to think of the evolution of the human body. Wigley analyses the implications of this argument to networks: '*Networks of communication, like* *any technology, are prosthetic extensions of the body. They are new body parts and constitute a new organism, a new spatial system, a new architecture. This image of prosthetics (…) was now reframed as an architectural image*' (Wigley 2001, 86). The transformations brought about by electronic technologies, he proposed at the Delos event, are now within the province of architects and urban planners. McLuhan develops his argument:

> *The electronic age with its tremendous speedup of communications has created a situation of 'implosion' rather than explosion. The technological age extended man's physical senses enormously, the electronic age is now extending the nervous system. Technology separated our different functions and distributed them widely in space; electronics fuses them together and overlays them (McLuhan in 1963 Delos Documents, quoted by Wigley 2001, 115).*

In the Ekistics journal edition covering the Delos symposion, McLuhan will be reported as stating:

> *Electronic technology has extended the brain to embrace the globe; previous technology had only extended the bodily servants of the brain. The result now is a speedup of information that reduces the planet to the scale of a village—a global consciousness thus becomes the new human scale (McLuhan in Ekistics, October 1963. Quoted by Wigley 2001, 115–16).*

McLuhan suggest a gradual augmentation of the technological body. Mechanical technology had extended the reach of the human body by creating new means of transportation, distribution and production. Electronic technology, however, extended the human body in a deeper sense, by modifying the nervous system—it effectively creates new senses.

The evolution also hints at a continuity between the theory of McLuhan and Fuller. McLuhan reportedly met Buckminster Fuller for the first time on board of the New Hellas, and confessed to having modelled the notion of the electronic prosthetics of the human body an earlier concept by Fuller of the mechanical prosthetics of man (Fuller 1938). Fuller proposes a vision of the mechanised man, in which the human body extended by machinery is symbol of progress and prosperity. In a poetic rendition of this argument, Fuller likens technology to deity: '*I see God in / the instruments and the mechanisms that / work / reliably, / more reliably that the limited sensory departments of / the human mechanism*' (Fuller 1971, 2). The poem, written at the height of second world war, praises the mechanical extensions of the body, and highlights the progress it affords:

> *(…) there are those / who cogently argue / that man still falteringly progresses / by the two forward and one back / locked-step of / an active inferiority complex. / But any way / we may choose to argue, / the fact is unaltered that / man has already captured / harnessed and put to work / what is relatively / a whole lot of motion / He has already devised / certain mechanical extensions / of his integral mechanics, / one thousand square miles of whose/ bearing surfaces / are now all in motion / relative to / one thousand square miles / of their complimentary / supporting and controlling mechanical surfaces (Fuller 1971, 36–37).*

The argument of Fuller reaches the natural conclusion of the work of German philosopher Ernst Kapp, who proposed the thesis that technology is modelled after the shape and function of human organs:

> *The intrinsic relationship that arises between tools and organs, and one that is to be revealed and emphasized (…) is that in the tool the human continually produces itself. Since the organ whose utility and power is to be increased is the controlling factor, the appropriate form of a tool can be derived only from that organ (…) the bent finger becomes a hook, the hollow of the hand a bowl: in the sword, spear, oar, shovel, rake, plow, and space one observes sundry positions of arm, hand and fingers (Kapp quoted by Mitcham 1994, 23–24).*

The thesis of organ projection, Mitcham argues, set the groundwork for a philosophical understanding of technology: the possibility of looking at technology not only as a way of solving practical problems, but also as a way in which humans project themselves onto the world. His work follows early ideas of technology in the work of Aristotle, but explore it at depth and provides specific examples of organ projection. He reflects, for instance, how railways can be described as an externalisation of the circulatory system, or telegraph as an expanded nervous system.

2.2 ***WIRELESS AND TERRAIN***

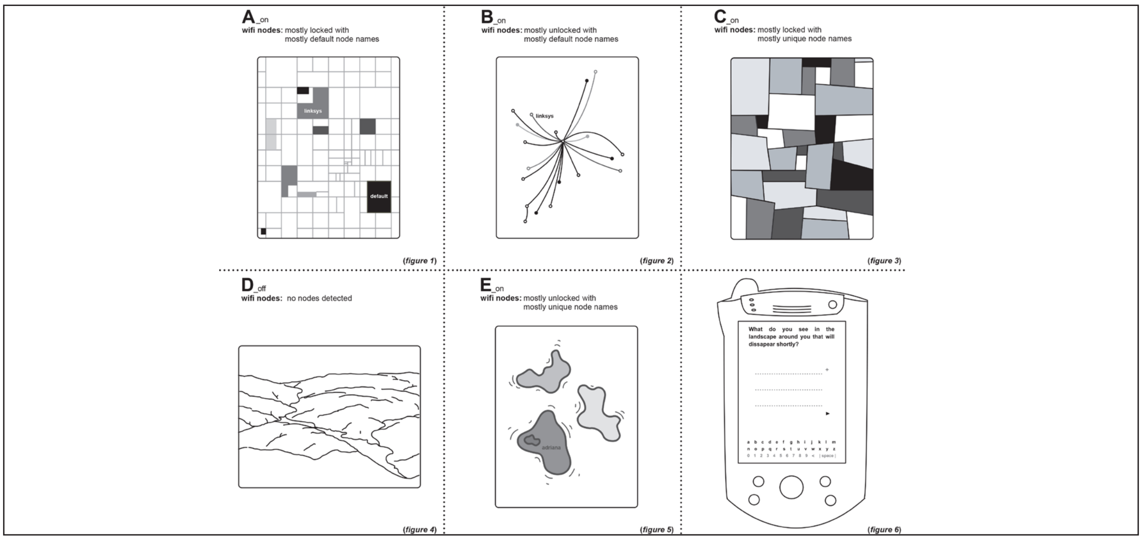
Kapp's philosophy of technology provides the basis to think of technology beyond its pragmatic dimension, and more as an expression of the self. Additionally, notions of technology as prosthetic extension of the body prefigure 20th century approaches to technology, especially in the interpretation of wireless technologies as electronic terrain of the city.

Wigley has argued that the 19th century discourse of philosophy of technology is updated in the work of Buckminster Fuller and Marshall McLuhan to expand the conception of the body to that of, first, the city and, eventually, the whole world. Given the scale of the technological body, Fuller and McLuhan believed that electronic technologies would need to be engaged by architects and planners in order to produce the new spatial and architectural logic that enabled its full potentiality. Later in the century William J. Mitchell participates in this argument and proposes that electronic technologies can be understood through the terms and logics of the physical city. By describing wireless as an electronic terrain, he highlights the relevance of wireless infrastructure in the organization of cities, bringing it within the area of concern of designers. The image proposed by Mitchell establishes a particular materiality for wireless. Its features can be thought of in terms of topography: it possesses a changing profile, with high and low points which present obstacles or facilitate human activity. More explicitly, it can be approached using methods similar to those of cartography. I described in the previous chapter how the Immaterials project draws inspiration from the techniques and instruments of land surveyors to develop the pole they use to create their visualisations. Similarly, Alison Sant produces *maps* to describe the experience of wireless, exploring the use of conventions used to describe land features to codify material aspects of wireless infrastructure (see figure 8). Also related is the work of *LaLaLab* (see figure 9), the artistic duo or Clara Boj and Diego Diaz who embedded a device to visualise the density of wireless networks in the city inside a tower viewer ("Observatorio, Clara Boj and Diego Diaz" 2008). Other explorations also depend on the materiality of wireless connected to the urban environment. Gordan Savičić's *Constraint City* consists of a corset that signals the presence of encrypted networks in the city by tightening its straps (see figure 10). The project is intended to make tangible the '*resonant landscape, consisting of electromagnetic waves*' which '*bypasses human, buildings as well as vehicles through the streets*' (Savicic 2007) and has been deployed in different cities where different *walkers* participate to create a catalogue of urban pain experiences.

3

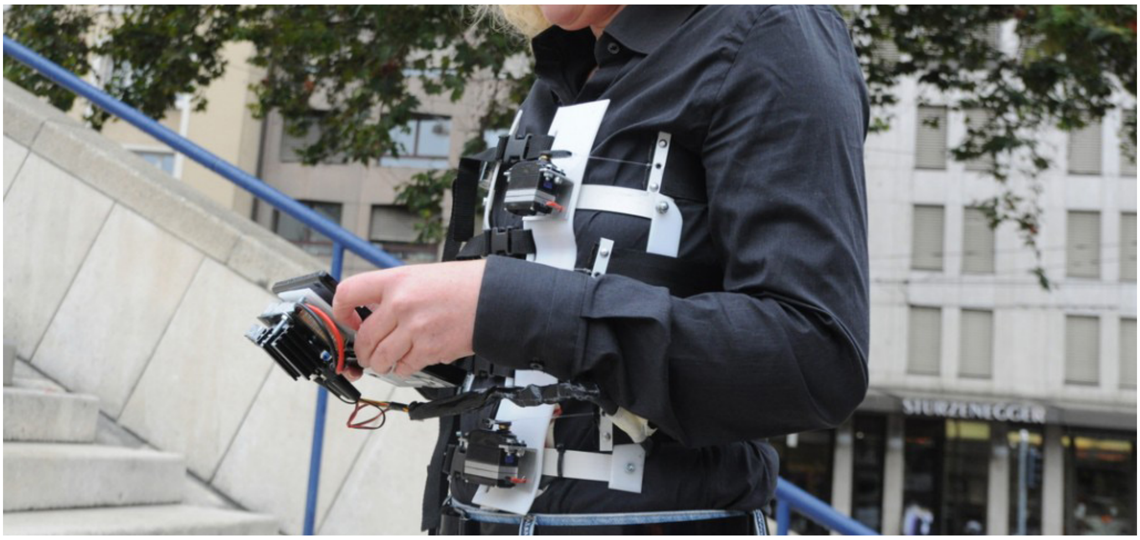
SHIFTING THE BASE METAPHOR

In the previous chapter, I have analysed the use of metaphor as heuristic tools, and in how they are useful in guiding exploration while, at the same time, limiting the way we can think of certain subjects. As an example, I referred to the use of trees as analogy to the theory of evolution. While the image of trees is generally useful in describing shared descent, it is also limiting as it flattens the complexity of the early history in the evolution of life. A similar argument can be constructed around the use of terrain as analogy for wireless infrastructure. William J. Mitchell uses it to great effect in his trilogy of bits, and especially in *Me++ The Cyborg Self and the Networked City*, where the analogy is used with two goals in mind: First, Mitchell is interested in bringing digital technologies to the realm of traditional design disciplines such as architecture and planning. Second, to offer an alternative interpretation to the notion of technology as prosthetics, which had until then taken the guise of cyberspace that separated the mind from the shackles of the physical body. Kinsley reflects on the role of Me++ in bringing the materiality of the



8 Map of corporeal experiences facilitated by wireless

9 Tower viewer fitted with visualisations of wireless in the city



10 Constraint device prepared for a wireless walk body to the discussion of digital evolution:

> *Me++ attempts a shift in spatial registers, with the (human) body as much more of a focal point. Gone now is the earlier (1995), somehow separate realm of 'cyberspace', replaced by 'a world of less rigid, more fluid and flexible relationships – of knowledge to action, of shape to materials, and of people to places' (Kinsley 2013, 1520)*

By describing wireless as part of the terrain of cities, Mitchell inspired a generation of designers to think of the consequences of technologies in architectural and urban spaces. It is limited, however, in imagining its materiality: in finding specific design possibilities of how they can be integrated in producing objects and spaces. I have argued that the metaphor of electronic terrains constrains the materiality of wireless to the city, and provide specific ways of thinking about it. It enables imagining a *texture* of wireless indexed to the physical features of terrain: as a changing profile with highs and lows which constrain or facilitate human activity in a geographical area. In this thesis, I propose that by using a conceit we might be able to *creatively re-appropriate* wireless infrastructure: uncovering new possibilities that might suggest new ways of thinking of these technologies and of their integration with artefacts and spaces. In the second part of this chapter, I will propose an analogy that predates the interpretation of technology as prosthetic extensions and that, I will argue, tune into other aspects of the relationship between body and technology that the notion of prosthetic extension usually overlook. I am particularly interested in the way nineteenth century interpretations of wireless as spectral technologies enable exploration of three material possibilities. First, the notion of aether presents an image to think of wireless as an invisible substance that infuses the spaces, affecting its inhabitants. Second, ether also presents new ways of thinking of the interface between body and technology, such as mesmerism and mediumship. Third, mesmeric trance also suggests the human body as a form instrument to reveal invisible fluids.

PART 2. *WIRELESS SPECTRES*

1

INTRODUCTION

The 19th century saw a period of rapid technological and scientific development, which caused momentous social and cultural changes. In dealing with these, a tradition arose of representing wireless technology using mystical and fantastic figures, especially spectral and monstrous ones (Blanco and Peeren 2013). This catalogue of analogies and parallels slowly built a public imaginary that connected the scientific with the occult. Example of this, Sconce proposes, is the parallel emergence of telegraphy and *New Spiritualism.* In 1844, Samuel Morse demonstrated the use of a telegraphic line to transmit a message encoded as a series of dots and dashes. The first public demonstration involved transmitting the message '*What had God wrought*?' from Washington to Baltimore, inaugurating with this a rapid expansion of telegraphic lines across the United States and later between countries. The telegraph captured the public imagination. An 1860 journalistic report on the telegraph described how it enabled '*to send communications, by means of the mysterious fluid, with the quickness of thought, and to annihilate time as well as space*' (Gleick 2011, 148). A British engineer would also observe: '*Distance and time have been so changed in our imaginations that the globe has been practically reduced in magnitude, and there can be no doubt that our conception of its dimensions is entirely different to that held by our forefathers*' (Idem).

Sconce analyses how the telegraph also suggests to think of human consciousness as detached from the human body, opening the possibility of a telegraphic line to the spiritual world. Four years after the introduction of the telegraph in 1848, Lea, Margaret and Kate Fox reported a series of events that would lead to the emergence of *New Spiritualism.* On the night of March 31st, the Fox sisters experienced a series of night disturbances in their cottage in Hydesville, New York. Previous tenants had reported strange noises in the property, including knocking and rapping, without being able to locate the source. The Fox sisters engaged the events playfully, aping the sounds. At one point Kate shouted '*Here, Mr. Split-foot, do as I do*' and clapped three times, which were followed by three raps in response. Later their mother, Margaret Fox, started a dialogue with the unseen presence: '*by rapping its answers to the questions (…) the spirit correctly counted to ten, identified the ages of the Fox children, and numbered how many of the Fox family were still alive and how many were dead. Later the spirit responded to more complex questions by rapping once for "yes" and twice for "no"*' (Sconce 2000, 22). The events triggered the emergence of *New Spiritualism*, a collection of mystical beliefs revolving around the possibility of communicating with the spirit world, inspired by the operation of emerging technologies, especially telegraphy and electricity. This resulted in a blend of mystical and technological terms and concepts. The popular press, for instance, described the events in Hydesville as having inaugurated a telegraphic line to the spiritual world. Chronologist Mary E. Cadwallader (1917) extended the metaphor to refer to the Fox family as *spiritual telegraphers.* Similarly, in *Present Age and Inner Life*, Andrew Jackson Davis includes the illustration in Figure 11, depicting an assembly of people around a so-called spiritualist circle. A cable connects them to the skies, channelling the spirits:

> *The spirits (…) sustaining a positive relation to us, are enabled through mediums, as electric conductors, to attract and move articles of furniture, vibrate the wires of a musical instruments, and, by discharging, through the potencies of their will, currents of magnetism, they can and do produce rappings, on principles strictly analogous to the magnetic telegraph, and may move tables, or tip them, to signify certain letter of the alphabet (A. J. Davis 1853, 66).*

Noakes reflects on how telegraphy and spiritualism was perceived as indistinguishable to the 19th century British public. The notion of communication at a distance, first through wire and then through the air, presented as magical a possibility as communicating with the non-living. This explains the slippage between technology and mystical thought, where the spirits in the Fox family cottage seem to communicate with raps in the same way the Morse code was transmitted through electrical impulses. He writes:

> Indeed, Victorians in the mid- nineteenth century often found it hard to distinguish between telegraphy and spiritualism. In the early 1850s, the British public grappled with mysterious spiritual communications at the same time as new telegraph companies told them it was possible to use electricity to contact friends on earth. Spirits of the dead 'rapped' out messages on a 'spiritual' telegraph, much as messages on the electric telegraph were exchanged via Samuel Morse's code of raps (Noakes 2008, 422).

11 Engraving explaining the mechanisms of spiritual communication, originally included in Present Age and Inner Life

2

WIRELESS SPECTRALITIES

The discovery of electromagnetism, and later the development of wireless technologies, amplified the exchanges between mystical and techno scientific thought. This is a period characterised by a cross fertilisation between both fields, with a rapid succession of technological advances inspiring developments in the spiritualist movement, and mystical concepts inspiring new scientific models and technological developments (Noakes et al. 2002; Noakes 2008; Sconce 2000). Luckhurst describes the interplay between magical and technological thinking during the 19th century:

> *Every scientific and technological advance encouraged a kind of magical thinking and was accompanied by a shadow discourse of the occult. For every disenchantment there was an active re-enchantment of the world. Because the advances in science were so rapid, the natural and the supernatural often became blurred in popular thinking, at least for a time (Luckhurst 2015).*

Luckhurst challenges prevalent historical accounts which see the 19th century as the pinnacle of the *disenchantment of the world*, a term used by sociologist Max Weber to refer to modern culture as characterised by a decline in mysticism and magical thinking, brought about by the scientific revolution. Luckhurst observes how Victorian fascination with supernatural forces, ghost stories and energies attest to a complex and nuanced process, in which '*it is much easier to grasp the religious and scientific strands of the century as closely intertwined*' (Luckhurst 2015). Looking at contemporary culture, Landy and Saler (2009) similarly propose that whilst rationalisation is the driving force of modernism, there is an equally powerful undercurrent of mysticism and magical thinking, a *reenchantment of the world*. In digital communication cultures, for instance, Erick Davis (2004) has explored the influence mysticism and magic thinking has had in the development of technological devices and social practices around them. In this thesis, I propose to use 19th century spectral metaphors of wireless as a device to explore new materialities.

There are three specific aspects I am interested in. First, early work on electromagnetism involved the theory of aether, an invisible substance thought to serve as medium for electromagnetic phenomena. Although its scientific validity was eroded by the theory of relativity, notions of ether suggest that space is filled with a rarefied form of air that thickens it, allowing for signals to travel. Second, the notion of aether is often associated to the interface between electromagnetism and body, exemplified in the action at a distance of animal magnetism, mesmerism and mediumship. Third, mesmeric trance also presents the human body as a form of instrument which allows to reveal the different qualities of electromagnetic signals. This derives in a number of morphological detectors, where bodies' electrical conductivity is used as a means of producing a probe for the unseen. These three themes are analysed in the following sections to create a context for the explorations documented from the following chapter onwards. These will provide inspirations in the form of general concepts, practices and instruments, as I will detail in the exploration of material engagements in chapter four.

2.1 ETHEREALITY AND SPACE THICKENING

Ether refers to a model in 19th century physics which attempted to reconcile the discovery of waves with prevalent mechanistic models. In the classical physics model proposed by Newton, gravitation was the only force capable of acting at a distance: without a chain of direct mechanical contact. Early research by Coulomb and Ampere conceptualised electric and magnetic forces as a special form of gravitation force in keeping with Newtonian physics. In 1820 however, Hans Christian Oersted discovered that electrical and magnetic forces combine, creating a new form of wave that could not be entirely explained mechanistically. During a lecture at the University of Copenhagen, he noticed that a magnetic needle was deflected when electric current was passed through a wire nearby, describing the action of an unknown force travelling through space: '*(…) the electrical conflict is not confined to the conductor but is dispersed quite widely in the surrounding space. It is also evident that the forces of the electrical conflict operate in circles*' (Oersted cited by Garratt 1994, 3). In building a mathematical model to account for Oersted observations, Maxwell proposed a special form of air, the *ether*, as the medium through which electromagnetic forces travelled. This allowed an explanation of how light travelled through space despite the absence of air. In his contribution for the Encyclopaedia Britannica, Maxwell explained:

> *ETHER, or Æther (αἰθήρ, probably from αἴθω, I burn, though Plato in his Cratylus (410, b) derives the name from its perpetual motion — ὅτι ἀεὶ θει περὶ τὸν ἀέρα ῥέων, ἀειθεὴρ δικαίως ἂν καλοιτο), a material substance of a more subtle kind than visible bodies, supposed to exist in those parts of space which are apparently empty (….) Whatever difficulties we may have in forming a consistent idea of the constitution of the aether, there can be no doubt that the interplanetary and interstellar spaces are not empty, but are occupied by a material substance or body, which is certainly the largest, and probably the most uniform body of which we have any knowledge (Maxwell 1891, 568).*

Ether has a mystical lineage. Aether is a central figure of greek mythology, located amongst the so-called elemental gods. Roman historian Hyginus places him as the son of Erebus (personification of darkness), and Nyx (that of night), and brother of Hemera (that of day). Aether is among the primordial elements out of which the world was created, and constituted the mist of light that enveloped the world of gods, in parallel to *Aer*, the mist which mortals breathed, and *Erebus*, the mist of the underworld. Aether was to be found in mountain tops and the celestial bodies (Smith and Stray 2007). Aristotle believed ether to be the substance of '*the supra-lunar sphere of the divinely changelessness*' (Armstrong 1967, 40) and proposed that ether constituted a semi-corporeal soul, the *primum movens* or that which moves without being moved. The concept of aether found in Aristotle is inherited by medieval philosophy, and became a central notion of Alchemy in the shape of quintessence. Alchemists believed quintessence to be the substance of the heavenly bodies, present in small quantities on earth and that could be distilled to prepare elixirs (Taylor 1992; Haeffner 2004).

In Physics, the notion of ether provided a proxy concept, whose properties were never exhaustively defined, thus remaining flexible enough to explain electromagnetic forces in a way that made sense within a Newtonian framework. Hunt (1986) describes how Oliver Lodge developed a series of experiments in the 1890s to provide the existence of the ether in an experimental setting. Despite the sophistication of his instruments and methods (see figure 12), he was unable to provide any evidence for its existence. Instead, he proposed that the ether was too subtle and perfect in its properties as to be directly detectable, a strategy Hunt describes as the *etherealisation* of ether: the stripping down of most physically detectable properties from its concept. The flexibility of the ether also allowed for the merger of techno scientific and mystical discourses. The *Cambridge ring* for instance, a group of physicists based in Cambridge University, used the figure of aether to develop a holistic philosophical system which merged spirits and electromagnetic forces. The merging of mystical and physical forces operates in contrast to materialism, the philosophical school which positions matter as the basis to explain any phenomenon in the universe, including the emergence of human consciousness. As a consequence, any event in the world can be assessed and described through the senses and by following a scientific methodology. The materialist position was largely promoted by the industrial revolution in the Victorian period, producing counter movement within science and philosophy that sought to re-establish the paradigm of an unified cosmos that allowed for the coexistence of matter and spirit (Bowler 2010). The group had a considerable number of adherents, such as Rayleigh, Thomson and William Barret. The most vocal member of the group was Lodge himself, who would produce a considerable amount of scientific and mystical texts intertwining both narratives. On refuting the notion that everything that is real can be measured and scientifically accounted for, Lodge writes:

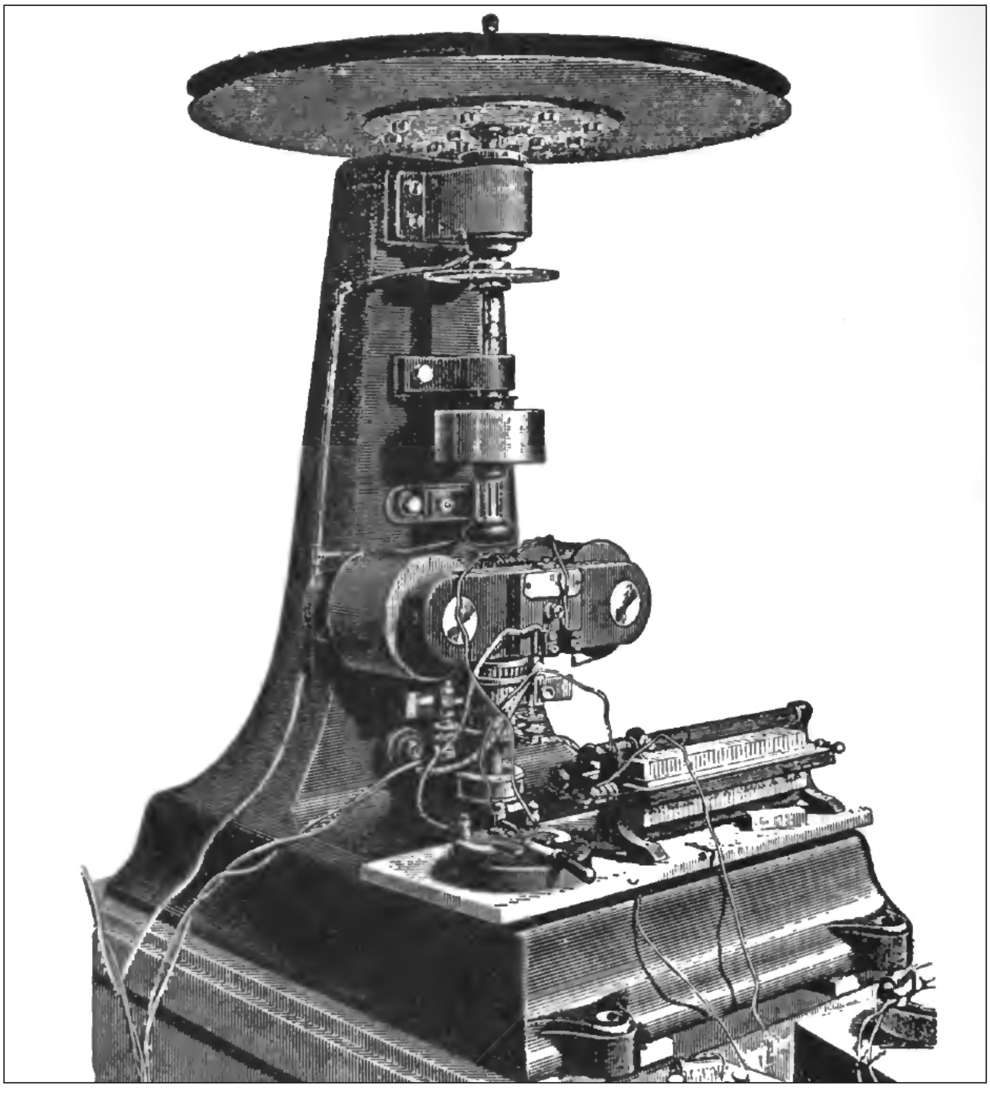
> *Our senses limit us, but do not deceive us: so far as they go, they tell us the truth […] To suppose that our experience of the necessary and fundamental connexion between the two things—the something which we know as mind and the something which is now represented by matter—has no counterpart or enlargement in the actual scheme of the universe*

> *[…] is needlessly to postulate confusion and instrumental deception. Philosophers have been so impressed with this that they have conjectured that mind and matter are but aspects, or modes of perception, of one fundamental comprehensive unity; a unity which is neither exactly mind nor exactly matter as we conceive them, but is something fundamental and underlying both, as the ether is now conceived of as sustaining and in some sense constituting all the phenomena of the visible universe (Lodge 1908, 256–57).*

In the same tradition, Emile Berliner, inventor of the microphone and gramophone, speculated on the possibility of radio as means of communication with the after-life. Radio, he suggested, picks vibration from the ether, and the dead '*simply vibrate at a slower rate*' (Blanco and Peeren 2013) as compared to the living.

In borrowing from mythology, the theory of ether also allowed a *thickening* of space. Ether was understood as an oceanic presence, omnipresent and inescapable that took possession of the space, and that served to sustain a *cosmology of invisible fluids*: a collection of invisible technologies and mystical entities which interacted in the same space: it thickened what before was considered to be empty. Natale (2011) uses the term of invisible fluids to signal the public imagination in which invisible technologies, such as early wireless and x-ray technologies, were inserted in a *cosmology* of invisible fluids that remapped the mystical onto the techno-scientific and back. The cosmology causes fascination because they encompass a range of invisible entities which are capable of acting at distance over tangible reality.

Notions of space thickening are particularly relevant to the development of digital networking technology. Schaefer has analysed how early development of Ethernet, a protocol for Local Area Network systems, used the metaphor of ether as a resource to ascribe meaning to the emerging technology. Describing the space in which information transaction occurred as ether, allowed them some design flexibility which maintained open a number of possibilities. Robert Metcalfe, one of the main designers of the Ethernet system, used the metaphor extensively in early documents to describe how '*the essential feature of our medium — the ether — is that it carries transmissions, propagates bits to all stations*' (Metcalfe quoted by Schaefer 2013, 5). This allowed an image of a new technology that allowed *propagating* information freely in space. Elsewhere, he writes: '*The new ether, in Ethernet, is also a ubiquitous passive medium for the propagation of electromagnetic waves, in our case, data packets*' (Ibid). In the case of Ethernet, the thickening of space is made by the digital technology which infuses freely throughout.



12 Ether machine developed by Lodge to corroborate the existence of Ether. Taken from The Ether of Space, p.76

2.1 THE INTERFACE OF THE BODY AND THE INVISIBLE

Connected to mystical notions of ether is also the interface between human body and invisible fluids. In the late 18th century, Franz Mesmer developed a method that sought to expand theories of gravitation and electricity to the operation of the human body. Mesmer proposed the existence of an invisible physical fluid pervading the universe, whose force is exerted between all real entities and thus serves as a communication medium. Diseases were explained as imbalances in the fluid. Healing required an experienced practitioner to balance the vital force in the body of the subject. The mesmerist began by passing hands throughout the body of a sitting patient, without touching them but close enough to feel the warmth of the skin (see figure 13). The subject fixed their stare into the eyes of the mesmerist, and after a while would fall into a state of mesmeric trance:

> *(…) her senses of smell and touch disappeared, as did all awareness of her surroundings. She also lost her speech and hearing, unless the mesmerist addressed her. A strange communion would develop between them: she would speak his thoughts, taste the food in his mouth, move her limbs in a physical echo of his (…) A new sense would open to her shut eyes. Subjects might claim to see events occurring in the future, inside the body, in distant lands, and even in the heavens (Winter 2000, 3)*

Towards the 19th century, mesmerism morphed into a form of stage entertainment, with a host of well-known mediums performing spiritual communication. In these, the body manifested the invisible with violent movements and convulsions, but also through the expulsion of ectoplasm, a gelatinous substance thought to be the connected to spiritual activity. Physiologist Charles Richet describes ectoplasm expelled from the body of well-known medium Eusepia Palladino:

> *'it is a kind of gelatinous protoplasm, formless at first, that exudes from the body of the medium, and takes form later (…) In the early stages there are always white veils and milky patches and the faces, fingers, and drawings are formed little by little in the midst of this king of gelatinous*

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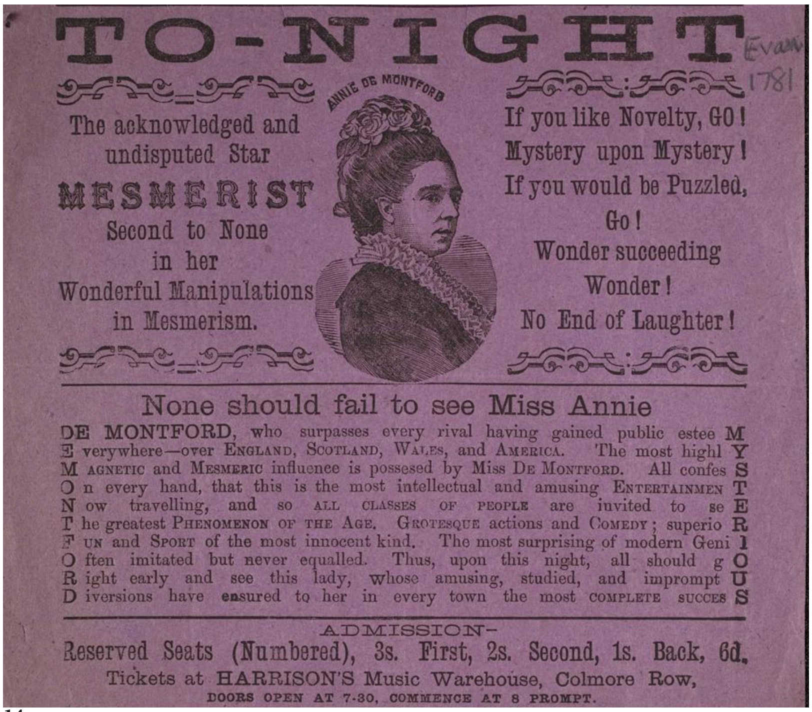

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13 Engraving used by LaFontaine in the cover of his treatise on animal magnetism, intended to provide a theoretical, practical and therapeutic approach to mesmerism.

14 Poster advertising the performance of mesmerist Annie de Montford at the Music Hall, Barnstaple, Devon. It is estimated to had been printed in 1881, when mesmerism had morphed fully into stage entertainment.

paste that resembles moist and sticky muslin (…) sarcoidic extensions emanating from the body of the medium, precisely as a pseudopod from an amoeboid cell' (Richet, Charles quoted by Brain 2013, 115)

Hillary Mantel dramatises ectoplasm in her novel *Beyond Black,* where central Alison Hart, a modern-day medium, describes: '*the dead manifested in the form of muslin, stained and smelly from the psychic's body cavities. The dead were packed within you, so you coughed or vomited them, or drew them out of your generative organs*' (Mantel, H. quoted by Kontou 2008, 275)

2.2 THE BODY AS INSTRUMENT

The interface between invisible fluids and the human body in mesmerism and mediumship also inspired an understanding of the human body as a form of electric instrument, capable of tuning into electromagnetic signals. The precedents of this can be found in Galvani's early explorations of animal electricity (Galvani 1792; Piccolino 1997). Galvani discovered by accident that a dead frog's leg would twitch when touched with metallic cutlery in response to electric fields generated nearby — a phenomenon he called *distant spark* (see Figure 16). Galvani proposed this was due to animal electricity: a vital force that is generated in the muscles and transmitted through nerves. The theory, later disputed by Alessandro Volta, was influential in developing an allegorical understanding of life tightly linked with electricity. For instance, in 1803 Giovanni Aldini, descendant of Galvani, performed an experiment on the body of the recently executed prisoner George Forster (see Figure 15). The experiments consisted of hooking a series of metallic terminals on the body, which were used to apply electrical current (Piccolino 1997). In the words of Aldini:

the jaw began to quiver, the adjoining muscles were horribly contorted, and the left eye actually opened(…)The action even of those muscles furthest distant from the points of contact with the arc was so much increased as almost to give an appearance of re-animation(…)vitality might, perhaps, have been restored, if many circumstances had not ren-

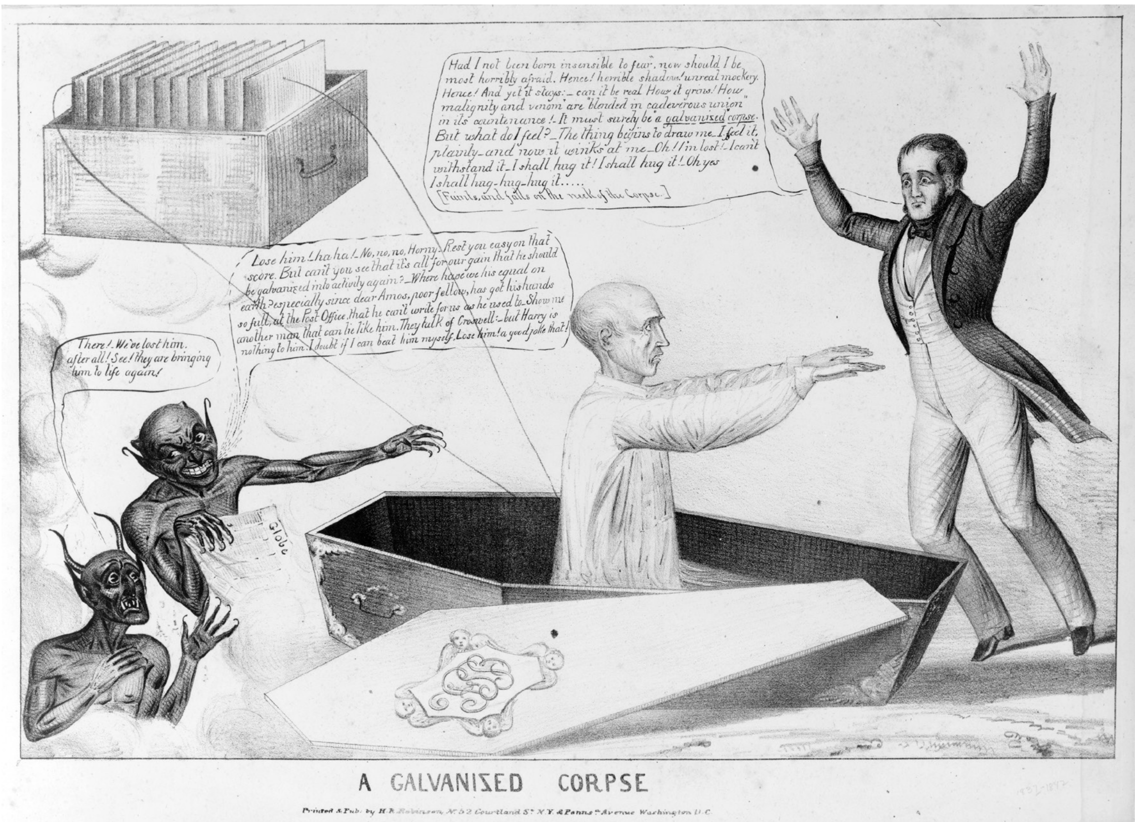
dered it impossible (Aldini 1803, 384–85).

The experiments of Aldani and Galvani sparked new interpretations of electricity as the vital force of the body. It provided inspiration, for instance, for the creation of *Frankenstein*. Goulding describes a series of animated exchanges between Lord Byron and Percey Shelley during a summer holiday at Byron's Villa Diodati. Mary Shelley, herself an avid reader of natural philosophy, picked up the theme and started working on *Frankenstein, or the modern prometheus*, in which a creature assembled from parts of different corpses is brought into life by infusing life through electricity (Goulding 2002).

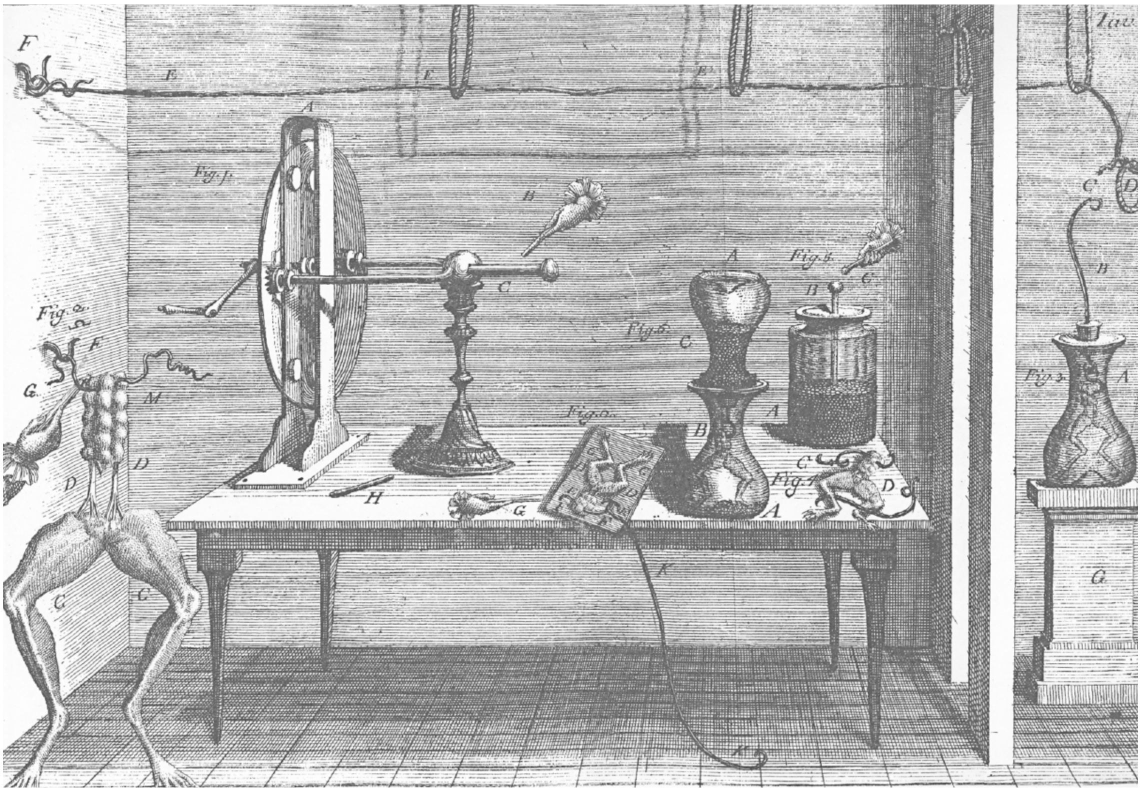
Notions of mediums as a form of instrument for spiritual telegraphy foreshadow the development of detectors where the human body is used as actual electromagnetic receptor. Lefeuvre, professor in anatomy, developed a so-called *physiological detector* for telegraphic signals based on the work of Galvani. Published in 1913, the detector used the sensitivity of the sciatic nerve in frogs to electrical discharges. The apparatus mounted a frog's leg and wired it directly to an aerial antenna (see figure 17). Once an electromagnetic wave was detected, the muscle would contract moving a lever, which activated a revolving drum that was registered in blackened paper. Morse codes were interpreted by the duration of the leg's contraction—a long contraction indicated dash and a short indicated dot (Fleming 1910, 540).

Similarly, Collins developed a detector using brain tissue. His experiments were aimed at determining if the human nervous system was affected by the electromagnetic fields generated by oncoming storms — thus verifying claims that certain sensitivity people were indeed able to sense their approach. To do so, he constructed a spark transmitter, similar to that of Hertz, in which the gap between the two metallic spheres was bridged with brain tissue. Figure 18 shows schematics of the experiments, with parts labelled as *b* described in the original as needles directly inserted into the tissue.

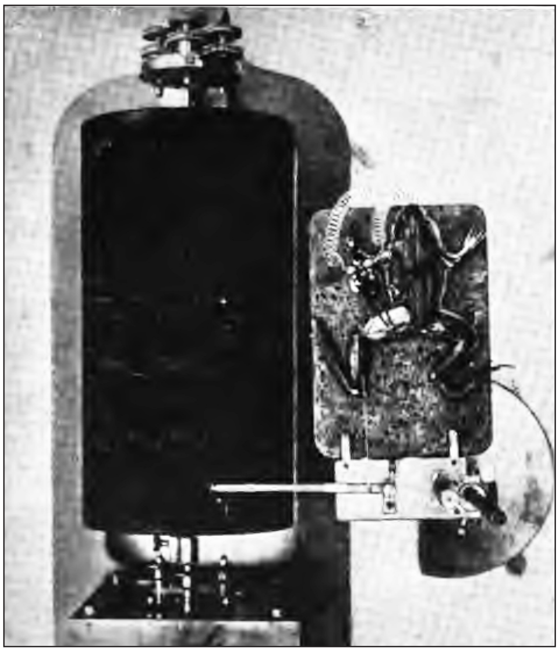
Collins conducted variations of the experiment using different tissue sam-



15 Illustration of Galvani's experiments on contraction at a distance, published in his 1792 treatise Aloysii Galvani de viribus electricitatis in motu musculari commentarius



16 Allusion to Aldini experiment on prisioner Forster, included in Aldini's Galvanic Experiments



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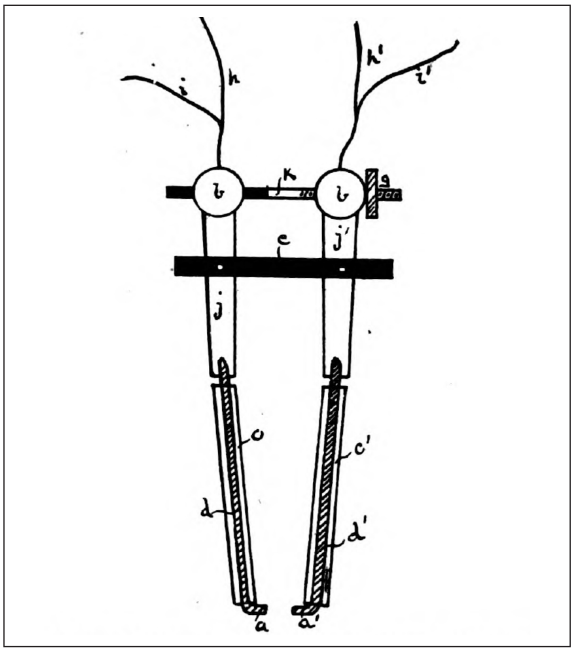

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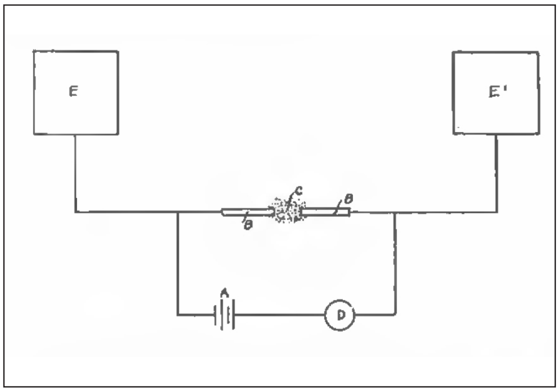

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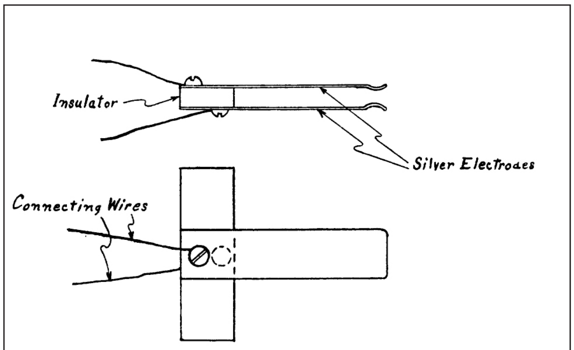

FIGURE 1

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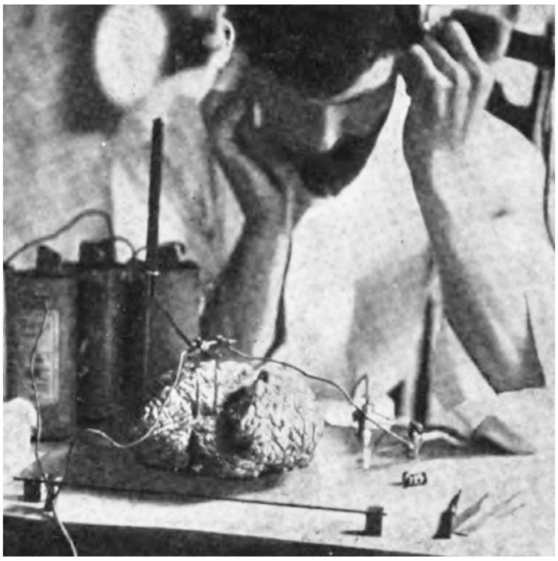

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17 Physiological detector by Lefeuvre. In this variation, the whole body of a frog is mounted on the panel to avoid inacuracies brought by the onset of rigor mortis

18 Collins experiments on conductivity of the brain as electromagnetic detector

19 Collins experiments on brains as electromagnetic dectector. The original caption reads: 'listening to cohesion of human brain under action of electric waves'. From Collins' article The Effect of Electric Waves on the Human Brain, published in the 1902, number 39 edition of Electrical World and Engineer.

20 **S**pecial design of needles in Collins experiments. Long leads are designed to sunk into the brain tissue

21 **D**iagram by Goldsmith of his Radio Taste Perception prototype, showing the silver electrodes designed to connect directly to the tongue. In Goldsmith, 1921.

ples, including a dead cat, a living cat and a human brain (see figures 19 and 20). Collins reported considerable electric excitation on cerebellum tissue with an electrical storm outside the laboratory. He concluded suggesting that the human brain had certain capacity to sense electromagnetism beyond regular sensory pathways (Collins 1902).

There are also instruments that seek to extend human sensory pathways to detect electromagnetic signals. Goldsmith and Dickey (1921), for instance, report on an early prototype to receive telegraphic signals using the sense of taste. Their instrument used silver electrodes, which were inserted into the operator's mouth, and amplified the received signal to induce stinging taste sensations. It was thought as an alternative to then traditional means of operating telegraphic stations. Using the sense of taste, they advanced, might help in interpreting telegraphic messages in locations with great amounts of noise. In commenting on telegraphic taste perception, a contemporary Pickard reflects on the notion of physiological perception of wireless and points to early speculations by Oliver Lodge: '*It is just conceivable that at some distant date, say by dint of inserting gold wires or powder in the retina, we may be enabled to see waves which at present we are blind to*' (Lodge, O quoted by Pickard 1921, 221).

3

CONCLUSIONS

In this chapter, I have set up the context for the exploration of material engagements. I started by reviewing the metaphor of electronic terrain, which is prevalent in representing and thinking of wireless infrastructure. I have reviewed how Mitchell uses the allegory in his *Me++*, in a bid to bring technology closer to the domain of designers. In doing so, he draws from the work of Marshal McLuhan and Buckminster Fuller, who most famously developed the notion of technology as prosthetic extension of the human body. These figures connect in *Delos*, a series of events organised to discuss the future of cities, and the impact of electronic technologies on their organisation. In it, McLuhan developed his theory of the city as electronic projection of the human nervous system, which he would go to encapsulate in his work of extensions of man. The work of McLuhan and Fuller, in turn, draw from the philosophy of technology developed by philosopher Ernst Kapp in the 19th century. I have argued that the metaphor of electronic terrains constraints the materiality of wireless to the city, and provide specific ways of thinking about it. It enables imagining a *texture* of wireless indexed to the physical features of terrain: as a changing profile with highs and lows which constrain or facilitate human activity in a geographical area.

Following the methodology proposed in chapter two, I introduced a *material conceit* in the form of *wireless spectralities*. The allegory refers to the reception of early wireless technologies in the 19th century, characterised by a process or *re enchantment of the world*: a term which alludes to the way in which techno scientific advances were understood and represented through mystical figures. I have described at some depth three specific aspects of this tradition. First, the way notions of ether, a rarefied form of air thought to provide a medium for the diffusion of electromagnetic fields, point towards a thickening of space. By this, I have referred to the cosmology of invisible fluids, technological and mystical, that filled what was previously thought to be void. Second, the way ether is also associated with the interface of the body and the invisible, often made manifest in mesmeric trances. Third, the way mediumship and mesmerism predates the understanding of the body as an actual instrument for the detection of electromagnetic fields. These themes are provided in this chapter to set the tone for the exploration of *material engagements* in chapter four. In developing these, I will return to the concepts developed here, reflecting on new materialities opened up by the allegory of spectres.

All I do hope to establish is, not a proof, but a presumption; and the conviction I desire to awaken in people's minds is, not that these things are so, but that they may be so

Catherine Crowe in The Night Side of Nature

PART

II

CREATIVE EXPLORATION

INTRODUCTION PART II

In this part of the thesis, I will develop textual accounts of three instruments: Space Reader, Kirlian Device and Kirlian Device mobile.

In Part I, I have contextualised this research within a discourse that links representations of wireless infrastructure with technological literacy. Ubiquitous digital technology, it is argued, is increasingly relevant in everyday life. Traditional design disciplines, however, are ill-equipped to respond to these changes in the design of experiences, artefacts and spaces, as designers often do not understand their mechanisms of operation. In this context, increased legibility of wireless infrastructure is intended to provide the context to discuss technologies, their impact and future development. I have proposed an alternative discourse, challenging the claim to indexical representation of wireless infrastructure, and proposing instead that there are a host of decisions that are taken in the process of representing the invisible, and that shape our perception of their materiality. In this context, the role of representation extends beyond mimetic documentation, and into exploration of speculative materialities: the different ways wireless infrastructure can be thought of, and integrated in a design context.

Central to this discourse is the notion of materiality. I have reviewed how the concept is understood in different disciplines and traditions, and proposed that, in the context of design, materiality refers to the way designers acquire knowledge of how a material can be manipulated and acted upon. I have referred to the work of Donald Schön and others in describing that notions of materiality are often developed intuitively, through systematic encounters with the material and that depend of a bodily, direct engagement. A good way to illustrate this is the image of the carpenter, who develops an intimate connection to the tool and the material, internalising the way that, for instance, different species of wood react to their movements according to its grain structure and orientation.

In this part of the thesis, I will develop a creative practice addressing the relationship between body, instrument and material. As described before, this is guided by the exploration of the prevalent analogies used in representing wireless infrastructure, and use material conceits: metaphors that draw from poetic traditions to enable new ways of understanding the invisible. Moreover, chapter two and three are articulated by what I call *material engagements.* I have advanced the notion of material engagement in the first part of the thesis, and used as means of highlighting the way materiality is assembled by its context. The materiality of wood, for instance, is contingent on the tools that are used to manipulate and measure it. Likewise, the materiality of the invisible is dependent on the instruments and techniques used in representing it. This model of materiality participates in the tradition of New Materialism. Karen Barad (2006), for instance, proposes that what we understand as tangible material is the alignment of agents, an agential cut, which congeals them in a specific configuration. Similarly, I use the term of *engagements* to refer to specific configurations in which instruments and techniques align to reveal material aspects of wireless infrastructure that suggests novel design opportunities.

This part of the thesis is articulated by the design of three instruments. The Space Reader draws from techniques and tools developed by other practitioners, and adapts it to survey interior spaces. I draw from the nineteenth century tradition of spectral technologies to redefine wireless fields as ether, a fluid that saturates physical space and affects the experience of its inhabitants. An early photographic exploration using the Space Reader reveals points where the material conceit can be used to explore new material engagements, and explore the role of the body in the process of representation. Chapter two documents the design of the Kirlian Device, a redesign of the Space Reader that understands the combination of instrument and performer as the apparatus of detection. The instrument changes the relationship between operator and instrument fundamentally, and enables the development of Spirit Photographs: a design intervention that show signal strength dispersion, and involves interpretation of signal dispersion and the process of scanning in a choreography. The third chapter documents the development of the Kirlian Device mobile, an Android app that performs detection of wireless fields in a way similar to the Arduino version, but that improves on mechanisms of feedback. The KDm enables the design interventions of Wireless séance, the Glass prototype and the Chandelier. These explorations deal with different modalities in which the body connects to instrument and material.

CHAPTER 4

4

VOLUMES AND METAPHORS

VOLUMES AND METAPHORS

1

INTRODUCTION

In this chapter, I will explore existing materialities of wireless infrastructure. It will do so by engaging with the techniques and practices used to represent wireless by other practitioners, specifically in Immaterials and Immaterial fabrication. The strategy reflects an earlier structure, in which this research was aimed at adapting existing instruments to the scale of interior, architectural spaces. The exploration described in this chapter, however, contributed in shifting the focus towards analysing how notions of materiality are constructed through the analogies used in understanding their operation and context of use.

I will begin by developing an anatomy of wireless, analysing the way electromagnetic signals are used in broadcasting digital information. I will especially analyse the dispersion of electromagnetic signals in space, and the difficulty of modelling it when interaction with physical context is brought into consideration. I will introduce the *space reader*, an instrument developed to register signal strength dispersion and that was modelled after the instrument used by the Touch Research Group in their *Immaterials* project. This exploration will enable me to reflect on the different design decisions taken in representing wireless infrastructure, the way these are informed by different metaphors, and how the process determines the resulting materiality. I will use the material conceit of ether to introduce a new way of thinking about wireless signals in space, and create variations on the measuring probe. Reflection on how these decisions inform the materiality of wireless is extended in the analysis of an initial set of test photographs generated to test the electronic circuit for the sensor. I will argue that these images are useful as they allow us to reflect on the connections between metaphors and instruments, and how these place wireless in contexts that determine their materiality. I will also reflect on how the improvised nature of the test allowed revealing the role of the body in the process of construction the materiality, and preface the exploration in the next section.

2 ANATOMY OF WIRELESS

Central to representing wireless infrastructure is the process of identifying aspects that can be measured, recorded and translated into a tangible event. The set of design explorations by others analysed in previous chapters often rely on signal strength as index to the quality of wireless networks. Signal strength is a metric describing the relative power of an electromagnetic signal when measure at different points in space.

2.1 Electromagnetic field

Wireless technologies depend on electromagnetic waves to transmit information. These waves result from the mutual interaction between electric and magnetic fields, and can be defined as an energy disturbance traveling through space. The term *field* is connected to analogies used in the 1800s to describe invisible, physical forces. In classical physics, objects are thought to exert influence upon each other by means of direct, mechanical contact. There are, however, a number of events, such as gravitation and magnetism, which cannot be described using this model. Until the 19th century, these cases of *action-at-a-distance* had been treated as an exception. Plato, for instance, talked of *demonic* forces to refer to instances in which a physical object had an effect on another without visible connection. Michael Faraday, however, proposed that action-at-a-distance was the visible manifestation of an underlying set of forces, which were capable of acting away from the object, thus generating a *field* around them: an area of space in which they have influence. James C. Maxwell developed the notion of field further and proposed that every point in space can be described through a chart of numbers that capture the strength and direction of electric and magnetic forces (McMullin 2002).

2.2

Wireless protocols

Wireless protocols operate by manipulating different aspects of the electromagnetic field. Wireless telegraph, for instance, change the duration of electromagnetic bursts to codify the Latin alphabet as sequences of dots and dashes. In Morse code, A is encoded as one dot followed by one dash, while B is formed by one dot followed by three dashes. When detected at a distance, the bursts can be reassembled into the original message.

Digital protocols used for information exchange use more sophisticated means of modulation, which include modifying the phase and amplitude of an electromagnetic wave. They do, however, follow the same basic principle: information is sectioned into discreet packets, translated to analog signals, and broadcasted as an electromagnetic wave. Detected at a distance, these packets can be reassembled into the original information. Exchanging a photograph over Wi-Fi, for instance, involves translating image information for every pixel into a binary sequence. Each of these digits are then modulated into an analogue wave using a digital-to-analogue converter. The resulting wave is combined with the carrier signal, and broadcast over the air multiple times. The receiving station detects the signal and converts it back to digital form. Once all the pieces have been received, the data can be translated back into colour pixel information and reassembled into the original photograph.

2.3 Signal strength

One of the key aspects in broadcasting information is the distance at which the electromagnetic signals can propagate and be detected. Generally, the stronger the signal means the better transmission quality. This is measured by the Received Signal Strength metric, which indicates the strength of an electromagnetic field detected at different points in space (Sauter 2010, 160). In obstacle-free spaces, signal strength decreases as the receiver gets further away from the emitter, as described by the equation:

$$L = \left(\frac{4\,\pi d}{\lambda}\right)^2 = \left(\frac{4\,\pi d f}{c}\right)^2$$

Where L stands for propagation loss, d for distance between transmitter and received, λ wavelength of the radiofrequency used, and *c* the speed of light. This means that for a transmission in the 2.4 GHz wavelength, used by Wi-Fi, signal strength drops by 60db in a distance of 10 meters. (Behzad 2007, 9).

Signal attenuation is, however, more complex in actual, architectural environments. In an indoor environment, for instance, electromagnetic signals interact with different surfaces—such as walls, ceilings, doors, people, furniture, cats—which attenuates them to different degrees. Rackley (2011, 115–16) suggests that a concrete wall produces a loss in signal strength of 10-15 dB, whilst metal structures can attenuate signals in excess of 15 dB. This produces a complex geometry of signal propagation, which is contingent on the geometry and distribution of the architectural space. More importantly, this geometry also changes constantly in time: as people move about in space, reposition small pieces of furniture or close doors, the distribution of signal shifts. As a result, the same point in space can observe high signal strength, and drop dramatically at any single moment.

3

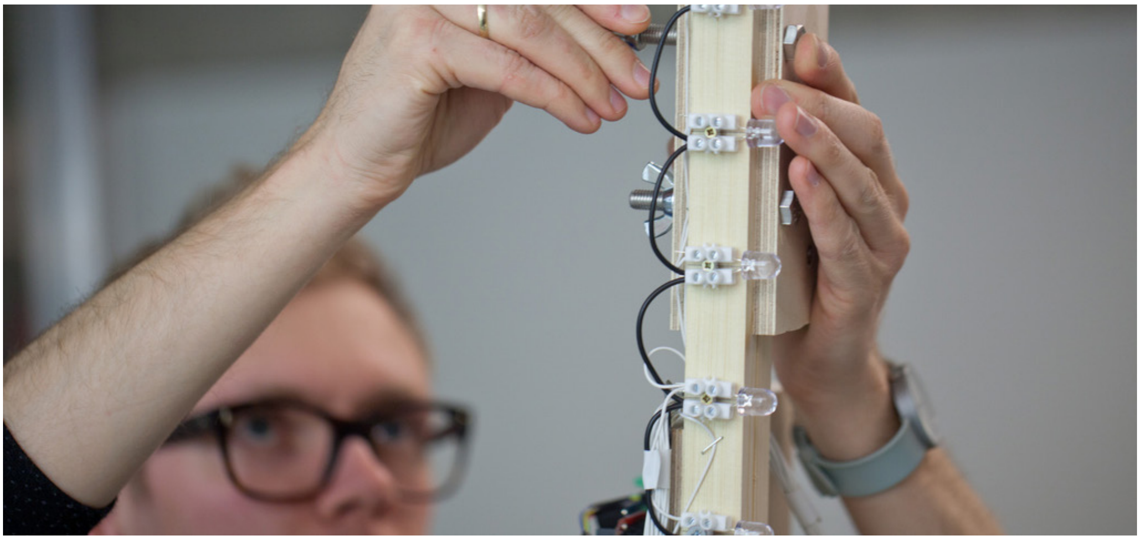
SPACE READER

The space reader is an instrument developed to explore the techniques involved in representing wireless infrastructure. It was developed as a continuation of the instruments used by the touch research group in Immaterials, specifically in the 10m pole used in a mapping exercise of Wi-Fi networks in the city Oslo. I was interested in how similar instruments could be developed to survey interior, architectural spaces. In *Immaterials*, an operator carries the pole in a straight line, holding it still at equal intervals (see Figure 1). The electronic circuit in the pole scans for a specific network, registers its signal strength and translates it into the height of an imaginary bar. Collected signal strength information is translated and mapped into height of an abstracted bar graph, rendered by the stack of LED light points shown in Figure 2.

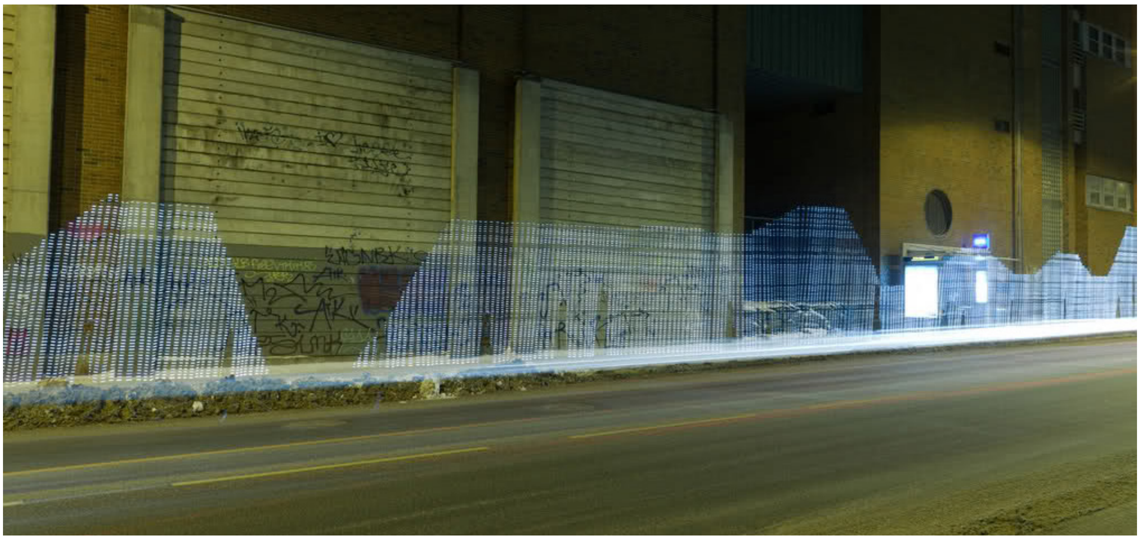
In the previous chapter, I have analysed how the materiality of wireless is often explored through the analogy of *electronic landscape*. A consequence of this is that techniques and tools often draw from the language of cartography. In this context, I have analysed how the researchers in *Immaterials* make explicit reference land-surveying poles in developing their own instruments to register wireless. Poles are metallic or wood rods that are used in land-surveying for a range of tasks, often related to determining level readings of landscape features. Level poles, for instance, are graduated and provide a visual aid to determine elevation when observed at a distance. Similarly, Lenker poles integrate an adjustable metallic ribbon, which enables recording elevation directly (Deumlich 1982).

The metaphor of surveying poles is useful in constructing a materiality of wireless connected to urban environments. In cartography, landscape elevations are relevant as they constrict or facilitate human activity, such as the movement of military troops or the construction of buildings. Signal strength can be understood in similar terms. The quality of wireless signals facilitates or thwarts the use of digital technologies, creating dark areas

1 Immaterials project, operator placing the probe in place and mapping signal strength



2 For Immaterials project, stack of LED lights used to represent signal strength



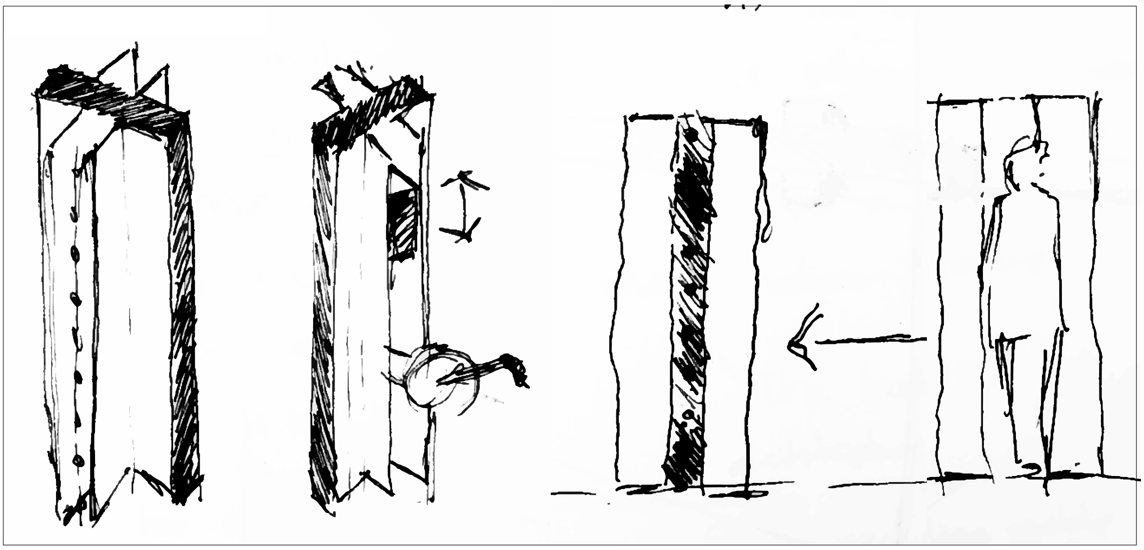
3 Image showing attenuation of a Wi-Fi network along a street, and its relationship with a Bus Stop where connectivity is impossible, or where data transfers are fast. The features of wireless infrastructure are therefore similar to vertical terrain, in that they generate the optimal conditions for human activity. Martinussen reflects on this materiality of wireless when he situates the vertical features of their photographs with specific conditions of use in the city. He described how the image in figure 3:

> *(…) shows the same far-reaching AHO network covering a nearby street and a busy bus stop. Here we have the overlapping of one invisible digital structure, the network, with the highly visible infrastructure of public transport. This unplanned overlap allows students and employees of AHO to use this bus stop as a space for accessing the Web while waiting. Here the wireless network connects the semi-private indoor work spaces with the public outdoor commuting environment. This illustrates how wireless networks, both practically and metaphorically, can connect different environments and settings (Martinussen 2012, 243).*

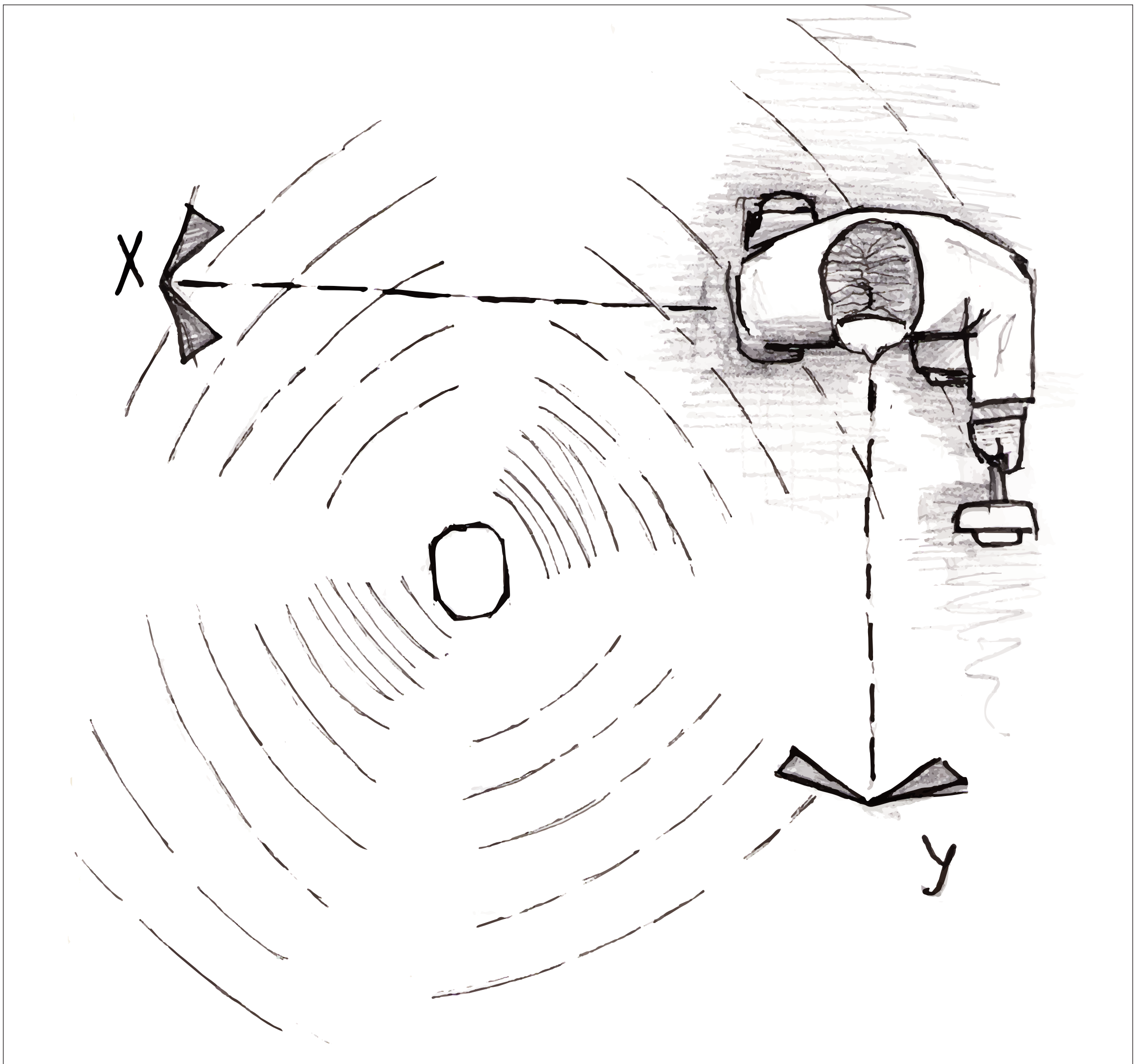
The materiality of wireless as terrain, however, is less relevant when understanding the interaction between wireless infrastructure and architectural space at smaller scales. There is no direct referent in how, for instance, landscape affects the experience of space in a corridor or the reading room of a public library. In addition to this, the analogy to surveying poles also influence the level of data granularity the instrument is designed to capture. The diagram in figure 4 shows the location of the sensor, labelled A, fixed to the surveying pole. Considered in a plan view, the instrument allows capturing signal attenuation at different distances in relation to the emitting station, which can be represented as coordinates in a two-dimensional *(x, y)* coordinate system (see figure 6).

Signal strength is measured consistently at a fixed height, as represented in figure 4, The pole enables mapping the signal strength in the *x, y* plane (see figure 6), relative to the position of the emitting station, but gives no information on how these values change in the vertical plane. Instead, the instrument uses height to represent signal strength captures in a two-dimensional

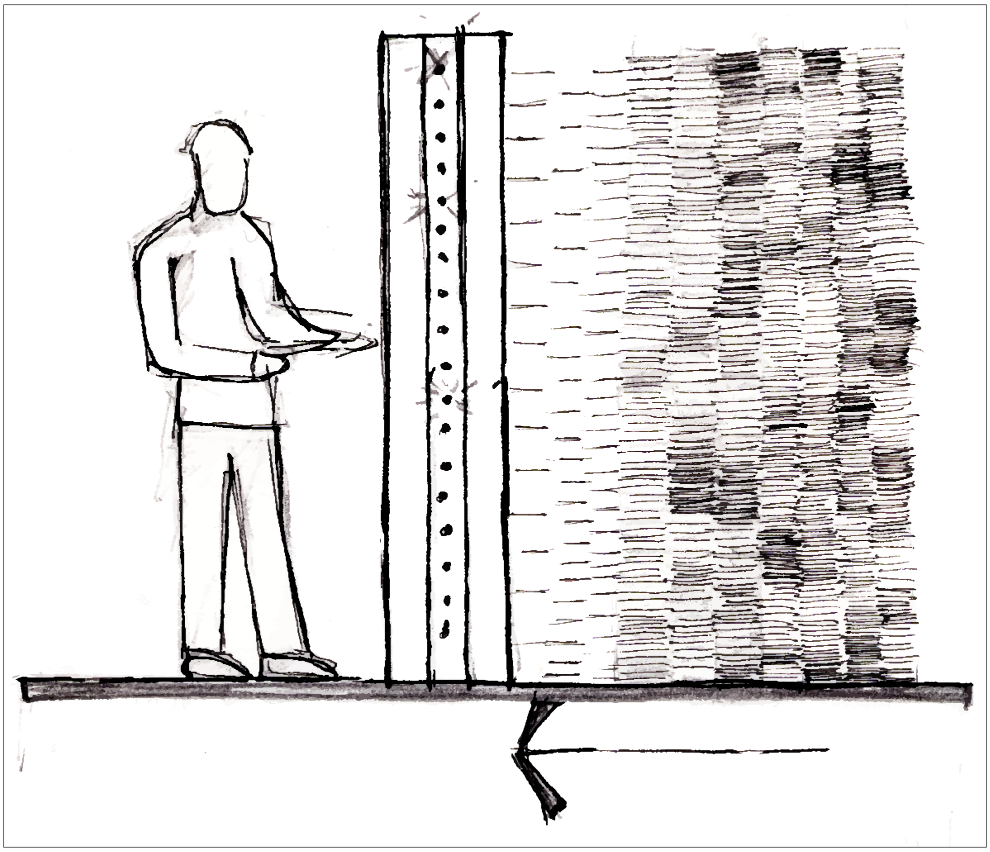
4 Diagram showing the sensor at a fixed height (labelled A), and how it is mapped to a stack of LEDs (labelled B)



5 Sketches for the Space Reader showing form of operation and mechanical lever



6 Diagram showing the 2D nature of WiFi Lightpainting. The sensor is moved in X and Y, but remains fixed in Z (see diagram 4)

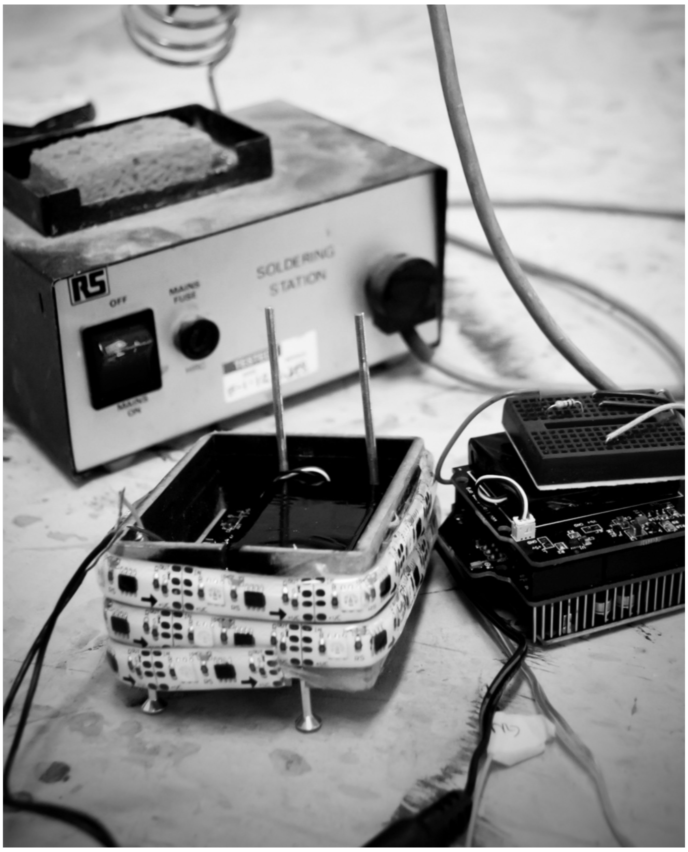


7 Diagram showing the projected operation of the Space Reader. The rig s moved horizontally, leaving a trace of readings that are registered as light densities in the scene

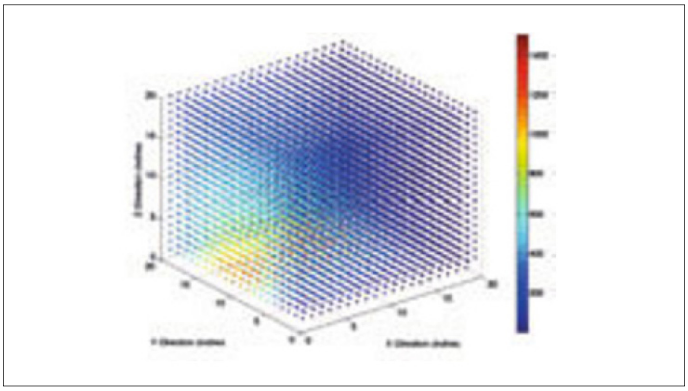
plane, which enables a visual metaphor of an electronic terrain with peaks, valleys and depressions of signal strength.

In the previous chapter I introduced the material conceit of wireless as spectre, and I've analysed how the notion of *ether* invoked images of spaces *suffused* with a substance different to the air, thickening it by creating different densities. Mobilising the material conceit in the image of ether enables an alternative exploration of the instruments used to describe signal strength. Instead of interpreting signal strength as vertical feature of an unseen electronic landscape, it enables thinking of it as densities of an unseen fluid infusing the space.

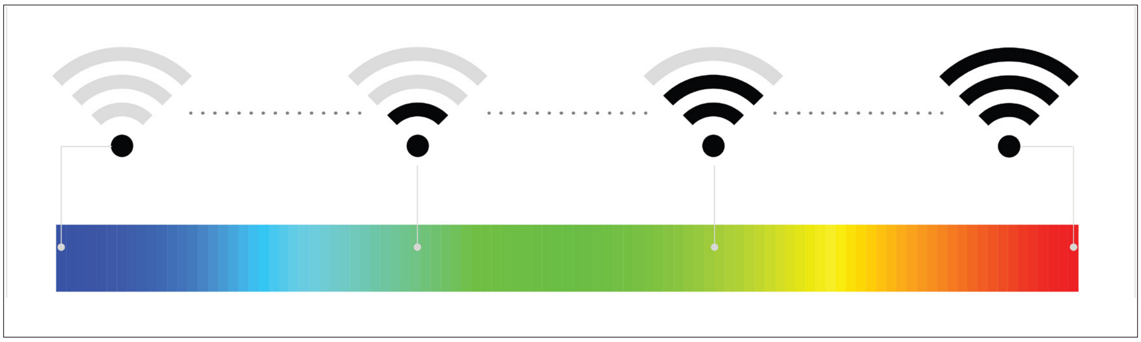
8 Picture of the Space reader initial prototype



9 Picture of bare electronic components



11 Diagram used by Oxman et.al to describe the data capture in



10 Perceptual colour spectrum used in the early

A notion of space thickening has consequences for the data granularity the instrument is designed to capture. In this context, the *Space Reader* is designed as a scaled down version of the surveying pole used in Immaterials: a probe instrument which transforms Received Signal Strength (RSSI), captured at different points in space, into a light output which would be recorded using Long-Exposure photography. It is, however, designed to interpret densities of wireless fields as greater granularity in the data-gathering process. With a height of 2.00 meters, the Space Reader would be used to capture signal strength in three planes: moving the sensor in *x*, y, and z axis. These planes would then be aggregated to produce a volume of wireless signals. Combining images taken from different starting points would aggregate into a cube that would provide information on how wireless signal distributes across a room, changing signal strength depending on the layout of walls and furniture.

One way to provide more granular information on signal strength is to incorporate a moving sensor, which captures signal strength data vertically as well as horizontally. Figure 5 shows the design for a pole which incorporates a moving sensor. The sensor slides along two rails, and is driven by a crank which enables an operator to lift and lower the sensor. Collected information is mapped onto a strip of LED lights, which use the light points to represent signal strength at different heights. Instead of translating signal strength to bar height, each light point represents discrete signal strength values (see figure 7). The operator would repeat the procedure in different points in space. Captured in long exposure photography, this results in a series of light pillars which aggregate to produce a consistent plane that represents the shifts in signal strength. Combining several planes would result in a volume of light that captures the shifting strength of wireless signal within a room.

An initial scale model was built to test mechanisms for the sensor movement. Figure 8 shows the model, which integrates a chain and sprocket system acting as elevator. The sensor was projected to be housed on an especially designed box, represented in the model as a box fixed to the metal rings.

This model also integrated a servomotor that connected to the chain through a worm gear to drive the elevation movement. Although the mechanism was successful, it added unnecessary complexities to the assembly and operation of the instrument. For instance, driving the mechanism in the full-scale probe would require a relatively powerful servomotor, which would inflate the cost of fabrication. Also, vibrations from the servomotor would put an additional stress on the structure, making it vibrate and potentially affect photographic record.

3.1 Sensor prototyping

The analogy of wireless fields as ether has also consequences in the way data is acquired and interpreted. To explore this, a prototype of the sensor was built using Arduino components. Arduino is an electronic prototyping platform oriented to artists and creative practitioners. Three electronic components were required to detect Wi-Fi networks and register their signal strength. First, an Arduino UNO, which refers to a microcontroller board to process information. Second, a tri-colour LED strip which acted as display to render signal strength values. LED strips offer a convenient way of addressing individual LEDs to display different colours, and were suited to be mounted in the projected form-factor of the space reader. The geometry of the LED strip would have specific effects on the initial tests, and contribute a distinct aesthetics to the whole exploration as it will be analysed later on. Third, a Wi-Fi module used to probe RSSI values continuously. Figure 9 shows the initial setup.

The sensor unit was driven by an algorithm which prompted the Wi-Fi unit to perform an active scan every few seconds. The active scanning process is an authentication and discovery protocol part of the 802.11, the family of specifications issued by the Institute of Electrical and Electronics Engineers and de facto standard for Wi-Fi networks. In active scanning, devices tune into all the possible frequency channels, wait for indications of active broadcasts, and then transmits a probe signal to request response. Access points reply with all necessary data for synchronisation and connection. Devices then measure the Signal Strength of the transmission, registered as the Received Signal Strength (RSSI). The algorithm driving the sensor was programmed to perform an active scan every four seconds, looking up a predefined network, and registering its RSSI continuously.

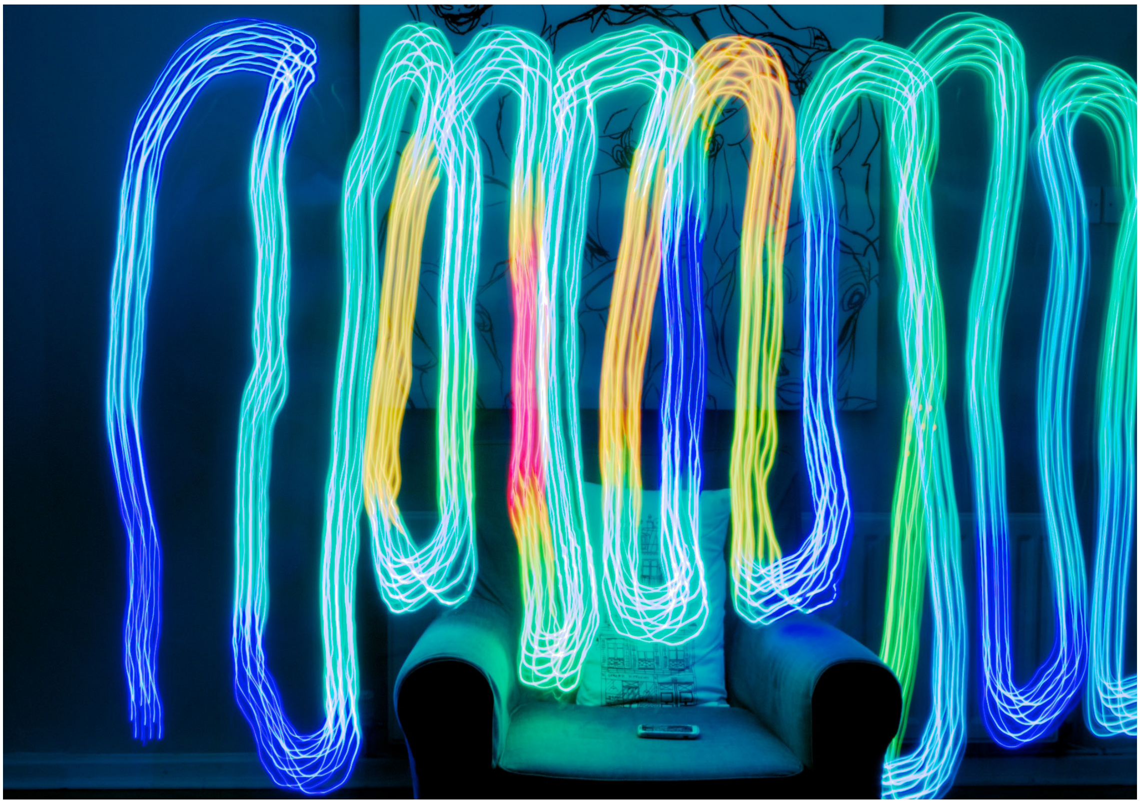
Collected RSSI data was parsed and mapped into a corresponding position in a colour gradient, as shown in figure 10. In information visualisation, colour gradients are often used to convey intuitively complex data patterns (Simmon 2013). They have been used extensively in cartography for instance, where different colour gradients are used to convey information such as depth of water bodies or heights of vertical features in terrain. In the context of wireless technologies, rainbow gradients have been used by the *Immaterial Fabrication* project to convey signal strength, as seen in figure 11. Rainbow gradient refers to the strategy of assigning lower values to blue hues, higher to red and interpolating intervening values in the RGB colour space. Although the scheme is widely used to represent continuous, numerical data, it has several shortcomings. It tends, for instance, to produce inexistent contours and limits in data, giving the impression of stark differences between contiguous values (Rogowitz, Treinish, and Bryson 1996). The stark differences between ranges of data, however, results in an advantage in a photographic environment, where light is superimposed on the existing background. The high contrast provided by the shifts in hue contribute in making information legible. This is ideal in conveying a notion of shifting densities of wireless. The rainbow gradient is alleged to follow an allegorical perceptual model, which connects degrees of intensity in data with colours associated with warmth. In this model, red is generally mapped to higher values due to its connection with fire. Conversely, blue is assigned to the low end of values due to its perceived connection with ice and cold (Bertin and Berg 2011).

3.2 Initial exploration

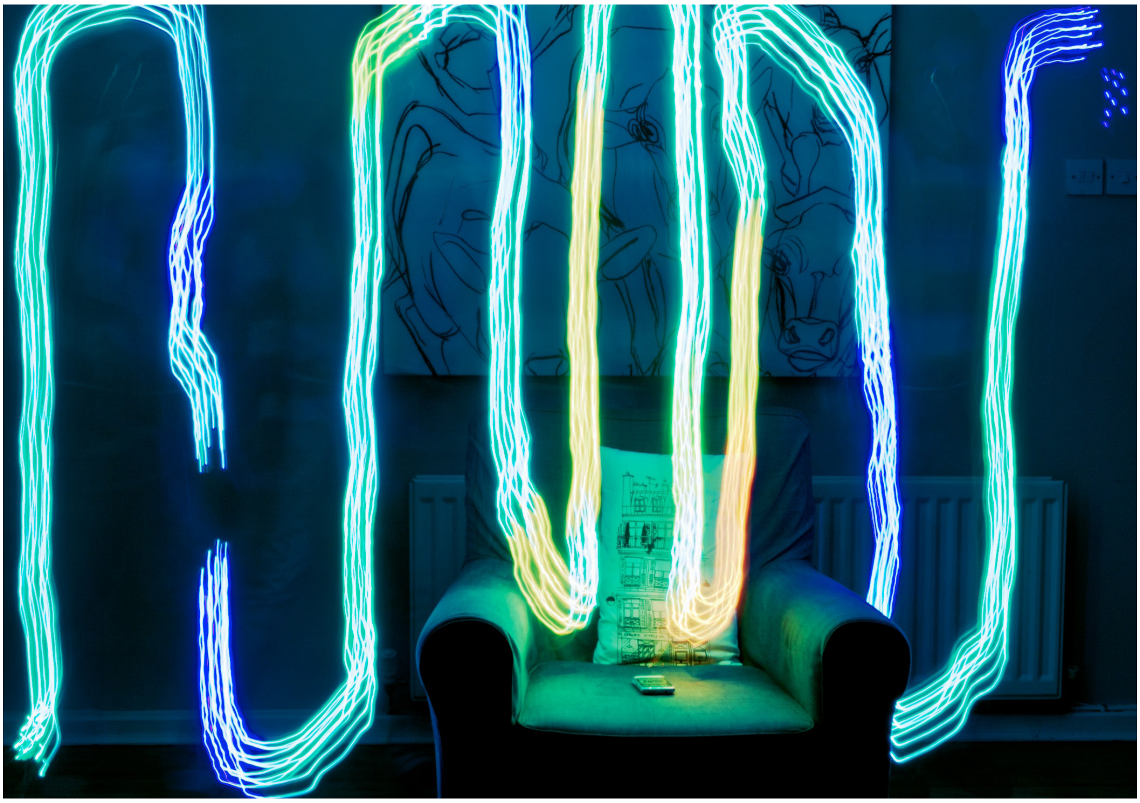
An initial concern in developing the sensor prototype was whether the light source would provide enough brightness to be registered in long exposure photography.
Photography generally records light through a light-sensitive medium. Film photography uses a combination of silver halide crystals which, suspended on a gelatinous media, provides a photosensitive medium. In digital photography, a digital sensor substitutes the chemical means of recording. In order to capture a scene, the photosensitive material is exposed a specific amount of time, which varies on the sensor or film sensitivity. In long exposure photography, the photosensitive medium is exposed to the light for relatively long stretches, generally in the order of seconds up to few minutes. The effect of this is that everything that *moves* in the scene whilst exposing is registered as a consistent trail. The moving subject is registered with varying degrees of transparency, depending on the amount of light it emits, and its velocity. A *dark* object would be registered more tenuously than a bright one, and a fast moving one might not be registered at all.

Light emitted by the reader, thus, had to be bright enough to be registered in the picture, and to be distinguished against the background. For this reason, I carried a series of initial test photographs. Since the only completed element of the reader was the bare electronic components, I performed the tests by holding the stack of electronics in my right hand, and moved them across the scene to simulate the operation of the *Space Reader*. The scene is put together to provide a setup as close as possible to the projected context of operation: interior spaces with different materials and geometries that attenuate Wi-Fi signals. Figure 12 and 13 show the initial results.

The exploration provided valuable insights into the technical implementation of the *Space Reader* and the complexities of its use. Figures 12 and 13 show, for example, a delay in the location of data capture and rendering. The



12 Early sensor tests



13 Early sensor tests

14 Image produced after the button trigger was implemented

15 Image produced after the button trigger was implemented scene features a couch against the backdrop of a wall decorated by a painting. A mobile phone sits on top of the couch, broadcasting a small Wi-Fi network using the personal hotspot functionality. In personal hotspot, mobile phones share connectivity received by mobile networks by creating a low-powered Wi-Fi station with a reach of a few meters. The light trail in Figure 10 shows red values, denoting higher signal strength approximately one meter away from the phone. In contrast, sections physically closer to the phone render a lower, green value. Mathematical models described above, however, suggest that stronger signal values are located closer to the source, dissipating outwards. Examining the value logs in the microcontroller, however, revealed a delay in the active scan process. If the network analysed was, for instance, broadcasting in channel one, the active scan would have to perform search on the remaining twelve channels before transforming the RSSI value into colour. By the time the colour was rendered, the sensor would have been moved physically from the location where the signal strength had been registered.

Integrating a button solved this issue. Initially, the routine was configured to continuously perform an active scan. The button enabled the performer to trigger the process and hold the instrument still. The LED strip is switched off during scanning, and only renders the corresponding colour until the process is completed. LEDs remain on for two seconds, and then shut off. Figure 14 and 15 were produced using the new process. Compared to figure 12 and 13, the colour strokes feature nodes—points of brighter light, which mark the spot I used to pause and perform the scanning routine.

The set of images is relevant in that it enables reflection on the design decisions which construct the materiality of wireless. There is, for instance, ghosts of the performer whose legs and upper body can be observed against the background wall. The areas on either side of the couch on Figure 15 show subtle hints of the presence of the performer. This contrasts with the images in the *Immaterials* and *Immaterial fabrication* project, where the process of visualising wireless fields is invisible to the viewer. In *Immaterials* the wooden stick is faded out of view by the bright LED lights it contains. Images

16 Exploration with improvised movement

only show a bar of blue light which seemingly floats across space on its own devices. Something similar is observed in *Immaterial fabrication*, where a robotic arm performs precise movements. The results are images which show a stroke of light, homogenous and perfectly flowing across the scene. What is more, if a second image were taken, the trail would follow the exact same coordinates, changing only the colour of the light.

The texture of the images also highlights the process by which the images were produced. The use of a rod in Immaterials enables the production of planes, composed of a succession of standardised light dashes stacked vertically and that represent the cross section of wireless fields. The robotic arm in *Immaterial fabrication* produces a homogeneous field of light, in which a seamlessly changing colour signals the fluctuation in signal strength. In the images above, the broken, wavy trace of light has a rougher texture — a feature that can be observed in the first pair produced without the button implement, and that is more pronounced in the second pair after the button had been implemented. The texture is connected to the choreography used in producing the images. In order to test the light in conditions that mimicked the imagined operation of the Space Reader, I decided to follow straight lines with my arm whilst operating the prototype. Each image was produced in time lapses of around four to six minutes, which resulted in a shaky stroke, as my arm grew tired.

Artefacts in the light trail texture could be dismissed, as they would recede when the sensor was mounted in the rig projected for the *Space Reader*, bringing images closer to the projects used as inspiration. The imperfections, however, invite reflection on how the relationship between sensor and operator is conceptualised. Figure 16 shows further exploration, with the bare electronics, still held fast in the right hand, in a completely improvised trail. The only parameter planned prior to execution was that the trail had to be composed of two strokes. One movement that approached the emitting mobile phone from the edges of the image; and a second that veered away from the mobile phone toward the edges of the scene. The resulting image amplifies the shaky strokes of the previous examples. It is still depicting signal strength in a wireless network, changing colour depending on the perceived RSSI at each specific spot. The effect the image creates is, however, entirely different to that of the previously analysed projects, even when they both follow similar conventions and aim to represent the same process. Somehow, the choices taken in the development of the instruments and mapping processes inform how the invisible is represented. It also invites us to consider the body as a sensor itself, and the electronic circuit as an instrument that enables revealing an interaction between body and the invisible.

4

CONCLUSION

In this section, I have introduced early exploration on the instruments and techniques of representing wireless. The exploration is articulated around the design of the *Space Reader*, an instrument which adapted the techniques of *Immaterials* and *Immaterial Fabrication* and endeavoured to produce similar surveys in smaller, interior spaces. The exploration described in this chapter, however, suggested an alternative area of exploration dealing with the way metaphors and analogies influence design decisions of instruments and techniques and, as a result, our notions of materiality of wireless. I have analysed, for instance, the way that understanding wireless as electronic terrain has an impact in the way it is understood spatially, and the granularity of information the instrument gathers to represent it. In this context, the *Space Reader* introduces the notion of wireless as ether to think of thickening and densities of space, recasting the connection between wireless infrastructure and physical space. I have reflected on the design consequences of this alternative analogy, and follow through in the design of the instrument and the prototype of the sensor circuitry. I have also reflected on early photographic tests, which enable further analysis on the way materiality of wireless is constructed by the way it is represented. The exploration also contributed in moving the exploration towards the role of the body as instrument to reveal wireless signals, which will be analysed in the next section.

The reality of the alleged facts, supposed to be spiritual, must be tried as any other class of alleged facts [but] whether scientific men are the best qualified to decide this point may well admit of doubt. They have no instruments to lay hold of spirits no chemical tests by which to detect their presence. Retorts and galvanic batteries are here of no avail.

Epes Sargent in Planchette: Or, the Despair of Science

CHAPTER 5

5

KIRLIAN DEVICE

KIRLIAN DEVICE

In this chapter, I will describe the development of the *Kirlian Device*, designed around the interaction between body and instrument, and that uses unstructured bodily movements in re-cording wireless fields. The exploration enables analysis of four *engagements*. The first, *Body as instrument*, builds on notions of unstructured bodily movements, and draws from allegories to instruments, developed in the 19th and 20th cen-tury, and which registered physiological changes resulting from the interaction with invisible fluids. Of these, I will analyse in some detail Kir-lian Photography, a form of electrophotography developed in the Soviet Union. Although the process registers coronal dis-charges caused by electrostatic charges in the skin, the resulting images have been interpreted as inscribing human aura. Analogies to these instruments are relevant in that they enable a different status to instruments. In *Space Reader*, the instrument is modelled on surveying instruments, which detach record from process. In contrast, the *Kirlian Device* mobilises the material conceit to conceptualise the body as part of the apparatus to detect wireless signal.

The engamgent of *Trance* will explore the way bodily movements can be used to represent signal dispersion, as well as technical complexities of recording wireless fields. It will draw from analogies to creative mediumship, an artistic movement that used trance states as a strategy to inscribe the invisible. I will draw from creative mediumship in producing a choreography to manipulate the Kirlian Device and capture wireless signals. The process, I will argue, is reminiscent of the systematic encounters with materials which is often thought to constitute the basis of design materiality. In chapter three I have referred how, in the context of design, knowledge of materials is constructed by systematic encounters with the material, and that contribute in creating an intuitive knowledge of how materials can be manipulated and acted upon. This is contingent on a process akin to a conversation with the material: where designer listens how the material perceives and expresses itself. Similarly, a trance enables unstructured exploration wherein the performer is subject to external forces which influence their decisions. In creative mediumship, this included a sort of system, in which the medium contributed the style, and spirits were thought to dictate the content of the art piece. In this exploration, I use the analogy to construct basic body movements, and establish principles that dictate how they adapt to fluctuations in signal distribution and to the process of detecting them.

In the third *engagement*, I will look closer at the implications of the substrate used in creating the images. This involves understanding how the contracted sensitivity range of digital sensors conditions long-exposure photography, which is produced through layering: the blending of individual images into one, which mimics capture in low sensitivity materials. The techniques used in layering, such as blending modes and masking, create further levels of interpretation and mediation between process and image. In keeping the indexical link between process and image, different strategies are introduced in the choreography, such as fragmenting performance into 15 seconds sections, and keeping notes of the process that enables a better interpretation in post-production. I will argue that post-processing can also be understood as a form of asynchronous feedback, which enables the performer to understand the relationship between body movements, signal dispersion and technical process.

The fourth *engagement*, Feedback, will develop the notion further and analyse how different aspects of the process afforded ways of developing an intuitive understanding of the relationship between body and wireless field. I will connect the notion of feedback back to that of materiality, and argue that it is central in developing an intuitive understanding of the material. I will analyse how the Kirlian Device falls short of providing cues to enact feedback. Although some feedback mechanisms were designed to be integrated in the Kirlian Device, several technical complexities prevented implementation. The mechanisms will be further explored in the following chapter, which is structured around a redesign of the Kirlian Device.

1 BODY AS INSTRUMENT

In this section I will describe the development of an instrument designed around the possibilities offered by bodily movement as a means of mapping wireless fields. The section will draw on notions of the spectral metaphor to reframe the status of the instrument, from an object built to detect the presence of wireless fields, to instruments that *lay hold of spirits*: objects designed to operate in tandem to the human body in making evident the presence of the invisible.

In the previous chapter, I documented the development of the *Space Reader*, an instrument designed to map the propagation of wireless networks within architectural spaces, and which followed the tradition of projects by others that endeavour to create representations that contribute to technological literacy. I also analysed how these projects draw extensively on the analogy of wireless as electronic terrain, which results in constant references to the practices and instruments of cartography. I went on to reflect on early experiments using the sensor prototype for the *Space Reader*, and pointed at the different textures obtained in the photographs: shaky, broken strokes that revealed the process by which the images had been created. The *Space Reader* was initially modelled on surveying instruments, which are required to provide the possibility of repeatable, standardised measurements that minimise the effect of the operator and the capturing process as much as possible. Under this set of parameters, the instrument needed to implement a rig that allowed for standard vertical and horizontal movements of the instrument.

Moving the sensor by hand, rather than mounted in its intended rig, also invokes the material conceit, which can be used to frame the body as a medium to *channel* wireless — and in doing so, wireless becomes an extension of the human body, which takes on its materiality to gain a physical presence. In this section, I explore this possibility in the *Kirlian Device*, a redesign of the *Space Reader* which alludes to the conceit of *instruments to lay hold of the spirit*: devices developed to reveal the interaction between the body and invisible fluids, and that emerged as part of the overall theme of invisible technologies as spectral presences. Design of the instrument will make reference to *Kilian Photography*, an electrophotography technique which captures coronal discharges of the human body. The process has been adopted by so-called paranormal investigation, and became a by-word for notions of spiritual aura and bodily energies. I will provide some context to the allegory, and describe the design decisions it inspired. I will also analyse how the instruments enable a different process of capturing wireless fields, which involve choreographies in which the performer interprets wireless dispersion and the technical intricacies involved in capturing it.

1.1 Instruments that lay hold of spirits

Kirlian Photography refers to an electrophotography technique developed by Semyon and Valentina Kirlian around 1939. It was discovered by chance when electro technician Semyon was repairing a massage device and noticed electrical discharges between the electrodes and the skin of the patient (Ciesielska 2009). Together with his wife Valentina, he researched the phenomenon and developed it into an electrophotography process. Electrophotography refers to a contact photographic technique where images are generated by placing an object in direct contact with the photosensitive medium. The device developed by Semyon and Valentina Kirlian consists of a photographic plate placed on a light sealed casket on top of an insulated high voltage electrode. Electrolytes and water in the skin of a subject trigger ionisation inside the casket. Free electrons interact with the silver halides in the photosensitive medium, creating a latent image which describes the pathways where the discharge occurs (Duerden 2004). Valentina and Semyon developed research on the technique and described the process as '*the transformation of non-electric phenomena of living and non-living material*' (Ciesielska 2009, 37) and suggested some diagnostic potential in the patterns revealed by the technique.

Largely unnoticed at the time, the Kirlian technique was later rediscovered and published by Ostrander and Schroeder (1997) in *Psychic Discoveries Behind the Iron Curtain*, where the technique was appropriated as a tool of paranormal and psychic research. The technique was also popularised by the work of Thelma Moss in the Parapsychology laboratory in UCLA. Moss (1979) believed that Kirlian Photography revealed the bioenergy of the *astral body*, one of the alleged seven components of the human body according to Theosophy. The work of Moss promoted the notion that the patterns revealed in the images corresponded to the energy flow or aura of the human body (Carroll 2011). The interpretation follows the work of Jocob Jodko-Narkiewic, who in 1896 conducted experiments with Hippolyte Baraduc and Louis Darget to photograph the so-called human vital fluid (Chéroux 2005). Jodko-Narkiewic called the resulting images (see figure 1) *electrophotographs*, and suggested that the discharge patterns corresponded to the human aura (Ciesielska 2009). The photographs were rebuked by scientists Adrien Guebhard and Emil Jacobsen, who claimed the patterns were the result of heat and moisture interacting with the photographic plate (Cardin 2015) . Electrophotography and the Kirlian technique is nonetheless still widely connected to alternative health therapies, and is regularly cited in theosophy, paranormal and psychic research.

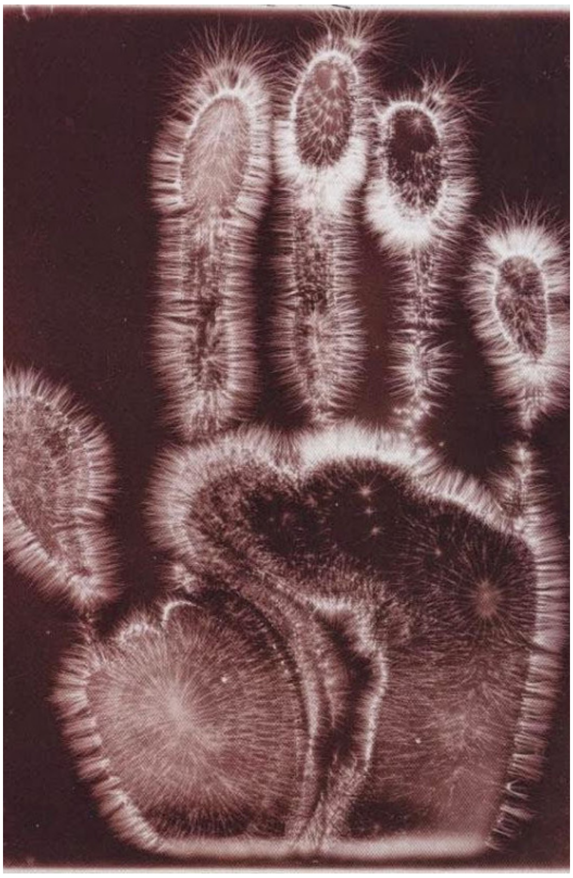
Kirlian Photography participates of a historical process of negotiation in the understanding of the human body and its relationship to technology and the invisible. Noakes (2002) argues that the history of mesmerism and spiritualism in the 19^{th} century can be characterised by a continuous shift in the understanding of the body as machine and instrument. Early in the 19^{th} century, communication with the spirit world was thought to be dependent on the constitution and sensitivity of the body of the medium and participants, which were considered as instruments to channel and manifest the invisible. The body was considered to possess certain electrical and magnetic qualities that, combined with the rituals and devices used in séances, formed a communication apparatus with unique features. This was understood as analogous to the way electronic components in a telegraph determined its efficacy to broadcast a message. William Fletcher Barret, Professor of Experimental Physics and member of the Society for Psychical Research, wrote in 1903 of the extended analogy between ether, wireless and spiritualism:

> *Physical science affords abundant analogies of the necessity for a medium, or intermediary, between the unseen and the seen. The waves of the luminiferous ether require a material medium to absorb them before they can be perceived by our senses; the intermediary may be a photographic plate, the rods and cones of the retina, a blackened surface, or the so-called electromagnetic resonators, according to the respective length of those waves; but some medium, formed of ponderable matter, is absolutely necessary to render the chemical, luminous, thermal, or electrical effects of these waves perceptible to us (Barrett quoted by Noakes et al. 2002, 9).*

Demonstrating how the human body channelled different forces required the development of instruments which registered its interaction with the invisible. It was hoped that by demonstrating that the body of the medium underwent a series of otherwise unexplained physical and chemical changes, would provide indirect evidence to the existence of action at a distance and spiritual communication. For instance, William Crookes, Member of the Society for Psychic Research and a prominent physicist and chemist, is notable for having adapted a series of instruments from his scientific work to study the existence of a so-called *psychic force*, which he believed responsible for mediumistic trances.

Example of this is the radiometer (see figure 2), a glass bulb which houses a pith indicator consisting of a set of vanes, mounted on a spindle inside a partial vacuum. When a light beam is directed to the instrument, the pith rotates in response. The same effect can be observed when the instrument is placed near the human body, with pronounced differences in speed across individuals. Crookes believed the internal chamber of the radiometer provided a full vacuum, which rules out explaining the movement as the result of heat transfer through air. Instead, Crookes proposed the existence of a physical, invisible force, emanating from the human body and that was more pronounced in mediums during psychic trances. The radiometer would become a conversation piece in Victorian England, as Crookes associated with instrument makers to produce the instrument in large numbers, and was often regarded as empirical evidence of the existence of supernatural forces. Crookes would later conclude that the phenomena observed in the Radiometer was not connected to a psychic force, as he had originally hoped, but was rather the result of radiation (Noakes et al. 2002). It is now understood that the internal movement in the radiometer is the result of thermal transpiration. The method used to produce the glass bulb provides only a partial vacuum and leaves residue gas. As a result, heat from the skin or light sources sets in motion gas particles which travel from one side of the vane to the other, pushing the pith in their wake.

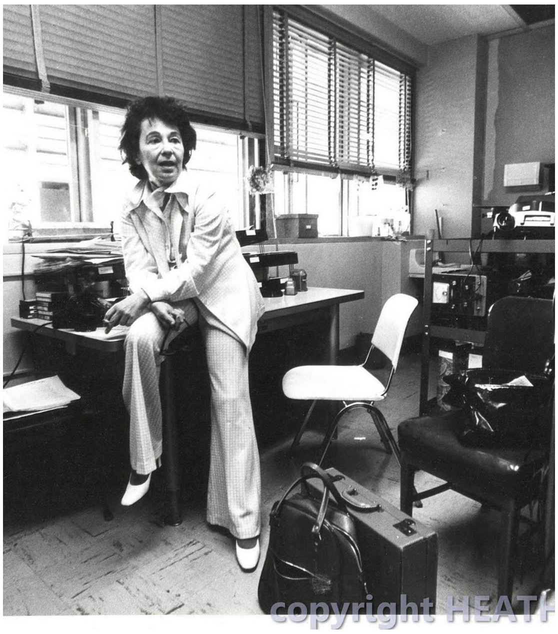
Kirlian Photography follows in the tradition of instruments designed to make manifest the interaction between the human body and invisible fluids. As a result, it has been deeply ingrained in cultural imagery as byword for spiritualism and mysticism. This is partly due to the work of Thelma Moss, who set up her Parapsychology Lab at UCLA reportedly after learning about Kirlian Photography in *Psychic discoveries behind the Iron Curtain*. Moss was instrumental in introducing Kirlian Photography to the wider public and in the cultural status it would take by working with public figures, such as



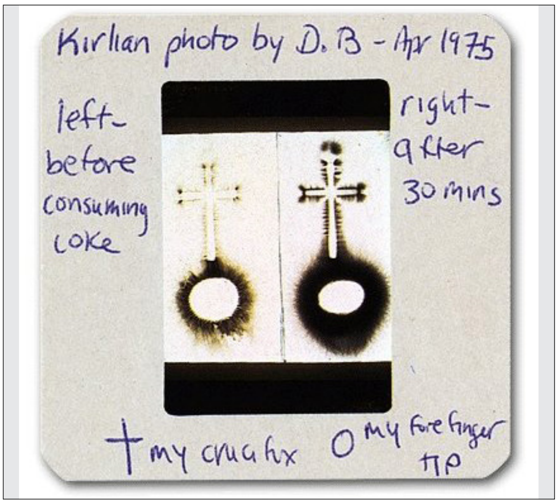
1 Figure 1. Effluvia from an Electrified Hand Resting on a Photographic Plate, 1896, Société Astronomique de France, Paris

2 Radiometer by William Crookes

3 Kirlian Photographic Device given by Thelma Moss to David Bowie in 1976



4 Thelma Moss at the Parapsychology Lab at UCLA. Photograph by Heather Harris



5 Kirlian photograph taken before and after consuming coke, David Bowie faith healer Olga Worral and illusionist Uri Geller. She also gifted a Kirlian Photographic device (figure 3) to songwriter and performer David Bowie, who used it to produce photographs (figure 5) before and after consuming cocaine (Cardin 2015).

1.2 The Kirlian Device

The name '*Kirlian Device*' makes reference to the lineage of instruments explored above and that focused on the interface between body and invisible fluids, technological and mystical. In this research, the instrument was modelled on the technical difficulties encountered during the test run of the *Space Reader*. In the previous chapter I described an issue in how the timing and unpredictability of the scan routine made it difficult for the operator to move the instrument at the precise time. The active scan routine consists of a process where the wireless radio is tuned into 13 possible frequencies. The process involves sending a probe signal and waiting for an answer. If a station is currently broadcasting, the radio waits for completion to begin broadcasting. Depending on the amount of stations broadcasting in the same channel, and of those active within reach, the process can take anywhere from two to five seconds. When this process is integrated into a moving sensor, it means there is a lag between the location where signal strength is probed, and where it is mapped, rendered and registered into light. The initial strategy to overcome this issue was to implement a software interrupt. The interrupt uses a button, which allows the operator to trigger and pause the scan function. The instrument would begin the process, and turn its light on only when the 13 channels had been swept. The operator would move the instrument slowly in a line. After two seconds, the light would switch off, cueing to hold the instrument, press the button and start the process again. The sequence provides a way for the performer to synchronise their movements to the triggering and completion of the scan routine.

The allegory to *Kirlian Photography* allows expanding this solution even further by imagining the operator as part of the apparatus which allows capturing and representing wireless networks. This involves recasting its role as performer rather than operator.

An operator follows a protocol and does not invest themselves in the process of observation. They do not interpret the images, nor project impressions or expectations of the observed process. In keeping with notions of objective, indexical representation, the space reader had to be redesigned to delegate parts of the process onto a mechanism that allowed for uniformity and repeatability of movement. In this context, instruments are considered as validation of objectivity and are designed on the ideal of unmediated representation: a noninterventionist, objective observation of phenomena which produces images that effectively render the operator and protocol invisible. In analysing the roots of image making in science, Daston and Galison describe the moralisation of objectivity which took place at the end of the nineteenth century**:** *'the all-too-human scientists must, as a matter of duty, retrain themselves from imposing their hopes, expectations, generalizations, aesthetics, even originally language on the image of nature. Where human self-discipline flagged, the machine would take over'* (Daston and Galison 1992, 81). In this context, the shaking arm can be interpreted as lack of self-discipline which had to be supplemented by the mechanical.

In contrast, the role of a performer involves some freedom in the way the instrument is manipulated, and is reminiscent of a mesmeric medium who channels the invisible through bodily movements. The conceit enables reapproaching some of the problems found in the previous section. For instance, the solution of software interrupt to synchronise the movements of operator and instrument can be re-approached to involve bodily movements that engage with the processes of data-capturing and representation. As such, the design of the *Kirlian Device* was remodelled around the relationship between circuitry and hand. The design is based on a simple geometry which follows the stack of electronics created for the Space reader (see Figure 6). In the initial test, I held the electronics tightly clamped in my fist. The LED Strip was wrapped around the fist and held into position by holding the ends in

6 The Kirlian Device

my fist. The body of the Kirlian Device mimics this arrangement. Electronics are cased inside a box, which is then used to wrap the electronics around and fixed with adhesive tape. The second part of the body comprised the handle, and closes the first box. An opening in the front of the device provides un-obstructed access to the device´s antenna, which is used to monitor the signal strength in wireless networks.

The main body incorporates edge fillets, which makes it more comfortable to be manipulated, and is reminiscent of 1960s product design, coinciding with the aesthetics of the time period referenced in the allegory to Kirlian Photography. I decided to fabricate the Kirlian Device in wood for practical reasons. One is the technical limitations I had at that moment. Although the design would have been more comfortable and lightweight in plastic, I didn´t have access to an extrusion 3d Printer which might have done this process quicker. There was also the possibility of fabricating the body in resin, but the requirement for the hollow space to fit the electronics in made this overly complex and time-consuming. I had, however, access to a laser-cutter and decided to section the design into layers, which were cut in plywood, glued together and sanded to achieve the shape. An unintended outcome of the fabrication method is that the aesthetics give the impression of an unfinished, rough artefact. This echoes the instruments originally produced to attest the existence of invisible spiritual forces in the 19th century.

The Kirlian Device materialises wireless fields as a weight in the arm of the performer, who can describe its dispersion through bodily movements. This locates the operation of the Kirlian Device between the mediumistic trance and standardised operation. In the next section, I will discuss the *engagement* of trance to describe the process by which the series, *Spirit Photographs*, were produced using the Kirlian Device, reflecting on the relationship between instrument, wireless field and performer.

2

TRANCE

This section will reflect on the integration of instrument and body, analysing the choreographies developed to integrate signal dispersion and technical intricacies of measuring wireless.

The section will introduce the use of the Kirlian device as a way of inscribing the invisible. In the previous section, I have introduced the redesign of the Space Reader, an instrument originally modelled on techniques developed by others to survey wireless dispersion (Keating and Oxman 2013; Arnall 2014; Martinussen 2012), into the Kirlian Device, a new type of instrument that acknowledged the role of the body in interpreting and capturing wireless fields. Key to this was a series of early photographic explorations which involved deploying the sensor circuitry prototyped for the Space Reader. Manipulation by hand highlighted a number of design decisions that, under scrutiny, revealed connections to base metaphors that described wireless infrastructure as electronic terrain. Chapter three argued that analogies used in describing the operation and context of use of technologies have an impact on the way their materiality is constructed. Spectral analogies, and specifically the allegory to ether, enabled a different understanding of wireless and the techniques used in representing it. In this context, the Kirlian Device was designed following notions of instruments aimed at detecting the physiological effects of the interaction with invisible fluids, and where the body itself becomes part of the apparatus of detection

The section will also argue that the material conceit of mesmeric trance is useful in exploring new roles for the body of the performer in registering wireless. In the mesmeric tradition, the body is subject to a host of invisible fluids, and is thought to act under the influence and detached from the conscious understanding of the subject. This extends to supernatural fluids, which make it possible for mediums to establish contact with the spirit world, which is made manifest through the emergence of ectoplasm, a form of bodily fluid that was thought to result from this interaction. The notion of mesmeric trance also extends to technological, invisible fluids. I have described how notions of trance and, generally, the idea of the body as a medium that channels the invisible, contributed to the understanding of wireless technologies and the development of instruments that detected and manipulated them. In this context, the section will use parallels to creative mediumship, an artistic movement of the turn of the century built around mediumistic trance as condition to create art. The allegory is useful as it enables the production of the *Spirit Photographs* series, but also in that it provides a novel method of generating an intuitive knowledge of the material.

2.1 Creative mediumship

Creative mediumship offers a useful model of integration between body and instrument as apparatus to detect the invisible. The movement emerged in 19th century Europe as a response to American New Spiritualism, and involved a number of artists which used mediumistic trance as a novel condition of art creation. The group has gained renewed attention in recent scholarship, as it has been reinterpreted as a form of proto-abstract art, which preceded the exploration of Avant Garde movements in the connection between consciousness and authorship (Foot 2016). Surrealism, for instance, experimented with automatic drawing, in which the hand would be allowed to move randomly across a paper, in the hope of enabling the expression of the sub-conscious. Creative mediumship, however, thought of art objects as spirit artefacts that witnessed to the existence of a spiritual plane. Foot writes that:

> *Their work ranged from abstract shapes to figurative forms, yet while their styles differed they were unified by the same goal, which was to use artistic mediumship to convince the viewer of the "truth": that the spirit world existed and that spirits could interact with the living (Ibid, para.*

7 The Large Figure Paintings, nr 5, The Key to All Works to Date, Group III by Hilma Af Klint

6).

Artworks were created in spiritual séances: gatherings where artists would enter a mediumistic trance, channelling the spirit of deceased artists to paint through them, or inscribing revelations made by the spirits. A good example of creative mediums is Hilma Af Klint, who described her process as a form of divide dictation, wherein her body was subject to an unseen force: '*I had no idea what they were supposed to depict… I worked swiftly and surely, without changing a single brush stroke*' (Kellaway 2016, para. 2). Kellaway describes Af Klint paintings as '*free-wheeling, psychedelic, animated with fat snail shells, perky inverted commas, unspooling threads, against orange, rose and dusky blue*' (Ibid, para. 4).

In the context of this research, the notion of creative mediumship is relevant as it connects with notions of materiality. In the first book, I have contextualised this thesis in the work of creative practitioners and researchers who engage in the representation of wireless infrastructure, often within an argument of technological literacy: designers are perceived as ill equipped to intervene technology as they don't grasp its mechanisms of operation. Producing representations induce a more active *engagement* with technology, providing the basis to debate their effects on everyday life and traditional design disciplines. I have argued that this is at odds with design notions of materiality. Donald Schön, for instance, advances that designers know more than they can articulate, and operate on a form of intuitive knowledge of the materials, a *repertoire*, that allows them to understand the opportunities for intervention. Similarly, mediumistic trance constitutes a form of knowledge acquisition which is not directly tied to a rationalistic description of things. Instead, it is contingent on systematic encounters with the material, where it engages in a sort of conversation with the designer.

Description of design materiality is similar to the way Pasi interprets the contemporary significance of creative mediumship. In writing of the work of William Blake, also adherent to creative mediumship, Pasi reflects how his work prefigures:

> *a model in which not just the content but also the technical side of artistic creation would be outsourced to a different world from the physical one, and to personalities other than one's own conscious self (Pasi 2016, para. 4)*

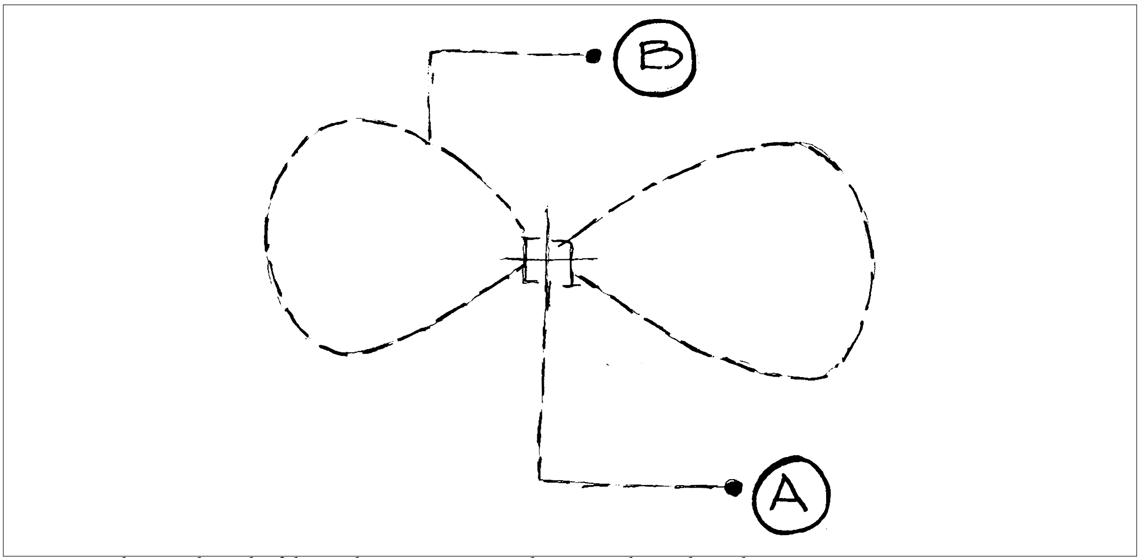
Pasi argues that until the Enlightenment, it was common to think of human beings as being influenced by a range of occult, astral forces. The word inspiration, he offers, '*is based on the idea of a person becoming the receptacle of such a subtle, aerial, but nevertheless overpowering presence*' (Ibid, para. 5). Modern notions of the self as a unified entity, however, displaced models of occult and divine influence. Understanding of the external influence in the creative process is at the core of materiality. Allegory to creative mediumship, moreover, is particularly useful in approaching invisible matter and the mechanisms by which designers understand its potential.

2.2 Choreography

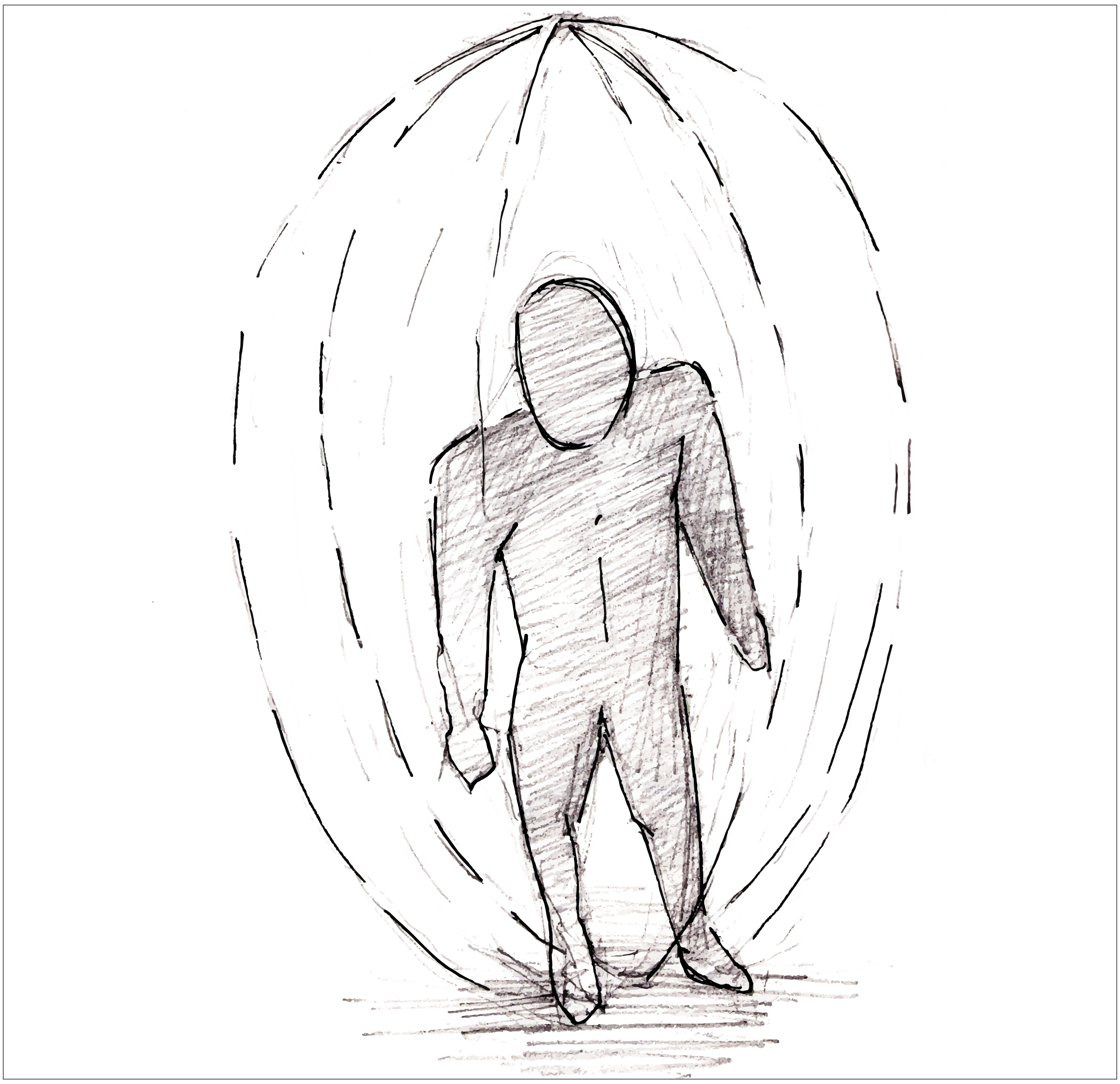
The conceit of creative mediumship affords a different interpreation for signal dispersion, and the technical complexities in recording. An example of this is the issue of lagging. In the early set of photographic experimentation, I worked around a strategy involving a software interrupt, which allowed pausing and triggering the active scan on command, and a series of slow, linear movements that guaranteed signal strength values were registered close to the place they had been gauged.

The Kirlian Device, however, enabled a different approach. As such, I constructed a choreography that involved moving the sensor in swirling strokes, which enabled *painting* values close to where they had been gauged. Figure 8 shows a diagram of this movement. *A* represents the location where the scan function is performed for a particular frequency. B describes a path that keeps the instrument close, without breaking the stroke as in the software interrupt solution.

The stroke is integrated into an overall movement shown as an arc around the body. Once an arc has been completed, the body pivots in its axis to repeat the process, incrementally building an ovoid around the body, as seen in figure 9. This choreography described the behaviour of wireless networks in the immediate surroundings.
The choreography bears resemblance to the non-figurative language developed by creative mediums to inscribe the invisible. The use of uninterrupted strokes, and their arc-like shape, is reminiscent of the work of Georgiana Houghton in *Spirit Drawings*, a series of watercolours composed by meshes of contour-like lines, as seen in figures 10 to 12. The lace-like, white traceries in the watercolours are the result of the process associated to mediumistic



8 Diagram showing the path of the swirling movements used in manipulating the Kirlian Device



9 Ovoid produced by the coreography. The instrument is translated in arcs, which are aggregated by rotating around the body's axys

10 Georgiana Houghton, Glory be to God, part of Spirit Drawings

11 Georgiana Houghton, reverse of The Eye of the Lord, part of Spirit Drawings

12 Untitled by Georgiana Houghton

trance, where the arm is seldom allowed to leave the canvas, moving continuously in swirling strokes guided by invisible, mystical forces. Similar to the development of the choreograph in this work, Houghton believed to be channelling the spirits by providing a stylistic, graphic language: '*Houghton and other Spiritualists believed that these spirit guides provided the content of the drawings, while Houghton herself was responsible for their style* ' (Oberter 2006, 222)

Similarly, the choreograph involves a series of rules that describe how the basic stroke adapts and reflects different aspects of the capture. An example of this is how the swirling movement of the device is modulated according to *signal blackouts*, producing traceries of varying density. Blackouts are connected to the algorithm written to drive the sensor, which was structured in four modules. First, a routine performs a custom active scan that returns a list of all broadcasting networks. A second routine passes the list to a search function, which looks up any occurrence of the network name (the Service Set Identifier) and retrieves the associated signal strength value. A third routine takes the numerical value and remaps it into a corresponding position in the colour gradient. A fourth routine passes the colour information to the LED strip. A glitch in the algorithm occurred when the scan function was not able to *find* the targeted network: a sweep of channels did not return information of that network, often due to interference from other channels, or poor signal quality. In this cases, the device would shut off abruptly, creating gaps in the signal ovoid.

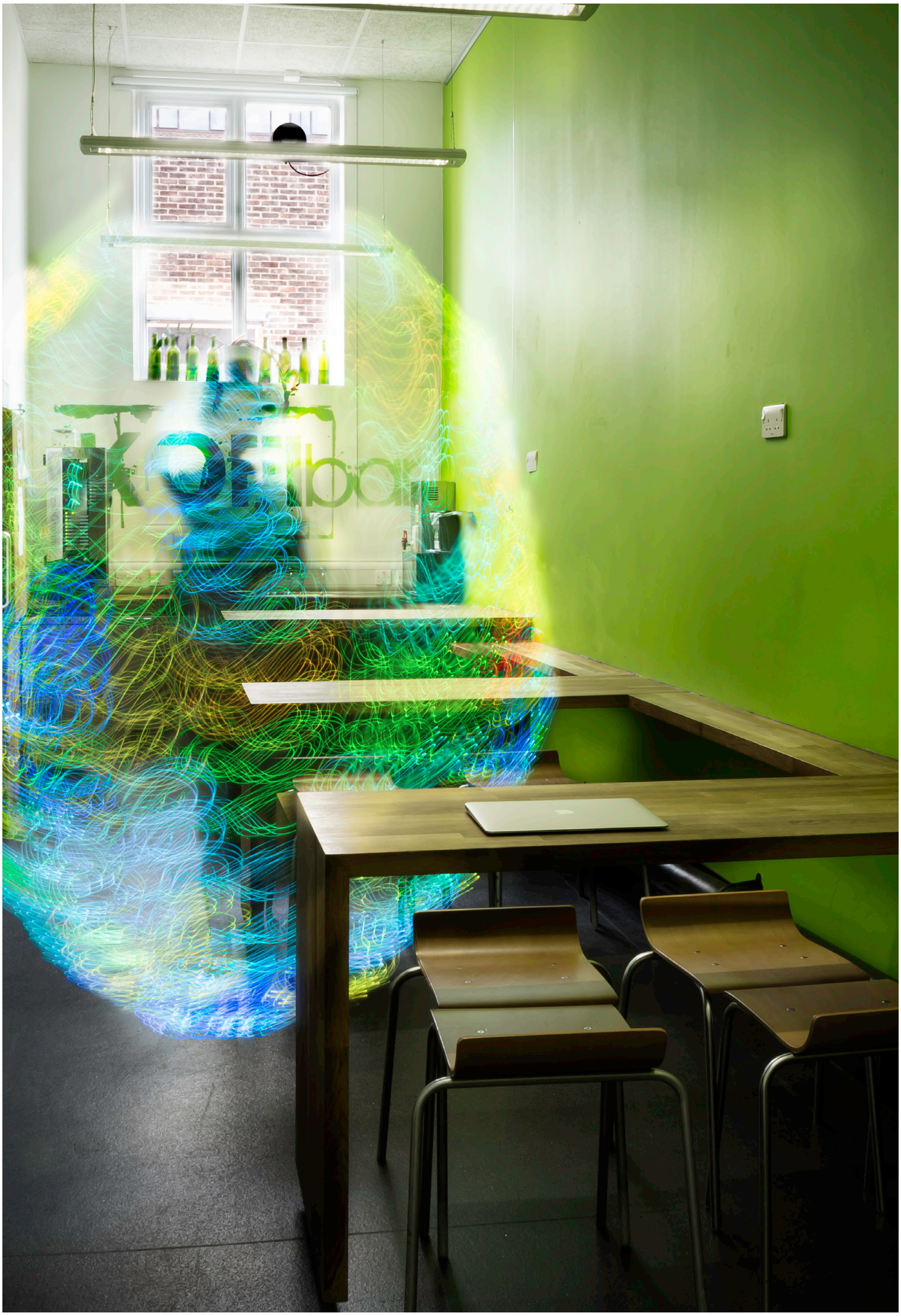
Blackouts were also produced when reported signal strength values fell outside set limits. Generally, residential Wi-Fi networks operate within signal values of -20 to -80 *dBm*. Mapping against these limits would mean that nearby values would be rendered in virtually identical shades of the same colour, making it difficult to differentiate in a photograph. Instead, the algorithm was programmed to *calibrate* within a compressed range of values, as will be analysed in detail in the next section. A consequence of calibration is that occasionally values would be reported outside the value, creating a logical exception that resulted in sensor blackout. I decided to adapt the choreography by, initially, pausing the stroke when the glitch occurred and, later, by moving the device over an area which had been already mapped. Nonetheless, there were spaces where signal dispersion was more erratic than average, creating several blackouts throughout the capture. In these cases, I adapted the routine by threading the movement tighter, offsetting the frequent occurrence of the glitch.

The effect of this strategy can be best appreciated by comparing figure 13 and 14. Figure 14 shows an image produced before integrating the strategy. A gap can be observed in the left hand side, produced by one of the blackout glitches. It is worth pointing out that the location of the glitch is surrounded by weak signal values (rendered in blue). By contrast, the filaments in figure 13 are closely knitted, which enables offsetting the effect of gaps due to constant connection drop.

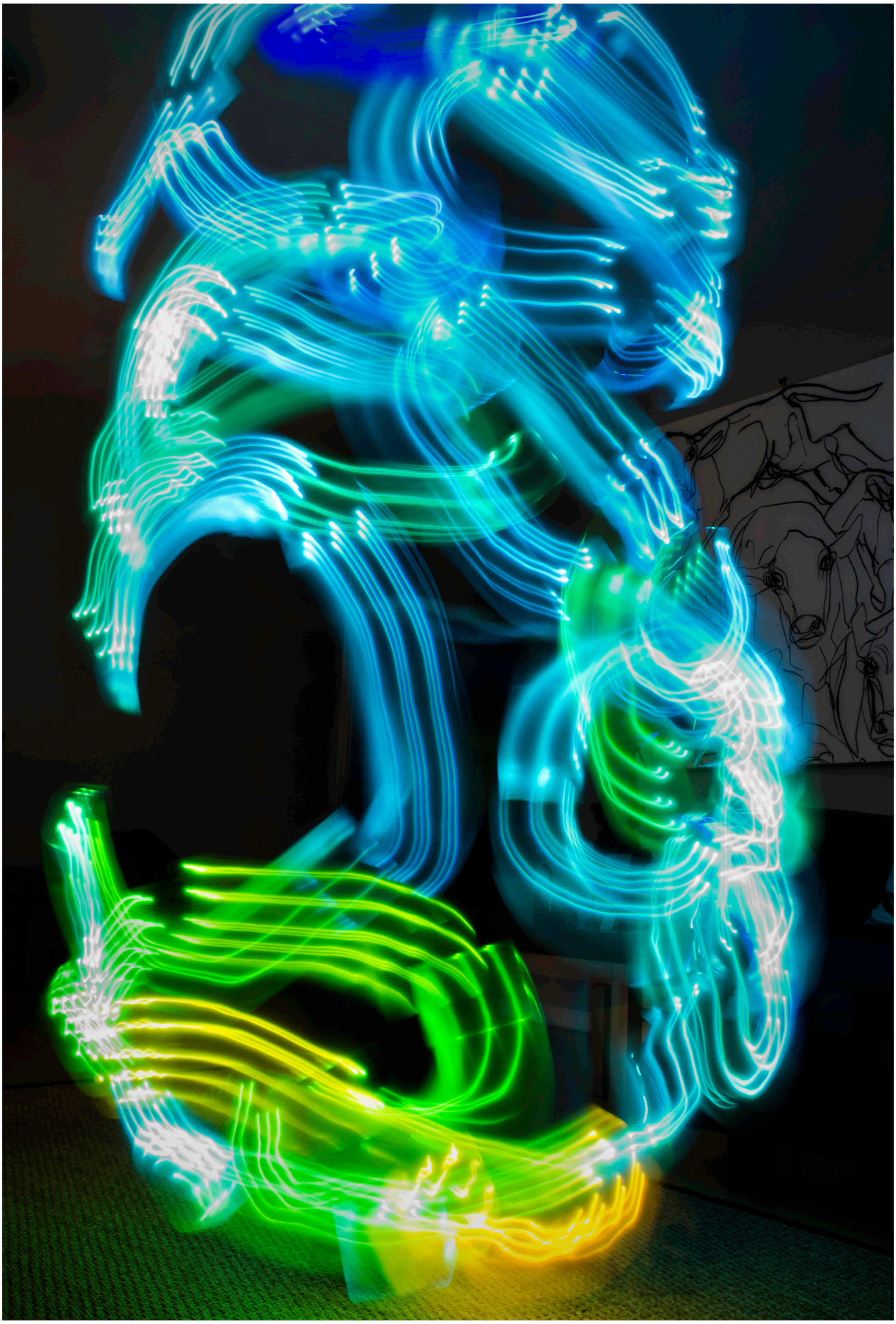
The choreograph is also shaped by the physical space, adapting to its surfaces and geometries. A good example of this is figure 15 and 16, a sequence of images created to map dispersion within a staircase. In figure 15, the choreography is adapted to fit within the relatively confined space of a stair landing. Although the swing of the arms is limited, they follow the same overall pattern of building up arcs and pivoting to construct the ovoid. In figure 16 however, the basic stroke remains, but the body adapts to the steps by crawling through them, as shown in figure 17.

Similar strategies are followed in figure 18 and 19, where movements are adapted to run along the surfaces of furniture. In both cases, an ovoid is generated in the background to map dispersion at different points. The foreground shows a movement produced close to the surface of a table, following a more linear stroke which is slowed down to keep the signal values close to their point of capture.

Analogous to the adaptation of the body through choreography, representation is also shaped by the *engagement* of calibration. One of the difficulties of operating the Kirlian device was in the appropriate calibration to use in each space. Received Signal Strength Index (RSSI), the standard metric used in determining signal strength in wireless applications, is reported in a logarithmic scale ranging from 0 to -100 dBm, where 0 represents the maximum. In practical terms, most WiFi access points deliver RSSI values between -20 and -80. When placed in specific locations however, these values tend to fluctuate within more compressed ranges. Figure 19, for instance, was created in the

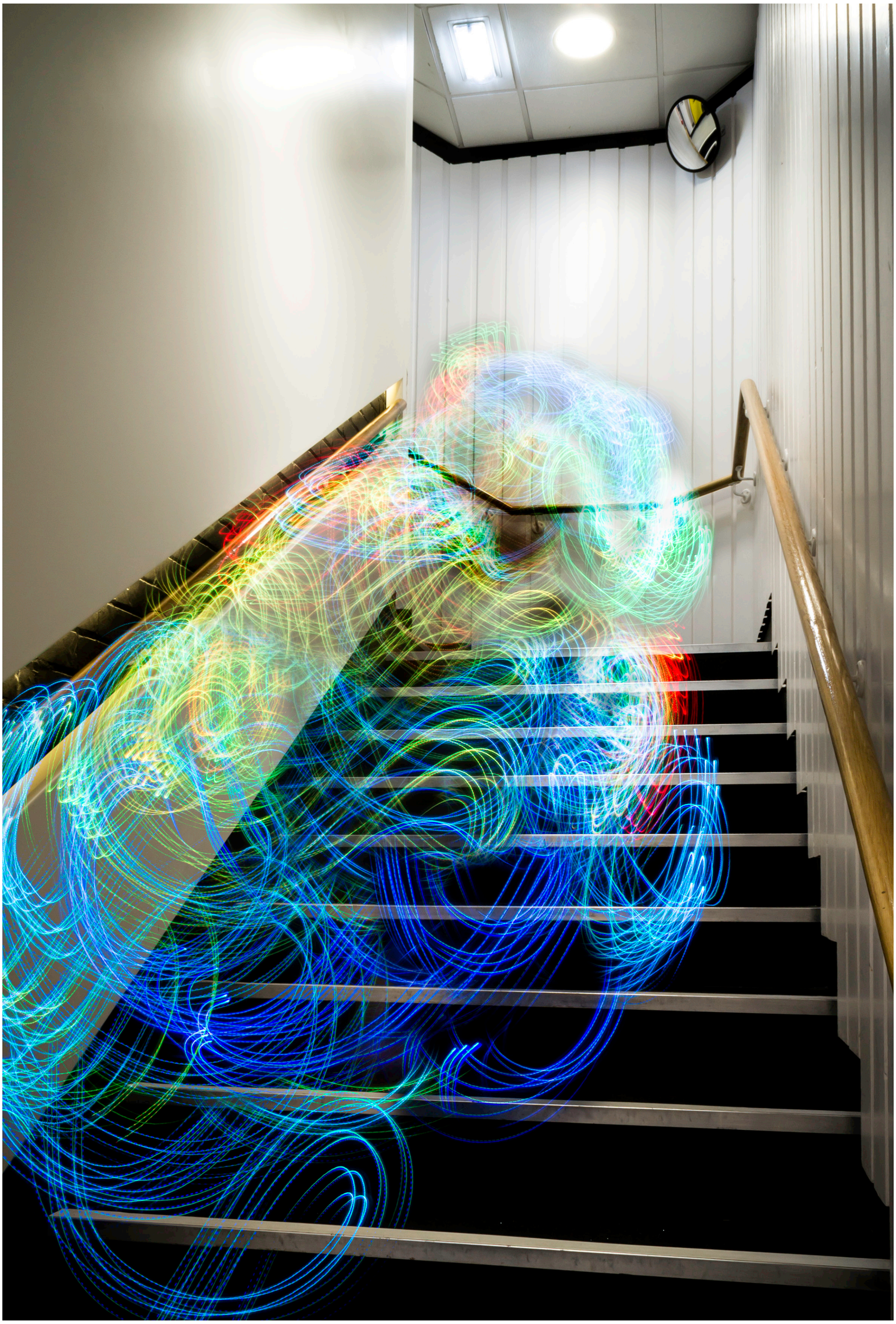


13 The density in the tracery is connected to frequent blackouts. A tighter swirling movement enables shifting the gaps in the distribution mapping



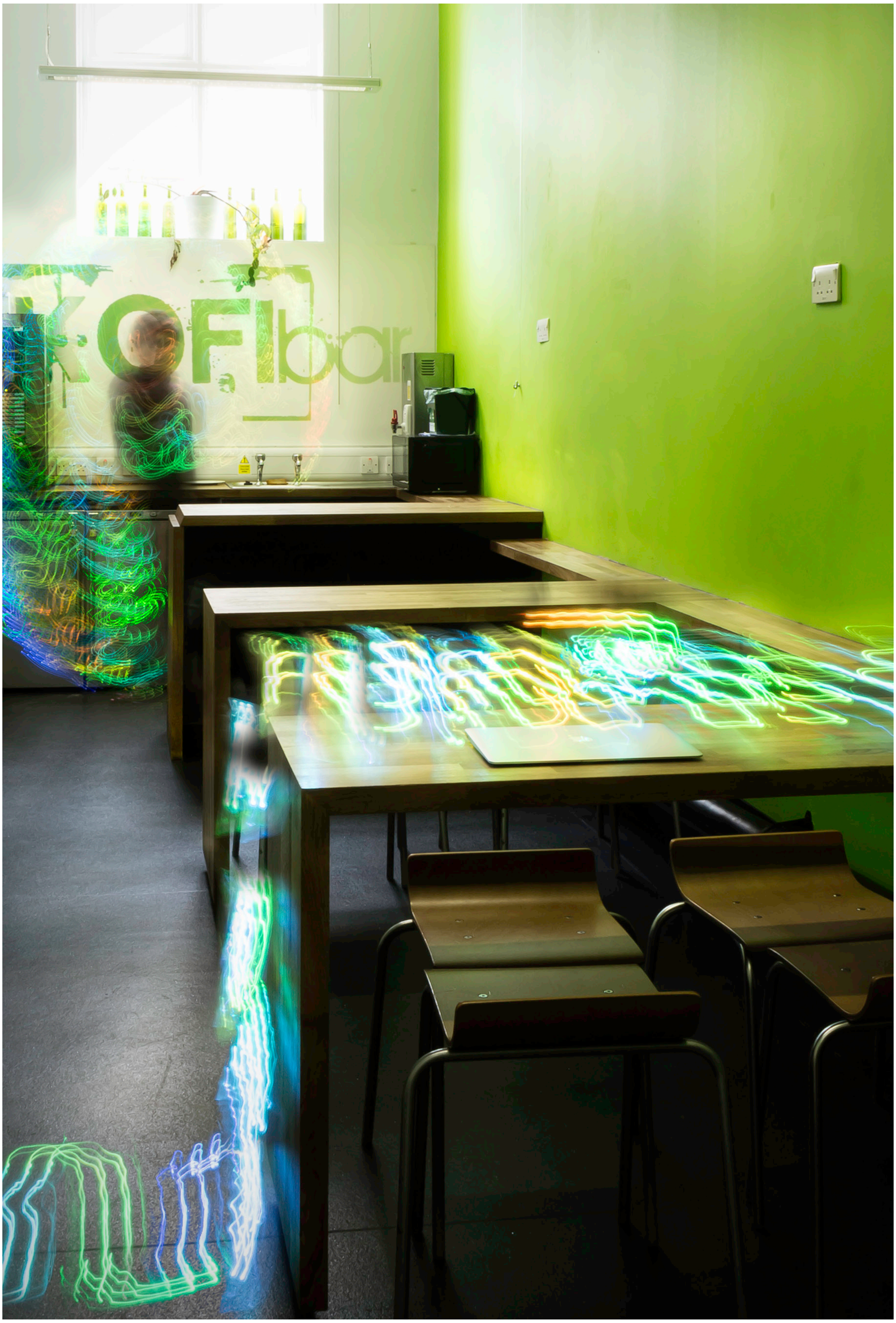
14 Image producing without adapting the choreography to blackouts. A noticeable gap appears to the left of the figure.

15 From the series Spirit Photographs, sequence 1 of 2

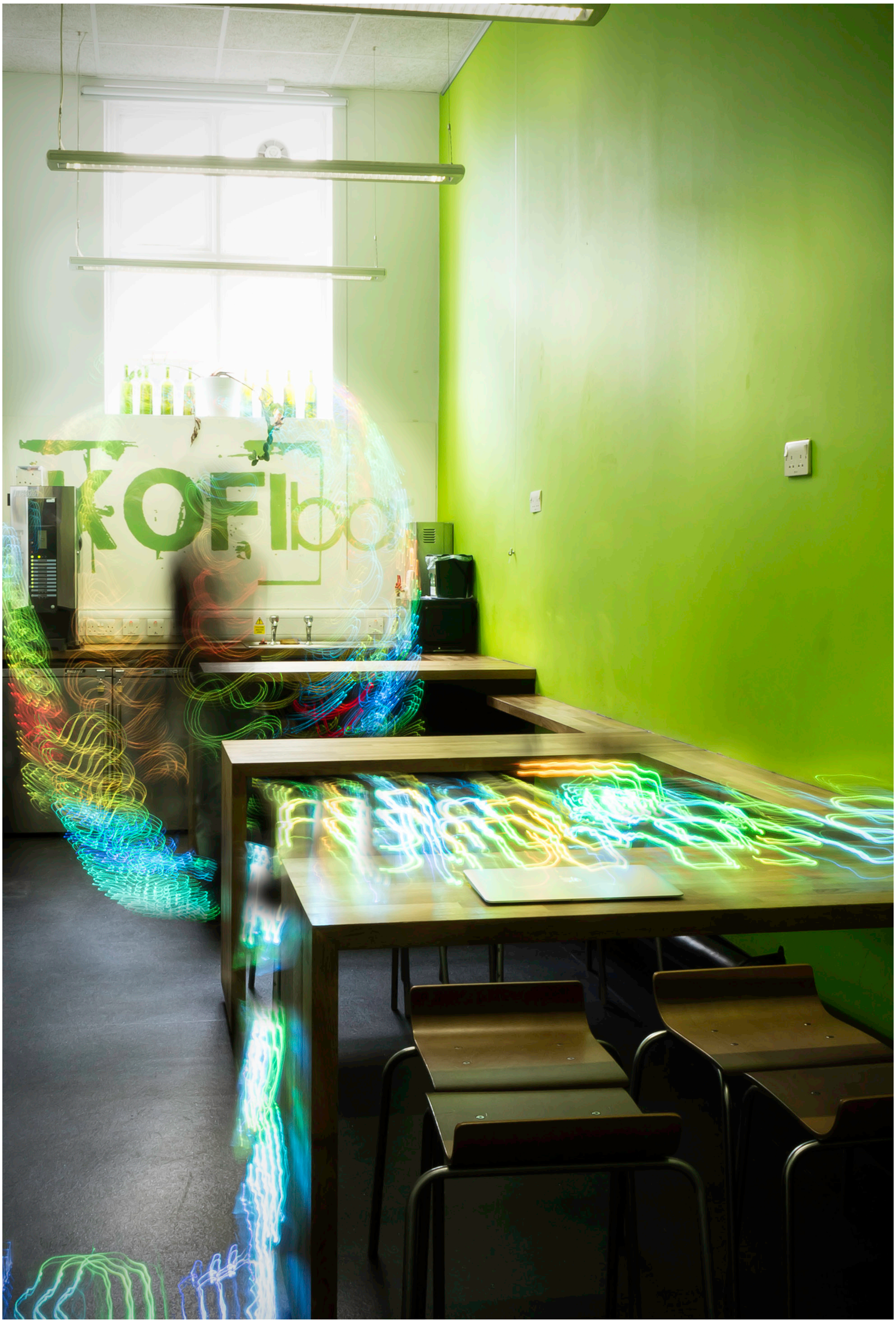


16 From the series Spirit Photographs, sequence 2 of 2

17 Diagram showing the strategies used to adapt the body to the spaces mapped



18 The sequence is adapted to run along the surface of furniture



19 Choreography is adapted to geometries in the environment main entrance of the Architecture building in Newcastle University where the range of values was between -80 and -95. In this scenario, assigning -20 to the absolute maximum of the colour gradient and -100 to the minimum would result in the image being rendered in shades of blue with nuances almost impossible to perceive in the photograph. This limitation was overcome by *calibrating* the Kirlian Device for each shot, which involves compressing the range of values considered for remapping. For the scene in Figure 19, this means assigning -80 to the red mapping, and -95 to blue. Intervening strength values are mapped across the full rainbow spectrum, which contributes to identifying them easily in the image.

Calibrating became part of the process of creating each photograph. After arriving to a location, I would *survey* the space to establish local limits by probing with a laptop. Observed results would be fed into the algorithm running in the Kirlian Device as new maximum and minimum. This was followed by a several cycles of refinements. The WiFi radio in the laptop was of a different manufacturer to the one used in the Device. Moreover, antenna configuration also varies, resulting in laptop and instrument reporting different strength values in the same space. As a result, I would have to survey the space with the device, observe the distribution and anticipate if the range needed to be contracted or expanded. This process had to be repeated over several times for each shot.

The material conceit of creative mediumship enables adopting body movements to the capturing process. Using a basic repertoire of movements, the choreography adapts to technical issues, different behaviours of signal strength and the physical space itself. Doing so positions the apparatus of body and instrument not only as a way of inscribing the invisible, but also as a means of making visible the process by which wireless acquires materiality: the coalescing of objects and situations that contribute to its shifting qualities. In this context, analogies to trance and mediumship enables a continuous process of calibration: the adaptation that the body and instrument undergo to adapt to the interaction between electromagnetic signal, physical

20 Colours are generated by calibrating the algorithm to local values, between -80 and -95 dBm

3

WET COLLODION SPECTRES

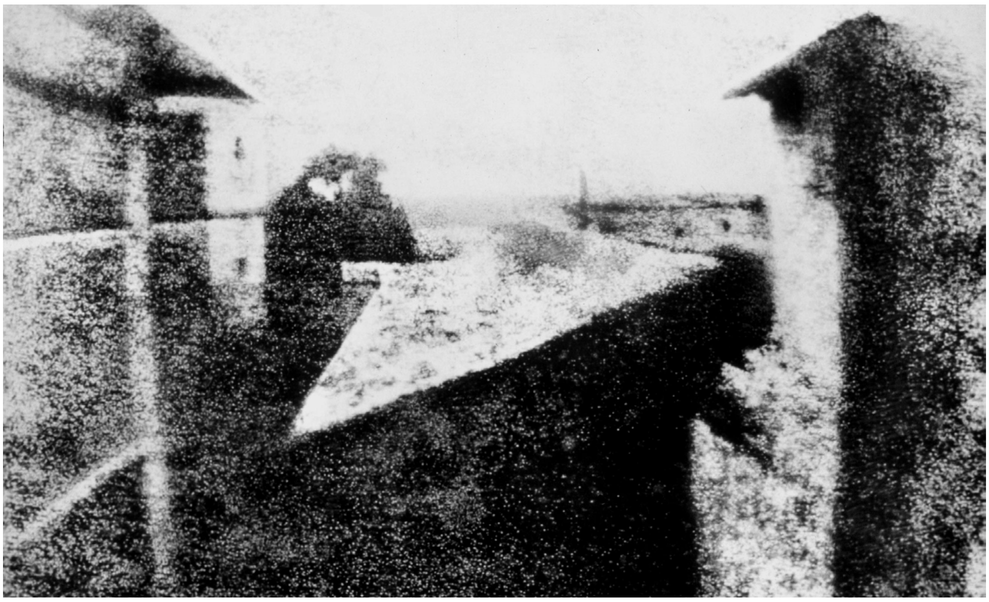
In the previous section, I made reference to creative mediumship, an artistic movement which used trance as means to produce works of art that, it was suggested, invoked mystical, invisible forces. The analogy enabled me to analyse the creation of a loosely structured choreography, which codified technical aspects of wireless networks. In addition to this, there is a further intersection of body and mystical themes in the use of light-painting, and that makes reference to the technical development of photography during the 19th century.

Light painting refers to the process in which the photographer manipulates light in the scene, and combined it with long-exposure photography to create an image (Keimig 2015). The technique can be traced back to the origins of photography itself. The first documented image to have been produced by exposing photosensitive material to light was the so-called heliograph. In 1826, Nicéphore Niépce placed a pewter sheet covered in bitumen of Judea inside a camera obscura, and placed it in his bedroom window. After eight hours, he washed the plate with oil of lavender and white petroleum, and produced an image, shown in figure 21, of undefined edges and poor detail. The texture in the image is partly due to exposure time, as any vibration in the camera or in the scene creates blurry contours.

Long exposure times represented a challenge to the adoption of photography in commercial contexts. Different photosensitive materials and emulsions, as well as improvements in the design of cameras and lenses, were developed throughout the 19th century, reducing significantly the time required to produce a photographic image. By 1830, for example, portraiture photography required subjects to sit still for around eight minutes. By 1840, the time was reduced to around 150 seconds. Exposure times quickly revealed an artefact inherent in the new medium of photography—photographing a moving subject results in a blurry image, much like in the early experiments of Niépce.

If the sitter blinked during exposure, their eyes would look as a blur. If the subject left the scene midway, his body would be capture as a transparent, ghostly trace of light across the scene.

Posing stands provided a solution to the problem of long exposure and the use of photography in portraiture. Stands were composed of a series of iron clamps which held different body parts of the sitter firmly in place throughout the process. An article in *Scientific American* in 1887 documents the process of Daguerrotype, which refers to a photographic technology developed by Jacques Mandé-Daguerre and that involved using a polished sheet of silver plated copper treated with fumes as photosensitive medium (Hopkins 1887). With this technology, exposure times were four to seven minutes in sunlight, and up to sixty in diffused light. Figure 22 shows an illustration prepared for the article, in which the Daguerreotypist can be seen in his studio, behind the camera obscura and with his subjects' heads clamped to a posing stand. The *Handbook of the Practice and Art of Photography* introduces the subject of the posing stand:
An important point is that during the exposure perfect steadiness should be secure (…) [However] No one can sit absolutely still. Evert pulsation caus-

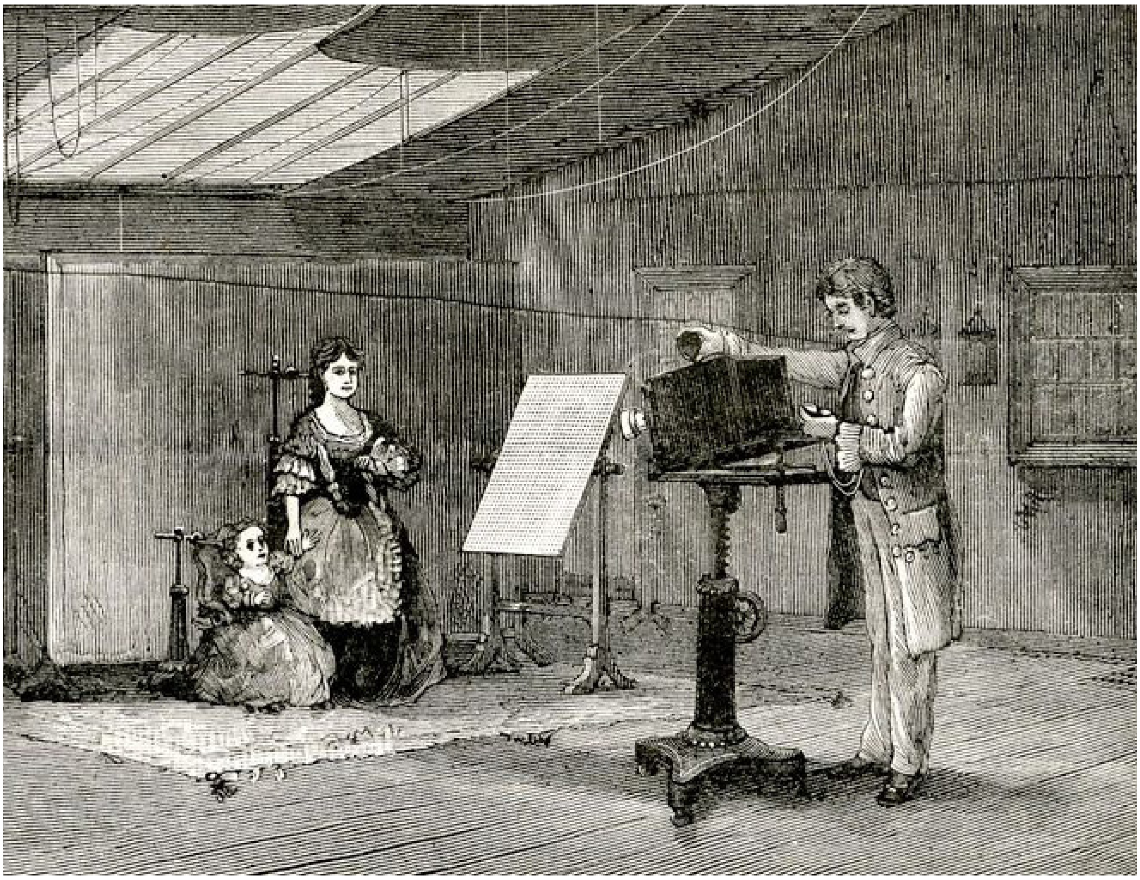


21 Niepce's photographic artefact, View From the Window at Le Gras, widely considered the first photograph es an imperceptible motion, and just at the moment of exposure, when the model is conscious that on his steadiness success depends, the spirit is most willing, but the flesh is weakest (…) Nothing can prevent this evil but the use of the head-rest, against which the public obstinately protests (Vogel & Moelling 1871)

Posing stands provide an interesting connection of body and technology. Manovich (2002) reflects on how posing stands are reminiscent of torture apparatus. The use of clamps to steady a living subject reveals, he suggests, a relationship imprisonment and containment. He goes on to track the relationship to *perspectival machines*: equipment designed to assist the precise drafting of perspectives in, for example, topographical surveys. An example of this is the *camera obscura*, which worked on to the optical principle whereby rays of light coming from a scene would pass through a small aperture, converge, invert and remerge on the other side of a dark chamber. A draftsman using the camera obscura had to remain within it, effectively being imprisoned inside. Similarly, photography imprisons the body of subject being portrayed to depict it as '*stable, eternal, unshakable*' (Manovich 2002, p.106). Manovich concludes: '*the iron clamps firmly held the subject in place—a subject who voluntarily became the prisoner of the machine in order to see her own image*' (Ibid)

The analysis of Manovick references the work of Barthes, who finds in the headrest the apotheosis of the transformation of subject into object through pain. In this, the posing stand becomes a prosthesis itself. Barthes writes:

> *in order to take the first portraits (around 1840) the subject had to assume long poses under a glass roof in bright sunlight: to become an object made one suffer as much as a surgical operation: then a device was invented, a kind of prosthesis invisible to the lens, which supported and maintained the body in its passage to immobility: this headrest was the pedestal of the statue I would become, the corset of my imaginary essence (Barthes 1981, p.13).*



22 Illustration prepared for the article on Daguerrotypy, published in 1887 by Scientific American

23 Cartoon by Honoré Daumier, showing the studio of a Daguerrotypis, with the subject's head clamped to the posing stand

In addition to its practical dimension, Sheehan (2011) proposes, the posing stand was also a signifier of authority. She contends that medical metaphors were used in the early days of photography to build the legitimacy and cultural identity of practitioners. The pain produced by the posing stand carries te meaning of having one's image taken and congealed in the photographic plate (Sheehan 2011).

Long exposure also led to the exploration of another sort of authority within photography: that of capturing reality, and its flipside of constructing it In 1856, amateur photographer David Brewster described techniques that produced what he called *ghostly photographs.* He described the effects of a moving subject on the photographic plate. If a subject left the scene, he observed, their image would not register. If, on the other hand, the subject stayed in the scene for some time, their image would partly register, producing a semi-transparent image. Brewster proposed: '*For the purpose of amusement, the photographer might carry us into the regions of the supernatural. His art (…) enables him to give a spiritual appearance to one of more of his figures, and to exhibit them as "thin air" amid the solid realities*' (Brewster 1856, p.205) The effects of long exposure could be combined, he suggested, with a number of optical tricks and composition effects. There is, for example, double exposure, where a photographic plate is exposed to two different scenes, giving the impressions of a coherent frame. Also listed by Brewster are optical effects of distance and proportion, where the effects of perspective can be used to create auras of light around subjects by placing a source of light in a distant point in the scene.

Although Brewster intended his catalogue as the craft's bag of tricks for amusement, the techniques were also used as a factual document for the spiritual world. Throughout the 1860s, American amateur photographer William H. Mumler established himself as a spiritual photographer: a trade which claimed to capture the image of deceased people into the photographic plate. His was a decisively commercial practice—Mumler would charge a fee to sit clients in his studio, and reveal the presence of their dearly departed in photographs they would carry home as a memento. The practice extended to Europe and Britain. By the 1870s, Frederick Hudson and Édouard Isidore Buguet had established similar studios in London and Paris respectively. The practice of spiritual photography developed and flourished in a specific social and cultural context. Apraxine and Schmit (2005) reminds us, for example, how commercial success of spiritual photography studios coincided with periods of war, such as the American Civil War and the War of the Communes in France. In these periods, relatives were eager for options to establishing contact one last time. Spiritual photography attended to this need.

The craft would later extend to provide experimental and documentary tools in the investigations of spiritualist practices. Photographs were used as means of manifesting the invisible forces at play in mediumistic activity. One of such practices involved the direct use of photographic plates to register emanations from the body. Photographers such as Baraduc, Darget and Bernard Luys experimented with placing different parts of their body onto sensitized plates, capturing what they believed to be their vital energy or thoughts emanating from their forehead or fingertips. The practice coincided, paralleled and cross-fertilised with research into X-ray and radioactivity at the turn of the century, and remained alive throughout the twentieth century in different forms. The experiments of Semyon Kirlian can be inscribed within this tradition. Likewise, spiritual photography was used as part of the arsenal used by spiritual investigators to document the visible effects of mediumistic powers during séance sessions of well-known performers, such as Florence Cook and Eusapia Palladino. Photographs were used to capture ectoplasm, the fluid thought to emanate from the body during mediumistic trances, and other phenomena such as levitation, transfiguration and telekinesis.

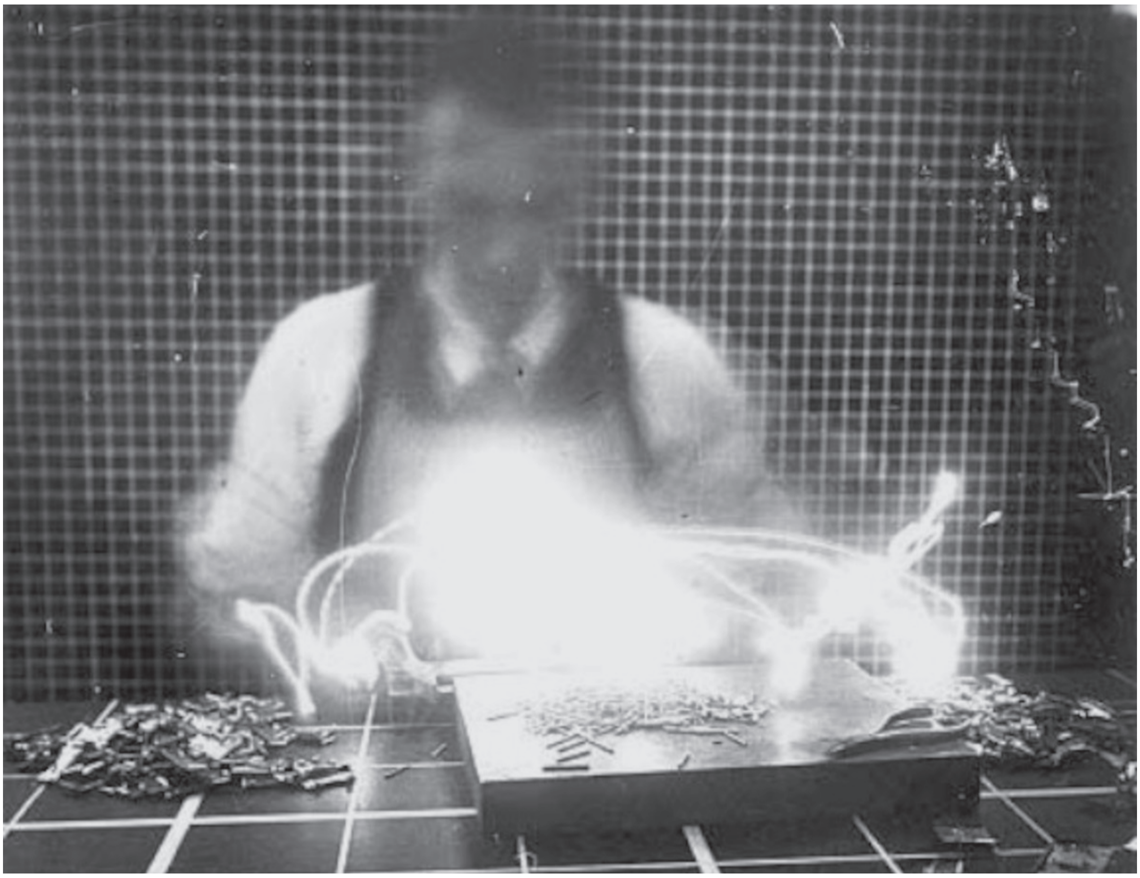
Similar to the case of wireless, Gunning (2007; 1995) observes a deeply ingrained paradox in photographic technology. On the one hand, photography is identified as a system of mimetic representation, and is therefore favoured by science as means of verification and documentation. This is connected to the way in which it constitutes an icon, a bearer of resemblance, and an index, a trace left behind by an event. Gunning reflects:

> *essential to the belief system which photography engendered was the fact that the image was created by a physical process over which human craft exerted no decisive role. Photography was therefore a scientific process (…) tool of discovery and means of verification in a new worldview constructed on an investigation of actual entities explored through their visible aspects (Gunnin 1995, 42)*

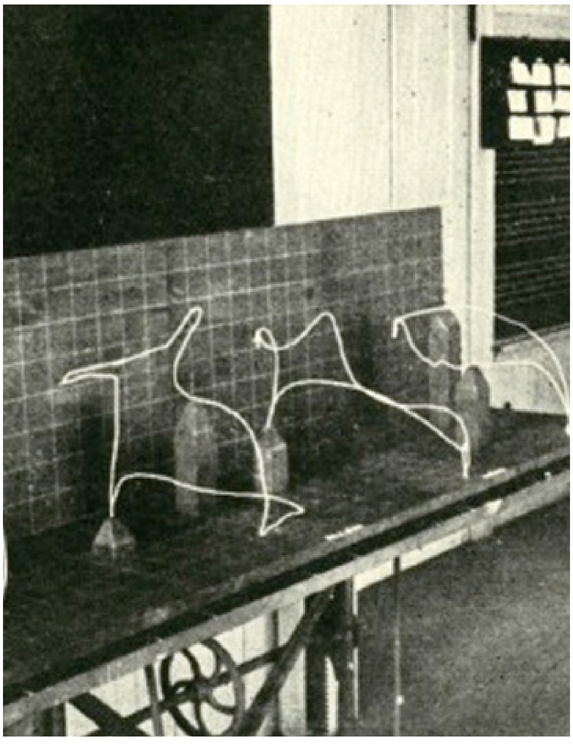
While the chemical process in photography ensures its indexicality, cultural perceptions connects it to the supernatural and the occult. Gunning suggest photography generates *phantasms*. Premodern philosophy uses the term of phantasm to describe images located between the material and immaterial, and serves to explain the connections between sight and imagination. For Aristotle, for example, uses the concept of *phantasia* to refer to a kind of perception that allows to pick out features of the environment, and to use those features represent the object where they come from in processes of abstraction and reasoning. Thus, a double of the original is created, which takes on some of its features but becomes an independent entity of its own: a phantasm (Osborne 2007). Photography creates phantasms: endlessly reproducing the appearance of the original.

It could be argued that the techniques used in spirit photographs are distant relatives of light painting. Light painting is generally defined as a photographic genre, derived from long-exposure photography, where light is manipulated by the photographer in order to construct an image. Its first historical ocurrence is in anatomical studies of movement. Keimig (2015) traces the genealogy of light painting to the experiments of Marey and Demeny, French physiologists who developed *chronophotography*, which encompasses a number of photographic techniques to record movement. Their efforts are contemporary to those of Muybridge, who experimented with arrays of cameras which allowed him to study locomotion through a succession of still images. Marey and Demeny used long exposure to record the trail of movement in a single photographic plate, instead of the series of images generally employed by Muybridge. One of such methods is the Quénu technique, which involves attaching light bulbs to the joints of subjects in order to record involuntary movements and locomotion. The techniques of chronophotography would be later used by Frank and Lilian Gilbreth to produce a series of efficiency studies in the workplace. Their technique was called stereochronocyclegraph, a compound word of the Greek terms for time, motion and writing, and consisted in attaching blinking lights to arms and legs of masonry workers (Page 2015). The study was aimed at revealing the more comfortable and natural movements for different tasks, in a hope to increase their efficiency (figures 24-26).

Light painting also has a considerable genealogy in art, where it has been used to experiment on bending mimetic representation, thus connecting to Spirit Photographs. One of the most famous examples is a series of photographs produced by Pablo Picasso, working in collaboration with by Gjon Mili, an engineer and self-taught photographer who worked under Harold Eugene Edgerton, professor at MIT who is credited with the development of stroboscope , sonar and deep-sea photography. Gion used stroboscopic lights to capture movements of dancers, skaters and jugglers in single, long-exposed photograms. Gijon's work helped convincing Pablo Picasso to collaborate on a series of Light Painting Photographs for a 1949 edition of Life Magazine. The article covering the series reports Picasso giving an initial shot at the technique in a 15 minutes session. After seeing the result, he agreed to five more: '*projecting 30 drawings of centaurs, bulls, Greek profiles and his signature. Mili took his photographs in a darkened room, using two cameras, one for side view, another for front view. By leaving the shutters open, he caught the light streaks swirling through space*' (Cosgrove 2012). Over the years, Gijon would collaborate with Picasso in more light drawings, which would be later featured in different Life Magazine issues. In a 1968 retrospective issue, the photographs were included alongside portraits also captured by Gijon (Figures 27 – 29). One of the descriptions included in the articles is

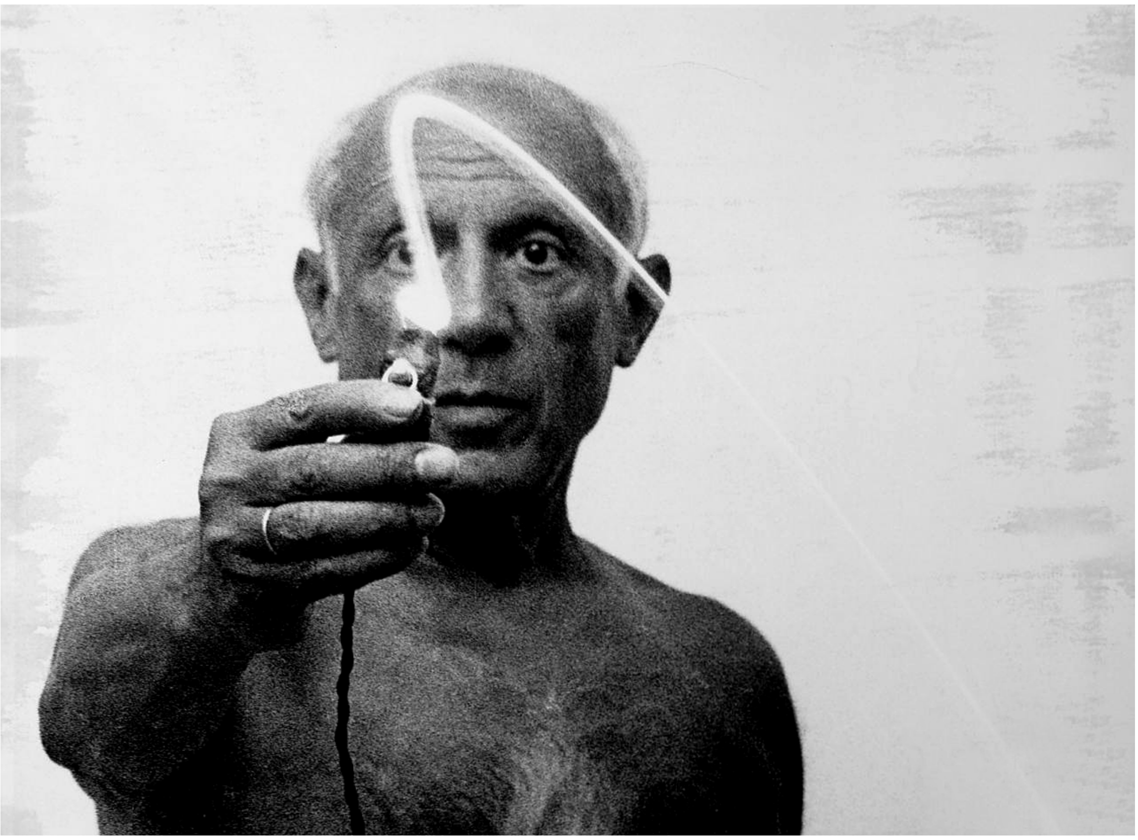


24 Frank and Lillian Gilberth's Efficiency Study

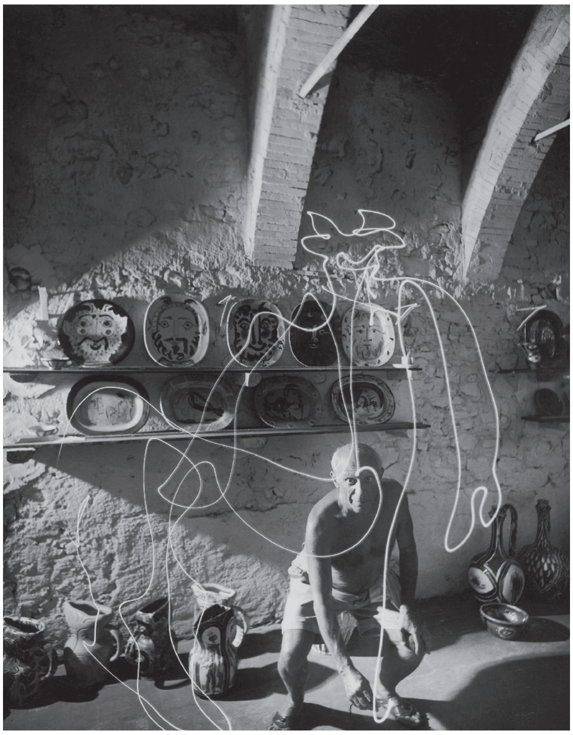


25 Part of Frank and Lillian Gilberth's Efficiency Study, showing travel of hands to sort materials on a bench.

26 Part of Frank and Lilian Gilberth studies on work simplification.



27 Part of the series published by Gjon Mili in Life Magazine showing Pablo Picasso holding one of the light pencils used in the experiments



28 Picasso Draws a Centaur, Gjon Mili in collaboration with Pablo Picasso for Life Magazine

29 Everything is illuminated, Gjon Mili in collaboration with Pablo Picasso for Life Magazine.

reminiscent of the mediumistic trances captured in spirit photographs:

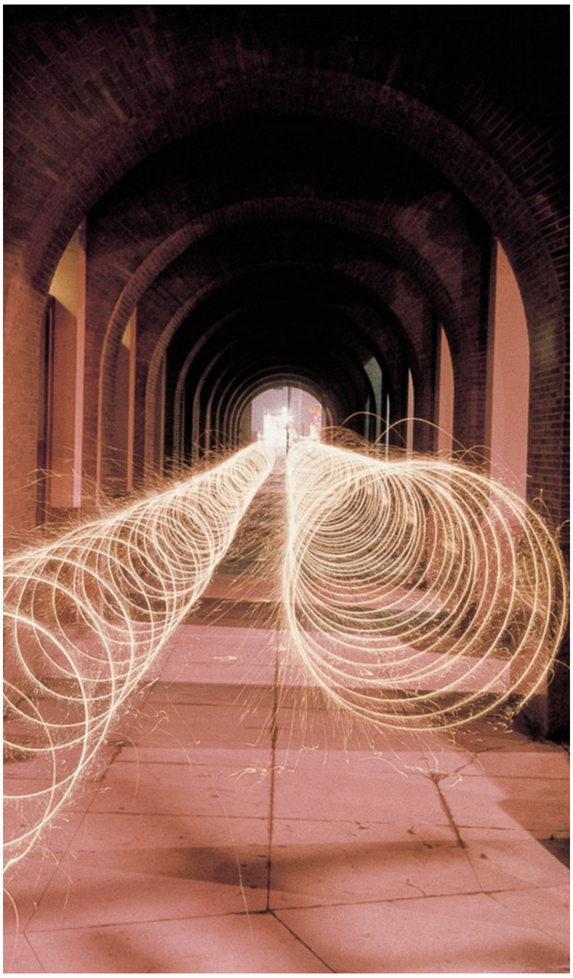
> *Putting on a mask is sometimes enough to set Picasso off into a kind of witch-doctor frenzy. He roars and writhes behind his gorilla mask, dances away to the mirror, returns in a rubber devil's mask to swoop down on his daughter Paloma. Picasso was one of the first European artists to recognize the magic and beauty of African masks, and his own masks show the enduring power of that early influence (Cosgrove 2012).*

The connection between long-exposure, body and trance is later explored by Eric Staller, who experimented extensively on choreographies of light. Staller created a photographic series which show New York during night time, super imposed by sparkling trails of light, filling the space. In the initial series, the trail was created by handheld fireworks which he would move with his arm. Originally trained as an Architect, Staller was interested in the way the movement of his body, in addition to makeshift instruments, would generate different *architectures* of light:

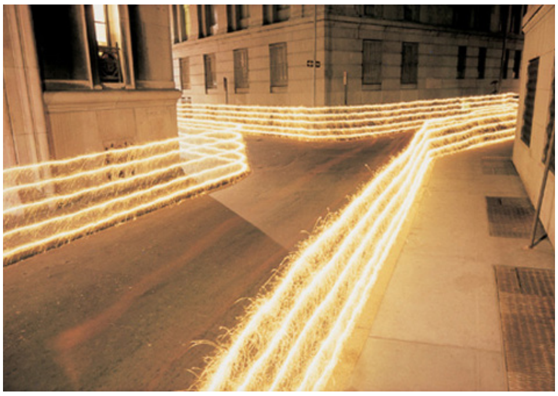
> *My dreams in 1977 were taking the forms of fantasy architectures of light. I invented choreographies and volumes of light. I remember being impressed by the architectural uses of the human figure in Fritz Lang's film 'Metropolis' and old Busby Berkeley films, and I began to think of the geometry of my body. (…) I attached one [sparkler] to the end of a broomstick and, using my arm as a compass, scribed arcs overhead as I walked up the middle of the street Lighttunnel (…) For Lightubes I spun the sparkler on the end of a string as I walked toward the camera; then ran back and did it again (Staller 2006, p.100).*

Figure 30 and 31 show the photographs referred by Staller. The geometries involve a vocabulary of shapes which describe the interaction between bodies and urban spaces. Figure 32 show Ribbon in Hannover Street, which was created by mounting five fireworks in a broomstick, which is held vertically and moved at arm's length. The aesthetics of this photograph, alongside the instrument, is reminiscent of the *Immaterials WiFI Lightpainting* project.

30 Light Tunnels, part of the Light Drawings series by Eric Staller



31 Light Tubes, part of the Light Drawings series by Eric Staller



32 Ribbon on Hannover Street, part of the Light Drawings series by Eric Staller

33 Light Domes, part of the Light Drawings series by Eric Staller

Similarly, Figure 33 show the Domes, whose shape and composition in the image are quite similar to those used in the Spirit Photograph series of this project.

In using the metaphor of choreography, Staller stresses the relation between space, body and movement. This is evident in the way each image is described in relation to the bodily movement it required, as well as the makeshift instrument needed for the particular effect. Tunnels, for instance, involve creating arcs with the arm, and a broomstick fitted with a firework on its end. Also worth of mentioning is the way in which the photographer refers to the process of enacting the choreography as a performance. Staller recalls drive around New York at night in a battered old van looking for locations. He would pick one, set up his photographic equipment, plan his choreography and perform it. Sometimes, he would find the locations deserted. More often than not, he had an audience: '*It occurred to me more than once that these were performances with light: crowds of curious garbage men, night watchmen, cops, workaholic Wall Streeters and the homeless gathered to watch the lunatic with the blazing broomstick!*' (Ibid). The description hints at the process of creating the images as a contingent event, in which both audience and performer are transformed, and in which the choreography is the result of an interaction.

4

LAYERS

This section will discuss the effect of layering. The term refers to a post-processing technique made necessary in the context of long-exposure photography due to technical limitation of digital sensors. The section will discuss the construction of digital sensors and the mechanisms they use to record an image. It will then describe long-exposure photography, and analyse how reduced sensitivity range of digital sensors is offset by blending several images, which substitutes for low-sensitivity films which enabled greater flexibility in long exposures. In the context of this exploration, the process constitutes a further level of interpretation and connection between performer and capture.

4.1 Long exposure photography and digital sensors

Long exposure photography refers to a photographic technique where the photosensitive material is exposed to light for relatively long periods of time. Conventionally, photography is based on a process whereby an image is captured by exposing a photosensitive material, digital or analogue, which registers the effect of light on a scene. This is done by activating a mechanism, the shutter, which enables light to reach the sensitive medium for a fraction of a second. Long exposure photography works by stretching exposition to seconds or minutes, recording moving objects as a consistent light volume.

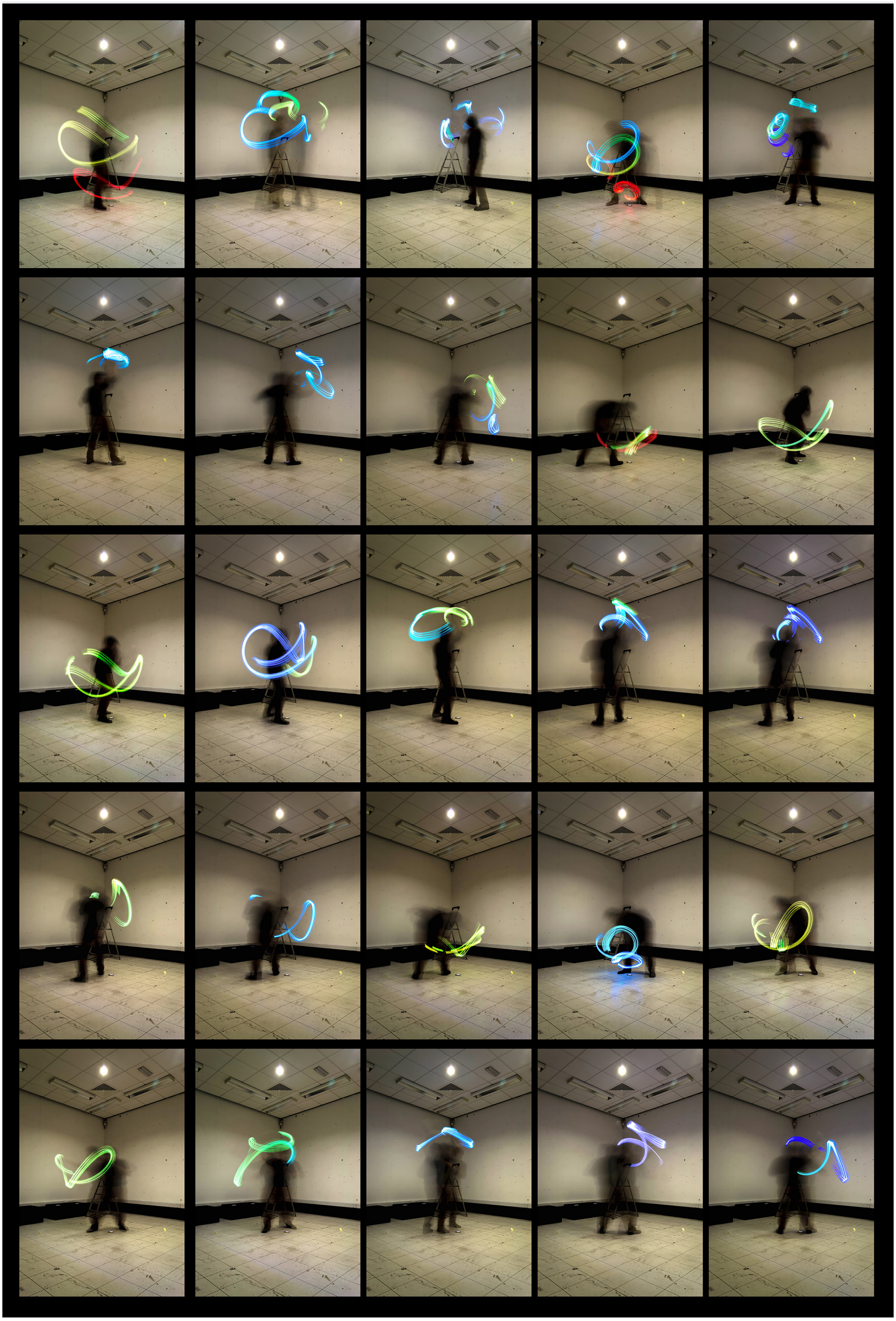
Long exposure photography, however, presents several challenges in digital media. Compared to film, digital sensors offer a limited sensitivity range and requires constructing the images in layers. Analogue photography works by using a photosensitive film, consisting of silver halide crystals suspended in a gelatinous emulsion. Exposition to light photons triggers a reaction in the crystals, where an electron is released from the bromide ion and attracted by the silver ion. This transforms the silver ion into metallic silver, which enables recording a photographic image (Bogost 2012). The size of silver crystals, also known as granules, determines the sensitivity of the film. Bigger granules take longer times to be *burnt* and form the image. Substrate sensitivity is measured using a number of standards, such as the ISO. Sensitivity determines the exposition time required to form an image: burn silver crystals enough to generate an image that resembles the scene. This is controlled in camera by the synchronised action of two mechanisms. The iris, an interloping, radial set of blades, regulate the size of the aperture through which light passes. In addition to this a shutter controls the amount of time the photosensitive material is exposed to light. Long exposure photography is generally achieved by using a low sensitivity sensor, which enables using longer exposure times in which movement is registered as a blur.

The sensitivity range offered by digital, CMOS sensors present challenges in creating long-exposure photographs. A CMOS sensor, acronym for complimentary metal-oxide semiconductor, uses an array of sensitive elements connected to an integrated circuit. Each sensitive element consists of a photo detector, which modulates the input voltage according to the strength of light it receives, and a signal amplifier. With this technology, sensitivity is tuned by varying the voltage supplied to the circuit, which in turn affects its signal response and noise. This has an effect on the range of sensitivities that can be achieved. The Nikon D3100 used in this project, for instance, uses a range of sensitivities with a lower limit of ISO 100. The choreography used in capturing the ovoid around my body takes three to six minutes. Using the lower ISO 100 and aperture of f-8, the light trail left by the Kirlian Device is correctly exposed in a time range of 1 to 3 seconds. To stretch exposition time, I decided to use neutral density filters, which refer to sheets of optical material that reduce the amount of light that passes through the lens and reach the sensor. With this strategy, time exposure could be stretched to the region of 15 to 30 seconds. In order to capture the entire ovoid, I had to recourse to blending, a post-processing techniques where several images are blended into a single image.

4.2 Blending and masking

Image blending was done in Photoshop, a graphic editor software commonly used in photographic editing. The process involves using the layering functionality of the software, which combines the individual pixels of each image by performing different mathematical operations on their colour value. The specific algorithm is determined by the blending mode used to combine each image. A multiply blending mode, for instance, works by multiplying the value of colour in the corresponding pixels of each image. A linear burn, works by adding both and then removing white from the result (Valentine 2012). The process is illustrated in figures 34 and 35. Figure 34 represents the collection of images captured in performing wireless in a room. Each image covers a segment of the ovoid, which results from my body rotating around its axis throughout the capturing process. Blending these fragments results in the image in figure 35.

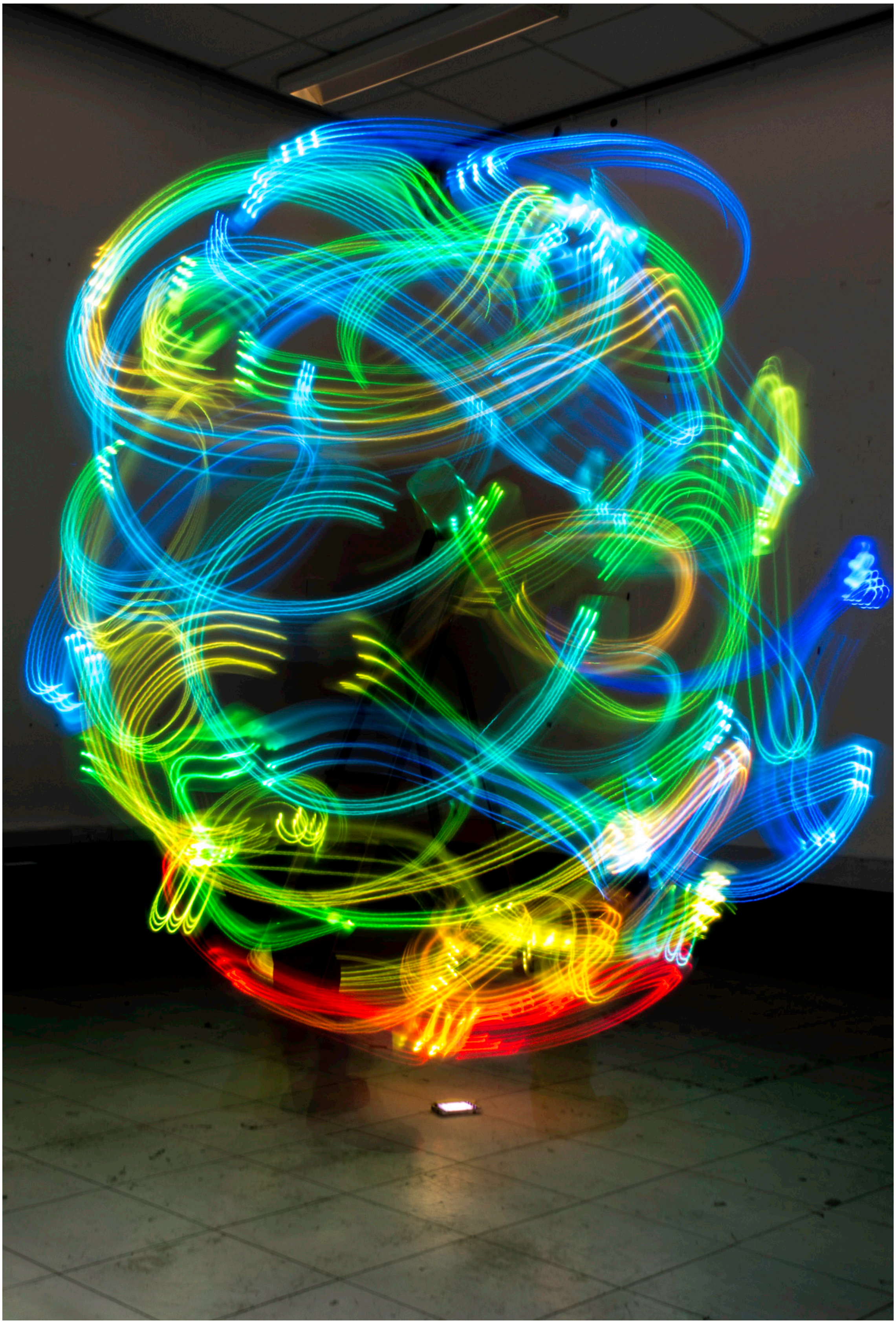
The process of blending, however, involves a number of complexities that, given their influence in the capturing process and in the final image itself, are worth exploring. There are conflicts, for instance, in the points where images are stitched which require modifying the choreography. Capturing an image involves creating 15 seconds long performances of a portion of the ovoid. Each session is recorded in an individual photograph, and there are a few seconds required by the camera between photographs to write the image to memory. As a result, the performer is required to remember the place where one performance stops, and start the next one at the same spot. The system, however, is prone to create several overlaps: spots mapped by two contiguous performances and that, in blending, cause *burnout*: colour information of pixels cancels each other due to the additive nature of the process. Figure 36 shows a photograph that has been produced by creating fragments of the performance, and then blended together. Note how several areas of the image result in white strokes, which convey no information on signal strength. A way to reduce burnout is to use an additional technique called *masking*,



34 Sequence of images showing the pieces required to assemble an individual image which involves selecting portions of the image to be selected, filtering out areas of overlap. The technique, however, affords a number of decisions that can manipulate the resulting image in post-processing. Some decisions are taken, for instance, in manipulating the blending mode: the algorithm used to combine images and that vary in the mathematical operations used to combine individual pixels. This enables greater control, for instance, on how specific colours are shown against dark or light backgrounds. Other decisions require forms of interpretation that change the meaning of the image itself. Contiguous performances, for instance, might have recorded the same location in red and yellow. As only one can be shown to eliminate burnout, a decision is taken in post-processing of which signal strength to filter out. Similarly, trail thread can be manipulated in post-processing, by allowing larger or smaller portions of close or overlapping sections to be shown in the final image. The sequence of figures 37 and 38 show the incremental process of blending. Individual images in 37 show sequential stages in which different portions are added into the image using the techniques of blending and masking described previously. Figure 38 shows the resulting image.

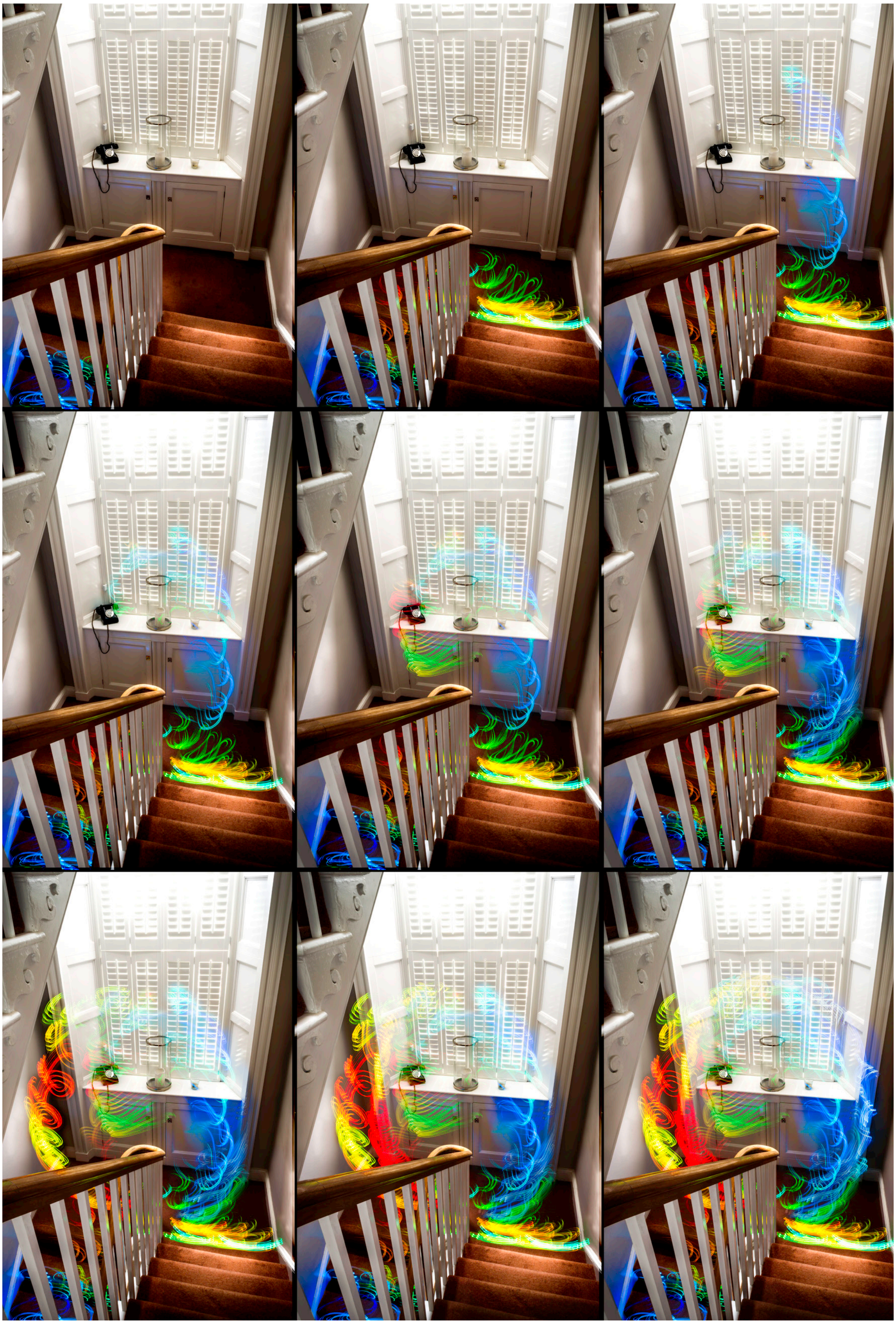
The problem described above is analogous to critical discussions triggered by the introduction of the layer system in Photoshop. Flagan (2002) recounts how the introduction of the functionality in the 1990 release of the software triggered a discussion around the possibility of indexicality in photography. It was generally argued that the use of layers, and the manipulation they afford in the final image, cancels the analogical nature of photography, as it erodes the connection between subject and representation. In the context of this exploration, one way of preserving the indexical link between image and process was to keep notes of the difficulties encountered in each performance. The notes are then used in post-processing to interpret images as close as possible to the conditions found in capture.

The additional layer of interpretation in post-processing, however, can be also thought of as a form of feedback, enabling further lines of connection between performer and signal dispersion. Allegory to the creative medi-



35 Image resulting of combining the fragments in figure 21

36 Image resulting from a non-selective combination of fragments. Notice the burnout areas, where overlapping sections are registered in pure white



37 Sequence showing the incremental buildup of the image. A new portion is blended in every photograph

38 Image resulting from the process shown in figure 24.

umship enabled non-structured techniques, in which body movements are shaped to technical challenges and signal propagation. This depends on forms of feedback between the process of scanning for wireless networks, and the performer: means by which the performer understands how signal dispersion changes with their body movements. The images presented in this chapter were created over a course of six weeks, with one or two sessions per week. Images were post-processed at the end of each week, giving the performer some time to reflect on the process and plan improvement before performing the next set of images. This constitutes an indirect connection that enables some understanding of, for instance, how different strokes are best suited to be registered at different angles of the ovoid. Nonetheless, this is an imperfect form of feedback that provides weak notions of how body movements connect to the capture process and signal dispersion. The next section will explore this in more depth, reflecting on the *engagement* of feedback.

5 FEEDBACK

Feedback is the *engagement* that has been least explored in producing *Spirit Photographs*. In this context, the notion refers to forms of connection with signal dispersion which enables the performer to adapt their choreography in response. In the previous section I have analysed how the process of blending image fragments constitutes a form of feedback, in which the performer adapts their choreography after the event. In this section I analyse other forms of feedback occurring during the capture and how they influence the representation of wireless. Moreover, I will suggest that the notion of feedback was not explored sufficiently, and provide further routes of exploration developed in the following chapter.

Compared to post-processing, the capturing process offers more immediate forms of feedback. There is, for instance, the image preview displayed in the digital camera: the performer can see images of each performance immediately after they are created in the 3-inch screen. This was used throughout performances to, for instance, make sure that fragments had enough information recorded, that enough fragments had been collected to assemble an ovoid, to attune body movements, and to understand how strokes and their spacing were registered at different angles of the ovoid. These mechanisms, however, still constitute a delayed feedback, as insights learnt from looking at the registered image can only be improved on a following performance.

Moreover, the Kirlian Device implemented few ways for the performer to gain intuitive understanding of signal dispersion and the technical process of capture. The Kirlian Device, for instance, was modelled to maximise exposure of the light source by placing a translucent lid that faces directly into to the camera and away from the performer. However, the configuration of the LED strip, wrapped around the logic board and WiFi radio, produced a fair amount of lateral light which the performer could use to react to and adapt their choreography. The process nonetheless is at odds with the allegory of creative mediumship developed in an earlier section. The notion of trance alludes to a process of capturing and mapping signal dispersion that is not directly linked to conscious decisions, but that rather makes use of less structured forms of connection between performer and scanning process. Keeping track of the changing light colour requires conscious attention from the performer, who needs to constantly refer to a mental equivalence table to translate them to signal strength. This enabled adapting the choreography, for instance, by retracing zones where blackout had happened, or varying the spacing of the stroke to evidence connection drops. While these mechanisms are adequate in creating images, they fall short of providing enough cues for the performer to incrementally build an intuitive understanding of signal dispersion in relation to their own body.

Other feedback mechanisms can be integrated into the Kirlian Device to improve understanding of signal dispersion, such as, for instance, vibration. Mechanisms of tactile experience are often used in interaction design to create environments which encourage exploration and a connection between technology and bodily movements. References are often drawn to the work of psychologist James J. Gibson, who developed a body of work around the role of touch as exploratory sense. Gibson argues that senses such as sight are receptive, in the sense that the observer has no way of controlling how stimuli reaches their eyes. Touching, on the other hand, produces a direct link between information and the body, as information is released linked to motor activity (Gibson 1962). In the context of the Kirlian Device, this would provide a more direct connection between how the movements of the body make manifest the qualities of the wireless field. Another potential, feedback mechanism is the use of sounds. This would involve, for instance, mapping signal values to a range of sound pitches from high to low pitch.

There were several technical challenges that prevented implementation of these additional feedback forms. The Kirlian Device comprises an Arduino UNO, an Arduino WiFi Shield, a Pololu LED strip and two Li-Po batteries to power the circuit. Early prototypes of the circuit were implemented with one battery, but created voltage issues. The LED strip is rated to draw 3V to 5V depending on colour brightness. Likewise, the combination of Arduino UNO and WiFi shield operates on voltage peaks of 5V when performing the active scan. This resulted in several issues where the Arduino UNO would shut down and reset during active scanning as it competed with the LED strip for power. A solution to this was to include two batteries in the circuit, one feeding the logic board and WiFi radio, while the other was dedicated exclusively to the LED strip. A potential solution is to upgrade the battery used in the circuit, for instance, to a 7.5V source. This, however, would have created other design issues as higher voltage batteries are bigger and could not be fitted in the Kirlian Device.

Integrating a vibration motor or a small speaker on the circuit would put additional strain on the batteries, and required a complete redesign of the circuitry and body of the device. I decided instead to carry on the exploration in Spirit photographs with the feedback mechanisms in place, and explore the notion further in a second design of the Kirlian Device, covered in the following chapter.

6 CONCLUSIONS

In this chapter, I have developed an annotated portfolio of Spirit Photographs, articulated by four *engagements*: *body as instrument*, *trance*, *layers*, and *feedback*. In *Body as instrument* I reflect on the insights from the previous chapter, and develop further the conceptualisation of the body as part of the apparatus to record the invisible. In this context, I have explored the material conceit of *instruments that lay hold of spirits*, and which makes reference to a series of devices developed to make manifest the changes that the body undertook in its interaction with invisible fluids, technological and mystical. Of these, I have looked at Kirlian Photography, an electrophotography technique which enables registering coronal discharges, and that has been often interpreted as providing an outline of human aura. The conceit is relevant as it enables thinking of instruments as operating in tandem with the human body, and provides the context to redesign the *Space Reader*, an instrument modelled in surveying tools; into the *Kirlian Device*, a device modelled around the movements of the human body as a means of registering wireless signals. I have described how the form-factor of the device is modelled after the makeshift configuration of electronics used in early photographic tests, and used fabrication techniques which resulted in aesthetics reminiscent of the original Kirlian photographic device.

In *Trance*, I explore further *engagements* developed in the Kirlian Device, and analyse how body movement can be structured into choreographies that integrate aspects of signals dispersion, and of the process of detecting and registering them. In this, I have drawn from the conceit of creative mediumship, an artistic movement from the turn of the century built around the use of mediumistic trance as creative process. The movement is relevant as it provides a framework of inscribing the invisible with bodily movements: creative mediums thought of themselves as providing the style, while invisible forces provided the content of the art object. Similarly, I have built basic movements and rules by which they adapted to changing signal strength, and then articulated choreographies which enabled me to build an *ovoid* that represented signal dispersion around my body. Both choreography and technical process incorporated strategies of *calibration:* dynamic adaptation to the signal strength and technical complexities. An example of this is the way density of the resulting traceries reflect signal dispersion and the connection drops and blackouts encountered in gauging it, or the way the body contorts around spaces to reflect their geometry. I have proposed that these positions the apparatus of body and instrument not only as a way of inscribing the invisible, but also as a means of making visible the process by which wireless acquires materiality: the coalescing of objects and situations that contribute to its shifting qualities.

I have gone on to explore the *engagement* of *Layers*, referring to the imprint of the substrate used to produce the images. I have analysed the implications of using digital sensors, which afford a limited range of sensitivity. The implication of this is that long-exposure photographs need to be created by combining fragments into a single image, emulating how the image would result if recorded in a single operation using less photosensitive materials. The techniques used to combine images as layers, such as blending and masking, have an effect not only in the appearance of the final image, but also in the process of capture itself. There is, for instance, the requirement to fragment the performance into 15-second sections. The process, however, creates further layers of interpretation and mediation, such as in deciding which colour to filter out in conflicting, overlapping areas; or in balancing the density of the filaments shown in the combination. Notes were kept of each performance, which provided a basis to maintain the index of the image to the signal strength and the process of capture. Post-processing, however, can also be interpreted as a form of asynchronous feedback, where the performer can understand the impact of choreographic decisions, and improve them in the following round of performances.

The final *engagement Feedback*, continues the thread of Layers and reflects on the different mechanisms of connection between signal dispersion and performer afforded by the process. I have analysed how the notion of feedback is particularly relevant in the exploration, as it connects back to notions of materiality as intuitive understanding of how a material can be manipulated and acted upon. In this context, the notion of trance is intended to allude to a process of capturing and mapping signal dispersion that is not directly linked to conscious decisions, but that rather makes use of less structured forms of connection between performer and scanning process, and that mimic processes of systematic encounter with the material. The section goes on to analyse that, although there are some incidental forms of feedback, the design of the Kirlian Device falls short of providing means of assisting the designer in creative intuitive notions of how their body movements connect to signal dispersion and technical process. Although some feedback mechanisms were designed to be integrated in the Kirlian Device, several technical complexities prevented this from happening. These shortfalls are addressed in the next chapter, which pivots around a redesign of the Kirlian Device.

CHAPTER 6

6

KIRLIAN DEVICE MOBILE

KIRLIAN DEVICE MOBILE

INTRODUCTION

In this chapter, I will reflect on the design of the Kirlian Device Mobile (*KDm*), an Android application which builds on notions of feedback and calibration developed in the previous chapter. The redesigned instrument enabled a number of design explorations, including event such as the wireless séance, a prototype running in Google Glass, and the installation *The Chandelier*. These contribute in reflecting around four *engagements*: *calibration*, *séance*, *immersion* and *atmospheres*. In the last chapter, I have analysed how the Kirlian Device provided few feedback mechanisms in its original design. Although aspects such as vibration and sound were considered, technical complexity prevented implementing the necessary hardware in the original circuitry. Mobile phones, however, offered a convenient way of exploring notions of feedback in a platform where hardware is readily available, which minimises prototyping challenges. The chapter will analyse affordances of mobile phones which enabled other exploration media beyond the photographic, such as wider distribution of the instrument and community experimentation.

The first *engagement* will reflect on the improved format of calibration afforded by mobile phones. In the last chapter, I described how creating the Spirit Photographs required a process of calibration, where the algorithm was modified to respond to local, instead of global, signal strength limits.

This was implemented by cycles of adjustments that required disassembling the device, wiring to a laptop and hardcoding values. The Kirlian Device mobile afforded more flexibility, integrating a graphic user interface through which calibration could be triggered. The section will also analyse the programming strategies necessary to adapt the scanning routine to the Android platform, including the use of passive scanning and the development of sound mapping.

The affordances of the phone as prototyping platform, however, suggested further design exploration besides the photographic. *Séance* will reflect on how the Android app enabled distributing the instrument to a wider audience, eliciting others to produce their own rendition of the Spirit Photograph. It also enabled *séances*, social gatherings which provide the context to discuss wireless and its materiality. This is implemented in the context of an Interaction Design module, where architecture students are asked to engage in a format reminiscent of the séances used in 19th century spiritualism, with the objective of developing alternative understandings of invisible technologies.

The android platform also enables experimentation on Google Glass, a set of augmented reality glasses, as described in *immersion*. The *KDm* was ported to the Glass platform, and a prototype deployed during the *Invisible Body of Wireless* exhibition. The section will argue that the experiment suggests a new model of immersion in which the wearer can explore how signal dispersion shifts as they walk through physical spaces. This is in contrast to the model used in *Spirit* Photographs, where the texture of wireless fields emanates from the body movements. The model of immersion also connects back to notions of space thickening, first floated in the previous chapter and that suggests wireless as an invisible fluid that saturates physical space.

Notions of immersion are further explored in *atmospheres*, which details the development of *The Chandelier*, an installation designed as the central piece of the *Invisible Body* installation and that integrates a number of Android devices running the *KDm*. I will suggest that the configuration of the *Chandelier* provides fixed reference points to understand the dispersion of signal strength, creating an unmediated experience of wireless. More importantly, it enables exploration on atmospheres: intangible areas of influence which connect to humans, and disturb their sense of time and space. I will draw from research in affective atmospheres to analyse how the installation produces forms of immersion that also allude to space thickening.

1 CALIBRATION

In the last chapter, I analysed how the Kirlian Device provided few feedback mechanisms in its original design. The Kirlian Device was designed around the interaction with the performer, understanding the coupling of instrument and body as the apparatus that detects the invisible. I suggested that creative mediumship was a good material conceit to explore this possibility, as it alludes to an intuitive understanding of signal dispersion and resonates with notions of materiality explored earlier in this thesis. I also discussed how incidental feedback mechanisms in the original Kirlian Device were inadequate to sustain this mode of interaction and, although other modalities such as vibration and sound were considered, technical complexity prevented implementation.
In this context, Android mobile phones offered an ideal platform to explore notions of feedback, materiality and mediumship further: they constitute a package of readily assembled sensors and input devices, which offload from developers the complexity of electronic prototyping.

Development of the Kirlian Device mobile started as an informal experiment. At the time of developing the gradient algorithm for the Kirlian Device, I became aware of the Android mode in Processing, a module that compiles Processing sketches as Android mobile apps. The feature is an experimental module built into Processing and is designed as a proof of concept of its flexibility. The first conference discussing its potential and future development, the Processing.Android symposium was held in 2010 in Chicago (Sauter 2010). From its initial release, Processing for Android has been conceptualised as a platform for rapid prototyping of mobile sketches, which leverages smartphones as ubiquitous computing and sensing devices.

Processing offered a convenient platform to develop the colour mapping algorithm, responsible for transforming a numerical scale value into a colour gradient, before committing it to Arduino. Initial versions were tested by connecting the variable for signal strength to a graphic slider, which enabled real time manipulation of mock RSSI values, and provided a way to simulate colour mapping and transition. This, nevertheless, created an artificial sense of linearity: since values were manipulated through a slider, the stream of resulting colours followed a smooth, linear sequence. It was expected however that RSSI values would behave erratically, which would significantly change the performance of the instrument. As a way of anticipating this, a further exploration was made to interface the Wi-Fi card in Android phones, and retrieving RSSI values from it to be fed directly into the colour gradient sketch.

1.1 Passive scanning

Probing wireless networks in Android, however, requires modifications to the algorithm used in the Kirlian Device. Due to security restrictions, for instance, signal strength can only be monitored through an active connection, rather than an active scan. In the last chapter, I described the procedure of active scan, in which a Wi-Fi radio emits a beacon to probe the presence of access points broadcasting in its vicinity. Nearby stations reply to the beacon by broadcasting their service name and connection protocols, which is used by WiFi devices to determine the signal quality at the point of reception. The process is repeated by sweeping all channels, providing a full report of Wi-Fi stations broadcasting nearby. The Kirlian Device filters this report for a specific, predefined network name and retrieves its data connection.

In Android, however, signal strength can only be gauged using the WiFi Manager public class, part of the Net WiFi Package index. This returns general information about the phone's active WiFi connection, including RSSI. This means that in order to evaluate a network, the mobile phone requires the security details to establish an active connection before it can start mapping its signal strength. There are also disadvantages in terms of data handling and flexibility. The active scan offers the possibility of combining and interpreting data in different ways. For instance, the number of broadcasting stations and their signal strength can be combined to produce an index of *density*, indicating how busy a location is. Android, however, restricts analysis to one active connection. Aside from scanning method, the Kirlian Device mobile works in the same way as the Arduino version. It collects RSSI data every two seconds, parses it into a percentage value, and transforms it into its corresponding location in a colour gradient, and rendered as the screen background.

Greater availability of hardware also enabled improved forms of interfacing with the instrument. The screen, for instance, offers real-time adjustments and calibration of the mapped values. In the previous chapter, I described a calibration process which enabled mapping values against local limits. This was motivated, initially, by the resolution of the rainbow scale: mapping against operational limits meant that most values would be represented in shades of colour difficult to distinguish in a photograph. Figure 1 shows the colour gradient mapped to global, operational limits. Values ranging from -60 to -40, for instance, will be rendered in shades of green hue, which perceptually blends into one colour. To increase visibility, the value scale was compressed to operate within observed values in a specific location. This is illustrated in figure 2, which remaps the colour gradient to local limits of -40 dBm and -60 dBm, enabling a more legible recording of minute fluctuations in signal quality.

Calibration in the Kirlian Device involved a long, complex process. First, I would have to move the instrument in the space to capture values. Then I would disassemble to connect the circuit to a laptop computer to analyse signal value log for local limits. I would then hardcode these values into the algorithm, and upload it again to the Arduino board. Once reassembled, I would use the Kirlian Device to make a second performance, observing how adjusted values behaved. The process would normally be repeated several times, as signal dispersion changes over time. The Kirlian Device mobile offered a more efficient way of calibrating. The software included a minimal interface, positioned in a floating window, and that consists of two buttons and two text boxes. The buttons enable users to reset the application to operational limits of -20 and -80 dBm. A second button triggers a calibration routine: values are captured and stored in a data array. When the user presses the button for a second time, values are sorted to determine local limits. After calibration, the instrument maps reported RSSI values in relation to the smaller range of values observed in the space. The text boxes provide numerical output of the process, displaying current RSSI values and their relative position in the mapped scale.

1 Colour gradient for default values

2 Colour gradient for calibration values, taking the range of -40 to -60 dBm as an example

1.2 Soundscape

Hardware availability also allowed further exploration on sound as output. As described in the previous chapter, the analogy of creative mediumship alludes to processes where the body of the performer becomes part of apparatus that materialises the wireless field, in the sense that bodily movements are influenced by invisible forces. Enabling this, however, requires a range of cues delivered by the instrument and that the performer can pick up and react to throughout the performance. In the original Kirlian Device, only incidental forms of feedback were available. The design included a diffused, plastic cap, which enabled coloured light to be directly visible to the camera, and diffusely to the performer. Using the phone as instrument, however, leaves the screen out of the performer's sight. Sound provided a secondary cue that complemented colour when the screen was facing away from the performer.

The code in the Kirlian Device mobile includes a module which takes the reported RSSI value, and transforms it to a sine wave with varying frequency pitches. Sine sound waves are one of the four fundamental wave shapes in sound generation, characterised by a smooth and repetitive rise and drop in amplitude which is described by the trigonometric sine function. Sine waves are especially useful in techniques of digital sound generation. Mathematician Joseph Fourier first described the possibility of reproducing any sound by combining simple waveforms that could be characterised with specific frequency and amplitude of sine waves (Russ 2012).

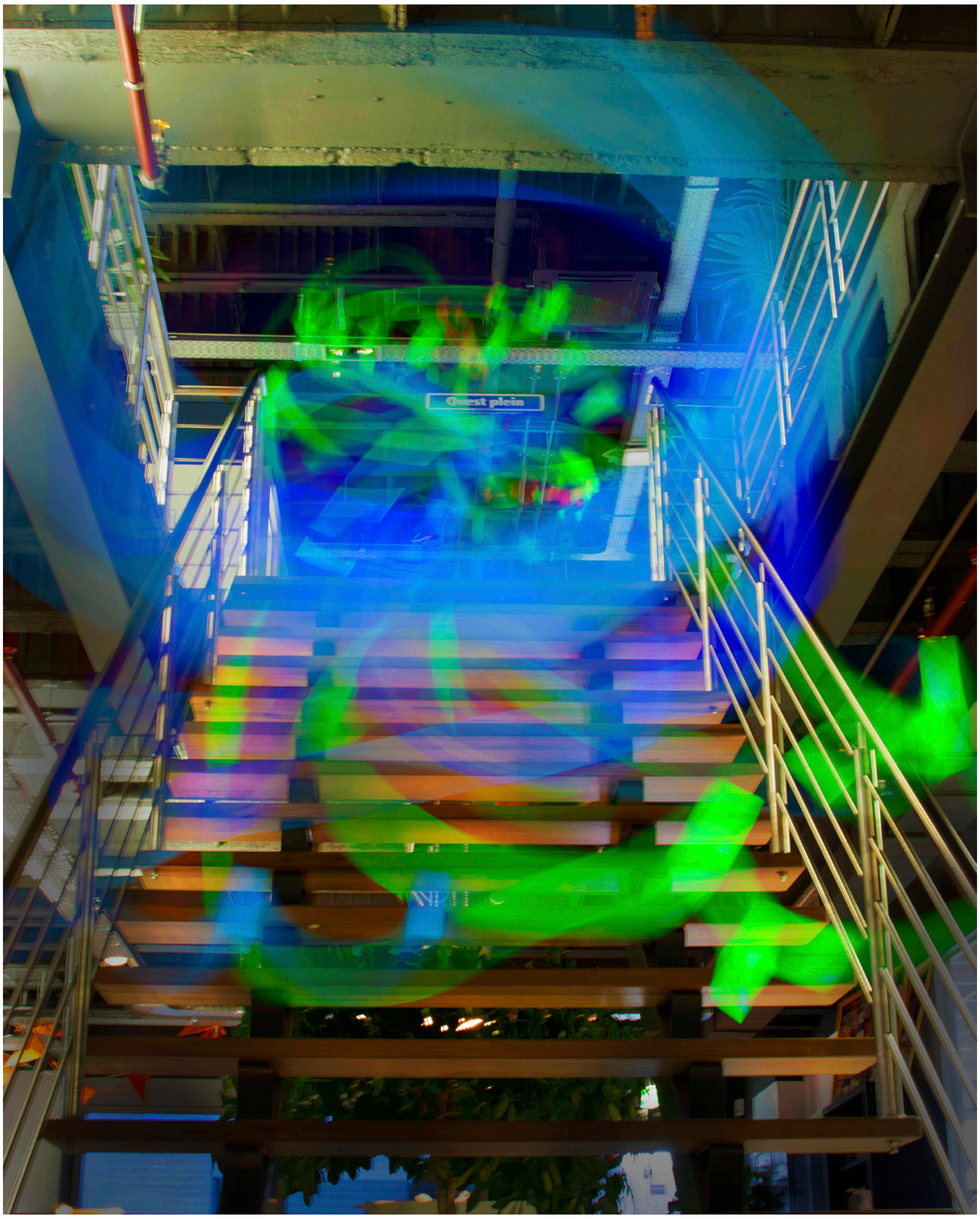
Initial strategies involved indexing RSSI values to sine wave frequency, which involved real-time audio synthesis. This represented a challenging programming task in Android.

Processing in desktop environment offers a number of libraries which take off the coding complexity of implementing a sound synthesiser. These, however, are not available to use in Android mode. The alternative was instead to construct an algorithm that would generate amplitude values for a trigonometric sine wave, and transpose those to a corresponding sound signal. As the complexity of this was beyond my programming skills, I decided to use pre-recorded sounds instead. The strategy, however, had an effect on resolution, as only a limited amount of sine wave tones could be pre-recorded and loaded on the app. Ten sine wave clips of ten seconds each were generated, starting at 60hz and in increments of 10hz. Frequencies were selected according to typical acoustic performance for handset speakers, which in tests showed to reproduce audible sounds on the 50 to 300hz range. Each sound was associated to an RSSI value range of 10 points. In a mapping exercise considering the limits of -20 to -60 dBm, for instance, all values fluctuating between 10 and 20 dBm would be mapped to 20hz sound. This generated disjointed transitions between contiguous values, especially those located in the 10 points threshold, and that resulted in noticeable tone shifts. The effect is, however, analogous to that of the rainbow gradient: it creates pronounced gaps between contiguous data values, highlighting fluctuations.

2

SÉANCE

The Kirlian Device mobile was initially developed as an incremental improvement over the Arduino version, aimed at registering signal dispersion photographically. However, the affordances of the phone as prototyping platform suggested other *engagements*, and lead to different design exploration. It enabled, for instance, distributing the instrument to a wider audience. The Kirlian Device was initially intended to be published as open-source, enabling other researchers and practitioners to use it in exploring different aspects of wireless networks. The Arduino code was released in the website of the project, which prompted others to create a GitHub repository for the project. GitHub is a hosting service which enables collaboration in software related projects, and operates by making source code freely available to download and modify. The complexities of electronic prototyping, however, prevented users from implementing their own version of the Kirlian Device. I received emails of people interested in following this, and asking advice on different aspects of the process, However, all of them expressed that electronics were a big obstacle and none carried on with actually producing the instrument.



3 Image produced for the Quest Magazine article. Copyright Gaby Baas

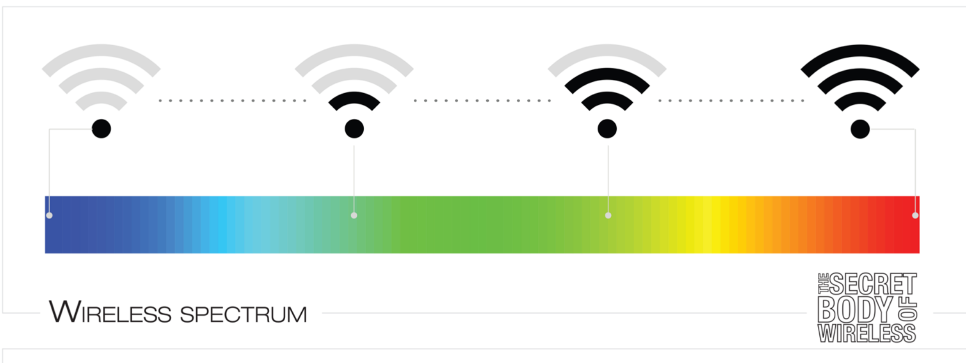
The KDm, however, partly solved this issue and made the instrument available to a wider audience. This enabled a different *engagement* in presenting wireless fields as a something that could be discussed and interpreted in a larger community. This involved users downloading the app from the Android Store, and producing their own photographs creating their own interpretation of the process. A good example of this is figure 3, produced by journalist Gaby Baas, who used the Android app to encourage readers of the Dutch magazine Quest to download the app and produce their own interpretation of the spirit photographs.

2.1 **Work in progress**

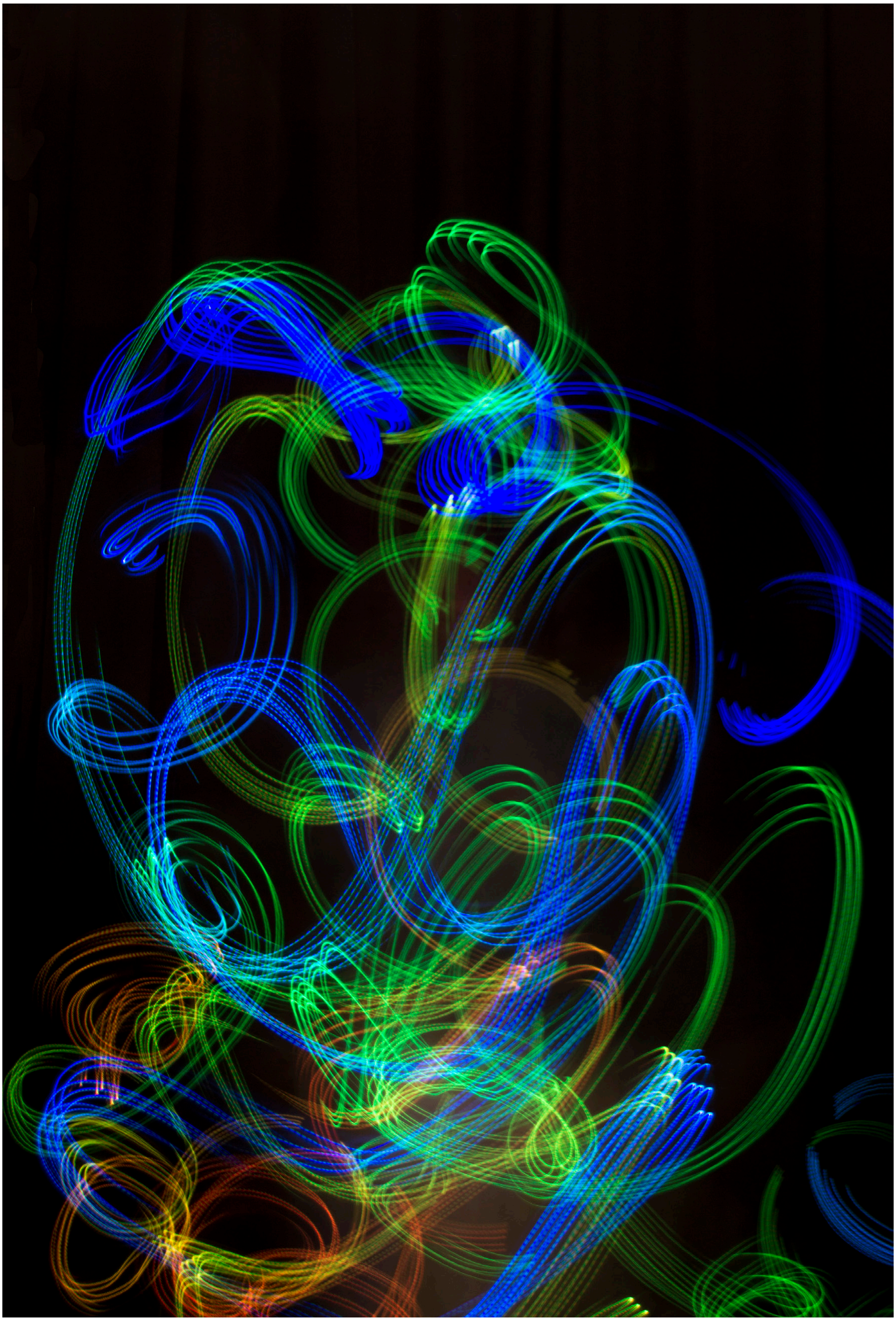
The app, however, also enabled me to explore participative models of representing wireless fields. The first exercise of this was developed during the *Work in Progress*, hosted by the Culture Lab in Newcastle University. The event is a yearly gathering of researchers working at the Culture Lab research centre to showcase their work and initiate discussions with colleagues. The organiser of the event attended the *Secret body of Wireless* exhibition, and invited me to mount some elements of the original exhibit in the Culture Lab event. I decided to use the opportunity to include a space where visitors would be invited to use the Kirlian Device and produce their own choreography of Wireless fields.

The space destined to take the pictures was structured as a booth between two movable partitions set next to the Chandelier piece and three framed pictures from the *Spirit Photographs* series. Within the booth, two placards were set showing the correlation between signal strength and mapped colours, as shown in figure 3. Participants were approached individually, and invited to produce their own picture. I was keen to understand the way in which people would react and interpret non-specific cues about the representation process. For this reason, I provided no instructions on the use of the device, and encouraged participants to improvise their choreography. After the process I chatted with them about the decisions they had followed. Some participants decided to follow a geometric pattern, adjusting their bodily movement to describe an outline. In figure 7, the participant drew a box around him. Similarly, in figure 10, the participant decided to follow straight lines in random directions to describe the field. There was also allusion to mathematical representations of electromagnetic waves. The participant in figure 6 started by following a sinusoidal trace, and followed with an improvised choreography. Some participants asked for rehearsal time to define the sequence of movement they wanted to follow. This is the case of figure 5, 11 and 12. In figure 12 the participant decided to hold the instrument at a fixed distance while pivoting around their axis, creating rings in an ascending spiral inscribing their body. Participants in figure 5 and 11 followed a similar choreography, which started by creating circles with their arms behind their waist, followed by an ascending move of the arm to cover the sides. Participant in figure 13, on the other hand, decided to mimic the trail of a two-dimensional plotter head, which moves in two directions to fill the extend of a planar surface.

It is worth contrasting these images against the Spirit Photographs. In the



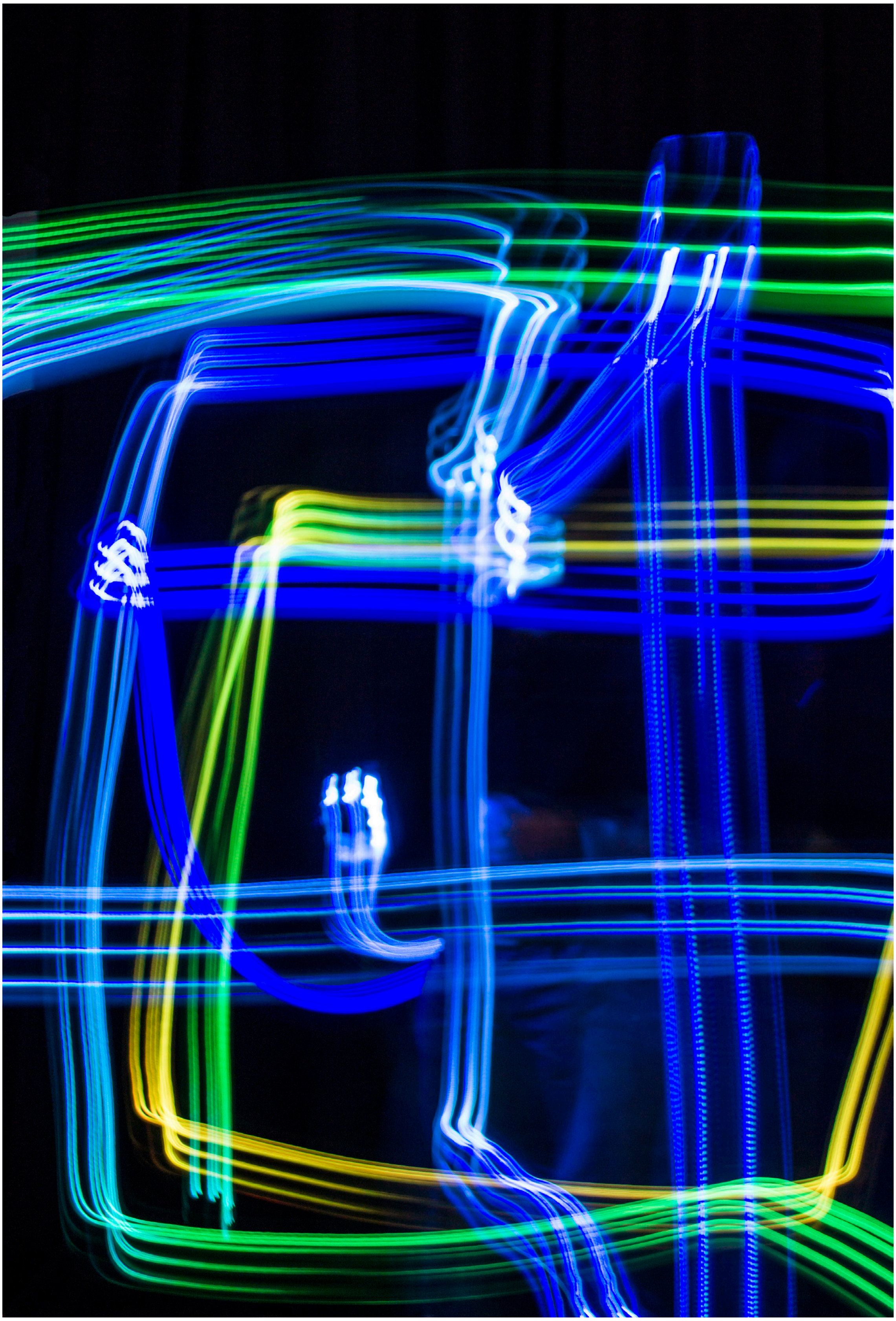
4 Placard shown at the Work in Progress exhibition



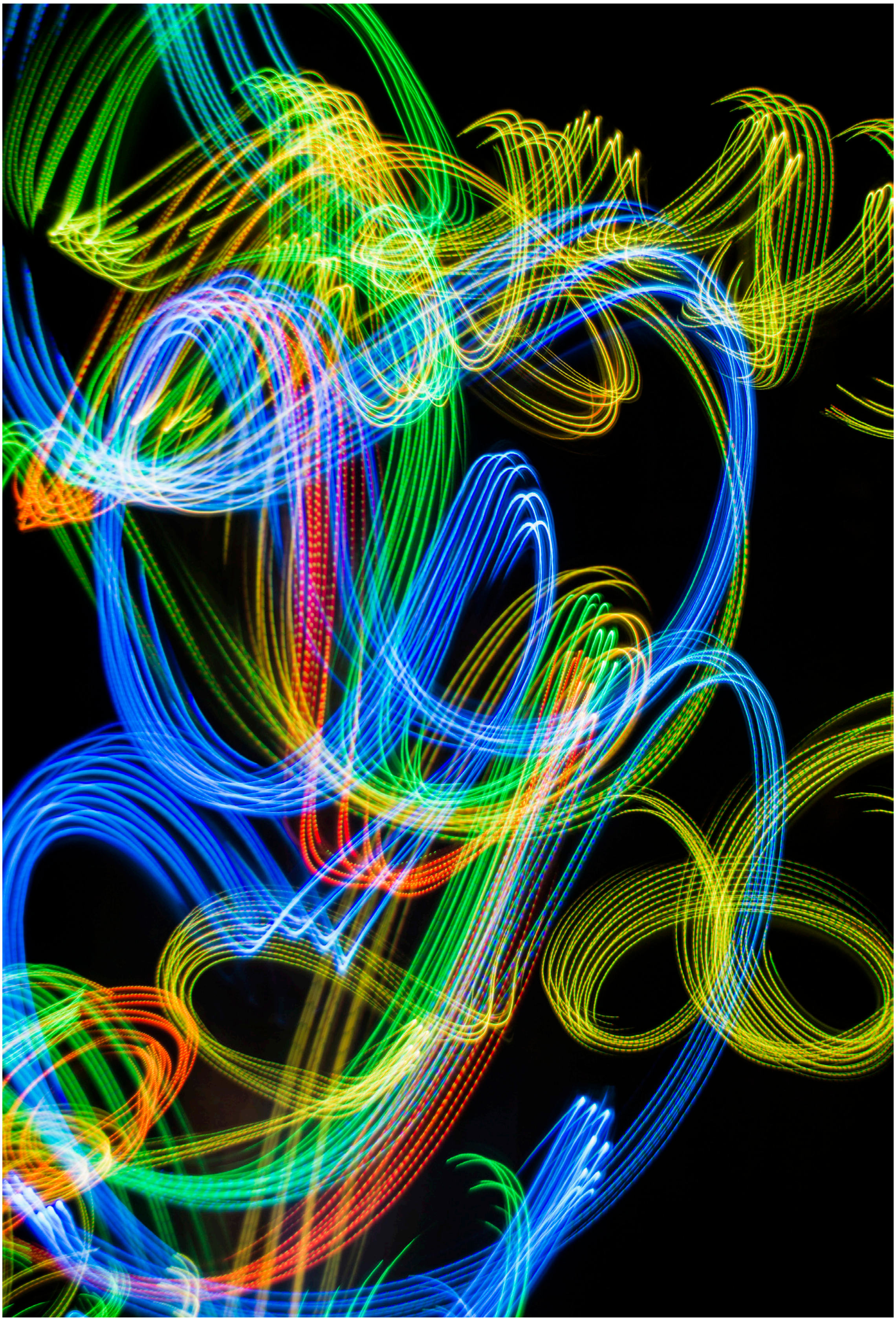
5 Image produced during the Work in progress event, Culture Lab

6 Image produced during the Work in progress event, Culture Lab

7 Image produced during the Work in progress event, Culture Lab

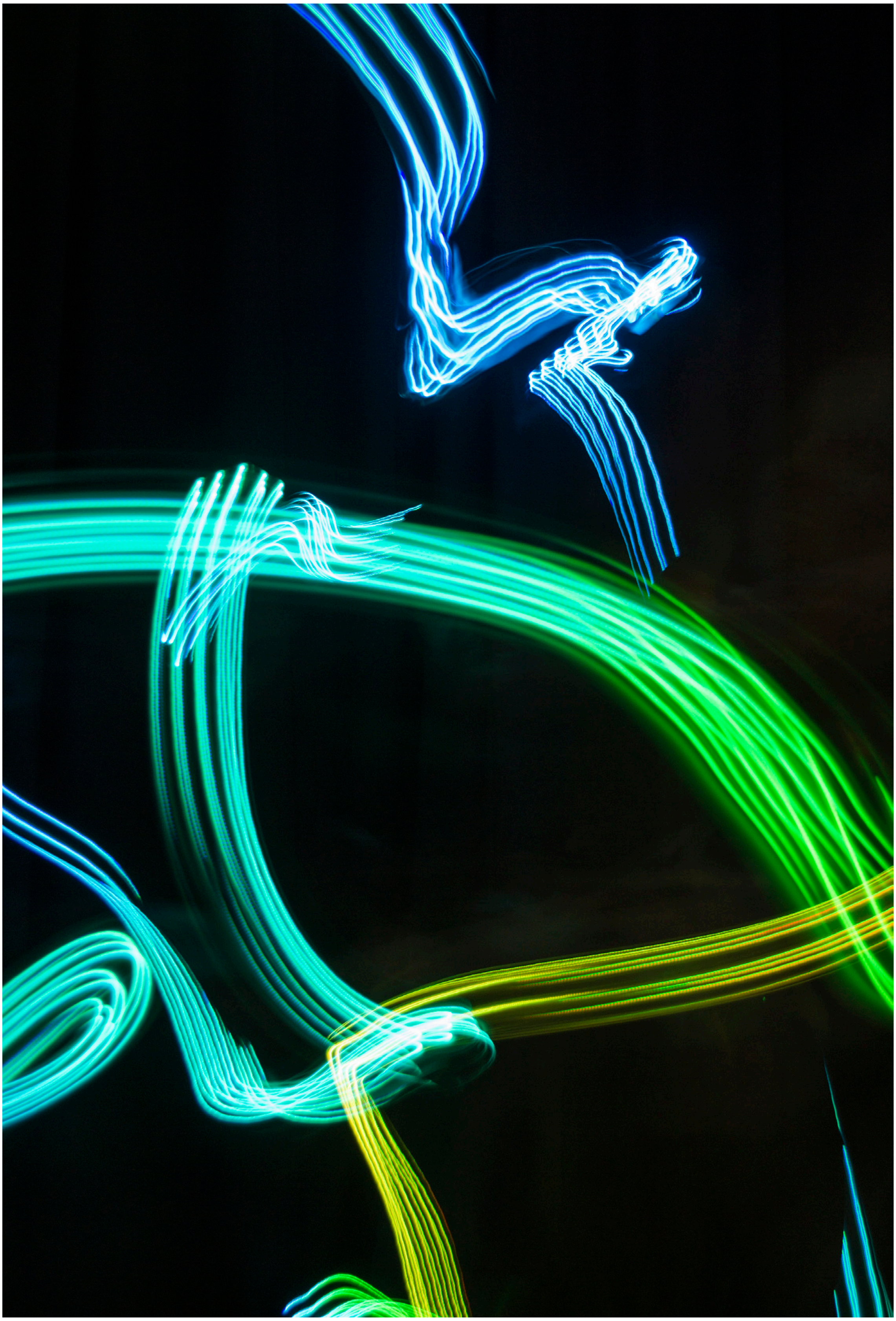


8 Image produced during the Work in progress event, Culture Lab

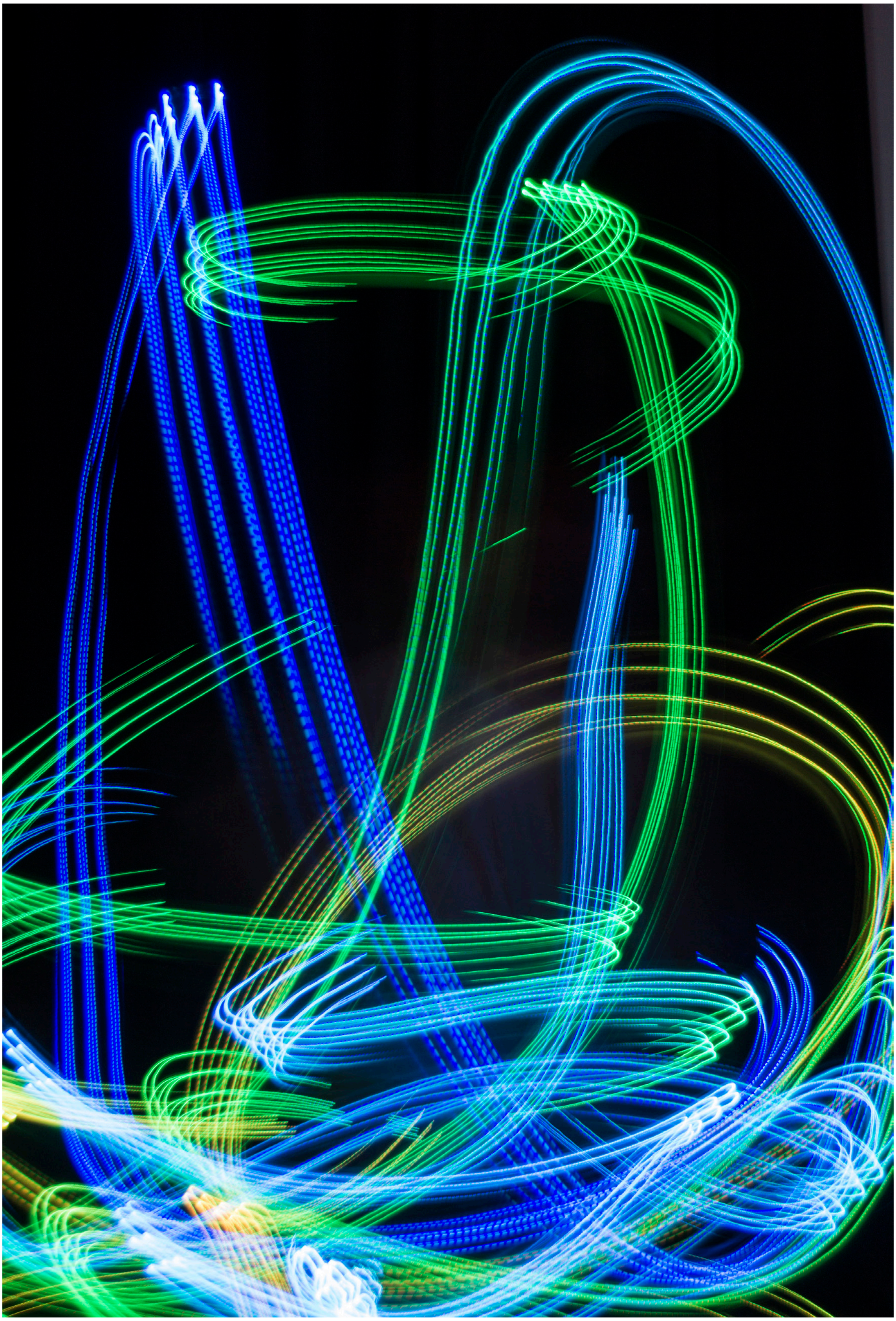


9 Image produced during the Work in progress event, Culture Lab

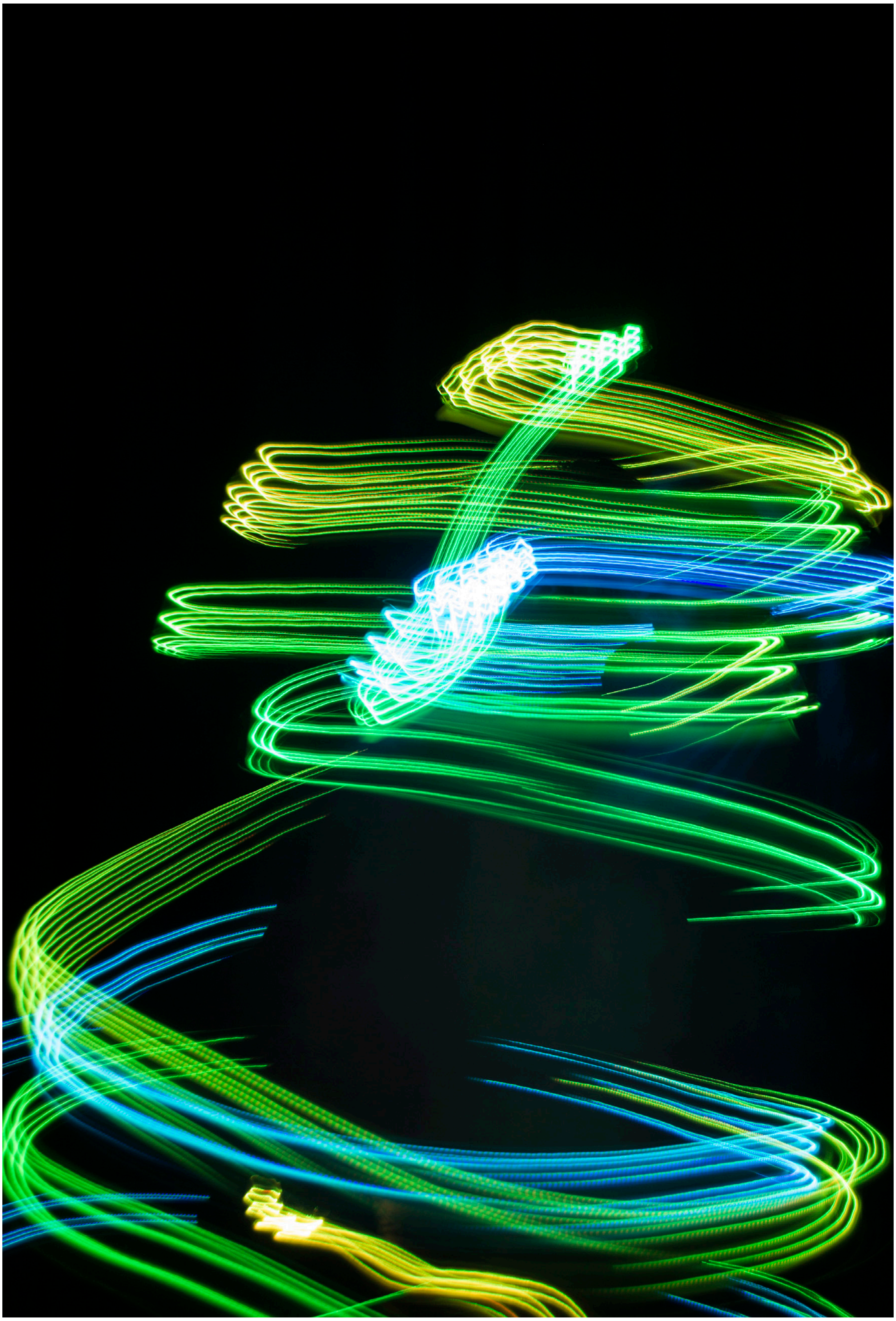
10 Image produced during the Work in progress event, Culture Lab



11 Image produced during the Work in progress event, Culture Lab



12 Image produced during the Work in progress event, Culture Lab



13 Image produced during the Work in progress event, Culture Lab

14 Image produced during the Work in progress event, Culture Lab

images above, performers were drawn from an audience of, mainly, postgraduate and postdoctoral researchers working in some aspect of digital technologies and interaction design, which suggests they possessed some operational notion of the behaviour and characteristics of wireless technologies. Their performance can be understood as responding more to the process of photograph itself and to the technique of long-exposure photography. In addition, they would have responded to a quick browse through the exhibition, and might have been influenced by the work and the analogy of wireless as spectre. The images, nonetheless, can also be understood as evidence of the way the instrument enables participation in describing wireless fields: in providing a context to discuss how they behave, and what strategies are best in representing them. This notion is explored in more detail in the more structure formal of *wireless séance*, as described in the following section.

2.2 Wireless séance

Combining the original Kirlian Device with the mobile app enabled me to explore different formats of participatory representation of wireless. This is the case of the *Wireless Séance*, a workshop developed in the context of the Interaction Design module from the Masters in Design and Emergence at Newcastle University. The module consists of a design-oriented programme, which looks at key concepts of interaction design, and investigates its relevance to Architecture through a design intervention. The project revolved around the figure of T. Dan Smith, a local left-wing politician famous for progressive and modernist policies implemented during his term as leader of Newcastle City Council during the 1960s. The project explored the modern-day influence of T. Dan Smith through his urban regeneration scheme, which involved ambitious, modernist infrastructure projects. This was intended to turning the city into the '*Brasilia of the North*'. He is notorious for his dictatorial style of leadership, and for being convicted of corruption charges while in office (Foote-Wood 2010; Davies et al. 2010).

The project aimed to use wireless technologies to develop interactive, urban interventions that would make historical content contextually available. The material conceit of séances was used in structuring an introductory workshop that would fulfil two tasks. First, to engage students in considering wireless technologies as part of their material repertoire. Second, to suggest that the project involved *bringing back* the ghost of T. Dan Smith into modern day Newcastle.

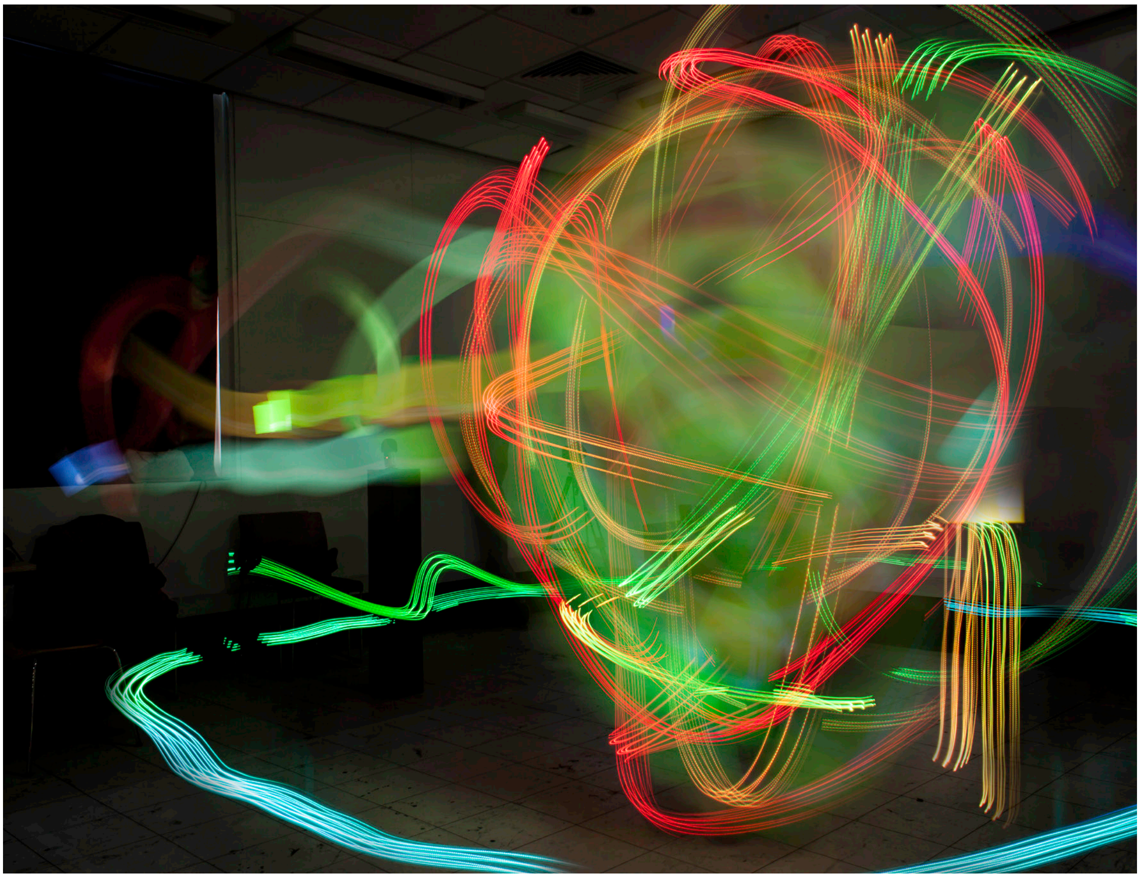
Séances refer to performances that emerged in the 19th century as part of the New Spiritualism movement. It generally involves the presence of a medium, who would assemble a group of people, curious or devoted spiritualist, and who would assist in summoning supernatural forces. Séances are deeply connected to development of wireless technologies, and reinforced connection between technology and mysticism in the public imaginary. Noakes, for instance, analyses the exchange of terms and concepts between technological and spiritualist realms:

> *Spiritualists' claim that spirits used electrical and magnetic powers to manifest themselves informed their choice of metaphors for managing bodies in the séance room (…) spiritualists not only spoke in terms of the 'celestial telegraph' to the spirit world and used a 'telegraphic' alphabet of raps to communicate with spirits, but also believed that reliable interactions between terrestrial and spiritual intelligences depended on a well-managed séance 'apparatus' as much as successful telegraphic communication required proper working instruments (Noakes et al. 2002, 9).*

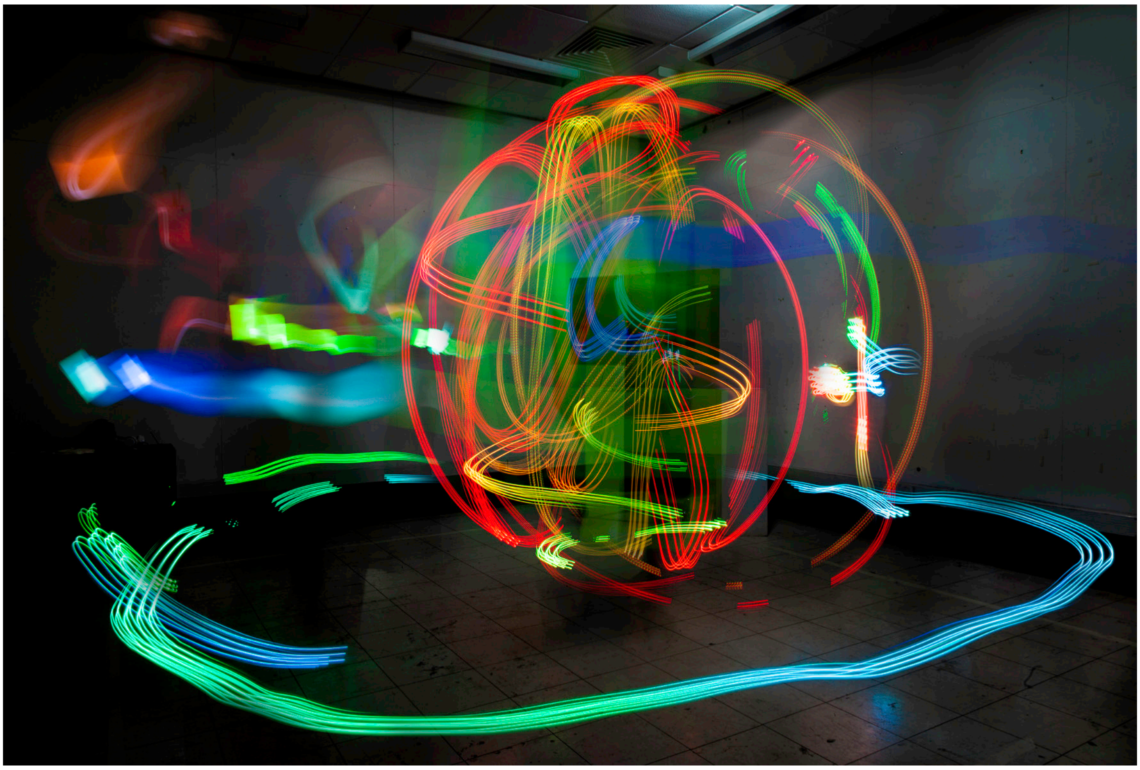
Séances were also an important element of creative mediumship. A crucial element in Hilma Af Klint production, referenced in the previous chapter, was 'De Fem' ('The Five'), a group of five women artists who met regularly to hold séances, seeking mystic communication with spirits of deceased artists, and that engaged in techniques of automatic drawing and writing that Af Klint would later assimilate as integral part of her own work. Séances, however, are also relevant in the way they contribute in opening topics to public debate. Kontou, for instance, has analysed how séances were useful tools in exploring gender issues in the 19^{th} century society. In this context, women '*deployed the supernatural on literary and metaphorical levels in order to engage with contemporary debates (…) that problematized rather than resolved their ambiguous status*' (Kontou 2008, 277). Similarly, I was interested in exploring how figurative reference to séances might be useful in exploring alternative engagement in architecture with invisible technologies.

The Wireless Séance was prefaced by an introduction to wireless technologies, their technical operation and properties. In the main event, students were asked to work in teams of four. Each team would be provided with three Android phones running the *KDm* app, and would be given a five-minute slot to interpret their choreography. As a constrain, the choreography would have to be performed in a three by four-metre area, delineated in the floor. Three cameras would be used to capture the performance simultaneously from three angles. After an initial period of ten minutes to plan and rehearse, students were asked to leave the room and for the first group to perform. After each choreography, I would talk to the group about their interpretation and the strategy they had followed to produce it. Figures 15 to 24 show the resulting images. Each is accompanied with in-frame captions, describing the group the image was created by, and a situational floor plan showing the position of the camera and the delineated area.

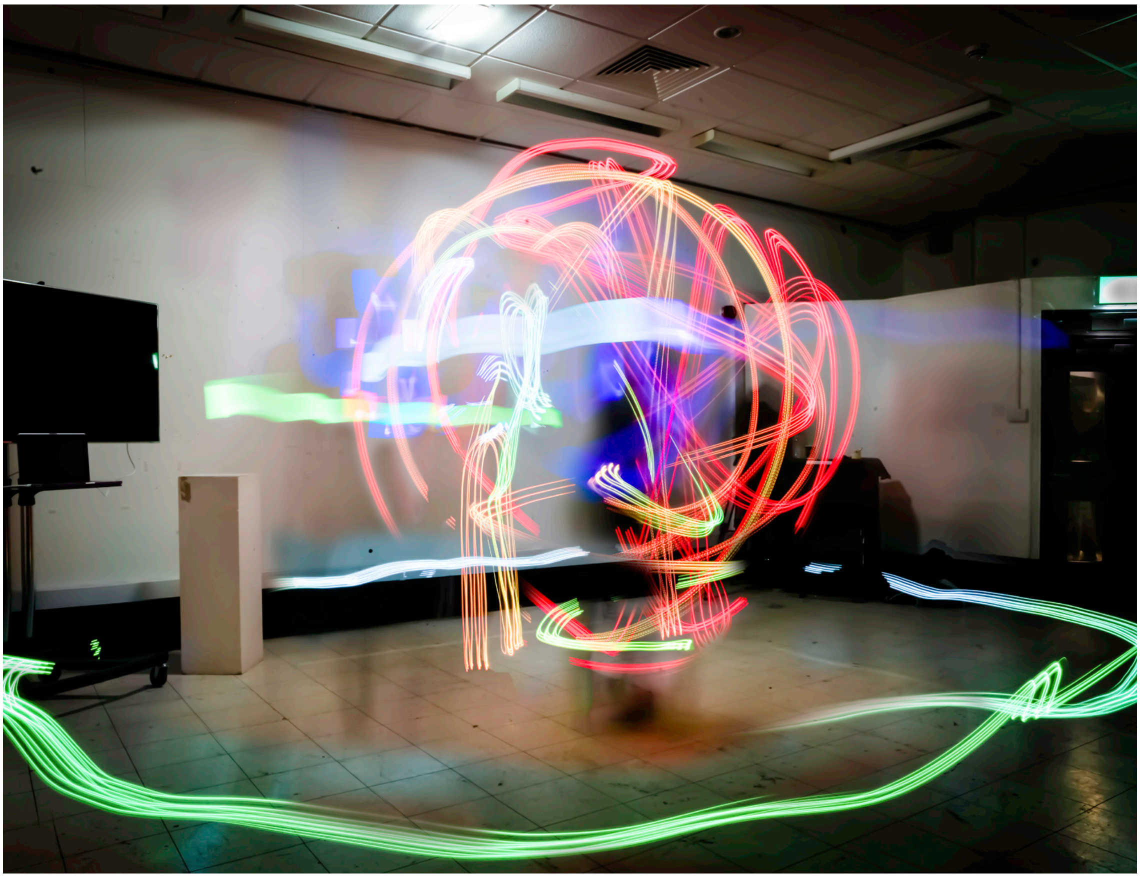
Strategies described by participants are similar to those of the *Work in Progress* event. Group 1 described to mimic the images in Wireless séance by assigning one member to creating a sphere at the centre of the space. The rest agreed on delineating the boundaries of the working area, one at waist level and one at feet level, by walking in circles holding out the instruments in their arms. Trails of this process can be seen in the ghosted human figures in figure 17. The remaining member of the group decided to stand in front of camera 1, moving the phone in two axis following the shape of a square, as seen in figure 15. Members of group two agreed on describing the space by allowing everyone to circulate around the boundary of the rectangle. Al-



15 Image produced as part of the Wireless Séance event



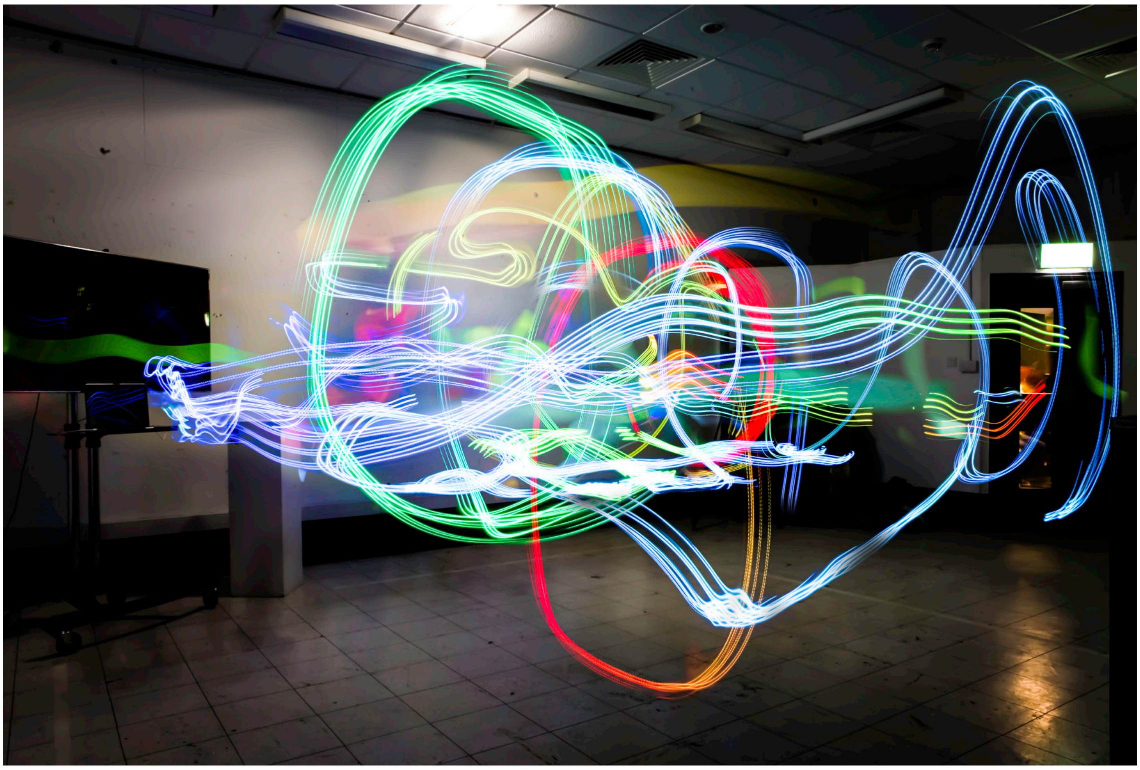
16 Image produced as part of the Wireless Séance event



17 Image produced as part of the Wireless Séance event

18 Image produced as part of the Wireless Séance event

19 Image produced as part of the Wireless Séance event



20 Image produced as part of the Wireless Séance event

21 Image produced as part of the Wireless Séance event

22 Image produced as part of the Wireless Séance event

23 Image produced as part of the Wireless Séance event

though no formal arrangement was made, each paced at different speeds and at different body heights. What is more, some followed a straight line, others followed a zig-zag and one member decided to combine this with curves drawn towards the centre of the space. Group three combined a strategy whereby a member of the group would remain static and off-centre, moving the instrument in circles around their body in what was described as a dress-like shape. The rest of the group paced around the boundaries of the area, combining linear with zigzag movements.

The relevance of the Wireless Séance is in the way it enables engagement with invisible technologies, and contributes in understanding it as material in a design context. This is of particular importance in Architecture. Lloyd-Thomas (2007) has analysed the deep disconnect between design and technology, which is manifested in the way the latter are often relegated to the margins of the profession, and only mentioned as text descriptions in drawings. The workshop provided an instrument to monitor signal strength, and forced students to connect this to the movements of their body through a choreography. This is similar to the way they develop an understanding of tangible materials, such as wood, by systematic encounters with the material in a workshop. I have referenced the work of Donald Schön and others in describing the way notions of materiality are often connected to the relationship between material, tool and the body. Similarly, the wireless séance provides a context where these encounters are possible for intangible technologies.

3 IMMERSION

The Kirlian Device enabled a mediated way of understanding signal dispersion, where photographs are used to analyse wireless field after a performance has taken place. In addition, the materiality of wireless fields is connected to the human body, as its movements contribute in shaping it. Implementing the Kirlian Device mobile in the Google Glasses, however, afforded an immersive understanding of wireless fields in space.

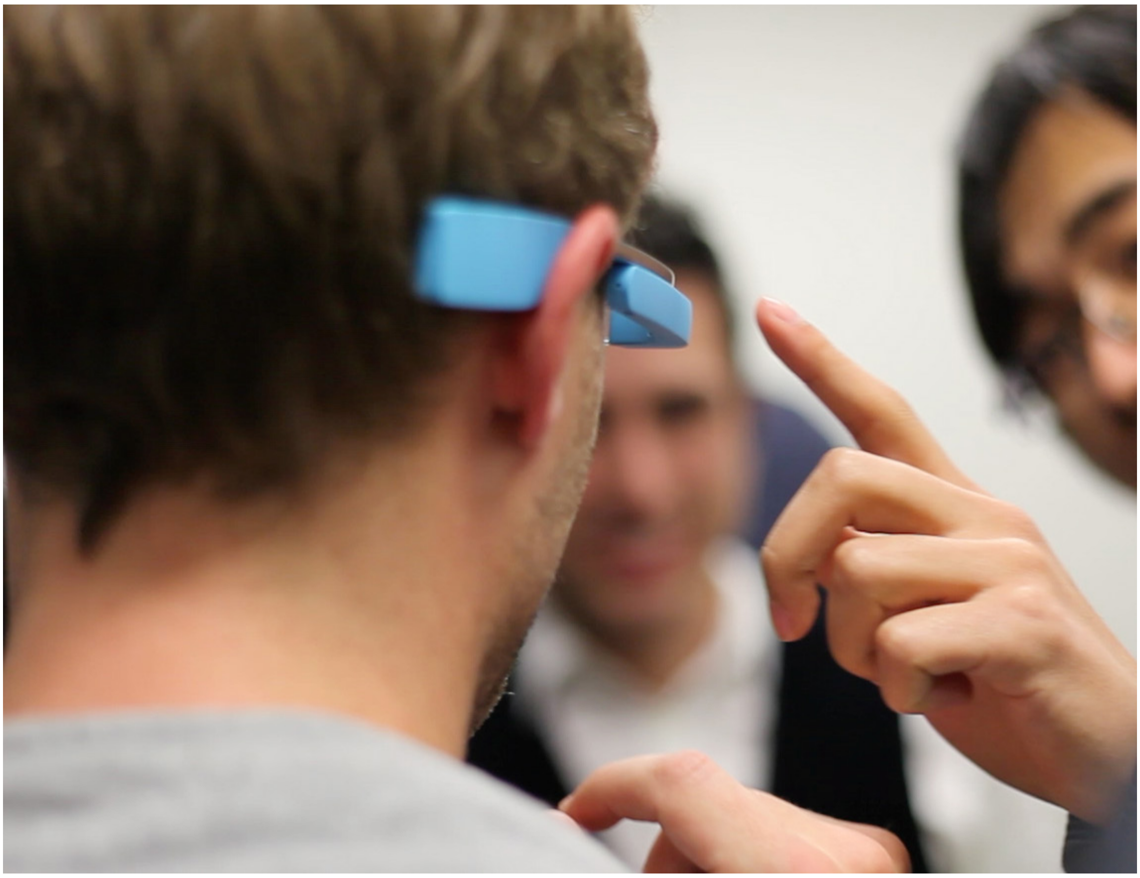
Although the Kirlian Device was initially coded to run in phone platforms, informal conversations with fellow researchers raised the possibility of experimenting with Google Glass. Glass is a head-mounted display released by Google in 2013, and composed of a lens frame, whose right temple houses a battery and processing unit. A small screen, projected onto a piece of thick plastic, is mounted on the right rim. The distance between the eye and the projection plastic affords a magnified perception of the image. More importantly, the Glass operating system is based on Android, which makes it possible to port applications developed for smartphones relatively straightforward. This afforded the possibility of exploring how a head-mounted display might enable a sense of immersion in the wireless field: a performer would move in space, with a flickering colour screen on their top right vision, indicating the changing qualities as the body traversed the field of wireless. To achieve this, the application was modified to adapt the user interface to display only the background, eliminating the floating menu and information panel. Performance was also optimised by eliminating a routine which smoothed out the transition between colours — an algorithm designed to interpolate far off values with the intervening colour frames, eliminating the flickering that occurs when non-contiguous values are rendered in sequence.

The *KDm* app was deployed in Glass as part of *The secret body of wireless,* an exhibition mounted to present the *Spirit Photograph* series, alongside the *Chandelier* installation. Deployment was done in collaboration with Carlton Shepard, researcher at Newcastle University's Culture Lab. Carlton's research was based on the Glass platform, and offered programming advice on porting the application successfully. In addition, he offered to bring a set of Glass to the exhibition, and to set-up and assist visitors in operating the application.

The prototype proved difficult to implement during the exhibition. Among other technical problems, the main issue was the way networking hardware was handled in Glass. Specifically, the Wi-Fi radio on-board Glass could not

24 Google glass prototype during exhibition be accessed directly to retrieve the net WiFi package Index. As a result, the application had to run in tandem with an Android Tablet, which would perform the actual scanning routine, and use Glass as display. For this reason, only a small group of visitors could use the prototype, and for a limited period of time. Also, the novelty of Google Glass diverted attention from the app itself. At the time of the exhibition, Glass had only been released to a small number of developers, and had enjoyed a wide media coverage which caused curiosity in the device. Images 23 to 31 show a playful interaction between users and prototype which can be ascribed, in part, to the status of Glass as new technology rather than with the application per se.

There are also limitations inherent in the way Glass projects information. The screen is mounted slightly up from the natural line of vision, forcing the wearer to look upwards to look at the screen directly. Since information is only displayed in one side, users often close one eye to focus their sight in the information, as seen in figures 23, 27 and 30. This makes it difficult to pay attention to the changing colour screen in the app. However, the way Glass displayed information can be said to amplify the sense of wonder prompted by the discovery of an invisible space superimposed on the one immediately perceived. Problems in information display are also compounded by the tonal range of the Glass speakers. In the previous section, I described how the range of sine wave frequencies was determined by the range speakers in mobile phones are capable of reproducing. Glass uses a different form of sound reproduction, which depends on bone conduction to send vibrations to the inner ear. As a result, the range of tones that can be reproduced is offset, and outside that chosen for the KDm. In the intervening time between deployment and writing this thesis, Google Glass has undergone a number of controversies, some of them connected to the set of limitations and challenges described here, and has been discontinued as an experimental project. Google has since indicated that is working in a new project which integrates insights and technology from Glass (Metz 2014).

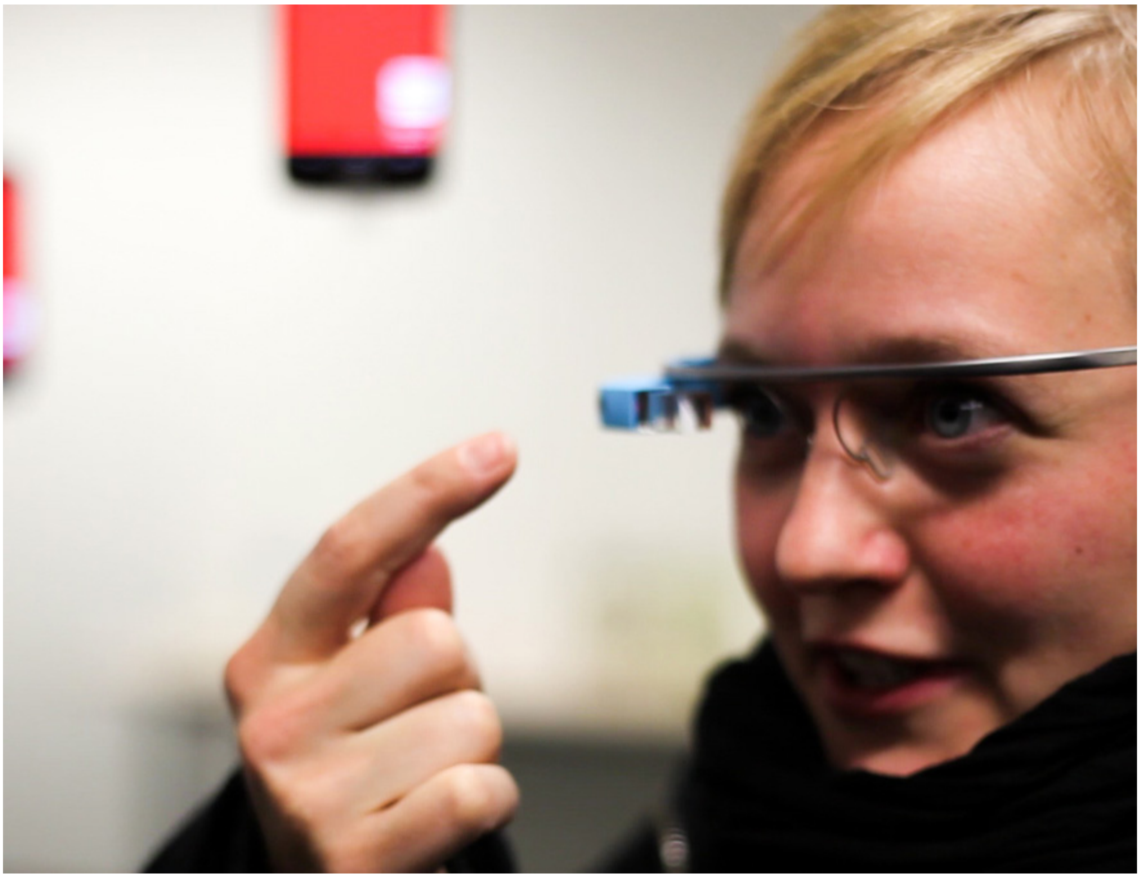


25 Adjusting and booting application

26 Kirlian Device mobile running on Google Glass

27 Experiments with Google Glass during exhibition. Screen from the Kirlian Device Mobile app can be seen in the projecting

28 User wearing google glass. Adjusting one eye to the screen running the Kirlian Device app



29 Experiments with the Kirlian Device app during exhibition

30 Experiments with the Kirlian Device app during exhibition. Screen of phone and Google glass running the Kirlian Device app

31 User wearing Google Glass running the Kirlian Device Mobile

32 User pacing the exhibition space whilst using the Kirlian

Despite technical problems, augmented reality platforms such as Glass offered an interesting platform to explore different forms of connection between body and signal dispersion, and enables a less mediated experience of wireless fields. This extends the exploration started in the Wireless Séance, and constitutes a further mode of experience which connects body, tool and material, and that contributes in understanding wireless fields in terms of materiality. In the context of the exhibition, deployment sparked conversation about the strangeness in the behaviour of wireless fields, suggesting a volatile field whose edges are in a constant process of reconfiguration.

4 ATMOSPHERES

The materiality of mobile phones — their form factor, context of use and combination of hardware — suggested interventions where devices are embedded in space, used as fixed reference points to monitor fluctuations in signal spread. This possibility is explored in the installation *The Chandelier*, originally conceived to be the centre piece in *The Invisible Body of Wireless* exhibition and since then mounted in two more events in two different configurations. The piece is composed of a number of Android phones suspended from a structure, which serves to delineate a space beneath the gallery's ceiling, as shown in figure 33. In its initial version, nine Galaxy S4 phones were suspended through a holder laser cut in clear 3mm acrylic (see figure 35). Combined, the devices provide a series of semi-fixed reference points which makes evident changes in wireless signal strength relative to its position in physical space.

An important aspect in the development of the Chandelier was the calibration of the instruments to the local limits, which tend to shift across time. In the original app, a button allowed users to perform a calibration process which involved capturing signal strength data. At the end of the capturing process, data would be sorted and used to establish local limit values. This is especially useful when the instrument is used to create a photograph of the space, as it contributes to creating a colour distribution which increases legibility of signal strength fluctuations. When observed in longer periods of time, however, limit values tend to shift, expanding and contracting. As the installation would operate unattended for a period of three hours during the exhibition's opening, it was necessary to implement an algorithmic strategy to adapt to the changing signal strength conditions. The solution was to implement a self-calibration routine, which collected and stored recent RSSI values in a temporary array. Once twenty values had been collected, the list would be sorted to find maximum and minimum and to the ones in use. If collected values varied for more than ten percent, the range would be expanded or contracted accordingly.

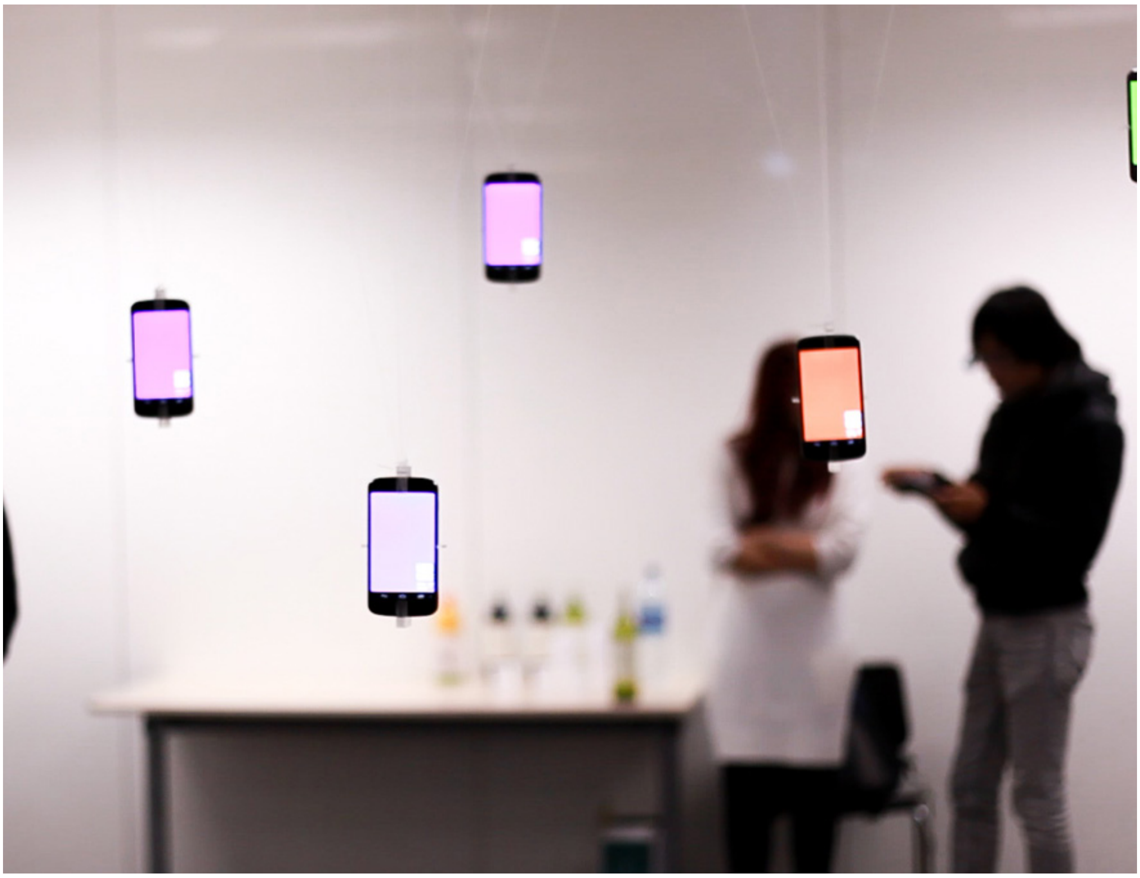
There are aspects of the devices' materiality which shape the interaction between visitors and installation. For instance, the intrinsic relationship between phone and hand is actualised in the way visitors engage with the instrument, using their hands to block or perturb the propagation of signals. Figures 34 and 40, for example, show visitors shading phones to test signal distribution. The installation, however, can also be said to produce atmospheric effects. By creating an unmediated display of wireless fields, the chandelier also affords experimenting with alternative material engagement with wireless. It affords, for instance, creating atmospheres: intangible areas of influence around mobile phones that perturb the sense of time and space of humans. James Ash has explored the concept of affective atmospheres to refer to intangible aspects of technological objects that have the capacity to draw the attention of humans and, as a consequence, modify their perception of space and time. The notion is proposed as an enabler to think of materialities as '*something that is not reducible to static matter or interacting through brute causality, but as dynamic and selective in how aspects of an object engage with aspects of other objects*' (Ash 2013, 21). A good example of atmospheric effects, Ash suggests, is the antenna configuration in the iPhone 4. The design of the antenna consists of a stainless steel band, running along the edges of the phone's body and sectioned in two parts. One part of the band carries signals for Bluetooth, WiFi and GPS, while the other services GSM. A disadvantage of the design is that holding the phone in certain grips bridges both sections of the antenna, creating interference between the two. Ash suggest that the configuration of the iPhone 4 shapes unique atmospheres, in the sense that they affect the sense of time and space of their users. He writes:

> *When the user squeezes the phone in their hand, this causes signal strength to drop and, in doing so, information to be accessed slower. Analyzing the intrinsic and extrinsic perturbations involved in this exchange, the appearance of slow information transmission and translation is actually time itself slowing down, as a human hand unintentionally blocks and alters the perturbations that can occur between antenna and radio wave. Poor signal strength also points to how extrinsic and intrinsic perturbations between hand and phone (and the relations and non-relations that emerge from these perturbations) produce the appearance of proximity and distance that humans experience as space (Idem).*

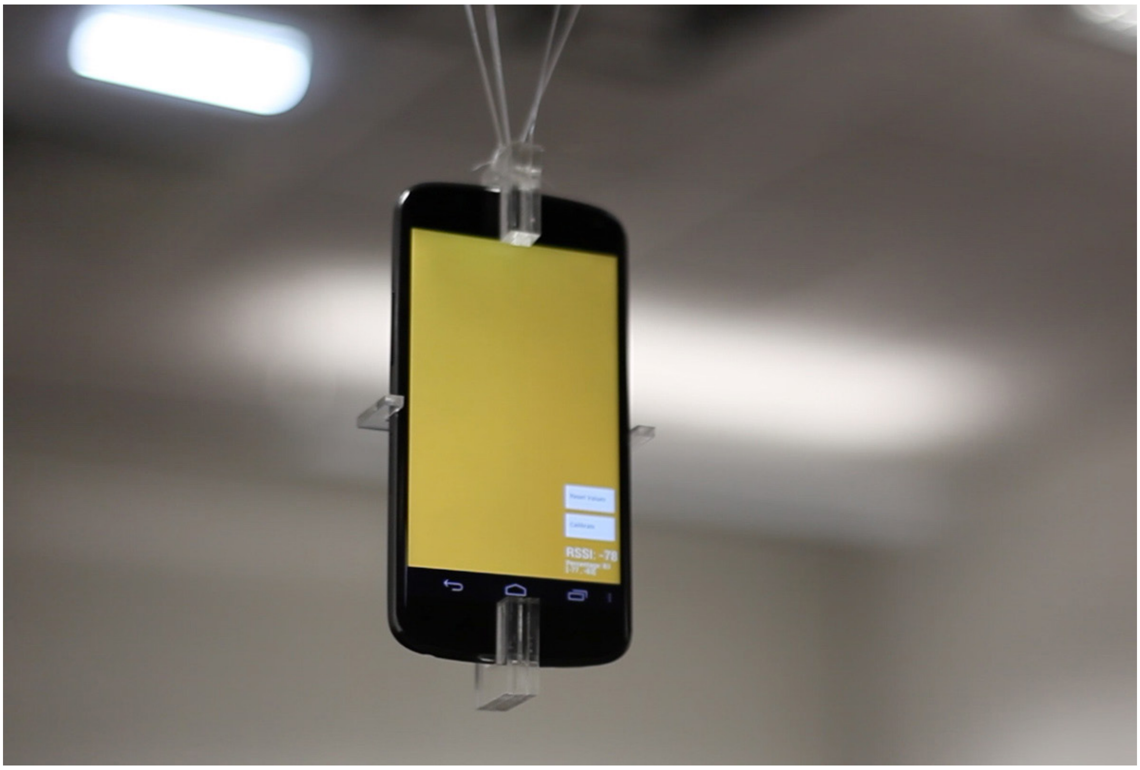
Similarly, the chandelier enables the creation of different atmospheres of wireless fields. The configuration, with its distribution of phones at uneven heights (see figure 12), contributes in generating a sense of providing a fragmented window into an invisible world: one that can only be examined through crannies. The glass prototype, for instance, was intended to enable users to perceive fluctuations in signal dispersion by moving across space and observe a flickering reference in their line of sight. Observed at a distance, the chandelier shows fluctuations across space. However, it also provides a way of manipulating the perception of space within the installation. In the previous chapter, I floated the notion of thickening and ether in suggesting wireless fields saturating the air with an invisible fluid. This *engagement* is actualised in the chandelier through the sound mapping of the KDm. The cumulative effect of sine wave tones creates a soundscape: the aggregation of individual instruments mapping signal strength to tone

33 The chandelier in the exhibition

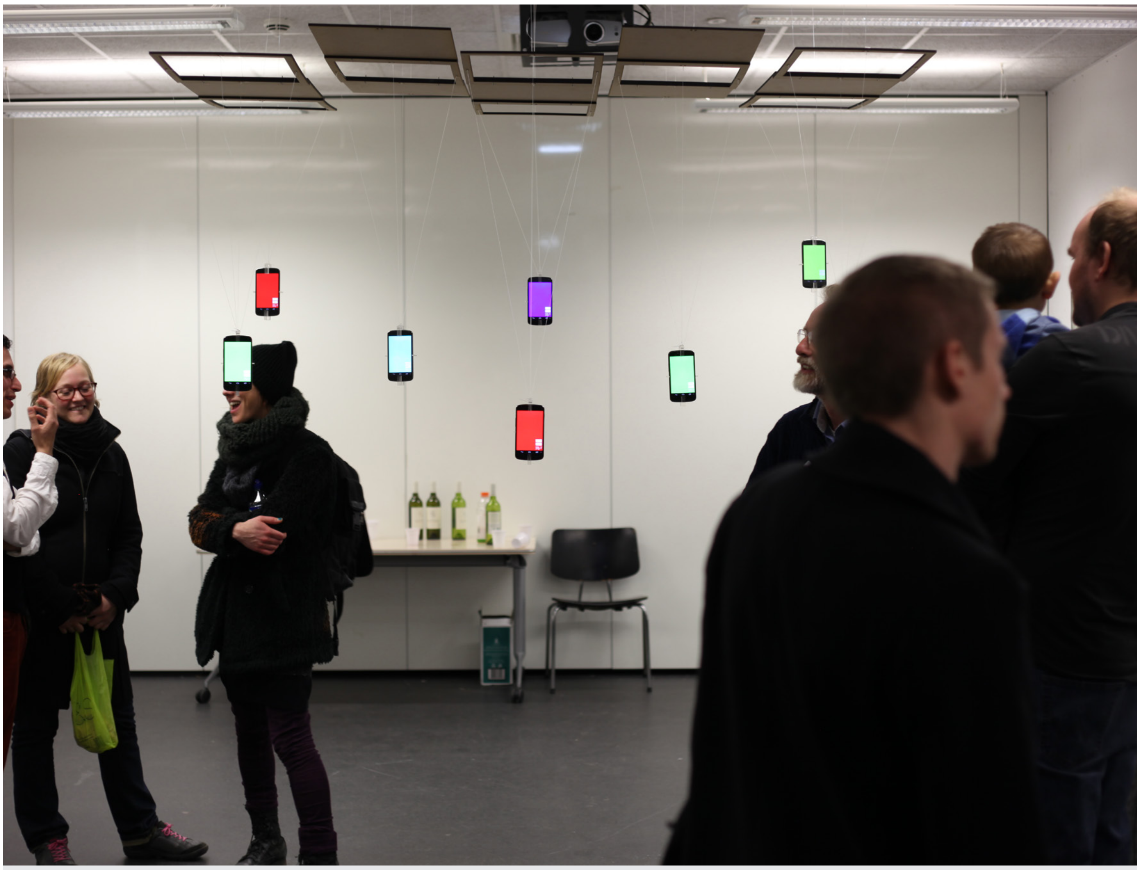
34 Visitor shading a phone to induce fluctuation in field strength



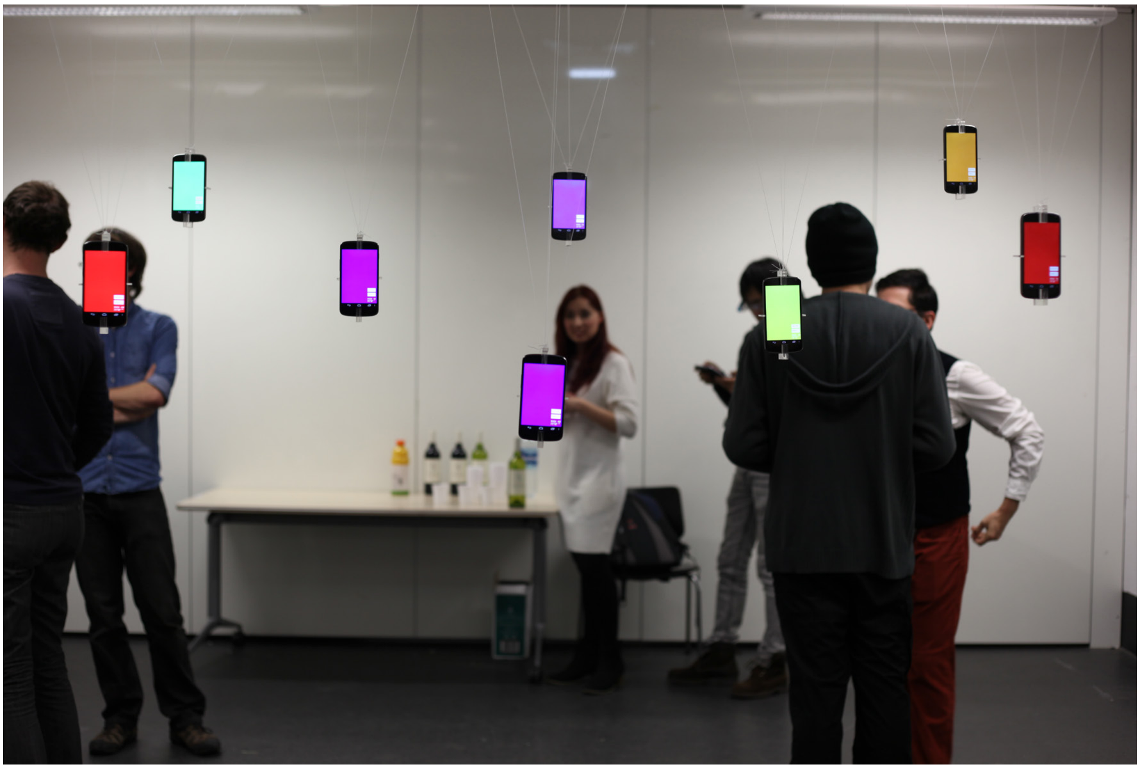
35 View of the suspended phones



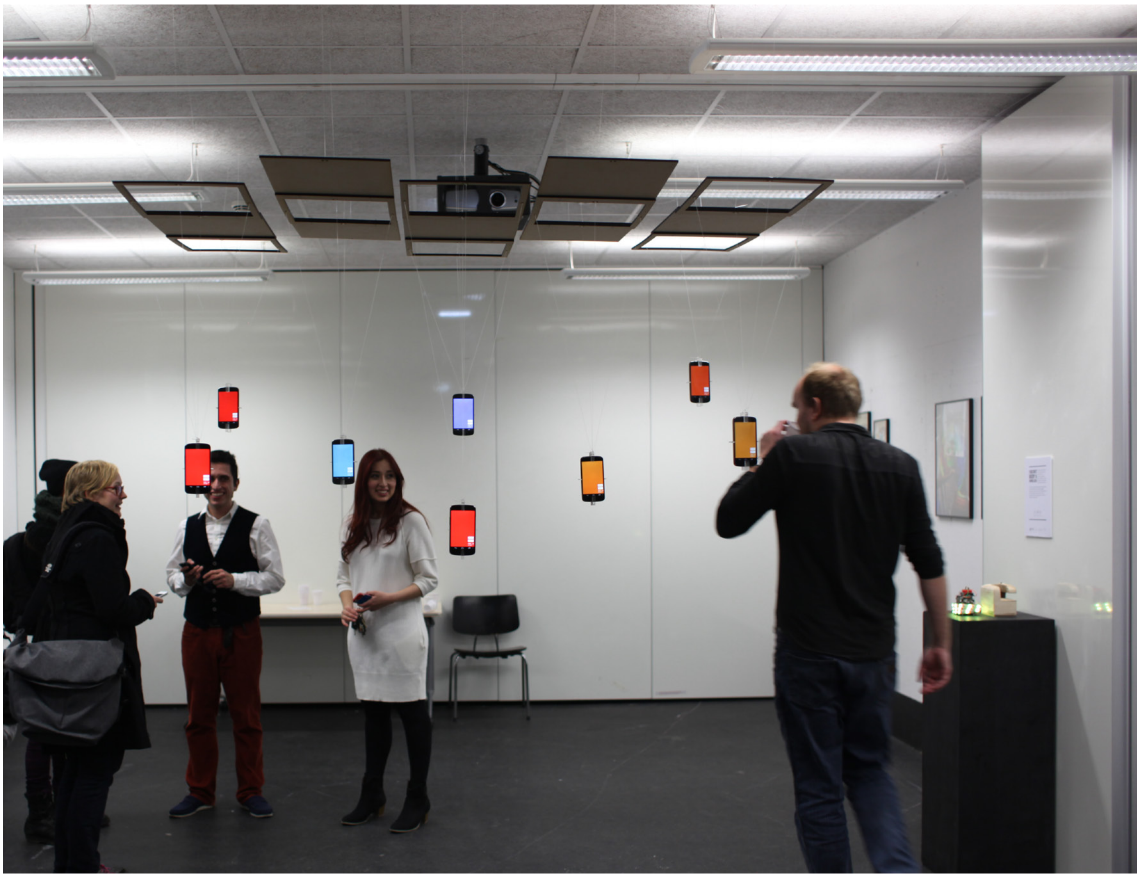
36 Acrylic holder with phone



37 View of the installation in the middle of the room

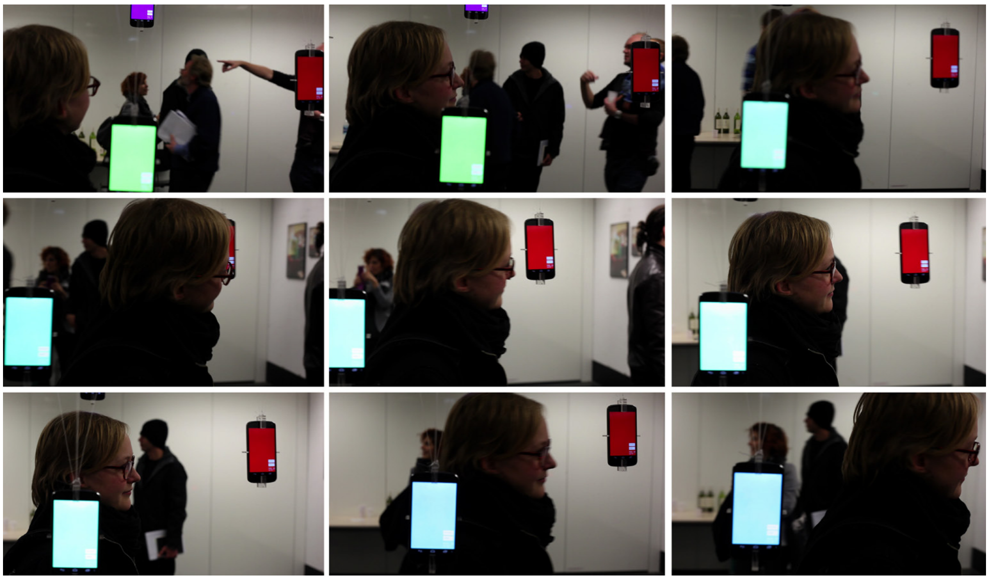


38 View of the installation



39 Image produced as part of the Wireless Séance event

40 Image produced as part of the Wireless Séance event



41 Image produced as part of the Wireless Séance event

frequencies. From a distance, it is perceived as a cacophony that attests to the fluctuations in signal dispersion. However, when visitors walk inside the installation, they immerse in the fluctuations and track the changes in signal strength by listening to the way the soundscape around evolves. Figure 40 shows the time lapse of a user walking through the installation. In the original video, the visitor enters the installation walking slowly, the retraces their steps and sways to and fro, concentrating in the sound shifts inside.

4.1 Hamster, Hipster, Handy

A second configuration of *The Chandelier* was prepared for *Hamster Hipster Handy, Spellbound by the mobile phone*, an exhibition held at the *Museum Angewandte Kunst* of Frankfurt. I was invited to participate by Eleni Blechinger, curator of the exhibition, who had become interested in the project after reading the media coverage. This second configuration is worth of analysis, as curatorial decisions fundamentally changed the atmospheres generated by the installation. In *The invisible body,* the chandelier is situated in the middle of the space, enabling visitors to approach the piece from different angles and dip in and out of it playfully.

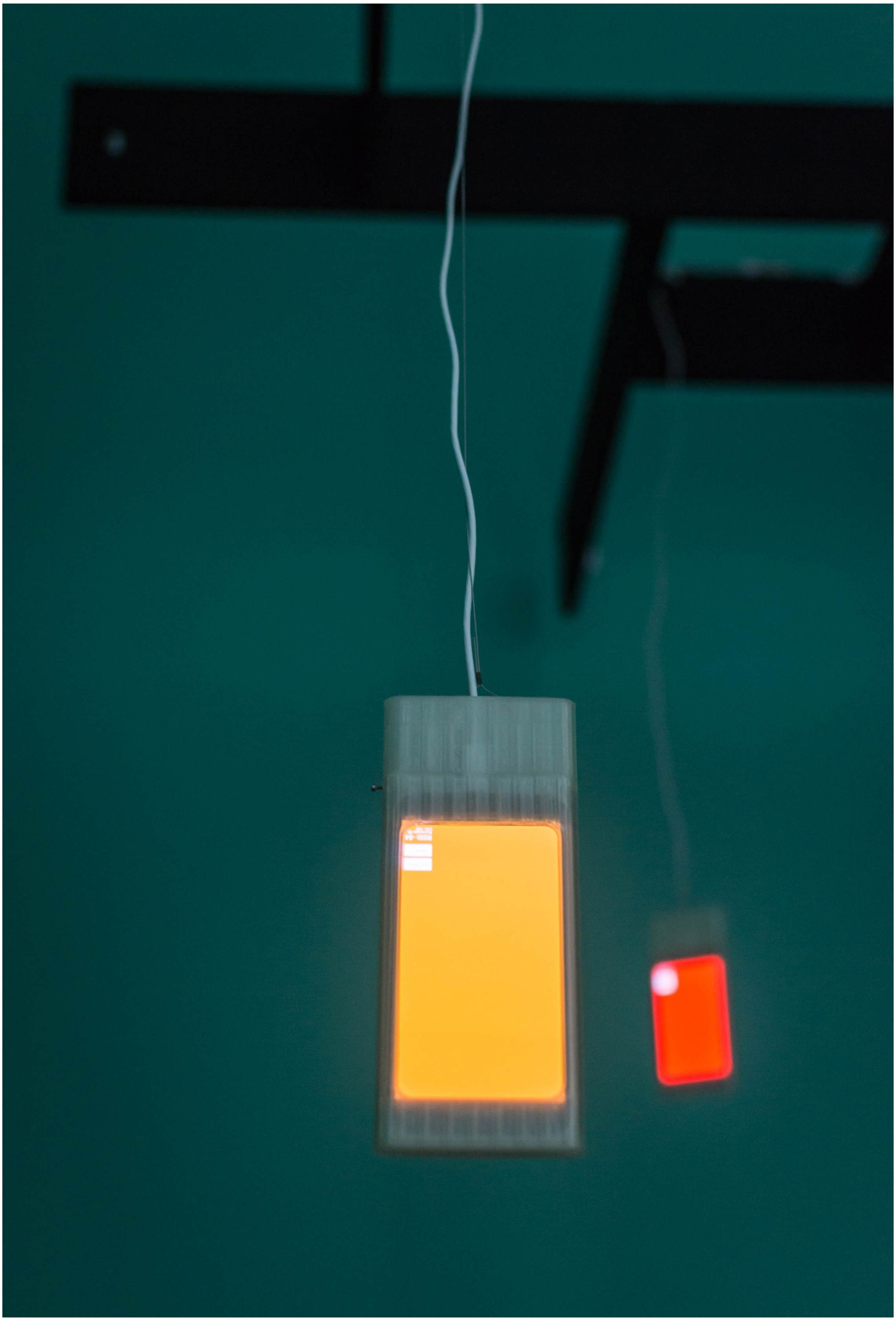
Hamster, Hipster, Handy is part of the research project *Aesthetics of Consumption — Acting and re-enacting with commodities*, based at the Goethe University Frankfurt am Main (Richard 2015). The exhibition aimed at looking at the many facets of the mobile phone inscribed in its social and cultural context. The name makes reference to three perceived stages in the cultural assimilation of mobile telecommunications. Hamster alludes to the laboratory experiments on rodents, performed at the turn on the century, to test the impact of use of electromagnetic devices on hearing and neural pathways (Salford et al. 2003). The figure of the rodent serves as the cultural extreme of worries over the negative health consequence of wireless infrastructure. This is contrasted by the Hipster, the affirmative consumer and its corresponding early processes of assimilation. *Handy* is a slang word in German for mobile phones, and represents the current state of consumption of mobile technologies, in which phones are perceived as an indispensable component of modern life. (Richard et al. 2015).

The curatorial team of the exhibition decided to place *The Chandelier* inside a semi-enclosed space. Since the installation made use of the phones' displays and speakers, it was deemed that a controlled space would work best in the context of the museum. The exhibition would be divided into four big rooms, which means the amount of noise would be considerable, and risked drowning the sounds emanating from the installation. Also illumination was difficult to control. All rooms were brightly lit through floor to ceiling windows, which meant that during daytime the colour shits in the installation would be difficult to see from a distance. A solution to this was to build a semi-enclosed space with a single point of entrance for the visitors to enter the installation, and providing controlled illumination and sound conditions to appreciate the shifts in the installation. Although this contributed in providing a more intimate context to the exhibition, it also meant that fewer visitors would immerse in the installation. In the night of the opening, for instance, most visitors would tend to look at the piece from the threshold of the enclosed space. This enabled a different interaction between public and piece, in which the latter is understood more like an object rather than as a space they could immerse themselves in.

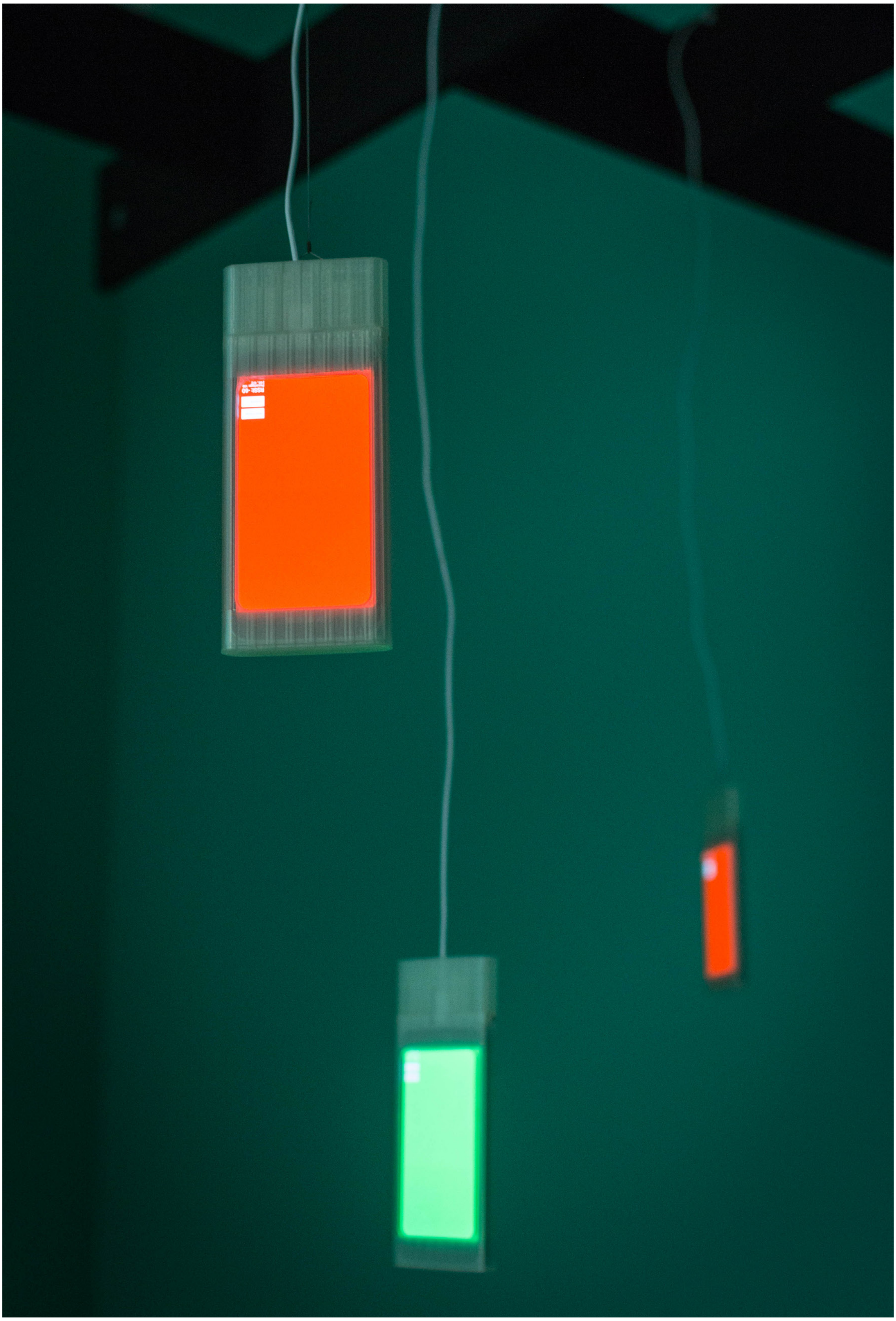
Although some changes to the design of *The Chandelier* were necessary due to the setting, the overall layout remained the same. The previous design of the installation involved an overhead structure which served as anchoring point for the mobile phones, and as a visual element to delineate a space beneath the piece. Figure 32 shows sagging in the elements of the structures. This is due to the configuration of the pieces, which are arranged as horizontal flat pieces, with fastening placed on the weak joints. The second iteration was intended to improve this by creating an irregular grid, with elements configured to work structurally against shear force by placing them vertically, as seen in figure 45. Other design changes were necessary. The exhibition ran for four weeks, which introduced phone battery and security issues. In the initial variant of the piece, phones where fully charged before opening and were capable of running the application for three hours before depletion. Moreover, the *Invisible body* exhibition was held in a small space, which made any concern for security unnecessary. A new holder was designed, modelled as an extruded rounded edge rectangle, which tethered phones to a power source, through a USB cable. The connection is hidden from view to avoid visitors fiddling with the cable or accidentally unplugging the phone and draining the battery. The case also connects to a steel rope line, which secures the phone to the overhead structure.

42 Visitor reading accompanying text to the installation

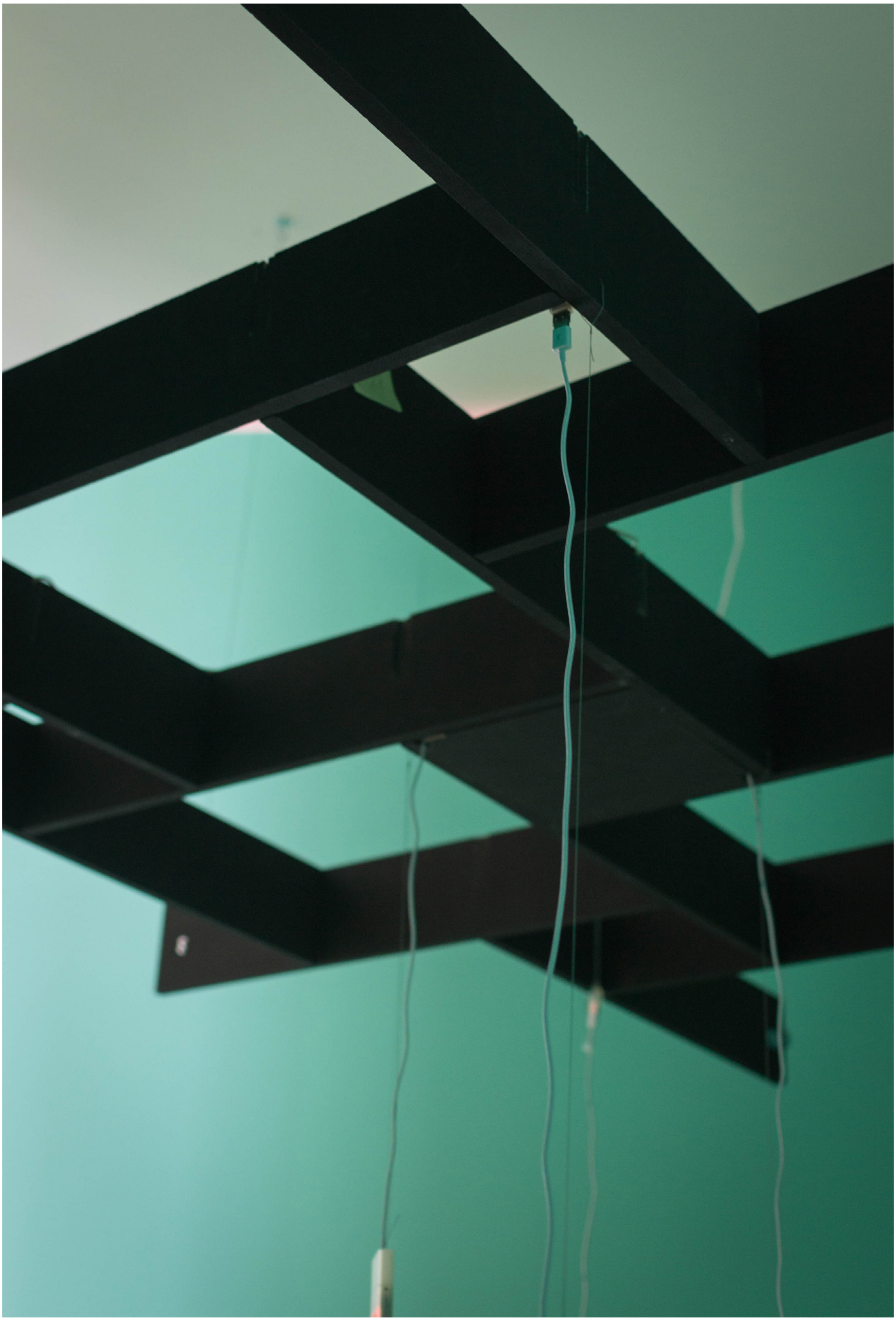
6 Image produced during the Work in progress event, Culture Lab



7 Image produced during the Work in progress event, Culture Lab

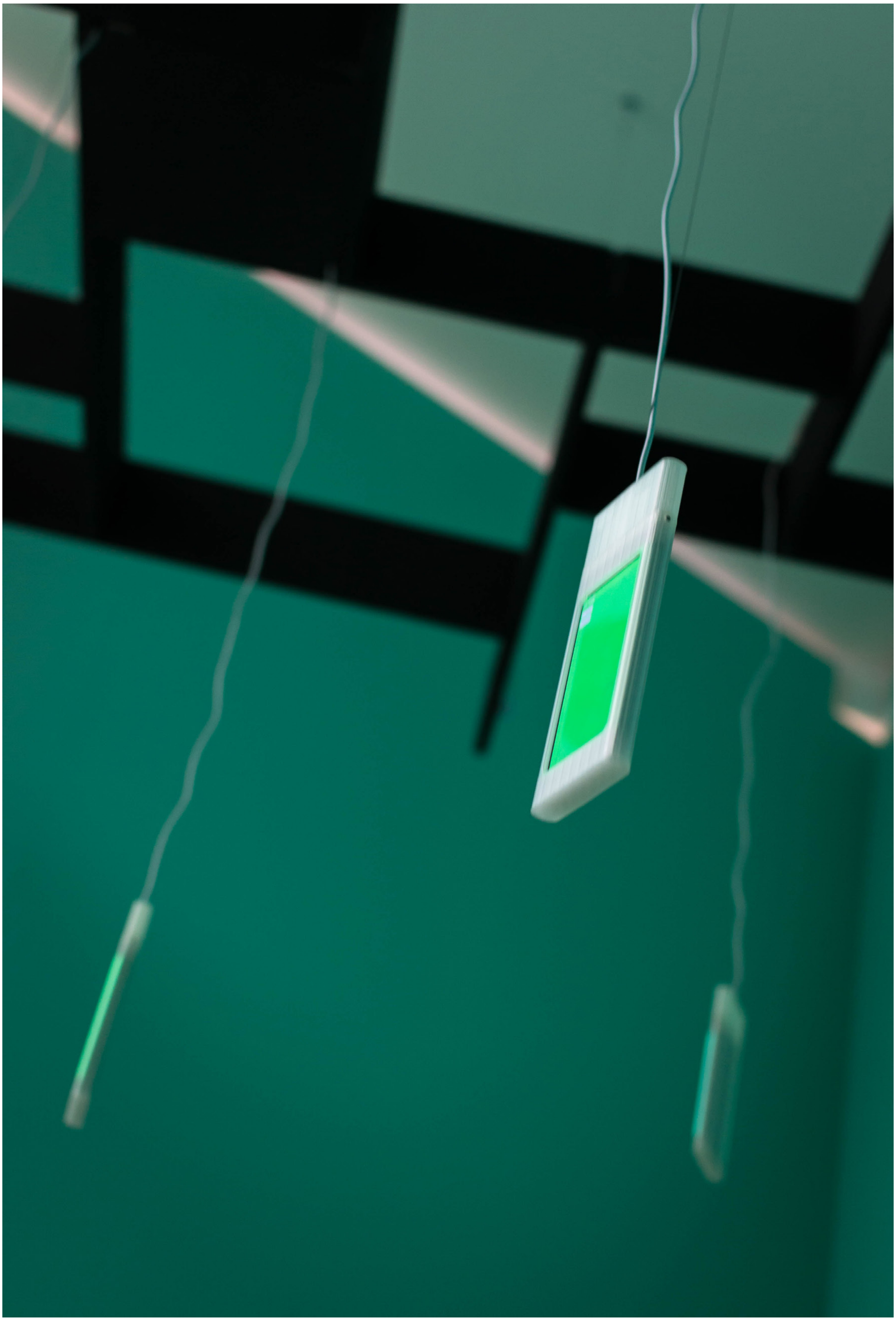


6 Image produced during the Work in progress event, Culture Lab



7 Image produced during the Work in progress event, Culture Lab

6 Image produced during the Work in progress event, Culture Lab



7 Image produced during the Work in progress event, Culture Lab

49 Robert Voit's visual essay in the exhibition space

50 Johannes Paul Rather's Walking Tree

51 Iphone Oil painting, by J.K. Keller

5 CONCLUSIONS

In this chapter, I reflected on the design of the Kirlian Device mobile, an Android app developed to explore enhanced feedback mechanisms. The instrument enabled the development of three design exploration: *Wireless Séance*, an immersive prototype running on Glass, and the installation *The Chandelier*.

The design interventions articulate four *engagements*. The first section of the chapter explored the improved mechanisms of calibration, enabled by the additional hardware available in the Android platform. The process made available a routine which enabled performers to capture an array of values, which are analysed to determine local signal strength limits. I have also described the programming strategies that were made necessary to adapt the scanning routine to the new platform. Security restrictions in Android, for instance, require the use of passive scanning. I have also described how the Android platform enabled signal strength mapping to tone frequency, which enhances the connection between instrument and performer, and that contributes to the development of an intuitive understanding of wireless fields.

In the second *engagement* I have analysed the way the KDm provides the context for participatory representations of wireless. This is done in an early exploration developed during the work in progress, an event organised by the Culture Lab and that provided the opportunity to invite other researchers to develop choreographies. I have discussed how this process exemplifies the way the Kirlian device enables connecting instrument, body and signal dispersion. I carry on the argument in *Wireless Séance*, where I describe a workshop organised as part of an interaction design module. I have argued that by drawing allegories to spiritual séances, the event provides a form of engagement where designers can explore the materiality of an invisible technology through their bodily awareness. I have suggested that this process is similar to the way designers acquire knowledge of materials through systematic encounters.

In the third section I discussed the connection of the body, instrument and wireless field through the implementation of the KDm in Glass. Common use of the Android operative system enabled porting the application to Google Glass, facilitating an exploration in which the wearer is immersed in the wireless field: they can monitor how signal dispersion fluctuates as they walk through a physical space. I described some of the technical challenges encountered in deploying he KDm, and suggested that despite of these, the intervention actualises notions of space thickening.

Notions of space thickening are further explored in the fourth *engagement*, which documents development of The Chandelier. The installation consists of a number of android devices, suspended from an overhead structure and that provides fixed points of reference to gauge signal dispersion across space. I have discussed how the installation can also be understood to explore the atmospheric effects of wireless fields. I have reviewed the work of Ash in describing the materiality of technological devices through atmospheres: the areas of influence that enable a device to draw the attention of humans, modifying their sense of time and space. The soundscape generated by the Chandelier, I have argued, produces a similar effect, suggesting that wireless signals saturate space, making it denser.

C

CONCLUSION

In this thesis, I have proposed that, in the context of wireless infrastructure, representations *construct* their materiality. The hypothesis upends a prevalent discourse which locates representation as means to increase technological literacy. I have proposed that understanding representations as indexical hobble imagination on how these technologies can be integrated in a design context, undermining the agenda of contributing new understandings as to how everyday objects and spaces can be interweaved with digital technologies. In this context, I have used representations of wireless infrastructure as a methodology to explore alternative materialities. To do so, I have proposed a methodology which manipulates the underlying analogies and metaphors used in different stages of the representation process, and uses *material conceits*: unusual metaphors that enable placing wireless technologies in unexpected contexts.

1 ARGUMENT

I have developed my argument through a combination of traditional scholarship and textual account of design work. The first part of the thesis provides an overview of wireless infrastructure and their role in the model of ubiquity; analyses how they are interpreted as material in design contexts; argues that representation of them constructs their materiality; and proposes a methodology that enables exploring alternative materialities. In chapter one, I have reviewed contemporary discourses on ubiquity, and analysed how wireless technologies constitute the invisible meshwork that connects digital devices, and embeds them into the physical space. I have also analysed how, given their relevance, a number of design explorations have set out to increase their legibility, often in a bid to increase technical literacy within traditional design disciplines. I have challenged this discourse, suggesting that these representations not only document technical operation, but also *construct* the materiality of wireless.

In chapter two I have developed the notion of materiality in detail, drawing from the contemporary school of *New Materialism* in describing it as an emergent feature, contingent on context and association between objects. The conceptualisation affords a creative methodology which makes use of material conceits: unusual metaphors that reveal new forms of materiality. In chapter three I have examined prevalent metaphors used in describing wireless technologies, and have proposed an alternative. In the first part, I have reviewed the analogy of wireless as electronic terrain, popularised by Mitchell (2003) and that draws from a tradition of understanding technology as prosthetic extension of the human body. The second part introduces the conceit of spectralities, which draws from the 19th century tradition of understanding wireless as infused with supernatural features. I have proposed that the conceit provides three avenues of exploration. One, to think of wireless as an invisible substance that *thickens* space by making reference to notions of ether. Two, the figure of mediumship draws attention to the interface between the human body and invisible fluids, technological and spiritual. Third, the figure of trance enables thinking of the human body as an instrument to detect wireless infrastructure.

I have furthered this argument in the second part of the thesis, which documents a number of design explorations that centre on the design of three instruments. First, the design of the *Space Reader*, which attempted to adapt techniques developed by others to map signal dispersion in interior spaces. Second, the *Kirlian Device*, a redesign modelled around the interaction between the human body and wireless signals. And third, the *Kirlian Device mobile*, an Android app which explored notions of feedback, participation and immersive environments. Together, these instruments explore different aspects of the interaction between designer, instrument and wireless infrastructure as design material.

Chapter four described the development of the *Space Reader,* and detailed how it drew elements from instruments and techniques developed in *Immaterials* and *Immaterial Fabrication*. I have reflected on the way different metaphors influence the design decisions of both projects, and proposed to use the alternative metaphor of ether to imagine wireless infrastructure as a fluid that saturates physical space, and affects the experience of its inhabitants. I used an early photographic exploration to highlight and reflect the interaction between wireless and the body of the performer. Chapter five documented the development of the *Kirlian Device*, and described how it enabled the exploration of *Spirit Photographs*. I have argued that the instrument reveals four material registers. First, it enables understanding the body of the performer as instrument, which works in tandem with the electronics, to register wireless. Second, it enables developing a choreography, inspired by mediumistic trance, and that uses gestures and body movements to represent signal strength and technical challenges in capturing wireless. Third, long-exposure in digital photography requires post-processing techniques which, I have argued, enable asynchronous forms of feedback and connection between designer and wireless signals. Fourth, the design of the instrument invites reflection on calibration as a form of feedback, which involves tuning the instrument to the operational conditions of wireless by defining local limits. Chapter six has described the development of the *Kirlian Device mobile*, an Android app which mimics the operation of the previous design, and that enabled the distribution of the instrument to a wider audience. It also enabled explorations beyond the photographic medium. It was ported, for instance, to a Google Glass prototype which was deployed during the exhibition *Invisible Body of Wireless*. It also enabled the design of *The Chandelier*, an installation that provide fixed points of reference to gauge signal dispersion, and that generates an immersive experience that produces atmospheres of wireless.

2

CONTRIBUTION

One of the main contributions of this research is in providing an alternative narrative to the debate of invisible technologies and design. In my introductory chapter, I have referred the increasing relevance that digital technologies have in design practices, as they evolve to be weaved into the fabric of everyday life. This is at odds with a perceived lack of technical literacy, which prevents designers from understanding how technologies can be integrated in the production of artefacts and spaces, and the broader public in debating the effects of technology. One of the components core to digital technologies is wireless infrastructure, which provide the invisible meshwork that weaves different devices together, and enact the ideal of ubiquitous computing. In this context, a number of practitioners have set out to produce representations intended to document the technical complexity of these invisible technologies. These projects are often presented as increasing literacy for those without a technological background, and help in developing a materiality of wireless infrastructure: the sense of how they can be integrated with other tangible materials in a design context.

I have argued that the argument takes a traditional understanding of materiality, in the sense that they consider it as a property inherent to the object: there is a materiality of wireless infrastructure that can be *revealed* through indexical representation. Instead, I have drawn from New Materialist schools of thought, and suggested that materiality is *constructed,* a term which makes reference to the fact that it is contingent on the combination of tools and materials in which a specific technology is situated. I have suggested that one of the downsides of the prevailing narrative on invisible technologies is that, by conceptualising representations as mimetic and indexical, we often fall back on established models of thinking about the invisible by situating the technology in familiar contexts. Instead, I have used representation as a means of exploring alternative materialities, a process which involves unusual metaphors that places technology in unfamiliar realms to reveal new design opportunities. In this thesis, I have focused on developing the argument linking representation, analogy and materiality, and explored this in the development of different instruments which present with alternative relationships between instrument, material and designer. There are also some hints of how the exploration might lead to new design possibilities, especially in the design of *The Chandelier* installation. Moreover, I believe the exploration is useful not only in the context of wireless infrastructure, but in a wider array of invisible technologies. The work contributes in presenting a methodology to engage with invisible technologies, defined broadly as resources which, given their scale or physical composition, cannot be engaged with using traditional methods of bodily awareness. The last decades have contributed with a growing host of invisible technologies, ranging from computational code to biotechnologies, which are relevant to design and architecture.

The research has also contributed in sparking the imagination of designers and general public, catalysing new ways of discussing wireless infrastructure. The Spirit Photographs gained substantial coverage in mostly online, popular media including the BBC, Wired and the blog of Fast Company (Editor 2014; Brownstone 2014; Sintson 2014) in addition to many other technology media outlets (O'Callaghan 2014; McDonald 2014; Zipkin 2014; Chartier 2014; Project 2014; Pooiee 2014). This coverage is revealing both in terms of the journalistic interpretation of the work and the comments generated by the articles. The project has prompted over 200 comments across different publications, and has been share up to 40,000 times in social media to the time of writing. Of 46 comments left IFLScience article (Luntz 2014) on the project for example, 26 engaged in a debate on how precise the representations were. Whilst some readers claimed that it was not a scientific depiction, other replied by stating that the pictures prompted speculation and curiosity on the technology. The Wired (Sintson 2014) audience in particular debated whether this was art or science and questioned the validity of the article with one commenter dismissing the validity of the images based on our use of the Kirlian name for the device itself. The way in which the images operate as probes to question and speculate on the materiality of wireless can be attested in the playfulness of its editorials. One article was headed—'Here comes the Wi-Fi ghostbusters' (Maturana 2014). In other cases, there are direct references to the notion of *Ghost in the machine: 'In his series of oddly haunting photographs, researcher and artist (…) has found the ghost in the machine. Or maybe it's the machine in the ghost*' (McDonald 2014)*;* a piece titled '*A Machine Is Visualizing The Ghostly WiFi Waves That Surround Us*' (Sokol 2014)*;*

an article with the opening line *'The ghost out of the machine?'* (Starr 2014). The exploration for language to describe different materialities can be seen also in associations of the work with the human body. One of the pieces, for instance was headed as '*This architect is wearing his Wi-Fi Signal*' (Brownstone 2014). The images also prompted readers across a number of outlets to discuss about health concerns regarding wireless technologies. In the online version of the Daily Mail article (O'Callaghan 2014) covering the project, around 70% of the comments discussed health concerns due to radiation exposure. The story was also covered in online publications specifically focused in Electromagnetic Hypersensitivity, and taken to represent how a person suffering the disease experiences electromagnetic field propagation (Burrell 2014). Additionally, the project´s website included a contact form in which visitors were encourage to contact the authors to leave their impressions on the projects. Some of the correspondence received through this medium discusses mystical notions of wireless technologies, as well as concerns on how wireless technologies affect human health. Media coverage of the project has also inspired other designers to reinterpret wireless infrastructure from different perspective. A good example is the work of Annabel Giraud-Telme, a fashion designer who created a collection using the *Spirit Photograph* images as source of inspiration, and that was shortlisted for Vogue's Graduate Fashion Week 2015. Annabel contacted me while developing the collection interested to explore the interaction between body and wireless technologies. I collaborated with her by providing additional sources, references and ideas to guide her interpretation of invisible technologies.

The work also contributed to the development of *Research Through Design* in Architecture. The term is used here to refer to research efforts in which *designerly* approaches and perspectives are used to address questions that are relevant to design disciplines (Dalsgaard 2010). The approach has been traditionally used in the area of interaction design, and is an emerging practice in other disciplines such as architecture. In this context, I was also inspired by a growing discourse that aspires to explore how design can be used to develop an *experimental metaphysics* (Kimbell 2013). The term was first used by Bruno Latour (2004) to criticise the way in which terms such as agency and actant are often limiting, in the way they provide a rigid framework to interpret reality. Instead, he proposes to start with as little preconceptions as possible, and to use terms and categories in a loose way that can be adapted to the specific needs of the situations under study: to experiment with concepts themselves to better fit reality (Hämäläinen & Lehtonen 2016). In the context of design, *experimental metaphysics* has been used to speculate on the way design can be used to do philosophical work: to actively question and transform our assumptions of how things should operate in the world. My aspiration in this thesis has been in developing a methodology which uses the process of design as means of reflection into the fundamental principles through which we understand technology. In other words, to propose a method through which we can escape, to some degree, the usual grooves threaded in integrating technology in everyday life. Similar efforts have been done in *re-enchanting* the world, a term that advocates for alternative visions of technology by bringing back the sense of wonder, magic and mysticism to otherwise banal elements (Landy & Saler 2009).

3 SPECULATION AND MATERIAL CONCEITS

The term of material conceit contributes to critical design, representing a new approach of how speculation can be used as a tool to interrogate technology. In this context, I refer to critical design in the wide sense of the term, referring to a number of design movements which share a non-commercial orientation, and an ethos to explore and critique potential futures. The term itself was coined by Anthony Dunne and Fiona Raby, who see design as '*a tool for critique, and aimed to explore the metaphysical possibilities of the designed object in order to "provide new experiences of everyday life, new poetic dimensions*"' (Prado & Oliveira, 2015, para. 2). Two of the most visible methodologies associated to critical design, Design Fictions and Speculative Design, share connections with literary fiction, and often involve extrapolating contemporary products and technologies by creating speculative settings and storylines, which are intended to reflect critical engagements and initiate public debate (Bleecker, 2009; Lindley, 2015; Prado & Oliveira, 2015). For example, Bleecker proposes that design fiction can be described as '*a conflation of design, science fact, and science fiction. It is a amalgamation of practices that together bends the expectations as to what each does on its own and ties them together into something new*' (Bleecker, 2009, p. 6). Similarly, Auger describes the way critical design uses fiction to remove commercial constraints, thus facilitating discussion of their social and ethical dimensions. He writes that critical design:

> *remove the constraints from the commercial sector that define normative design processes; use models and prototypes at the heart of the enquiry; and use fiction to present alternative products, systems or worlds (Auger, 2013, p. 11).*

The last few years have seen a growing debate on the challenges and limitations involving speculation as a critical tool. One challenge is that the use of the term already has a number of cultural associations, which are often difficult to remove. James Auger has argued that references to speculation are often connected to classic visions of the future, invoking images of flying cars and jet packs, thus: '*playing to spectacle and techno- centric dreams rather than being based on logical trajectories or contained by the rules of real life*' (Auger, 2013, p. 5). The existing cultural baggage of the term contributes in making it difficult for the audience to understand projects as a call for debate, and are instead read sometimes as part of consumer-oriented futurisms: design exercises promoted by industry and that are, largely, devoid of criticality.

The use of the term speculation is also problematic, Oli Stratford has suggested, as it makes the public confused as to how seriously the projects should be taken. Oli analyses the speculative project Seasons of the Void, in which Daisy Ginsberg imagines 'fruits that could be grown and harvested in spaceships during interstellar travel and genetically engineered species intended to balance shifting ecological systems'. Speculative design projects, Stafford suggests, are confusing because they are presented in such a way that is difficult to discern how much of the technology proposed is actual, which parts are not, and how they are intended to operate as a form of critical engagement. Stratford writes:

> *They are not the most accessible of projects, nor is it easy to tell exactly what they mean. Consider the space fruit. It's an intriguing idea, but confusion arises because as an uninitiated viewer it's difficult to tell whether it's serious or not, particularly given the slickness of the presentation (…) Confusion is one of the results that typically arise from design fictions like those Ginsberg creates. The discipline seems to suffer from a problem of how exactly its fictions are to be read. It is sometimes difficult to know how tongue-in-cheek its proposals may be or how seriously we are meant to take them (Stratford, 2014, para. 7).*

Part of the problem, Stratford goes on to suggest, is that the public doesn't expect design to operate in this way:

> *We know that art, for instance, is often oblique, non-literal or metaphorical; it cannot always be taken at face value. Yet literality is precisely what we expect of design, a discipline we are near hard-wired to think of as problem solving and practical. Qualities like humour, provocation, politicisation or subversion are common in art, yet their presence in design is rare (Stratford, 2014, para. 9).*

In this context, the use of the term conceit might offer a way of attending to some of the problems associated with the use of speculation. I have proposed the term of material conceit in reference to the poetic device that is used as a fanciful analogy that enables to see a familiar topic in an unfamiliar way — it introduces a different perspective to something that has been analysed extensively. In colloquial terms, the term also alludes to trickery: something that is overtly artificial and flamboyant. Describing design interventions as conceits signals their artificiality upfront, and enables a different engagement with the public. It is a way of holding our hands up to the public and saying — 'hey, this isn't true, but bear with me and see where this takes us'.

In addition to the nuances it provides as a term, material conceits as methodology also contributes a different way of using speculation that taps into contemporary philosophical movements. Speculative design and design fiction use speculation as a way of projecting a technology into the future. Joseph Lindley argues that is, by definition, a future-oriented activity as it attempts to depart from existing situations and generate new ones. Speculative Design attempts to redefine this engagement. He writes that: '*speculative design refines this relationship with the future; rather than the design process simply working towards materialisation of a future product or object, the focus shifts towards producing insights about future possibilities*' (Lindley, 2015, p. 3). In this thesis, I've used the notion of speculation as a way of building a bridge between research through design, and contemporary schools of new materialism. While speculation in design is used as a way of projecting into the future, these philosophical schools use speculation as a methodology to delve into the depth of things. Speculative realism operates on the assumption that humans have no direct access to objects, in the sense that there will always be aspects of the object which remain hidden to any form of interaction; that, however, doesn't preclude engaging with the object, and using speculation as a way of imagining what it means to perceive the world as objects do (Bogost, 2012; Harman, 2011).

Drawing on speculative realism enables thinking of design as a way of doing experimental metaphysics. Winograd and Flores (1986) have used the work of Heidegger to propose that design is an ontological practice, in the sense that it proposes new ways of being in the world. Lucy Kimbell (2013) expands on the argument and suggests that design can become a form of experimental metaphysics which engages in the active making and constituting of new realities. The notion of material conceit attempts to explore how critical design can do experimental metaphysics. And in this context, it uses speculation as a form of zooming into the material transactions that technologies have with other objects, and use these engagements as the basis for new ontologies: new ways in which these technologies can exist in the world. A way of framing this possibility is to say that material conceits share the aspiration of critical design to, in the words of Prado and Oliviera quoted above, explore the metaphysical possibilities of design objects, and find untapped poetic dimensions to them. However, instead of doing that by using speculation to set up a context of possible futures, it does so by delving into the technical depths of technology and zooming into its material transactions.

4 LIMITATIONS

The contributions above should be taken with the limitations of the thesis. The more visible is that the creative output did not reach into developing new forms of interaction and *thickened* spaces. Early outlines considered a three stage exploration. First, it would involve exploring the methods available to represent wireless infrastructure, adapting instruments developed by others to the scale of interior spaces. The second phase would involve developing a number of prototypes to shape signal dispersion, using materials with different attenuation values and adaptive geometries. The combined knowledge produced in phase one and two would serve as the basis to design new interaction modes in phase three. There were, however, a number of challenges in implementing the three phases. One of them was the fact that although the reference projects had been widely covered in popular media, there was little or no technical documentation to reproduce their instruments. As a result, I spent the first few months of this research developing circuitry and code to analysing operational metrics of wireless signals. These technical challenges prompted a revaluation of the research, contracting its scope to the first phase and concentrating in the connection between representation and materiality of wireless infrastructure.

One of the downsides of the contracted scope was that the practical work couldn't reach the final destination of the theoretical discourse. The thesis revolves around an argument of creative re-appropriation. It started by suggesting that the metaphors and analogies we use in describing the invisible have an effect in their materiality: the way we think of them as resources for design, and how they can be combined with tangible materials in shaping objects and spaces. In the context of wireless infrastructure, one of the most influential analogies is that of the electronic terrain of the city, which has determined the way we discuss these technologies in design discourses, and how they are understood and appropriated culturally. The thesis suggests that by changing this analogy, we are able to look at things in a different light, and to find new design opportunities. In this thesis, however, I haven't been able to reach this conclusion in the creative exploration by presenting new design outcomes. There are some inklings of alternative modes of interaction in the design of *The Chandelier*, which suggests the creation of a space which is perceived differently when wireless infrastructure is made manifest through sound and light.

The exploration on instruments and the ways they change our perception of wireless infrastructure lead, potentially, to more sophisticated forms of interactions. Example of this is in the way that signal strength is generally understood as a technical limitation of deployment. Understanding wireless as thickening space might lead to think of other interaction indexed to a notion of density of space. For example, how content delivery can be connected to diminishing or increasing signal quality. This could be done by adapting the quality of content, or by designing granular media that is constructed purely by spatial conditions. In the case of granular music, for instance, different instruments and sound sources can be mixed depending on the changing qualities of wireless infrastructure. Similar exercises might be done with non-linear literature, where minimal units can be shuffled and rearranged depending on the position of the reader relative to wireless. These possibilities might offer a new way of using space as an interface of digital information (Hernan 2011).
Criticism should be made of how, while proposing to shift the underlying metaphor governing our understanding of wireless, I have done so by using instruments and techniques corresponding to the prevalent metaphors. In

the introduction, I have referenced the work of Lakoff and Johnson (1980) in describing how metaphors are important in shaping our conceptual structures. The argument is parallel to the notion of paradigm shift by Thomas Kuhn (2012), who has suggested that progress in science is framed by the ideas used to conceptualise problems, and that it is only when a new way of understanding those problems arrives that we are able to produce a step change. I believe design is governed by similar processes, in the sense that our ability to understand the world, analyse problems, draw from our material repertoire and produce design solutions is often constrained by the metaphors we use to interpret the world. Similarly, by altering the metaphors and analogies we use, we are afforded with new ways of understanding our context. I have tried to explore the potential for new paradigms to think of wireless infrastructure. I have done so, however, by building upon tools that have been designed using prevalent metaphors. As a result, the work has not been able to depart entirely from the existing models of understanding wireless technologies.

There are also limitations in the way I have integrated the design exploration with the theoretical work, and that are to some extent inherent to Research Through Design. At the outset, I had an aspiration to weave both strands, theoretical and practical, into a seamless discourse that addressed the notion of materiality of wireless infrastructure. In principle, some arguments might be developed traditionally in a textual argument, presenting ideas and reaching a conclusion, to be then connected to a design process or artefact that might embody these ideas or develop new arguments. Early manuscripts of the thesis attempted this, but resulted in a text that was difficult to read. In this version, the thesis has followed a more traditional structure, bringing the theoretical argument to the fore, developing it independently and leaving it at a point where the creative exploration comes in to reinforce and advance some of the ideas. The development of the research, however, was less structured and a large proportion of the theoretical work came out of the practical work. For instance, the exploration started with attempts to reproduce the instruments used in *Immaterials* and *Immaterial Fabrication.* Technical challenges in assembling the electronics prompted reflection on the design decisions taken to translate operational metrics, and eventually lead into exploring how metaphors and analogies shaped our decisions and framed our interpretation of the invisible. Similarly, I came about Object Oriented Ontology by looking at different ways of creating textual descriptions of technologies, which brought me to the work of Ian Bogost (2012).

All translations from research to a textual account involve a flattening of a complex set of interrelations. This is, however, particularly true of Research Through Design, in which there is a rich interweaving of practice and theoretical work. Failure to reflect this richness in the work should be interpreted as my own limitation, and not as an impossibility of combining both aspects and reflecting their relationship in the structure of their textual accounts. Experimental literature in the 20th century, and specially the way in which books were deconstructed to enable multiple readings, offer some possibilities to improve the relationship between creative exploration and textual accounts. For instance, a more faithful presentation of this thesis would begin with the current Chapter Four, describing initial explorations on reproducing techniques and instruments developed by others, and that prompted reflection on design decisions, and on the way the body of the performer influenced the resulting images. This would lead then to Chapter One, where the reference projects are explored in a wider discourse of invisible technologies, and analysed through notions of representation and indexicality. This prepares the field for Chapter Two, which delves further into representation and materiality. The analysis operates as preface to Chapter Five, which describes the development of the *Kirlian Device* and the *Spirit Photographs*, and which prompted exploration on alternative metaphors of understanding wireless. Chapter Three would follow, presenting an in-depth review of the material conceit, and exploring how the spectral analogy invites new interpretations of wireless infrastructure beyond the ones described in Chapter Five. Chapter Six would work as a closing chapter, presenting the exploration around the *Kirlian Device Mobile*, and exploring aspects of immersion and atmospheres in the Glass prototype and *The Chandelier*. This reading sequence could be presented as alternative to the sequential narrative provided in this version of the thesis, starting in chapter one and following the numerical order. The possibility of two possible reading patterns, however, presents several challenges in preparing alternative opening and closing paragraphs, and potentially in fragmenting some chapters to improve clarity in the non-sequential narrative. However, this might present a worthwhile area of development for future explorations on how textual accounts of research through design are developed to reflect the richness of the design process.

It is also important to recognise the limitations of the frameworks I've used. I have proposed to use an Object-Oriented approach, which enables me to zoom into the material transactions of wireless, its contexts, the instruments used in representing, and the designer. I used this methodology within a framework of representation as a way of experimenting on how the association of objects determines the materiality of wireless, and speculating on new assemblages. The use of an object-oriented methodology has enabled this research to contribute a new approach to the field, distinguishing from previous work in the area as it brings the human body into the set of objects that negotiate the materiality of the invisible. However, taking a representative approach makes it difficult to recognise the way in which the materiality of wireless is co-produced, in the sense that it is contested in its context of use by a multitude of users. How, for example, the materiality of wireless in a domestic space is different from that of a commercial or an office setting, as the actors that meet and contest the use of technologies have different needs and goals. A different approach to representation might help to explore the material transactions among a wider cross-section of objects and entities.

Likewise, by focusing on representation, I've missed on the rich transactions that occur in the communities of enthusiasts that contest commercial narratives of how wireless technologies operate. The last five years have seen an explosion of electronic chips and circuits. When I started prototyping the first instruments in this research, setting up a microcontroller capable of connecting to Wi-Fi required a basic micro-controller, augmented by a shield, and both powered by independent batteries (as I've recounted in chapter 4). Currently, there are a number of System on a Chip solution, for example the ESP8266, which have significantly reduced the costs and technical hurdles of working with wireless. The possibilities brought about by this evolution of the electronics market have made it easier for enthusiasts and hackers to experiment with embedding wireless across a range of situations and objects. These projects often diverge from the official narrative of wireless as a way of convenient transfer of information, and edge into new territories of what wireless could be and, as such, offer an exciting area of study of how materiality is negotiated in practice.

Conclusion

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