DIGITAL SYNESTHESIA: USING MOBILE TECHNOLOGY TO INTERACT WITH OUR WORLD

BY

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EXECUTIVE SUMMARY

Humans have dreamt for many years of going beyond our physical capabilities. We have dreamt of flying, breathing underwater, exploring space or simply moving as fast as possible. All of these dreams have been made possible through the use of technology and our understanding of the physical world around us. We have also dreamt of augmenting our senses. In popular culture, we create characters who are able to see through walls, feel the presence of danger, use echolocation or sense the emotional state of others. Technology has already given us the tools to make most of these dreams a reality. Furthermore, mobile technology has made it possible for humans to use sensors as a ubiquitous just-in-time source of information. This ability to access digital information from anywhere at any time is the main value of mobile devices. But interaction with mobile devices relies heavily on transmitting information visually, which demands a high level of attention from the user.

This thesis explores a way of using sensor and mobile technology to create a superhuman sensory experience that feels as natural as possible to the user. I aim to develop a new paradigm of interaction between users and their mobile devices: one in which the device acts mainly as the "translator" of information while the users interact directly with the world they are trying to explore. This "Digital Synesthesia" can be achieved by using a sensory channel other than vision to relay the information detected by external sensors.

Digital Synesthesia refers to the ability to use mobile technology as the conduit between the body and aspects of the world that the human body is not able to sense. It will connect modern sensing technology with the brain's interpretation of external data. I will show that by using natural sensory channels to represent information beyond human perception, the brain will be able to interpret and assimilate the new stimulation as a new sense. Instead of giving the users an absolute value of the information being detected, the users will feel this translation on their bodies. This will allow each user to find a personal meaning for the information that they are experiencing and interpret it in a unique way. By spreading out the interaction across more senses, the experience will feel more natural and thus allow the users to more easily divide their attention between concurrent tasks. Thus, Digital Synesthesia creates a richer, more immersive experience.

The related work falls mostly into two categories, those that replace a non-working sense with another, and those that give the user a completely new sense. The results of these projects have proved that there is a great opportunity in using senses other than vision or hearing. They have also demonstrated the plasticity of the brain in interpreting information when received through different senses. This thesis will go further by building on top of these findings and asking how we can use Digital Synesthesia to create a new interface paradigm, one that will allow the users to interact directly with the world and not with the mobile device. Since we

understand our environment through our senses, having new sensory experiences will grant users a richer understanding of the world as they explore their new sensory capabilities.

The evaluation of this work will be done by conducting a series of studies in which users will wear devices that generate new sensory feedback loops. In these studies, the subjects will be asked to complete a task with the aid of one or more new digital senses. The studies will range from scenarios in which the subject simply compares the digital sense with a natural sense, to a situation where the subject can feel new information and has to discover what it means. Data will be collected on the time and accuracy of the completed task and a qualitative result will be obtained from discussion with the subjects about the wearable technology and the experience in general.

FUTURE PROJECTION

Many animals use natural phenomena to their advantage every day, such as sensing ultra-violet light to choose the best flowers or sensing magnetic fields to find direction. When humans are able to interpret these physical phenomena in a way that is more in tune with their bodies and less of a cognitive interpretation of quantity, then our interaction and general experience in and with the world will change dramatically. By understanding and interpreting these natural phenomena, designers of digital synesthetic interfaces will be able to create new sensory loops that offer new experiences to the users. Digital Synesthesia will give everyday users the ability to turn senses on and off depending on the experience they seek.

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ABSTRACT

Digital Synesthesia is the concept of using sensors and mobile technology to create a user experience that mimics the way people use their senses and enables the perception of information that is outside of our sensory spectrum. Modern technology already offers the ability to detect this information, but what has not been achieved is the way for our brains and body to incorporate this new information as a part of our sensory tool-belt. Then we can truly begin to understand our surrounding world in a new and undiscovered way.

The vision of Digital Synesthesia is to make the current idea of Human-Computer Interfacing evolve so that it gives way for a new Human-Environment Interfacing. Digital Synesthesia aims keep our mobile devices in our pockets while allowing us to experience the world by sensing information outside of our sensory capabilities.

The system will not only collect data through sensors, but also find the best way to pass the information to the body while bypassing visual and auditory channels. This way, the brain will be able to interpret the new information without shifting or dividing attention from the current task.

BACKGROUND

Many projects and research have sought to understand the feasibility of using touch, thermal, vibration and haptics to communicate information to the brain. I'll present here the research and projects that best support the basis of Digital Synesthesia.

THERMAL INTERFACING

Studies on a person's ability to discern between two materials using only thermal cues have been conducted. They show how such perception is possible when there is a large difference between the thermal capacity and conductivity of the materials[1]. Similar results have been used to present thermal cues to the users in virtual environments and teleoperated systems [2][3]. Digital Synesthesia will further this research by finding more effective ways of coding information through the sense of temperature.

VIBROTACTILE INTERFACING

LA Jones et al have tested a tactile display mounted on the user's arm and back[4]. Simple commands and instructions were communicated through a vibration pattern and tested for accuracy and efficiency. SenseableRays[5] from Rekimoto Labs uses a small finger-mounted module that detects a structured light signal and emits a vibratory pulse giving the sense of feeling the projected light. LA Jones has shown that vibrotactile interfacing is a very effective way of transmitting information while Rekimoto shows the added value that the tactile sense brings to an experience. Digital Synesthesia will try to join these two efforts to create a more immersive and efficient experience.

MOBILE COMMUNICATION

Rekimoto lab has presented AffectPhone[6], a system that gives a handset the ability to detect a user's arousal level through Galvanic Skin Response sensors and transmit it to another user as hot or cold sensations in the hand. Similarly, Pressages[7] is a system that translates the pressure with which one user squeezes the sides of the mobile phone into a vibration on the receiving phone. Both these projects are looking to create a better communication by using sensory feedback of the users' state. Connexus[8] was an ambitious project that attempted to detect several signals of the users in order to recreate an image of the non-verbal cues that were being lost in non-co-located communication. Even though these projects hit close to what Digital Synesthesia looks for, they are from the start limited in certain ways. Since Digital Synesthesia is based more on detecting occurring phenomena than on detecting the other users' willingness communicate in a new way, the experience is more reliable. Perhaps with the

findings from this thesis, other projects like the ones discussed can be revised with a better understanding of digital sensory loops.

SENSORY SUBSTITUTION

Either because a person may be lacking one of the five senses or because a different sensory input may offer other benefits like greater detail, sensory substitution has been seen in several fields. Most sensors translate information, such as temperature, wind speed, distance or the passing of time. All are things our bodies can perceive but by using a sensor and translating the information to a coded visual form we add the ability of greater accuracy and universal understanding. Brainport[9] is a system that captures images through a camera and translates it into electrical signals that are felt on the tongue. The artist Neil Harbisson and his team have developed Eyeborg[10] so that Neil, who is completely color-blind, can use this device to capture color information through a camera on his forehead and translate it to sound he hears through bone conduction. These hit at the core of Digital Synesthesia. But what this project proposes is that these kinds of interfaces will be useful in the everyday experiences of the average user. In order for this to happen, the interface has to find a way to be less obtrusive and more user friendly.

NEW SENSES

Another big area in this field is creating completely new senses. Adding a new sense to our repertoire changes the way we understand and interact with the world. The FeelSpace[11] belt was a device with vibrators that could be worn around the waist. The vibrator closest to geographical north would constantly vibrate, giving the user a sense of direction. Another take on navigation is Momo[12], a handheld egg-like device that leans towards the direction in which the traveler needs to go. The change in the center of gravity of the device is perceptible in the hands of the user. Dan Berg, a writer and technology advisor, implanted a small magnet into the little finger of his right hand[13]. One of the reported effects was the ability to sense electrical flow by the disruptions on the magnetic field. Disney research has developed Aireal[14], which uses air vortices to create a tactile sensation of virtual images or images projected on the body. These projects hint at the ability of the brain to interpret new experiences. Digital Synesthesia will make use of this ability to understand how the brain can learn to adapt to new sensory inputs.

SITUATIONAL AWARENESS

Situational Awareness is the ability to extract information from our environment and integrate it with previous knowledge in order to form a coherent mental picture[15]. The US military has done extensive research on Situational Awareness. They have explored the limits of the brain

when forced to work in an environment with many attention cues, as well as different strategies for reducing the cognitive load while conveying information to the brain through channels other than sight or sound. In addition to many studies in how to measure Situational Awareness in various users and situations, there are some papers on actual devices being tested that use Vibrotactile Displays[16] and Tactile Navigation Cueing[17]. The findings in these studies will inform Digital Synesthesia on the cognitive limits of the brain when presented with multiple sensory inputs at once.

NEUROPLASTICITY

The field of Neuroplasticity has explored the way in which the human brain is able to evolve and change given different sensory inputs. Studies have shown that a child's brain exhibits a greater range of neuroplasticity than the adult brain but that the adult brain is still capable of change and adaptation[18][19]. This research brings a very interesting question to this project. There might be an interesting parallel process in the way the brain adapts to natural sensory inputs and how the brain will map to the new digital sensory inputs. Even though most studies show that the time scale for these changes in the brain to take effect is longer than what this thesis will allow, some new studies are looking into more immediate effects of learning new skills.[20][21][22]

The promise of Digital Synesthesia

In his theory of the Umwelt[23], author Jakob von Uexküll proposes that every creature has an individual and unique understanding of their environment given the individual affordances offered by their senses. This leads to the belief that the access to new senses should expand the way in which humans experience their world and therefore is at the center of the Digital Synesthesia project. Modern technology already offers the ability to detect information from the world that is beyond our natural sensory spectrum, but what has not been achieved is the way for our brains and body to incorporate this new information as an addition to our sensory capabilities. Digital Synesthesia offers a way of taking new sensory experiences and transmitting them to the body in a way that mimics our other senses, without relying on a mostly visual and highly cognitive experience which demands a big part of the user's attention. With Digital Synesthesia, we will be able to understand our surrounding world in a new and undiscovered way.

In order to explore these new sensory experiences, this project proposes to divide the process into stages where I will learn different aspects of how users can cope with the objectives of Digital Synesthesia.

First Stage

This stage compares and contrasts natural sensory experiences with digital sensory experiences. This way I can compare how the users relate to new input by having it be analogous to one of their existing senses. This stage will also look to compare two sensory experiences against one another and explore whether the users might find an enhanced sensory experience to be of more use than the natural un-enhanced body experience.

Second Stage

At this stage, the project will look into the creation of new sensory experiences. Using some of the prototypes that I have already developed and some prototypes that are in the works, this project will study the users' acceptance of new information that will be consciously mapped to a particular sensory experience. This means that the users will have full understanding of the task to be accomplished, the new sense to be detected, and how the information will be translated into a sense they can actually feel. This will allow me to understand how quickly users can get used to their new sensory experiences and record their impressions on the experience.

Another aspect in the second stage will deal with the users' prior experience with a given task. I want to see if there is a difference in how valuable a user finds the new sensory experience

when it is part of a learning process and when the user knows the task and the new sensory experience might be redundant.

THIRD STAGE

Here the project will set up a new sensory experience in which the users have no prior understanding of the translation taking place. This situation mimics the pattern in which a newborn might search for patterns in order to understand its new senses[24]. This will be a useful experiment to see how quickly the users can find a correlation between something that could not previously be felt and the sensory feedback. This stage also seeks to investigate the impact that a subjects' age has in the way the brain will interpret new digital senses. The project will shed light on how a digital sense is learned and interpreted at different stages of human development.

FOURTH STAGE

This stage will look at the future of Digital Synesthesia. To understand this project as a whole, it will be important to take what has been learned in the previous stages and interpret those findings towards a Digital Synesthetic theory of user interface.

RESEARCH QUESTIONS

In each stage I will be looking to answer specific questions that will inform the next stage or the overall project. In order to answer the questions, specific test scenarios will be designed. The questions will look at, amongst other things, A) the relation between the type of data and the mode of transmitting this data to the body; B) how the user will understand an analogous sense, a new sense or the substitution of a sense; and C) how quickly the user will understand the sensory feedback loop.

DISCREET AND CONTINUOUS DATA

1. Will a discreet signal that just turns on and off to get the user's attention be more effective than a continuous signal that requires the user's interpretation of changing data?

2. Is there an optimal pairing between the input channel and the type of data to be analyzed (i.e. will temperature be better at data that relate to other's emotional states and vibration at data from the surrounding environment)?

SENSORY SUBSTITUTION

3. In a situation where vision is used to make a quick decision, will Digital Synesthesia prove to be a valid alternative to accomplishing the same task or part of that task?

SENSORY AUGMENTATION

4. In a situation where the user already bases a decision on information from a sense other than vision or audio, is there an advantage to being able to interpret that same data through a different sense and in greater detail?

NEW SENSES

5. How does a user perform in a specific task when using new information that could not previously be sensed, compared to completing the same task without sensory enhancement?

THE USER AND THE NEW STIMULI

6. How accurate is the interpretation of data when experienced through new digital senses?

7. Will there be feelings of "phantom sense" where the user will feel the effects of a stimulation that is not present anymore?

8. How valuable is Digital Synesthesia when used to complete an unfamiliar task? When used by someone who is experienced in the given task?

Escaping the visual user interface

Because visual interfaces are the most common, we tend to think of the interfacing with new senses in purely visual terms, where input signal is translated to numeric data and transmitted to the eyes.

9. Can this research start to uncover the particular ways in which information should be understood and interpreted when transmitted to the skin (or other senses)? Perhaps the idea of "value" is mostly a visual construct.

Design Thinking

10. Can a pattern be observed such that we can use the findings of this thesis to create a guideline for future Digital Synesthesia interface designers? Could this research pave the way for a new "Mixed-Sensory Interface" field in the user interface world?

Human Development

11. All babies learn to understand their sensory experiences as they explore the world. Can a similar process be identified when learning new digital sensory experiences?

12. Are children able to assimilate a new sensory experience faster than adults?

RESEARCH PLAN

FIRST STAGE– ANALOGOUS SENSORY EXPERIENCES

This stage looks to explore the users' ability to understand a sensory feedback loop that is felt in parallel to a natural sensory experience. Sensory experiences like pressure and temperature will be detected by the user and at the same time by an electronic sensor worn by the user.

PROPOSED SCENARIOS
In order to test a situation of sense augmentation, a wearable pressure sensor will be placed at the user's fingertips. Pressure information will be translated to the body through one of three sensory channels (vibration, temperature or bone conduction) and the user will have the ability to adjust the sensitivity level. The users will hold a plate on which different objects of similar weight will be placed one after another. This way the subject can feel the weight of the objects and the pressure sensor between the finger and the plate can also take a reading of the objects. The subject's task will be to organize these objects according to their weight. Some of the users will complete this task with no digital feedback, other will have a set digital feedback loop and a third group will be able to adjust the sensitivity of the digital sense. This will allow comparison between the hand's natural pressure sensitivity and the sensor's performance. Will the ability to change the sensitivity of a digital sense prove advantageous in other situations?

To compare the reliability of a visual decision making loop to a digital synesthetic loop, the user will be asked to look at a screen and press either a left or right button depending on a visual cue. Then this experiment will be replicated using vibration or temperature as the cue and the response time and accuracy will be compared.

ADDRESSED QUESTIONS
Discreet and Continuous Data, Sensory Substitution, Sensory Augmentation, User and New Stimuli

SECOND STAGE– NEW CONSCIOUS SENSORY EXPERIENCES

This stage looks to understand the users' ability to map information that cannot be sensed by the body, to sensory cues that are easily felt. The relation between the type of data and the type of digital sense will be explored. The users will be presented with two types of data, either binary or continuous, for them to interpret via one of three sensory outputs so not only will the results look at the overall success of augmented sensing but at which output best relates to the data.

PROPOSED SCENARIOS

For testing a new sense, the users will wear a head band that can detect the facial temperatures of a person standing in front of the user. With accurate temperature measurements, the user should be able to detect the stress level of the another person[25]. The information detected by the headband can be transmitted as bone conducted sound on the subject's forehead, or as vibration or temperature in other parts of the body. In order to test the reliability of this sense, a gaming scenario will be designed were one of the players will have a secret identity and the other players must find who it is. It has been shown that in this type of game, the player with the secret identity will have a higher stress level than the other players. Digital Synesthesia will be used by the players to help in identifying the secret identity and the time it takes for the players to guess correctly and the number of incorrect guesses will be recorded. This experiment will be repeated with the same subject more than once to see if there is any improvement in time and number of guesses.

Another new sense test will be a location awareness scenario where a user can receive feedback depending on their location around the Media lab. This test will be used to look at the user's response to an alert that they might not be constantly looking for, un-like the game scenario where the user will want to be constantly paying attention to the signal.

A third scenario will include the navigation of large datasets in a media consumption context. This way while the user enjoys a video storytelling experience, different signals will be sent to the body that will signify other media options that might be of Interest. This test will use a similar set up as the previous two but will test this new context.

ADDRESSED QUESTIONS
Discreet and Continuous Data, New Senses, the User and New Stimuli, Escaping the Visual Interface

THIRD STAGE– NEW UNCONSCIOUS SENSORY EXPERIENCES

This stage will explore how the users are able to understand an unknown sensory feedback loop. This is more ambitious because it will require a setting where the users are allowed to explore at their leisure and have enough time to understand what the new sensory feedback is responding to. The scenario is designed to look into the brain's ability to find the correlation between the digital sense and the source of the information being sensed. This stage will also be tested with users of different ages to see what differences there might be in the way the sensory experience is decoded.

PROPOSED SCENARIOS
I plan to take advantage of the data available in DoppelLab[26] in order to create a sensory feedback to specific contextual information. The users will be allowed to explore the Media Lab

building for a specific amount of time and try to figure out what their sensation is mapped to. The data could be temperature in the building, distance to a point in the building where there is a group of people or distance to a specific person. This scenario will use test subjects of different ages in ranges of 6 to 10, 20 to 40 and 50 and above. The time and accuracy will be measured and the findings from the previous stages about what data is better paired with what sensory feedback will be tested.

ADDRESSED QUESTIONS
The User and New Stimuli, Escaping the Visual Interface, Design Thinking, Children and Adults

FOURTH STAGE

A way to unify the findings will be explored and it will be looked at from two points of view. On the user side, this might be a way for a user to be able to access new sensory experiences in a daily setting. It might be that a combination of wearable technology and the mobile device will allow the user to access or turn the new senses on and off. On the designer side it will be important to understand the effect of the findings on the general User Interface Design world. Are there are learning stages that correlate to the user's age? Is there a time in life when the brain is more open to learning these new digital senses? The findings will be generalized in such a way that it will be easier for future designers to see the value of Digital Synesthetic interfaces and a guideline towards how to create new experiences will be established.

As the project advances and I am able to test new circuits and scenarios, I expect to be able to propose more input-output dyads to be tested.

Timeline

Phase One (January - February)

This stage is dealing with the final contexts that will be developed to prove my thesis as well as getting the proposal submitted and approved by MASCOM and defended.

Phase Two (February - April)

This is the development stage. Fabrication and initial testing will be made of each of the systems for the contexts chosen. Extra attention will be put on the mobility of the system and its future deployment outside the lab. User testing on the first stage will begin.

Phase Three (May - June)

User Testing will be done for the second and third stages.

Phase Four (July - August)

Thesis writing and defense.

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BIO

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