"HEIM": how the experience of sound-based spatial exploration can enrich our understanding of memory, place, and identity

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ABSTRACT

This paper proposes an initial framework for the research, development, and execution of the project *Heim*. The project builds upon ongoing studies on memory, using seminal ideas and innovations on the subject from throughout the twentieth and twenty-first centuries in the fields of art, psychology, entertainment, and technology as its foundation. In this paper, key concepts are outlined in order to: (1) provide a cultural context for the project; (2) situate the project within a larger historical narrative; (3) Identify a foundation of empirical research as the basis for the project – pointing to studies that have changed our understanding of cognition and proven the neural connections that tie memory to both music and space. Additionally, this paper details the project timeline as well as the methods and materials employed by the project.

Heim seeks to demonstrate how a greater understanding of cognition can be made possible through new media. In its investigation of the relationship between space, music, and memory, *Heim* aims to prove the potential of using an interdisciplinary approach to not only better illustrate the neurological underpinnings of cognitive processes and the problems that impact these processes, but to perhaps even propose a solution to these problems.

Keywords

Memory; space; neuroscience; cognitive psychology; Alzheimer's disease; GPS; interaction design; RFID; NFC; alternate reality gaming; mobile device.

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INTRODUCTION: THE INTERSECTION OF ART+SCIENCE, SOUND+SPACE, SENSE+MEMORY AS MEANINGFUL DESIGN

In recent years, much has been discovered about the relationship between space, music, and memory, particularly in the case of Alzheimer's patients, through studies in cognitive neuroscience and neurophysiology. Through the use of new media and technology, our understanding of this complex relationship can continue to develop over time. New media technologies such as the ones proposed by this project can allow us to experience ideas as abstract as cognition in fuller, richer ways.

Heim aims to demonstrate how technologically enabled ways of interacting with and perceiving our environment might enable a greater understanding of cognition and, more specifically, memory. The goal of *Heim* is to facilitate an immersive, exploratory, and sensory-based experience in the everyday world mediated through the digital visual and auditory interface on a mobile device.

In this initial iteration specifically, *Heim* has two key functions: (1) It tracks user movement through space over time using GPS data; and (2) It implants music tracks into physical space based on the user's cognitive associations between place and music – doing so through the use of RFID tags that can be read with an RFID reader or RFID capable device and subsequently heard from the device. *Heim* uses a designed interactive mapping interface to visualize user movement through space. The interface design aims to better illustrate the concept of the structural, neural networks of cognitive processes, and to relate these structures to the infrastructural networks of the everyday.

In relating the complex to the mundane, *Heim* acts as a multi-disciplinary, visually elegant model for understanding new discoveries in the cognitive sciences, and hopes to prove the value of this model as a visual tool for interpreting and possibly preventing cognitive impairment.

CONTEXTUAL POSITIONING + PRECEDENTS

Historical Context of Psychological Study: Understanding the Relationship Between Space and Memory

Throughout the history of psychology, scientists and philosophers have sought to better understand the relationship between cognition and spatial understanding. Because the cognitive functions behind our awareness and processing of space are so complex – relying on factors as varied as depth perception, temporal processing, directional understanding, and episodic memory – it has been a longtime goal to establish an empirical study that could effectively identify the origin of this process.

Until very recently, many efforts to identify the process that creates our sense of place and ability to navigate have focused primarily on qualitative data and more subjective, emotive interpretations of experience. Though these past studies prove scientifically ineffective in allowing us to make sense of this subtle, nuanced cognitive process, they do however allow us to gain a better understanding of how this understanding of space relates to our human nature and why it is a subject worthy of elaboration.

A subject of particular interest is the explanation of instances where this cognitive-spatial process has failed, creating a sense of disorientation. This failure of spatial awareness has been used to explain ideas as abstract as the Uncanny, as well as problems as weighty and prescient as Alzheimer's disease. The following philosophers, psychologists, and theorists provide a timeline of our attempts to study and explain this phenomenon.

1905: Ernst Jentsch

Jentsch's essay *On the Psychology of the Uncanny* is the first instance of the concept of "uncanniness" being addressed in psychology. Even from this early beginning, the idea of the uncanny is based on the inextricable ties between space and psychology. In his essay, Jentsch describes the uncanny as a sense of disorientation:

> "It seems to express that somebody who has an uncanny experience is not quite zu hause [at home] in the matter, that he is not heimisch [homely], that the experience is foreign to him. In brief, the word suggests a lack of orientation" [8].

1919: Sigmund Freud

Greatly influenced by Jentsch's essay, Freud continues to elaborate on the idea of the uncanny. The uncanny has become an integral part of psychoanalysis – the psychological method of study developed by Freud – and is proposed as an inexplicable emotional response to space. Freud frames the sense of disorientation initially described by Jentsch in physical, spatial terms in his essay, *Das Unheimliche [The Uncanny]*:

> "When, caught in a mist perhaps, or when one has lost one's way in a mountain forest, every attempt to find the marked or familiar path may bring one back again and again to one and the same spot, which one can identify by some particular landmark. Or one may wander about in a dark, strange room, looking for the door or the electric switch, and collide time after time with the same piece of furniture" [6].

1948: Edward Tolman

Tolman was the first to propose a map-type model of cognition in the brain. From studying animal navigation abilities, he reasoned that animals are able to encode their experiences in space to create a cognitive map, allowing them to figure out the optimal navigational paths over time [18].

1971: John O'Keefe

A physiological psychologist, O'Keefe studied animal behavior and spatial navigation, successfully identifying cells in the brain's hippocampus that fire in patterns according to precise spatial locations [14]. Naming these cells "place cells", O'Keefe's unprecedented discovery initiated a paradigmatic shift in our understanding of how neural networks made up of task-specific cells form our higher order cognitive processes and provided empirical proof for Tolman's initial hypothesis of the cognitive map model of spatial understanding.

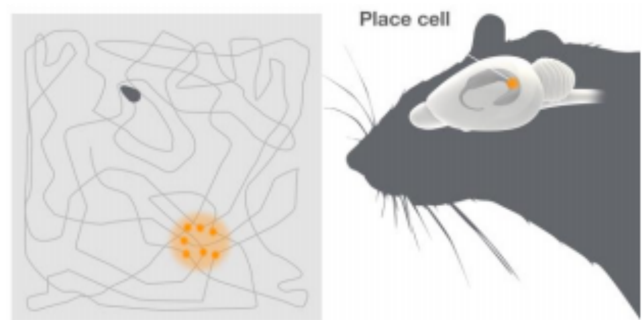

Figure 1. ***Place cells.*** *Right: Schematic showing the location of place cells in the hippocampus of a rat as discovered by John O'Keefe in 1971. The place cells fire when the rat navigates to precise locations within the enclosed space. Left: The rat's path through the space based on the firing of place cells. [5]*

1994: Anthony Vidler

In his book The Architectural Uncanny, architect and designer Anthony Vidler firmly cemented the correlation between the cognitive processes behind the uncanny – hard to describe emotional processes, a sense of unease, and feelings of disorientation – and the material, tactile qualities of space. Vidler defines unheimlich [the uncanny] as:

> "sudden transitions from the comfortable and secure to uncomfortable and insecure, producing an effect similar to that of the familiar turned strange" [9].

2004-2006: May-Britt and Edvard Moser

With their discovery of "grid cells" in the entorhinal cortex – cells that fire simultaneously based on adjacent place coordinates on a hexagonal grid – the Mosers established the circuitry that linked O'Keefe's place cells to other variables responsible for navigation. The circuitry of this neural network observed in their studies forms a coordinate system that allows for comprehensive positioning and navigation that has been described as an "inner GPS" [5].

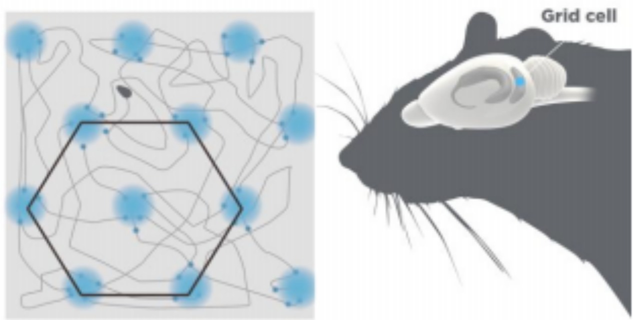

Figure 2. ***Grid cells.*** *Right: Schematic showing the location of grid cells in the entorhinal cortex of a rat as discovered by May-Britt and Edvard Moser in 2004. The grid cells fire when the rat navigates to precise locations within the enclosed space that are arranged in a hexagonal pattern. Left: The rat's path through the space based on the firing of grid cells. [5]*

Historical Context of Psychological Study: Understanding the Relationship Between Music and Memory

In addition to the conceptual models and proposed theories regarding the relationship between memory and space, many studies have also looked to music and other auditory stimuli as potential catalysts for both encoding and retrieving autobiographical memories.

The phenomenon of recalling past events through certain senses – be it sound, sight, smell, touch, or taste – has long been regarded as a common occurrence and has been attributed to the complex and dynamic way in which we as humans learn new things and take in the world around us – consciously or unconsciously – by encoding all of the information available to us via modes of sensory perception.

However, only very recently have certain scientists and organizations looked to this phenomenon of multi-sensory encoding of autobiographical memory as a potential method for combating dementia and retrieving memories in patients whose minds and memories were once thought to be lost forever.

1913: Marcel Proust, Swann's Way

Before the ties between music and memory were studied in a scientific setting, an understanding of this connection could be found in literary sources. In Proust's *Swann's Way*, he describes this phenomenon in poetic terms:

> "And before Swann had had time to understand what was happening, to think: 'It is the little phrase from Vinteuil's sonata. I mustn't listen!' all his memories of the days when Odette had been in love with him, which he had succeeded, up till that evening, in keeping invisible in the depths of his being, deceived by this sudden reflection of a season of love, whose sun, they supposed, had dawned again, had awakened from their slumber, had taken wing and risen to sing maddeningly in his ears, without pity for his present desolation, the forgotten strains of happiness [17].

1992: Han's Baumgartner

Baumgartner was one of the first researchers empirically study the phenomenon of music's ability to trigger the recall of memories tied to specific set of emotional, temporal, and spatial conditions. His study focuses predominantly on the importance of emotion in the encoding process, gaining insight into why the memories were encoded and recalled in the first place. [3]

Figure 3. ***Movie Still from*** **Alive Inside: A Story of Music and Memory** researchers provided elderly dementia patients living in a residential care unit with MP3 players (specifically, Apple's iPod Shuffle) pre-loaded with their favorite music [2]

2014: Alive Inside: A Story of Music and Memory

Alive Inside proves music's potential as a source for restoring memories that were thought to be lost in late onset Alzheimer's patients. What is most significant about the research and evidence presented in this documentary, is not only the idea of a single memory being restored, but an entire person. In the moments after a song is heard and memory is recalled, the patients seem to regain their identity: they are able to respond to questions asked of them, to identify who and where they are, and to retell different stories from their lives. Because of this, it can be argued that the more we engage with the various multi-sensory ways of both encoding and retrieving memories, the greater chance we have of maintaining our identity and mental fortitude over time. [2]

Precedents in Art and Performance

The relationship between cognition and space has been explored in domains beyond science. Here, two examples wherein this relationship is explored outside a scientific context are presented: Janet Cardiff's "Her Long Black Hair" [4] and Nonchalance's "The Institute" [7].

2003: Janet Cardiff, "Her Long Black Hair"

Cardiff's multimedia walking tour through Central Park creates a fictional narrative within a preexisting space for the audience to explore and imagine. The work consists of an audio-track available to users via a CD-ROM and player, as well as an accompanying set of physical, printed photographs to be looked at when prompted by the narrative. The work is described on the artist's website as follows:

> "Relayed in Janet Cardiff's quasi-narrative style, Her Long Black Hair is a complex sensory investigation of location, time, sound, and physicality, […] images link the speaker and the listener within their shared physical surroundings of Central Park, shifting between the present, the recent past, and the more distant past." [4].

Figure 4. ***Janet Cardiff, "Her Long Black Hair".*** Her Long Black Hair takes each listener on a winding, mysterious journey through Central Park's 19th-century pathways, retracing the footsteps of an enigmatic dark-haired woman. [4]

2008-2011: Nonchalance, "The Institute"

Nonchalance describes itself as "a situational design agency in San Francisco, CA" [7]. Through a documentary created to archive their mysterious project, Nonchalance documents how they were able to successfully create an immersive game based on augmented reality. The game is best described through the agency's mission statement:

> "Our mission is to provoke discovery through visceral experience and pervasive play. We achieve this by means of interactive narrative, game design, augmented reality, automated environments, event production, installation art, spatial navigation and cultural curation" [7].

Precedents in Entertainment and Gaming

Human interaction with space has also been of interest in the world of gaming, as new technologies that enable the manipulation or indexing of this interaction have been made available to a wider market through mobile and wearable technologies. Six to Start's "Zombies, Run!" provides an excellent example of integrating real-time GPS and accelerometer technologies into a fictional, digitally delivered audio narrative.

2012: Six to Start, "Zombies, Run!"

"Zombie's, Run!" creatively integrates the spatially oriented technologies embedded in smart phones with a traditional gaming narrative, allowing for an augmented reality that can be experienced naturally and at the user's benefit. Designed as a solution to the sedentary lifestyle, the game encourages movement through a clever narrative and well-executed audio-visual media [1].

Visual/Design Inspiration

The following images frame the inspiration for the project's visual components. These images include: neuroimaging techniques (figure 4), street art/graffiti (figure 5), and Golgi staining (figure 6).

Neuroimaging Techniques

Various image-capturing techniques are used in neuroscience to better understand the structure of the brain and its cognitive processes. Techniques include: MRI, CT, DOI, EROS, and fMRI (figure 4). These images show different areas of the brain "lighting up" as they are used for different cognitive functions.

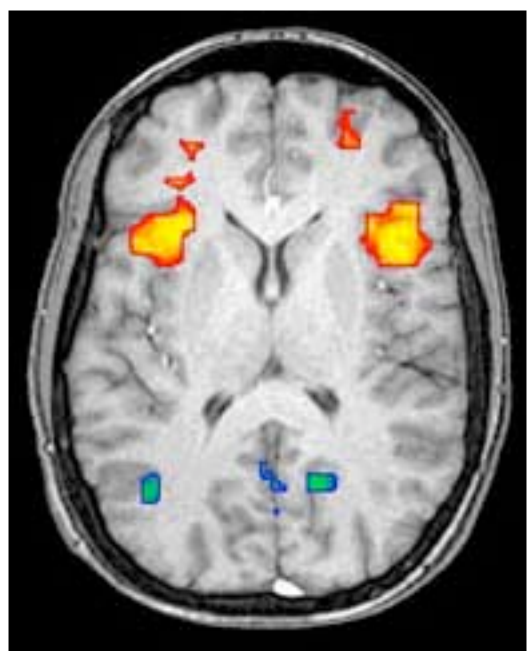

Figure 5. ***Example of fMRI neuroimaging***

Golgi Staining

A silver staining technique developed in the late 1800's to examine nervous tissue, Golgi's method (named after its inventor Camillo Golgi) allows individual neurons to be examined in precise detail.

Figure 6. *Golgi Staining* an example of the ability of Golgi staining to show the details of individual neurons within nervous tissue

Street Art / Graffiti

The RFID tags employed by the project are intended to blend seamlessly with the urban environment in which they are placed, doing so by mirroring traditional street art or graffiti techniques (ex. the use of tags or stickers as a mode of graffiti).

Figure 7. *Graffiti* example of the layering of different forms of public graffiti over time in a single location

HEIM: PURPOSE OF THE PROJECT

The primary goal of *HEIM* is to create an experience based on our current understanding of memory – aural, spatial, autobiographical, personal, and communal – that is:

1. Structurally reflective both of the city as an artificial, spatial infrastructure and of the biological neural network through its use of pathways and nodes
2. Able to strengthen memory through encouraged connectivity both within and between these biological/mental and artificial/spatial network systems
3. Adaptive and living: evolving based on personalized contributions by its players and growing over time
4. Accessed in real time and space through exploring new spaces and taking "the road less traveled"

Alzheimer's Prevention

The National Institute of public health lists ways in which one can prevent Alzheimer's disease, and on this list is the advice to "take the road less traveled", to keep your mind active by exploring new spaces and breaking away from the routine.

HEIM has the potential to create something that not only visually represents something as difficult to understand as memory and its pathology (Alzheimer's disease), but that can also act as a way to combat this pathology – something to encourage exploration, to create new neural networks, to strengthen memories, to transform space, and to promote the road less traveled.

Because what is a lost memory if not the road less traveled?

AUDIENCE AND APPLICATIONS: EASE OF USE

In executing this project, the goal is to allow for it to be experienced as easily as possible, both in a digital and physical sense. A quote from Mark Weiser's "The Computer for the 21st Century" will act as a guiding principle throughout the project's course:

> "The most profound technologies are those that disappear. They weave themselves seamlessly into the fabric of everyday life until they are indistinguishable from it" [19].

PROTOTYPING PROCESS: METHODS AND MATERIALS

The project has three main components:

1. Programmed digital interface for visualizing GPS data and movement through physical space over time
2. RFID "nodes"/tags to record and disseminate audio tracks in specific physical locations
3. Overall design cohesion between components / UI

Program Interface

The project consists of a visual interface that: (1) Records the user's movement through space (i.e. "pathways") using GPS-enabled technology; and, (2) Allows the user to read, record, and listen to RFID tags (i.e. "nodes") when encountered.

Pathways: GPS Data Visualization

A user's movement through space is shown on a map – the primary visual component of the interface that adapts traditional digital cartography to the project's aesthetics and conceptual concerns. As an initial, conceptual prototype, this iteration of the project used pre-existing GPS data retrieved from the sample user's mobile device. Using this sample data set allowed the foundational ideas of the project, as well as the design of the visual interface, to be tested.

The design of the interface involved interpreting the GPS data using both time and location to give the perception of pathways (in a geographic as well as cognitive sense) fading over time when not used. In this sense, the visual narrative of the interface design hopes to mirror the neural network model of memory: the longer a memory is not accessed over time, the greater the risk of losing it altogether.

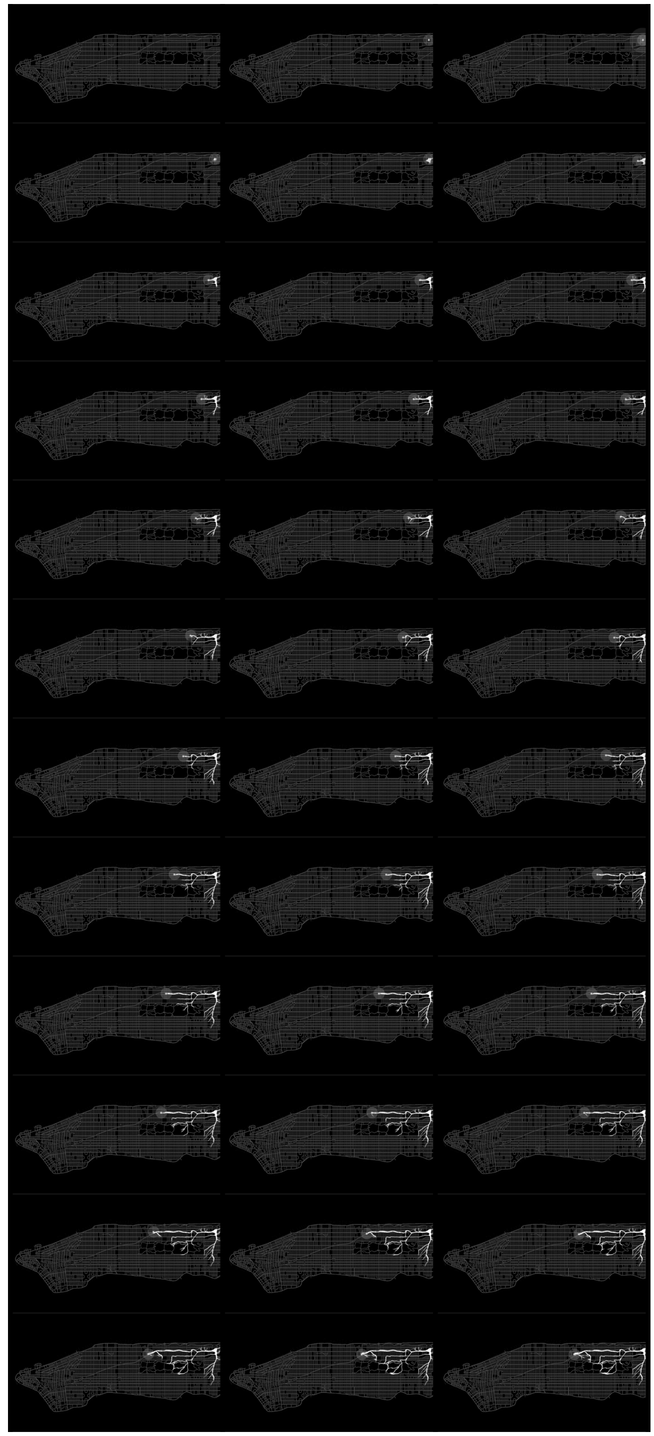

Figure 8. ***Time lapse view of mapped pathways***

Nodes: RFID Tag Input / Output

Similarly, the interface also acts as a way to record accessed "nodes" or RFID tags within the same visual map. As the RFID capable device reads a tag, its location is automatically recorded and its audio output is triggered (Figure 9).

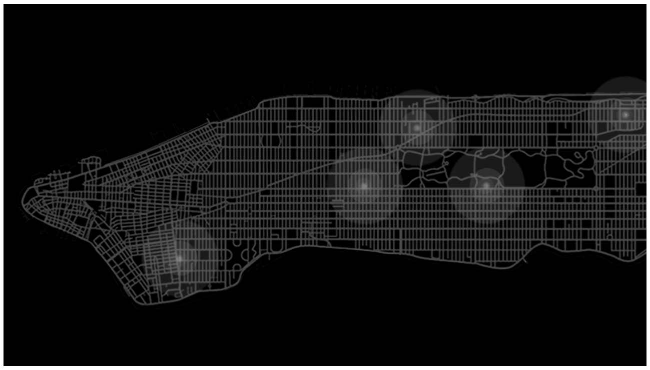

Figure 9. ***RFID "Nodes" as displayed on the interface map***
an example of how the "nodes" might look on a functioning interface. The locations shown here include: The Bowery Ballroom, Radio City Music Hall, Lincoln Center, The Metropolitan Museum of Art, and Columbia University.

RFID/NFC "Nodes"

RFID and NFC technologies allow data to be encoded into certain points in space through physical tags that then transmit the encoded data to appropriate receivers (Figure 10).

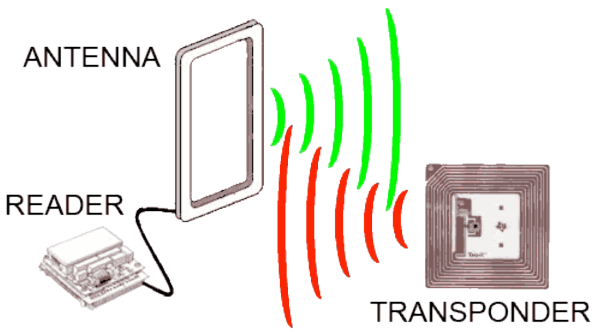

Figure 10. ***RFID Reader and Transponder***

The tags used in the project's current iteration encode pre-recorded music tracks that have psychological, memory-based associations to the locations in which they are placed.

As an initial prototype, these tags can only be written and read by an Arduino RFID shield connected to the computer application Processing via serial connection using Firmata. Additionally, the encoded content is only based on a single user as the current encoding techniques are less than ideal for creating the intended system wherein anyone could both write and read data to a given location, allowing for the experience to be a customizable tool for interacting with space in a new way.

This prototype used Adafruit's RFID/NFC Reader Shield for Arduino and MiFare Classic (13.56MHz RFID/NFC) clear tags (Figures 11 and 12).

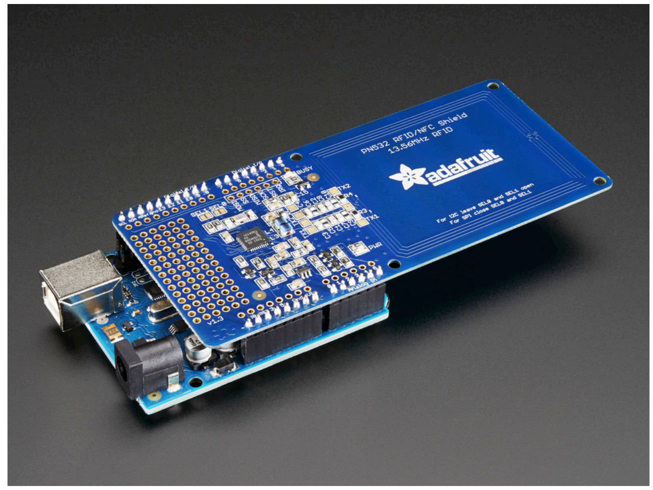

Figure 11. ***Adafruit's RFID/NFC Reader Shield for Arduino Uno*** (shown with an Arduino Uno)

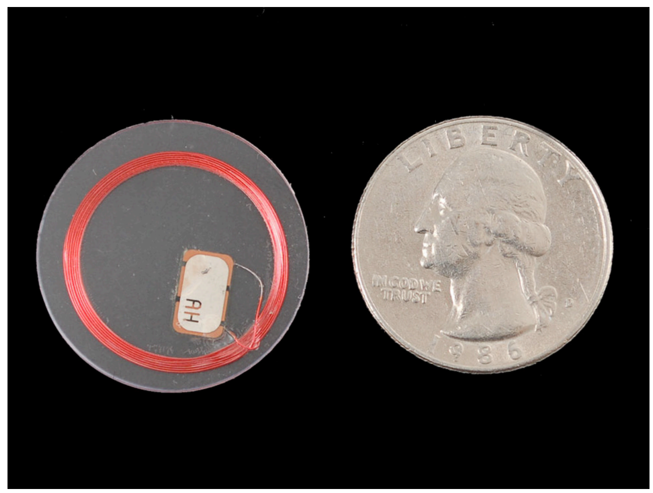

Figure 12. ***MiFare Classic (13.56MHz RFID/NFC) Tags***

Figure 13. ***MiFare Classic (13.56MHz RFID/NFC) As used in project prototype***

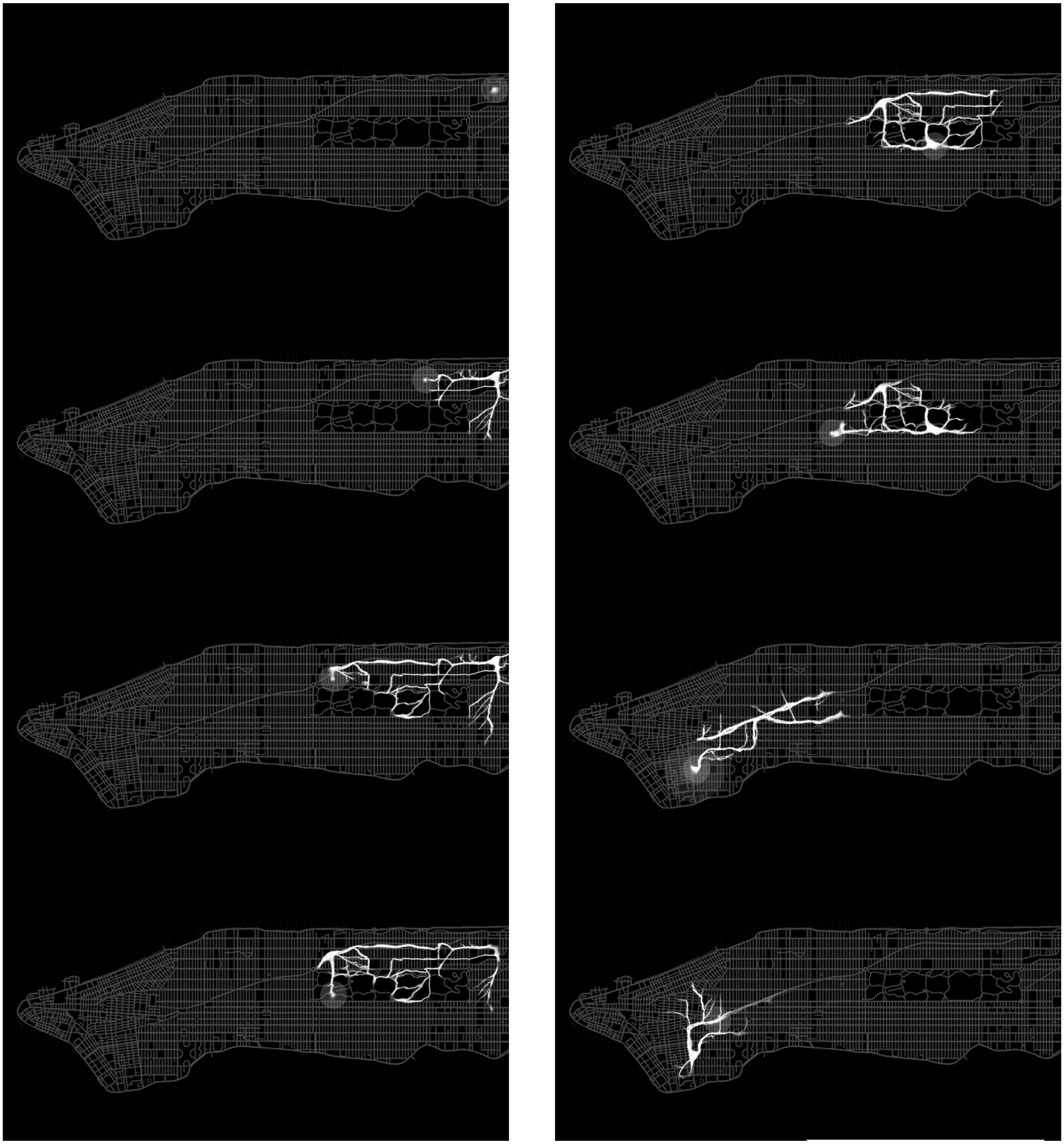

Figure 14. ***Mapped pathways*** an example of the design of the pathways to mirror neuron cells.

Overall Design

Much of the design of the project came from inverting the images retrieved from Golgi staining techniques (Figure 6). The key motive of the design was to have the users pathways through space appear as the same neural pathways seen on Golgi stains, and the discovered "nodes" to look like nuclei of neuron cells (Figures 14 and 15).

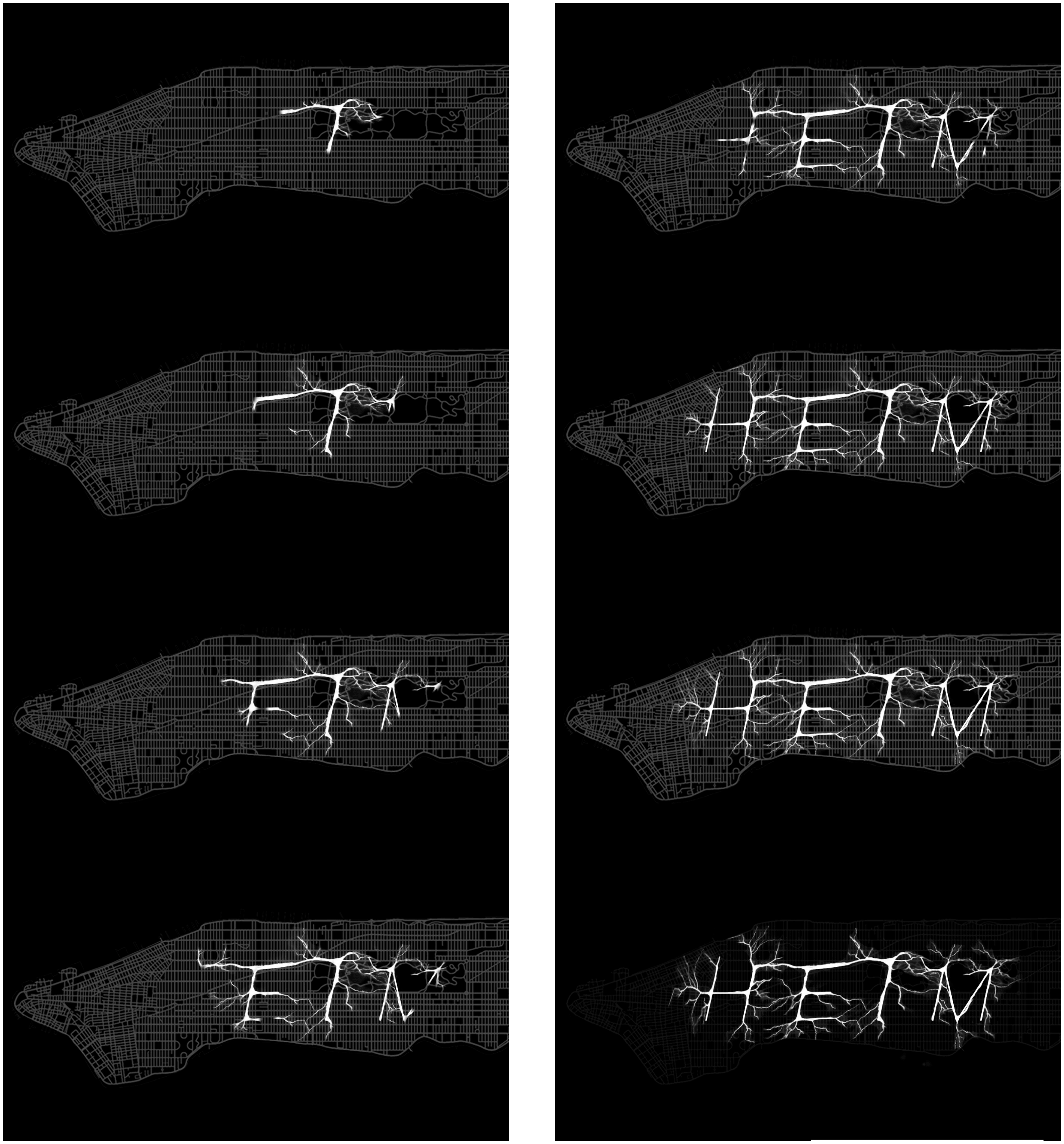

Figure 15. ***Project title design*** film stills from the project title animation.

PROTOTYPING PROCESS: SIMULATED EXPERIENCE

Much of developing a proof of concept for the project required me to use the skills that I did not have before this semester that I had gained through my experience with past projects – skills like recording and editing video, frame-by-frame animation, sound editing, Processing, Arduino, Firmata – to simulate how this project might function in the real world. I used myself as an example user and focused on how different musical-spatial associations might be conveyed visually to an audience.

Being able to clearly demonstrate my idea heavily depended on being able to animate a time-lapse version of the interface, as well as be able to edit video and audio components together in such a way that the project's concept made sense.

Figure 16. ***Project Simulation*** film stills from video depicting simulated iteration of project

FUTURE ITERATIONS

There are many steps to take in order to create the version of *Heim* imagined at the project's onset. Firstly, I would like to learn more about designing and developing mobile applications and/or wearable mobile hardware interfaces that might allow this project to freely exist without being tethered to a desktop or laptop computer. Second, it would be most effective for the project to solely rely on GPS data to transmit audio/visual information to users at a certain point in space – avoiding physical intermediary elements like RFID tags altogether. And finally, I would like to enable users to be able to contribute data to the program and to use it in anyway they would like as a way to enhance the spaces around us and understand how the ideas of both sound and space is interpreted from person to person.

CONCLUSION

Heim aims to develop upon discoveries made in cognitive psychology and neurophysiology through presenting current models of understanding cognition and memory through an interactive, immersive platform. The goal is to develop a sensory experience that will both strengthen our understanding of cognition as well as the process of cognition itself.

This paper has introduced the foundational research and design methods for the project thus far as well as its future possibilities.

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