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ABSTRACT

As cities strive to become more sustainable and highly optimized, they have begun to embrace the current trend of “smartness” in ubiquitous computing. This is seen in the implementation of “smart” infrastructure throughout neighborhoods. Objects which typically do not sense or respond to users, like benches, can now offer Wi-Fi, charging outlets and weather reports. “Very Good Benches” explores alternative networking strategies and interactions, using Research through Design, Speculative Design, and Prototyping methodologies, to create a series of smart benches that re-imagine smart infrastructure through the lens of social interaction and the optimization of public engagement.

The goal of each bench is to become a “very good bench” by attracting as many user interactions as possible from the public in order to develop an internal dataset that determines how and when the bench attracts users. Each bench senses occupancy and vacancy through the use of e-textile sensors and attracts interactions through audio and visual outputs by combining solenoids and LED lights. Wheels are incorporated in the design so users are able to arrange the set of benches in ways that best suit them. Through these interactions, a dataset is developed and used to create a ranking system amongst the networked benches which drives each one to compete to be the bench with the most frequent interactions.

By putting more emphasis on the benches and occupants themselves and less attention on larger ideas of optimization, more playful interactions are able to be developed through the object’s perceived personalities. These benches are then able to imagine new possibilities for smart technologies in the public realm as a result of reinterpreting the optimization and efficiency of urban infrastructure through this specific case study.

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Finally, I would like to thank my partner, Jonathon Regalado, for all the love and care that you have given both to this project and to me during this time of change. Thank you for being here this entire process. You are, most certainly, *very good*.

Dedication

To my partner Johnnie & and our feline companion Yoyo.

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1. INTRODUCTION

When someone is referred to as smart, it is received as a compliment. Deeming a person smart can imply that they excel at understanding and are able to respond appropriately. In other words, they are able to sense and respond accordingly in a situation. Smart can be seen as a positive quality in someone. We can trust them to make the right decision.

In the world of technology, “smart” devices are being developed to assist our everyday lives. Objects that previously had no ability to make decisions are now able to sense and respond to our actions. Bus stops can communicate to commuters when the next bus will arrive. Smartphones allow for easy access to data such as directions on a map or the weather. Home assistants such as Amazon’s Alexa and Google Home are voice responsive and can play the news or dim the lights on command. All of these “smart” devices respond to our needs and desires.

The blog “We Put a Chip in It” (We put a chip in it!) looks at the application of smart in everyday objects with a critical lens. “It was just a dumb thing. Then we put a chip in it. Now it's a smart thing.” (We put a chip in it!) These objects are mundane, everyday items, that are now “smart” after a type of technology is incorporated. The positive associated with smart can connote “better” and “innovative”. It can be a catch-all term for future forward thinking. “Dumb” objects can now be included in the “better” future.

As society develops, there is a trend to incorporate technology into public infrastructure. Smart infrastructure offers the ability to monitor things like pedestrian traffic or citywide water systems. These types of infrastructure are implemented with the hope of a sustainable and optimized future. Often when infrastructure is installed it is for long term, such as sidewalks. While technology developments accelerate, new technologies quickly become obsolete. Even though smart technology and infrastructure have conflicting life spans, creating public smart interactions is attractive as it promotes an image of a better future. The scale of widespread ubiquitous computing and the life span could become an issue due to the human factor required in the maintenance and service of infrastructure. Communities rely on infrastructure for functional purposes but also as cultural meeting points and identity. The infrastructure placed in communities that could incorporate smart technologies should be optimized for the user and sustainable as a part of the community. When designing an item suited for public infrastructure, the scalability, life span of technology, and importance to communities can challenge the ideas of sustainability and optimization.

1.1. Very Good Benches Issue and Contribution

"Very Good Benches" is a research project addressing smart and networked applications in objects that are not traditionally deemed as "smart" in the public environment. Using a speculative lens, this Research Through Design project results in a series of smart bench prototypes that aim to develop new interactions that could take place with smart objects in public spaces, that are not purely motivated by optimization of data. The questions that this research focuses on are:

1. What types of playful interactions occur when a mundane everyday object is made "smart"?
2. How can "smart" optimization be redefined for communities who interact with public facing smart infrastructure?
3. How can the notion of optimization be reinterpreted to evoke new types of interactions, both between the smart objects and also among the users who interact with them?

In *The Smartness Mandate,* Halpern et al. define optimization as "the technique by which smartness promulgates the belief that everything—every kind of relationship among human beings, their technologies, and the environments in which they live—can and should be algorithmically managed."

Optimization, as a motivation for developing smart objects, is looked at critically, by making the benches "Very Good". Other smart public seating offers users information such as the weather and free Wi-Fi. These benches use the term "smart" to elevate their purpose in public spaces, but do not outwardly sense when users are interacting with the features rather than the bench itself. "Very Good Benches" are smart benches that sense and respond to user interaction. In contract, the optimization of these benches is achieved by interpreting occupancy and vacancy data that is collected when users sit on and leave various benches in the networked system. This data is used to refine the benches' behaviour, enabling the benches to compete for users' attention via visual and auditory feedback. Through the network these benches communicate in order to try and optimize their ability to offer seats. These benches want to be “very good” at offering seats in public spaces. “Very Good Benches” questions the motivations of smart infrastructure placed in public spaces and proposes new interactions for creating relationships in public space.”

1.2. Scope and Limitations

A wide range of topics and themes are engaged through this work. However, in the implementation of prototypes select areas of investigation needed to be prioritize in order to match the scope of a one-year master's thesis.

This project acknowledges that the implementations of smart infrastructure reach beyond the examples referenced in this paper. Both the literature and context review look specifically at the scale of outdoor urban infrastructure, but for the prototyping phase this project focuses on a single site indoor implementation of three benches. The discourse about smart city and urban planning contribute to the discussion of this paper, but this research does not evaluate city-wide and pervasive implementations of smart technologies.

Data collected from the benches is used to inform each bench’s behaviour, which invites new types of interactions, but it is recognized that the collection and use of data presents certain concerns. Ownership of data and tracking are important to consider in the implementation of smart technologies and cities. The literature and contextual reviews do not directly address these issues but acknowledge that these are legitimate concerns for communities. The following research looks at the historic implementations of infrastructure and how public smart technology relates to long standing issues within community spaces. The focus of this paper is on the interactions and issues that could occur with smart technology affecting the people in public spaces. The ethical awareness of data privacy could affect this work in a public space, but due to time limitations this work cannot completely address these concerns.

“Very Good Benches” is developed to be a networked prototype to explore what interactions could occur with autonomous objects in public space. Networking is a limitation in public spaces through either radio interference or inconsistent internet connections. At this stage of development these benches are developed to exist indoors due to the need to monitor and maintain consistency in the network.

1.3. Overview of Document

This document addresses themes relevant to urban infrastructure and smart technology including ubiquitous computing, smart objects, urban infrastructure, emotional design, and public space. Case studies are then introduced which take into account the main arguments in these relevant themes. The case studies and themes position this research and aid in choosing appropriate methodologies. Using Research Through Design, Speculative Design, and Prototyping, a series of iterative prototypes are developed and evaluated on whether or not they are “Very Good”. The final results lead to user testing in which external users are invited to interact with the benches and discuss their experience.

2. Literature Review

This research explores how interactions with objects can change in public settings when the object is implemented as an autonomous networked device. By evaluating the different types of networking, the motivations of smart objects, how networking is implemented in urban infrastructure, the importance of interaction in ubiquitous computing, and understanding the multiplicity of public space, this research explores why objects are deemed "smart" in public spaces and what role designers have in the development of this type of ubiquitous computing. These evaluations work towards developing an argument against pervasive computing in all elements of urban infrastructure and proposes finding alternative motives for smart technologies.

2.1. Ubiquitous Computing

The first ubiquitous computing object was created in 1991 (Weiser). The object was a coffee pot with a webcam that broadcast images to a research lab so that researchers would know if the pot was full or empty. The internet has continued to stay inherently object-oriented and today has become ubiquitous in most technology we interact with regularly. This is known as ubiquitous computing, which is also referred to as the Internet of Things (IoT), or pervasive computing (Hammersmith). As society has shifted to a state of ubiquitous computing we now live in an embodied virtuality (Weiser). The physical sphere is intercepted with an overlay of the virtual sphere (Weiser). This virtuality can heighten our awareness of our environments in different ways. This is accomplished through the different types of IoT devices: collectors, actors, and creators (Cila et al.).

1. Collectors sense interactions and often have a web application that displays the aggregated data. These objects allow users to see patterns of behaviours that develop throughout the data visualizations. Example: Fitbit

2. Actors are devices that sense and respond to human interactions autonomously often through other products or services. Example: Google Nest

3. Creators are devices that specifically create futures. Example: A.I. Robots

Through ubiquitous computing and networked objects, we can see a rise in awareness of our body, our environments, and our futures. This research uses the premise of collectors, actors, and creators as forms of prototypes that further look at ubiquitous computing implemented in public spaces and urban environments and how these prototypes can affect our interactions through the body, space, and futures.

2.2. Smart Objects

Because ubiquitous computing can affect our bodies, space, and future, who designs these objects, and why, becomes an important consideration. IoT devices are becoming entirely pervasive in every object we interact with daily. Today we have doorbells with webcams that share a live feed of who is at our door, that we can share seamlessly to neighbours in our community (Addison), and buildings that can track how many people are in them using ambient technology in case of an emergency (Akhter). These technologies that process the information for us autonomously are referred to as "smart" objects, and the actions behind them are known as "smartness". Smart objects sense and respond autonomously to (both or either) passive or active input. The objects themselves are not inherently smart, but we presume they are because of the autonomous actions behind them.

Often this notion of smartness is developed to help society avoid crisis. Orit Halpern, a professor at Concordia University, discusses how smart implementation can be broken into four categories: zones, populations, optimization, and resilience. *Zones* determine the space where smartness is implemented. *Populations* include the people that contribute to the data sets, and the data that is produced by interacting with smart objects. *Optimization* determines how the data gathered can best be applied to optimize the zone and city. *Resilience* is how the implementations can adapt to rapid changes, whether it be technological advances or natural disasters (Halpern et al).

Halpern states that "[e]very present state of the smart city is understood as a demo or prototype of a future smart city." (Halpern et al) This asserts that smartness, though built for optimization and resilience, is not a viable solution for the present. Most of these implementations are demonstrated as prototypes for further innovations in optimization.

"Optimization fever propels the demand for ever more sensors, more sites of data collection, whether via mobile device apps, hospital clinic databases, or tracking of website clicks so that optimization's realm can perpetually be expanded and optimization itself further optimized" (Halpern et al). This focus on having a resilient future often disregards the complexities and multiplicity of spaces; these smart implemented prototypes are idyllic and hyper-focused on the technological future. "This evacuation of differences, temporalities, and societal structures is what most concerns us in confronting the extraordinary rise of ubiquitous computing and high-tech infrastructures as solutions to political, social, environmental, and historical problems" (Halpern et al). As demonstrations for the future, these prototypes disregard the present issues that we have within society. Smartness is a speculation of what is to come. Cila, who researched smart objects and interactions in public space, agrees with Halpern. "Expecting that a smart product would be able to foresee and respond appropriately to any possible situation is a naïve idea in our current reality" (Cila et al). Optimization is future and forward thinking but does not address any of the current socio-political atmosphere.

These future narratives are driven by the designers. During the rise of ubiquitous computing the adoption and progression of products were limited to the relationship between scale, location, and cost of materials (Estrin et al). The primary designers and manufacturers for these products often come from large corporations. The notion of designing IoT devices that operate as "creators" of new futures is often limited in scale and availability because of the monopolization of large technology corporations. In the journal "Selling Smartness," Sadowski and Bendor, look at how "sociotechnical imaginaries" like Cisco and IBM support the narrative of techno-salvation within urban planning. "Sociotechnical imaginaries illustrate the symmetrical relation of technoscience and society, which results in the coproduction of political orders and technoscientific projects." (Sadowksi & Bendor, 2019) Both major technology companies strive to show the innovation and visionary future of cities but disregard any alternative futures. This focus on technology only promotes the growth of the status quo. "Corporate narratives seek to provide the parameters of cityness - and, in the process, preclude alternative imaginaries - by constructing and extending the smart city sociotechnical imaginary." (Sadowski & Bendor) These motivations seem to be based on the idea of selling smartness at the cost of recognizing alternative solutions to a more inclusive future of all communities and designers.

The technological advancements for ubiquitous computing have been championed by large technology corporations. Due to money and the selling of a technological future, the status quo of “crisis”, “sustainability” and “optimization” are defined as ways to build towards the “best” future. This techno-imaginary is a future where ubiquitous computing is embedded in nearly everything we interact with. Sidewalk Labs, a project from Alphabet, looks at developing a neighbourhood in Toronto to truly encompass ubiquitous computing (Sidewalk Toronto). Tiles that change to either the role of sidewalk or street depending on vehicle and pedestrian traffic, open 5G internet for all devices to connect to effortlessly, and appliances that sense their use to be more sustainable. Those developments are solely focused on the infrastructure and utilitarian additions to the neighbourhood, but not for the people interacting with the city. This best future is best for the infrastructure, but can it create an optimized community for the people interacting within it?

Crisis, sustainability and optimization are primary motivations for companies in this future society. This vision promises that the optimization of resources will produce a more sustainable future that prevents crisis. The sociotechnical imaginary shows an “ideal” future, which influences technology and trends. “By bridging idealism and materialism - that liminal space where the smart city exists - sociotechnical imaginaries play a critical role in framing what technology is made and why.” (Sadowski & Bendor) The data collected in what Halpern calls *zones* is used for capitalistic motivations. This optimization for selling does not profit the population, especially the populations giving that data within the zones through free interactions.

The technological future is driven by the present notion that the future will fail. It is a fear-based prediction that seeks to implement technology in the present as a solution to fix unforeseen problems. Capitalism is a driving force for these products to be implemented quickly and ubiquitously throughout our public spaces. The data that is collected professes to create sustainable futures, when in reality the future is unknown. The driving force of these companies is to create optimized and resilient futures that will define what the future will resemble. The development of “Very Good Benches” embraces this concept that the present is a demonstration for the future, but seeks to explore how we can use these zones and populations to create a new vision of optimization and resilience that is not solely fear based.

2.3. Urban Infrastructure

Infrastructure is ubiquitous and also important in the sociotechnical imaginary. It is the ideal vessel in which to embed smart technology. The development of infrastructure through city planning is necessary, but is rarely matched to the community's needs because of issues like under-maintenance (Smith). When considering smart implementations in cities, the notion of ubiquity is challenged by the upkeep and maintenance of broad systems. Often, IoT integrated infrastructure is in inaccessible locations and relies on expensive to connect wires (Estrin et al) and therefore this infrastructure must also operate without human attendance.

Good and well-designed products do not necessarily mean that they are adopted for long term purposes (Kuniavsky). The interaction of the designs must have a purpose for adoption in the public and not just convenience to offer. This would be challenging as nearly all infrastructure is developed incrementally and is rarely maintained by the same company or city council (Smith). Infrastructure can also last for generations within community spaces becoming more meaningful for the specific neighbourhood than it is for the larger city. Walls, sidewalks, lamp posts, benches, and pipes can become important identifiers as the community adopts the infrastructure as a part of its identity. Smart technology is at risk of being one-off and unrealistic if constant care is not there, from the city or the community, and can result in becoming only a relic within neighbourhoods.

Technology often needs upgrades and software maintenance, which can be demanding on a city or product teams, especially if the product becomes ubiquitous in a city space. Risks of a delay or lack of maintenance could occur. In smart technologies this is important as many networked devices are prone to security risks, such as the now ubiquitous Philips Hue Bulb (Pauli 2016) and will require software updates. This can become a challenge in widespread implementations in city environments.

Infrastructural maintenance is often taken up by the communities it resides within. Considering this, designers could utilize Do-It-Yourself (DIY) Urbanism as a form of exploring the needs and concerns of the community. In the *Help Yourself City*, Gordon Douglas, an urbanist, looks at DIY Urbanism. Communities often create infrastructure that they deem as needed, like using a lawn chair as a seat at a bus stop or creating small bridges out of pieces of plywood that cover large unmaintained potholes in sidewalks (Douglas).

This creation, alteration, and adoption of infrastructure shows how communities care for their environments. Steele, a professor in urban studies in Melbourne, discusses how infrastructure shapes our cities, socially, environmentally, and politically. Because of how long infrastructure exists within cities, it is inherently ubiquitous through time, place, and space (Steele). Looking deeper into how smart infrastructure is placed in the city is important for communities. The placement and stewardship of spaces in neighbourhoods can work to make more resilient and optimized communities. The spaces can cater to the community's specific needs, not the major corporations that push their techno-salvation narrative of the disastrous future.

However, DIY infrastructure interventions are not received with the same response by all community members. As publics and communities inherently exist in a multiplicity of spaces, DIY urbanism can be viewed within a negative or critical lens and may not be welcomed by the wider community. The executors of DIY urbanism are often from a "creative class" with a professional practice in design or arts (Gordon). Many times, these interventions can be viewed as useless or cause frustration by long term residents in the community. The intervention of space needs to be considered with a wider lens; permanently changing infrastructure or implementing things like guerilla gardens may create additional challenges due to the further lack of maintenance or demand for maintenance from community members (Gordon). DIY urbanism is a useful lens for looking at community identifiers and markers, but any praise for the practice and the act of intervening and taking "stewardship" of spaces needs to be viewed with a critical lens.

2.4. Emotional and Interaction Design

Technology is not inherently good nor bad, but our experiences and interactions can be evaluated through a subjective lens. "Good" user interactions do not equate to "good" user experiences (Kuniavsky). Good user interactions can be useful, but simultaneously also unnecessary. Technology excels through a combination of good user interaction and experience. When designers take into consideration both of these goals, they have the ability to shape the future.

Smart infrastructure is typically a responsive tool within community environments; specifically, a human to machine relationship. This response creates the perception that the technology is a social entity in the interaction. Donald Norman, the author of *Emotional Design: why we hate or love everyday things* addresses how this feedback can create this perception:

With computers, we often fall for the social dynamics (or, as is more often the case, the inept social dynamics). Basically, if something interacts with us, we interpret that interaction; the more responsive it is to us through its body actions, its language, its taking of turns, and its general responsiveness, the more we treat it like a social actor. This list applies to everything, human or animal, animate or non-animate. (Norman)

This anthropomorphizing is caused by human's innate tendencies to create emotional connections to objects. "We interpret, we emote. We can thereby believe that the object of our interpretations is sad or happy, angry or calm, sneaky or embarrassed." (Norman).

The feedback must be believable to be affective. Emotional design provides an understanding of how to create attachment without the technological infrastructure itself being too intrusive or disruptive. Brookes and Brazeal look at the emotional design of robots and analyze what makes a successfully responsive robot. Signaling salience and the "correct" emotional response is important for feedback during the interaction. Having too little emotional response does not give enough feedback and can cause confusion. Too much emotional response on the other hand removes the salience and seems too programmed (Brookes & Brazeal). Effective emotional design helps people use technology seamlessly.

Carla Diana, a robotics designer, looks at "RoboPsych" and how we change because of our interaction with robots, rather than the design of robots changing for humans. Diana claims that the most prominent change is in our language and gestures. For example, in voice-controlled assistants, users will often change the way they say a musician's or businesses' name so that the assistant can parse the information successfully.

Alexa, Amazon's voice-controlled home automation system, is great, except she wouldn't play my favorite song, "Anna Ng" by They Might Be Giants. I tried saying it a dozen ways: "Anna Enge," "Anna Ennnng," "Anna! En! Ga!" Now, I just pronounce it the way Alexa wants to hear it: "Anna. N. G." It's just another item on the list of things that, thanks to the computers I talk to, now have mangled names. This happens because robots perceive only a miniscule subset of what we, as humans, do and say." (Diana)

When designing for the public, it is important to look at the zone where smart technology is implemented and how this can affect the community's interactions with the space. "Networked products should be a hybrid of technological developments and cultural articulation. They need to be in a form that enables users to invite these products into their lives and makes an impact on people's life quality." (Cila et. al) Even if the machine is not voice responsive, the gestures we use can be affected. This is not inherently a negative attribute of technology. Designers must consider the relationship and interaction between humans and machines, especially when designing for mass use by the public.

2.5. Public Space

The term "The Public Sphere" was first coined by the political theorist Habermas in the early twentieth century but has evolved and grown to be more inclusive and fluid. In his analysis of Habermas' work, Alan McKee explores the origins of the public sphere and how we can evolve from a modern lens to a postmodern lens. The modern lens of the public begins with the idea of congregating to discuss politics. In the postmodern, this can be expanded to the congregation of ordinary citizens discussing things beyond politics.

"The concept of the 'public sphere' is a useful one for researchers who believe that ordinary citizens play a role in the creation and distribution of ideas about how society works" (McKee). Habermas' term "the public sphere" relates specifically to the interactions of sharing ideas, rather than a space or a community. However, in Habermas' lens, to truly consider a space part of the public sphere, congregation must be directed by the people and removed from the government. This original idea of congregation was solely focused on academics and those who were privileged to debate in these spaces. This excluded many classes, genders, and society members who were not welcome to participate in any form of public discussion. Habermas' vision was clearly limited in the complexity of society and identity.

> [In Habermas' view] The public sphere should ideally deal only with serious issues of real importance - only party politics, and not celebrity issues, sport or entertainment. It shouldn't be sensations, easily accessible or commercialized… and it should be unified and homogenous, refusing the fragmentation of niche audience and different kinds of culture (McKee)

This framing is a singular approach to understanding the idea of "the public" and only sees use for homogenous political purposes. The post-modern approach considers multiplicities of publics in many spaces. The emphasis on the interaction amongst society members is what forms the right of a public in any space and can contain multiple publics at once.

Now in the twenty-first century, we are better able to examine "The Public Sphere" with a postmodern approach and take into consideration the multiplicity of public spaces. Professor of Geography at the University of Cambridge, Ash Amin proposes that through the multiplicity of spaces we are able to evaluate the temporalities of space. Spaces can change based upon who is occupying them, what the habitual use of the space is, what time of day it is, etc. "Every public space has its own rhythms of use and regulation, frequently changing on a daily or seasonal basis." (Amin) Amin discusses how the temporalities of space dictate that habitual use of space. This is what forms the cultural understanding of different spaces. "Ethical practices in public space are formed precognitively and reflexively rather than rationally or consciously, guided by routines of neurological response and material practice, rather than by acts of human will." (Amin) These reflexes shape public spaces, and the public shapes the cultural practices. These temporalities develop a rhythm in urban spaces and acknowledge that publics can form in multiple ways for multiple groups.

These evaluations of what defines "the public" are solely based on interactions. Habermas declared that the free congregation for debate and discourse is the defining moment of when a space truly becomes public. This point of view is not inclusive and does not effectively apply to the twenty-first century as many spaces are simultaneously private and public, containing their own rules and regulations. Amin states that publics are not static places or interactions. They evolve depending on the multiplicity and temporalities of spaces, and also the societal imposed rules and regulations. This can include the privatization of spaces, or the culturally learned behaviours of spaces.

This understanding of multiplicity of spaces can be leveraged by designers to develop smart and ubiquitous computing objects that are resilient towards changing use of environments. Acknowledging the multiplicity of spaces through user interactions makes smart objects more inclusive, which ultimately paves the way forward for a more inclusive future. As technology corporations dismiss the multiplicity of spaces through the static implementations of smart urban infrastructure, understanding the diversity of public spaces is key in creating dynamic smart objects that can offer more sustainable, inclusive, and optimized publics for those interacting in the space. Designers must consider the multiplicity of spaces, and how this can impact our understanding to better develop public spaces that serve everyone.

2.6. Relevance to Research

The design of the smart object is driven by crisis, sustainability, and optimization which may not wholly be inclusive to all designers, and therefore all communities, due to the societal capital that large tech-corporations hold. Using DIY Urbanism as a platform allows designers to create works that propel their future narratives and experiments without the necessary reliance on corporations. Smaller bespoke DIY Urbanism projects can create networked objects that are relative to the community and understand the manifold use of the spaces. Smart technology is often rooted in urban infrastructure to work towards a techno-imaginary dream.

This research acknowledges that smart technology can serve communities through infrastructure but the deployment of autonomous products should be aware that infrastructure is often poorly maintained. Through a speculative lens, this work critiques the notion of pervasive computing in vast amounts of infrastructure. Using the bench as a form of infrastructure, this research looks at challenging the current notions of smartness in public infrastructure and positions itself as a speculative act of ubiquitous computing through DIY Urbanism. It takes an approach of providing awareness of networked objects and how they can change our interactions with technology in public spaces.

3. Contextual Review

This project uses benches as a platform to explore how smartness and public interaction inform each other. Benches are often ubiquitous in public plazas and can inform how a larger space is used. As seen in the study from the SWG Group in New York City, if benches are not provided in a space other aspects of architecture are often sought out as seating, such as concrete planters (SWG Group).

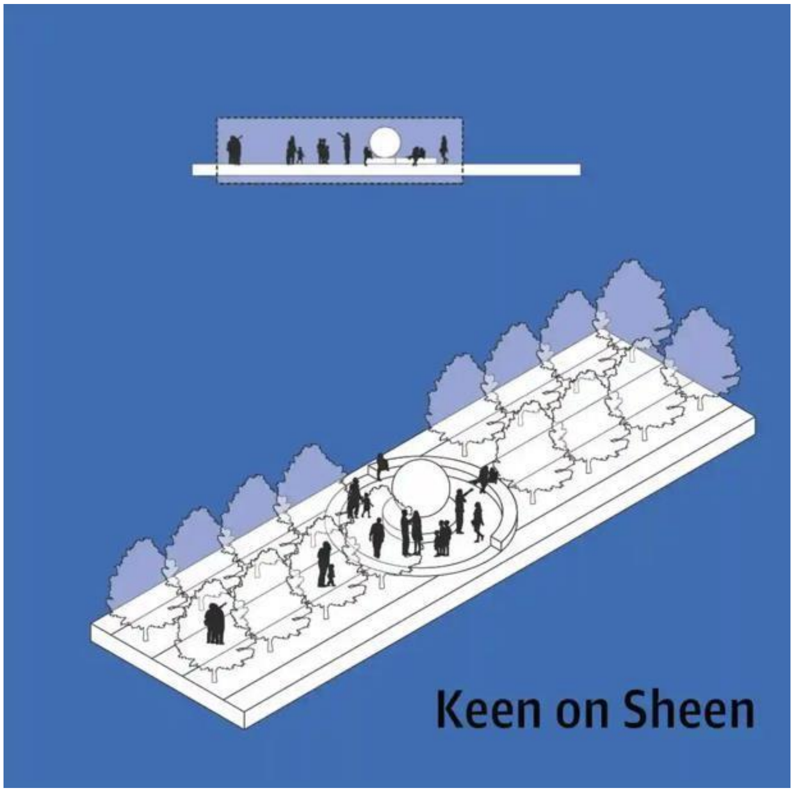


Figure 2: An image example from the SWG Group study: “Reflective surfaces were major plaza attractors."

The architecture and placement of seating arrangements often implicitly informs where people will congregate and for how long. The bench, as a general term for seating, is highly important to the physical connections we have within public space. The bench is chosen as a vehicle for this project because it is ubiquitous amongst public places, and is also commonly seen throughout DIY urbanism as a form of community action towards autonomy and agency. These “very good” benches will seek to alter perceptions of efficiency and optimization in smart and networked infrastructure.

These case study examples evaluate the current state of “smart” benches that are placed in urban environments to prevent minor crises and then are compared to speculative projects that use networked and smart everyday objects to increase awareness of our body, space, and futures. These evaluations inform the position of the development of the Very Good Bench prototypes; the smart benches show how industries adopt and propel smartness into urban environments, while the speculative projects demonstrate bespoke objects for users.

3.1. Smart Benches

Disaster and crisis, in their most minor forms, can include common occurrences such as over-usage of cellular data, or lack of information. Designers look at what common everyday “disasters” can occur and provide publicly accessible solutions. There are numerous smart bench products manufactured and placed in central city locations. These products offer Wi-Fi, outlets for charging your phone, light, and generic information like the weather. These interactions offer smart functionalities that are often found in smart devices. These features do not provide much for the public, except for proving that these products are indeed “smart”.

Figure 3: An image of the Steora from Include. (Include)

Figure 4: Image of the Dashboard interface from Include. (Include)

Steora made by Include in Croatia is a smart bench with a companion *Dashboard* application. The bench itself offers smart functionalities such as outlets, free Wi-Fi, and a display with the time and weather. The *Dashboard* offers an online application so owners can view bench activity. The company refers to the Dashboard as “The brains of the bench” (Steora) due to the ability to view the created data-sets. The public population that interacts with this bench gives data to the bench in exchange for the “smart” conveniences.

Figure 5: Marketing image for the Smart Bench from Strawberry Energy’s home page (Strawberry Energy)

Smart Bench, made by Strawberry Energy in the UK offers similar smart functionalities to Steora. The marketing and branding of *Smart Bench* claims to improve public engagement of public spaces by providing convenience. “Strawberry’s smart street furniture brings the Internet of Things to outdoor public spaces that people visit daily, improving urban living by making cities smarter and more convenient to live in.” (StrawberryE) This language propels a techno-imaginary vision of convenience rather than addressing community needs. Twenty of the *Smart Bench* units were installed in London in 2017 (Roberts, 2017). The placement of the benches were primarily in locations with heavy pedestrian traffic so that a passersby was able to wirelessly, or with a cable, charge their devices. Similar to *Steora's Dashboard* application, *Smart Bench* provides a mobile application for the public. This application is for users to seek out a specific bench that meets their ideal conditions of weather, air quality, and sound pollution. There is also a mobile application for the owners which is referred to as a dashboard. The dashboard allows the owners to look at the activity of each bench to offer insight into where the bench could be best located (StrawberryE). The bench is optimized to collect data through by offering inward and outward mobile applications and solutions for inconveniences.

Figure 6: Image from the Newmarket website on the Soofa information page. (www.newmarket.ca/soofa)

Soofa is another smart bench that was developed in the United States. The *Soofa* bench tracks how many people pass by each bench through sensing the presence of their mobile device. The benches are networked together to manifest how many unique visitors pass in a day, a week, and a month. Each bench reads the Media Access Code (MAC) address of any device that passes by and is actively looking for Wi-Fi. The device connects with the bench's broadcast Wi-Fi, and even without accessing the internet, the bench registers the MAC address into a cloud database. The interaction of passing the bench is passive rather than active. The MAC addresses are anonymized, but the bench will recognize the device as a frequent visitor if it attempts to register the address more than once. *Soofa* is successful in pairing with cities to place these benches amongst various parts of urban areas. In 2018, *Soofa* teamed with Newmarket, Ontario to implement 10 *Soofa* units in the downtown core. The data collection allowed the city to see what days of the week have the most common repeat pedestrians. The city was then able to offer recreational activities nearby the benches because they provided insight on when certain areas were busy. The benches provide data on pedestrian traffic as a form of ambient monitoring. This monitoring can be used to restrict pedestrian flow or for crowd control. The benches provide convenience in two ways: access to charging your phone, and information for the bench owners.

All three of these benches promote themselves as smart, convenient, and sustainable. Each bench advertises a core attraction of using solar energy to charge any device. Though the act of engaging with the benches is nearly passive, the data that is created is not offered to the public.

Collecting data through public technology is not inherently bad, nor does it indicate that it will be used in ill-faith. However, the data that is collected is done so under the guise of optimization and sustainability. Each bench is managed either by the city or the producer. These smart benches provide valuable information to the owners while only offering utilitarian services to public users. Arguably, the smart benches create physical awareness by being able to offer information, but this information is readily available through other IoT devices. This promotion of smart functionalities adopts redundant interactions to prove that these products are smart, while bringing into question their actual purpose in an urban environment.

"Very Good Benches" co-opts the term "smart" and questions smart implementations in urban environments and seeks ways to create purposeful interactions in spaces to heighten the user experience. Placing smart functionalities into publicly used items does not guarantee that the object will be "better" or change the environment entirely. The notion of smart is often a label placed over backend applications that aggregate the interaction data for the device's true owners. This smart factor is not truly for the public. Not all tools have to be so utilitarian. Instead, they can offer unusual or abstracted assistance. By looking at autonomy and emotional design in public spaces, smart benches could instead explore being transparent with their data. The interactions and user feedback could demonstrate the way users are affecting the environments, which in turn could change how the user thinks about their future actions.

3.2. Speculative Smart Designs

Smart technologies are inherently speculative in nature. Through the development of IoT devices, there has evolved a specific niche category of creators, products that are designed to speculate on future interactions. In this review we look at smart technologies that are primarily speculative, but also respond to the body and space. Each of these examples looks at object autonomy, optimization of interaction, and perceived smartness.

Figure 7: Image of Brad the Toaster. (Rebaudengo)

Brad the Toaster from Addicted Products is a networked toaster that can neither be bought or sold. Users can request to host the product, and the toaster can request to be moved to another household if it senses that it is not being used enough (Rebaudengo). The premise of *Brad the Toaster* is around autonomy and interaction with objects. *Brad the Toaster* requires no maintenance from the end user, nor does it offer any additional information. The sensing and responding to interaction is solely for the toaster itself, not the end user. This product can be seen as an actor and a creator; the product autonomously responds to interactions, offers a service and is also speculative in nature. This object offers speculation about the autonomy and decisions the toaster can make to change hosts. Human interaction is important, but the data gathered about it is solely for the toaster.

Figure 8: Image of SWAN

SWAN is a spoon that promotes mindful eating. Through the use of computer vision, the spoon detects if the user is eating in front of a screen, and how much time they spend looking at the screen, rather than mindfully eating their food (Koht et. al). The spoon responds by shaking or dropping the food of the user to draw attention to the act of eating. This work is not connected to a larger network so the data input is solely from the independent user. *SWAN* is a product that is directly related to the body, but does not provide a dashboard or mobile application to note trends in eating habits. The autonomous actions of the product speculate on networked products of the future that are aware of being used and the context that they reside within. If a mobile application would be included it could be seen as a tool, rather than an autonomous entity. The lack of screen interface creates a relationship directly with the spoon and the body and serves to heighten our contextual awareness in the home environment.

Figure 9: A user interacting with Norman White's The Helpless Robot

The Helpless Robot by Norman White is an artwork that asks users through a synthesized voice to rotate and move the robot (The Helpless Robot). The tone of the voice becomes more forceful and confrontational over time, telling users they are not completing the instructions properly. *The Helpless Robot* prompts further interaction by sensing and responding to users' actions; without the interactions from the users the work cannot function and therefore is "helpless". The work heightens the awareness of relationships to machines and how we are more inclined to interact with works that are anthropomorphized.

Brad the Toaster, SWAN, and *The Helpless Robo*t all show a form of autonomy through the relationship that forms with the user. These speculative designs and artworks show how perceived autonomy in objects can bring awareness to our environment and interactions. *Brad the Toaster* heightens our sense of the virtual overlay onto the physical through the pending risk of requesting to be moved to another household. *SWAN* highlights how technology can create an embodied and mindful experience through necessary tasks by intervening in how we act. *The Helpless Robot* is an early approach that shows how the dynamic between human and machine can change through intervening in interaction. These works together use human inputs to create optimized experiences for either the object themselves or for the user.

Speculative projects provide the opportunity look critically at interactions that seek to heighten our awareness in public and home environments. The prototypes that follow are positioned as a speculative public project that uses networked technology to create a heightened sense of awareness in our public spaces through autonomous benches which sense sitting and occupancy. The primary motivation for this project is to speculate on future situations that are not driven or motivated by crisis, either minor or major. Instead, it evaluates how smartness can encourage playful interactions through the form of infrastructure.

4. METHODOLOGIES

This project uses a combination of Research through Design, Critical Design, and Prototyping as methodologies. These methodologies utilize interaction design methods such as speculation, models, and iterative design. Speculation is a key method that is used in both Research through Design and Speculative Design. Removing the limits of designing for the present broadens the lens of what research artifact *could* be in the future. Prototyping and Research through Design both use iterative design methods that respond to user feedback. This flexibility allows for design processes to be adaptive instead of determining prototype decisions from the start of the research project.

4.1. RESEARCH THROUGH DESIGN

Research through Design (RtD) uses methods and processes from design practices and legitimizes it as a formal form of inquiry (Zimmerman). The outcomes are the knowledge that is gained through the design process. RtD does not start off with an end goal such as a defined product. Instead the artifact that is revealed at the end of the research process reflects the knowledge found and gained (Stappers & Giaccardi). The research questions and resources inform the decisions that the designer makes along the way.

Design processes allow for designers to imagine futures and possibilities that may not exist within the present (Zimmerman). The new knowledge that is found from RtD projects can allow for new discourses and ways of seeing the future (Koskinen, Ilpo, et al). RtD is a suitable option for designers who use design processes to inquire about future objects, environments, or scenarios which can lead to new research discoveries.

This research explores a final prototype for public engagement to heighten our awareness of networked and smart objects in future urban environments. RtD allows a platform for utilizing design processes as a form of research, such as prototyping, for determining methods of production to result in a final artifact that disseminates new knowledge, and acts as a tool for conducting the research.

This methodology allows for revisiting inquiries of hypothesis as design processes can change from methods employed, such as iterative design. RtD is flexible and challenges the notions of rigid research. The end result is sharing the processes and theories for imagining new scenarios.

4.2. Speculative Design

Speculative Design challenges the everyday knowledge and interactions of objects by re-designing them through the application of design fiction. The fictional future affects how a designer reimagines the objects; this future world changes our interaction which in turn re-informs our interactions with the present-day object (Dunne & Raby). This methodology employs techniques like observation to create alternative present narratives (Auger).

Observation is a large factor when considering how interactions in the public could change in a future where ubiquitous computing has been implemented in city infrastructure. “By observing and taking advantage of mundane, subtle, quirky but ultimately familiar behaviours or perceptions, the speculative designer can take the viewer on a journey to a technological future or alternate present that, whilst potentially alien, makes perceptual sense” (Auger). Through observation, new interactions can be created which build on those already found within the public with the aim to find new patterns and non-obvious. These patterns will define how to make a modular piece of infrastructure that can be multiplied to make an installation that speculates on future public interactions with technology. The aim of these models is to reframe the familiar interactions we know we have with a bench and place them in a new context as a critique of future developments.

Overall speculative design aims to help explore questions about how interactions in the public could change through the co-evolution of the city and technology. As well this methodology will help me explore what the definition of “smart” objects could be in the future and how we can harness these trends to raise awareness in the urban environment today.

4.3. Prototyping

Prototyping is a methodology that is about making modular and basic forms of a project to give insight into the final outcome. There are many different types of prototyping ranging from high fidelity to multiple variations produced in one swift outcome that are meant to throwaway. Prototyping is helpful for making decisions through methods such as proof of concept, horizontal prototyping, and iterative design. This methodology results in a realized product, though the methods utilized in the process are the only way to understand the interaction (Koskinen, Ilpo, et al.). Prototyping requires frequent testing to make decisions along the way to inform the final outcome.

Proof of concept is aimed to validate and confirm implementations of ideas and strategy in approaching a project. In this research, proof of concept will be important to validate ideas of technology, form, and interaction in my final outcome. Proof of concept also validates the feasibility of an idea and can help scope with the scale of the project.

Horizontal prototyping is a method that employs similar concepts of proof of concept, but aims to achieve a minimal viable product as a result (Singaram, M., & Jain 2018). Horizontal prototyping focuses on making a more high-fidelity interface for the prototype but with limited interaction. The horizontal aspect comes from the lack of depth in interaction the prototype is able to achieve. This method is used to help focus on initial interaction design, and to see how users want to interact with the prototype. The information gained from these interactions help develop the complexity of interaction of the prototype.

Iterative design uses strategies found both in proof of concept and throwaway prototyping, such as validating ideas and modeling forms etc., but includes a process of user feedback. In this research, the feedback will primarily be in focused groups of myself and research team. Iterative design requires external feedback and testing to help evolve the prototype into a finished product. The feedback from these sessions will drive the decisions in the following prototypes. In this research, formal user testing is used in the final stages to refine and understand the interactions. Iterative design is important for designs that are required for real world functionality.

Using proof-of-concept, horizontal, and iterative are methods for a starting framework in this research. Prototyping as a practice unintentionally uses other design processes, such as throwaway, vertical, or rapid prototyping. These other methods may be used in the design process of the research artifact, though the concentration of research will be utilizing proof-of-concept, horizontal, and iterative design. These methods allow for proof of technology, experimenting with the interface, and being able to iterate on both the decisions made in proof-of-concept and horizontal. The methods proceed from a test-like state to a reflective state which will be seen in the stages of the documentation.

5. PROTOTYPES

5.1. WHAT IS "VERY GOOD"?

This research works towards optimizing the act of sitting in a public space. The term "Very Good" is used playfully in this research, it is completely subjective and declaring a work as such would disregard any other possible experiences. Because transforming space into "smart" space is done through the primary motivations of crisis, sustainability, and optimization, this research hones in on the notion of optimization and how the term could be arbitrarily adopted by designers and developers. "Very Good" refers to the act of optimizing an object that is not commonly networked and how it can best exaggerate the object's purpose in a public setting. In this sense, "Very Good" relates to how well each bench does its job of offering seats by responding to being vacant or occupied.

Each of the subsequent prototype is evaluated by what was "Not Good", "Good", "Very Good" in order to determine how successful each bench is, such as:

- "Not Good": This aspect did not satisfy user testing or feedback or did not work well within the scope of this project.
- "Good": This aspect enriched the user interaction but needs refinement.
- "Very Good": This aspect is the final decision and interaction for the bench and will not be changed in the next iteration.

These evaluations are not ranked against a rubric, but through a reflective process of feedback sessions. Each prototype adds new hardware, physical interactions, programmed interactions, material exploration, physical design, and fabrication methods to the benches in order to refine the bench's user experience.

Until the final series of five benches, the works explore different inputs, outputs, and networking strategies. Though the benches may seem rigid due to the lack of diversity in interaction, these foundational steps are crucial to developing a stable IoT system. In the final series of the benches, the user testing of interactions will determine if the benches are not good, good, or very good. This information is derived from the qualitative comments given by the users. This differentiation between the testers and the research team in declaring if the benches are very good, good, or not good, is crucial as the research team may become too familiar with the project to truly assess what the outcome. In true public fashion, the final decision if they are Very Good, is based on the relationships the users form with them within the space.

5.2. Prototype Map

As iterative design can be a repetitive and reflective process, it is essential to identify the milestones sought out through this method. The key points identified that are important to the function of this project are:

- Input: What sensing methods do the benches use to read that someone is sitting on them?
- Output: What actuators are used to communicate the different states of the benches?
- Networking: What strategies are used and how to create a network that passes data amongst the benches?
- Interaction: What are the users' interactions?
- Construction: How does the construction inform the interactions of the benches?

The prototypes are focused on explorations of different combinations of these features:

	Prototype 1	**Prototype 2**	**Prototype 3**	**Prototype 4**	**Prototype 5**
Inputs	X	X			
Outputs	X	X			
Networking			X		
Construction	X	X	X	X	
Interaction	X	X	X	X	X

This map will be further expanded on in the subsequent sections, with evaluations on the very good, good, and not good aspects of each features explored.

5.3. Prototype 1: A Good Bench

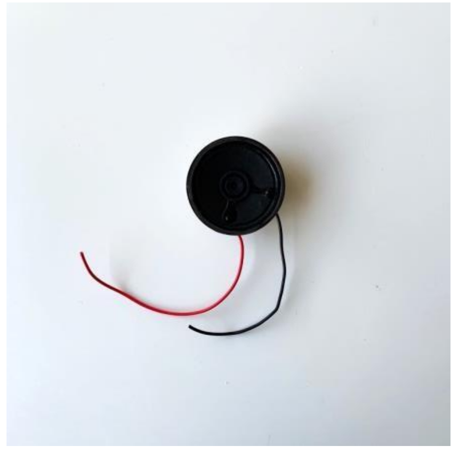
Explorations: Inputs, Outputs, Construction, Interaction

Figure 10: Image of Prototype 1 in use during a feedback session.

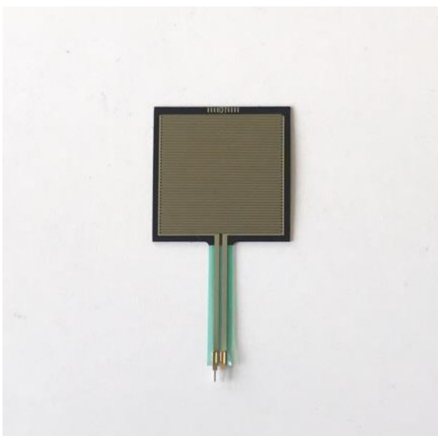
The first prototype consisted of a single bench. The objective of having a single bench is to first evaluate methods of recognizing when a user is sitting, not sitting and how the bench can respond to the actions. Though networking is a crucial part of this research, isolating the initial exploration to a single bench allows for the exploration of what other data sets can be created, rather than focusing on the communication between a set of benches. This prototype focuses on using time as a primary data set; the time the user sits on the bench and the time the bench is vacant. The goal for this initial bench is not to have a refined action, but to find what types of hardware are appropriate for sensing the act of sitting, and suitable actuators for providing feedback.

This prototype uses Force Sensitive Resistors (FSR) that sense when force is applied onto its surface as an input. The outputs are speakers for audio, LED strips for visual, and vibration motors for haptic.

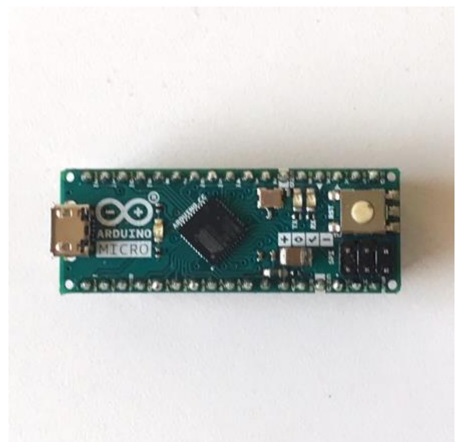
Components used:



LED Lights Speaker Vibration Motor



FSR Sensor



Arduino Micro

Figure 11: Images of the components used in Prototype #1.

Through time as a data-set and the listed inputs and outputs, a behaviour chart was developed to guide the interactions.

Bench Behaviours for Prototype #1

Bench States & Events	Light Feedback	Vibration Feedback	Audio Feedback	Intended Meaning
User stood up & now the bench is vacant	Bright red light flashing	Soft vibration	Soft beeps	Calling the user back to sit on the bench
Vacant for less than the average amount of time	Soft white light flashing	None	Quiet and rhythmic beeps	Satisfied with being sat on
Vacant for more than the average amount of time	Bright red light flashing	None	Loud and scattered beeps	Upset that it is vacant
Occupied	Random bright lights flashing	Vibration pattern for 5 seconds	Soft beeps	Welcoming the person sitting down
Occupied for less than the average amount of time	Bright red light flashing	Loud vibration	Loud beeps	Upset that it is vacant after a short "visit"
Occupied for more than the average amount of time	Bright white light flashing	Vibration pattern for 5 seconds	Soft beeps for 5 seconds	Content with the visit and saying "Thank You"

Figure 12: Behaviours chart for Prototype 1.

The construction and design of the bench was developed to be collapsible. Primarily this was incorporated into the design for easy storage as the project will be scaled to include more benches. This design was inspired by a park slat bench.

Figure 13: (Left) Bench #1 assembled, (Right) Detail image of Bench #1 legs folding in.

5.3.1. Good Results

Sensing sitting was effective, but was somewhat imprecise due to the surface area of the FSR input. The size of each FSR input is approximately a 2-inch wide square. The small sensing area made it challenging for users to identify where and how to sit on the benches. Overall this input was not very good since the users should not be confused about whether or not their interactions are affecting the bench due to the lack of sensing size of the FSRs.

The most effective part of the sensory feedback were the LED light strips. The LED lights allowed for very distinct and immediate changes between colour and light patterns. This diversity was very good and the most efficient in communicating the different behaviours.

In contrast, the audio and haptic feedback did not clearly communicate the states of the benches and ultimately seemed out of place in the context of the bench. The audio used a tone library from Arduino that sounded akin to tones of phones or other technology. In addition, the haptic feedback produced audio as well and was perceived as confusing through sound and touch. As a result, the haptics were not very good and the least important to continue exploring. However, the audio was a good asset, but needed to be actuated through alternative means.

The form of the bench was successful, as it utilized a visual language similar to a park bench. The collapsibility was seen as a very good asset to the bench, as it allowed users the ease of picking up and placing the bench in a spot that suited them. However, without a proper locking mechanism for the legs, it poses a risk of collapsing while the user is on the seat. This risk was not good and required further consideration.

Overall what became most important in the behaviours chart was the immediacy of feedback between sitting and standing. This communicated to the user that they affected the behaviour of the bench. In this case, time as a data set was mostly irrelevant to the users. It was not clear what states were caused by the time spent on the bench and time away from the bench.

Prototype 1 Overview Table

	Not Good	**Good**	**Very Good**
Inputs	FSR		
Outputs	Haptic and Speakers		Lights

Networking			
Construction	Risk of collapsing	Collapsibility	Form and reference to a park bench
Interaction	Confusion of the different time states		Immediacy of feedback

The single bench was a good bench as a foundational starting point for exploring how to communicate states and encourage. The single bench provided information on the initial interactions, but did not give any insight into how these interactions could evolve with multiple seats. The very good aspects of the outputs, interaction, and construction will be developed further in iterations, while the inputs and some of the outputs may be revisited.

5.4. Prototype 2: Two Good Benches

Explorations: Inputs, Outputs, Construction, Interaction

Figure 14: Image of the two benches vacant (and angled towards each other in feedback session).

The second prototype introduces a second bench to create a shared experience amongst users. Rather than using time as a data set, these benches use the occupancy and vacancy of the benches to determine behaviours. The occupancy and vacancy data is generated by the users interacting with the benches. The goal of this prototype is to explore methods of interaction using new inputs and outputs and how the states can be communicated between two benches and two users.

An e-textile sensing approach was used for the inputs. Based on a method developed by KobaKant (Perner-Wilson & Satomi), conductive fabric and velostat are used to craft a variable resistor that changes the analog input when force is applied. This method of craft and e-textile is important for the benches as it allows for custom sizing and adjusting the surface area of the sensors, addressing an issue in the previous prototype.

The LED lights are still used in this prototype, but solenoids are introduced as a form of audio output. The solenoids produce a rhythmic sound by tapping the underside of the bench through retracting and extending a magnetic coil.

E-textile Sensors

Solenoid

Figure 15: Images of the new input and output. An e-textile sensor (left) a solenoid (right).

The sensors and actuators of each bench are wired to a common microcontroller to emulate a wireless network. This configuration does not allow for any physical movement of the benches, but it does allow for the development of networked behaviours.

The programming logic will be focused on passing data reflecting the vacancy and occupancy between the benches. This set of benches aims for a state of equilibrium. If they are both vacant, they will provide similar feedback. If either is occupied while the other is vacant, the vacant bench will react to attract more attention. If both are occupied, they will be in similar stagnant states.

	Bench #1 Vacant	Bench #1 Occupied
Bench #2 Vacant	Both Benches: Soft flashing white light, Solenoids tapping the bench at a slow even tempo	Bench #2: bright flashing red light, Solenoids tapping the bench at a fast uneven tempo Bench #1: Solid colour for the light, no solenoid tapping the bench
Bench #2 Occupied	Bench #1: bright flashing red light, Solenoids tapping the bench at a fast uneven tempo Bench #2: Solid colour for the light, no solenoid tapping the bench	Both Benches: Lights are at a solid colour, none of the solenoids go off

Figure 16: Chart of behaviours for bench #2

The inspiration for the second bench construction was "flat pack" design. The bench is made out of plywood with legs that fold in and out. The legs fold up to be parallel to the seat rather than alternating slats. This is done for storage capacity and also to further explore mobility. When folded out, the legs are angled. This design explores other possibilities of collapsibility and strays from the visual language of a park bench.

5.4.1. Very Good and Not Good Results

The detection of vacancy and occupancy was very good. The method of sensor construction allowed for enough surface area for users to trigger the seat at any spot on the bench. The sensors responded to light touch and to vacancy immediately after the user stood up. The results provided a very satisfying and immediate interaction.

Since the benches were only detecting the vacancy and occupancy, the immediate response in state changes were prompt and easy to comprehend through the very good sensory feedback. The state changes controlled the solenoids which helped to anthropomorphize by giving them a "voice" through the tapping sound, and the LED lights used different colors which visually gave them different "identities". The benches and works towards creating a behaviour that resembled a personality. The solenoids provided a rhythmic waiting sound, which sounded like it was coming from the bench itself, rather than a mechanism attached. The lights were effective at showing the different states of the benches as there were only three states to understand. As the combination of occupancy and vacancy was explored by the users, the light and solenoid changes were immediate and quickly learned.

Figure 17: The research advisory team activating the different states of the benches.

The angle of the benches towards each other promoted a social interaction between the users which prompted a longer visit. This understanding was very good since the users knew that the benches wanted to be in the same state.

These benches were very good at showing how a possible interaction may occur between two responsive benches and two people. The wired together benches showed how networking could affect the understanding of communication between the benches and the user. Immediacy in the response once again was important in this understanding.

The mobility of the benches became an issue regarding the collapsible designs. The collapsibility of the benches was not a good solution for portability as even with the new bench design the folding in and out of legs still caused an unstable seat. This was a not good result and brought further questions of how to offer mobility through a safer means.

Prototype 2 Overview Table

	Not Good	Good	Very Good
Inputs			E-textile sensor
Outputs			Lights & Solenoids
Networking			

Construction	Collapsibility & Risk of unintentional collapsing		Visual cue and reference
Interaction			Immediate feedback between the occupancy and vacancy of the benches.

Overall the benches were effective at exploring the interactions of multiple users with multiple benches in a space but prompted a further need to explore mobility and different methods of networking. The immediate outputs helped communicate to users the different behaviours. The hardware for outputs and inputs was evaluated as very good. These benches show how the interaction could occur between two benches, but does not provide any information on how the interactions can become more complex with further benches included into the network.

5.5. Prototype 3: Three Good and Not Very Good Benches

Explorations: Networking, Construction, Interaction

The next set of prototypes are a series of iterations exploring data transfer between three bench designs that have different interactions, outputs and construction. Prototype 3a experiments with wireless networking technologies such as Wi-Fi and Bluetooth. Prototype 3b implements data transfer through multiple benches wired together using a single microcontroller. Prototype 3c incorporates radio communication using XBee radios. Each prototype uses the same three benches, but with different hardware. Though the prototypes visually appear similar, the differences in the interactions through the hardware require each version to have its own reflections. These reflections helped inform the hardware and networking paradigm for the subsequent prototypes.

5.5.1. PROTOTYPE 3A: WIRELESS EXPLORATION

Figure 18: Installation of Prototype 3a.

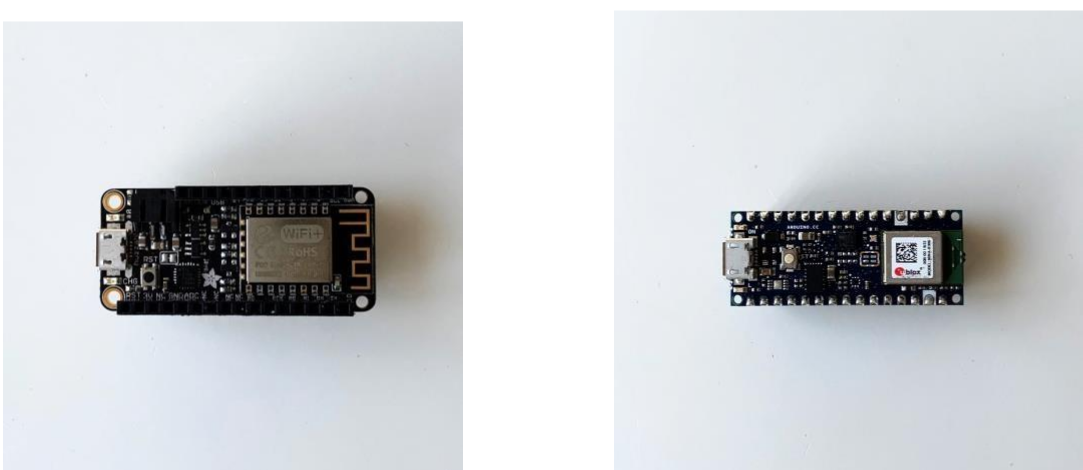
Unlike the previous benches, this iteration is wireless and explores wireless networks. A third bench is constructed. All three benches pass vacancy and occupancy data. The objective of this iteration is to explore mobility and wireless interactions between the benches and users. This iteration does not explore other forms of inputs or outputs, instead putting the primary focus on networking strategies. The two platforms tested in this iteration are Wi-Fi using a cloud-based server and a Bluetooth network.

The construction of this new bench is not collapsible, but instead includes wheels on the legs as a new way to explore mobility. The wheels allow users to push and move the bench to different locations within a space. This iteration also unifies the benches through similar upholstery to create a visual cohesion. The benches are upholstered with felt and a wooden frame to cover the foam tops and the components. Fastening the frames down secures the e-textiles sensors on the mobile bench.

Figure 19: Close up images of the third bench with wheels.

This prototype explores two methods of wireless networking: Wi-Fi and Bluetooth (BLE). The boards used to support these methods are:

- Wi-Fi: ESP 8266 Feather
- BLE: Arduino Nano BLE



ESP 8266 Feather | Arduino Nano BLE

Figure 20: Images of the microcontrollers used in this prototype: ESP 8266 Feather (left) and Arduino Nano BLE (right)

Different types of networking models have pros and cons for various applications. “Very Good Benches” requires a model that allows for a constant broadcast in the network, sharing the various bench states. This constant broadcast ensures immediate feedback from both the individual bench and all other benches in the network. Wi-Fi and Bluetooth communication handle this in different ways.

A common method of Wi-Fi networking in IoT devices is requesting information from a cloud-based server. This method is often seen in web applications. There are different cloud-based servers that IoT devices can connect with. Both PubNub and Adafruit.io were tested with the ESP8266 board. PubNub is a Data Stream Network (DSN) that allows for developers to build real-time applications on multiple platforms (PubNub). Adafruit.io is a cloud-based service that allows for IoT devices to request and post data (Rubell). Both of these platforms connect IoT devices for real-time networked interactions.

When requesting information from a cloud-based server, there is a chance in experiencing delays or missed messages.

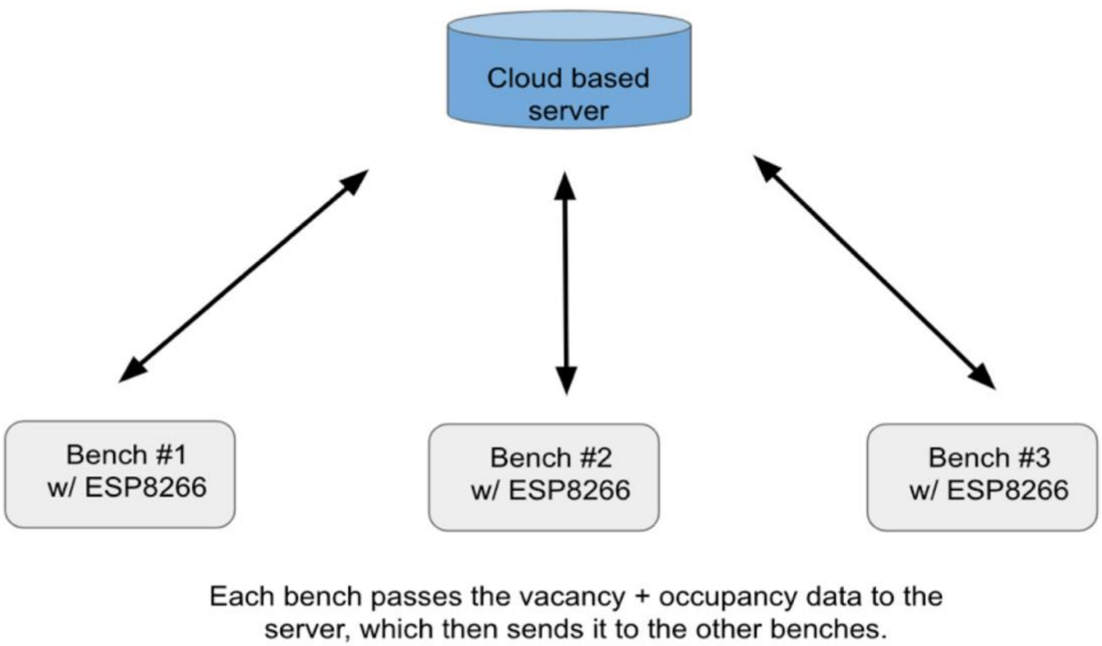


Figure 21: Diagram for showing how cloud-based services work with the ESP8266

In both the cases of PubNub and Adafruit.io there were issues with speed of communication, and server thresholds. PubNub exclusively caused timing issues with the request messages, which ultimately slowed down the response time of the benches. Adafruit.io on the other hand had a faster response time, but can only provide users with a maximum of sixty messages per minute. Between three benches this is only twenty messages per bench. In a system when constant communication is key for user experience, neither of these platforms provide the immediate information required to drive the bench behaviours.

Rather than using a server connection, Bluetooth (BLE) broadcasts different states and availability using direct communication between IoT devices rather than using a cloud-based server. The framework for BLE uses the paradigm of peripheral and client. The peripheral device broadcasts its name and services available on the device, while the client can connect to the peripheral and use these services.

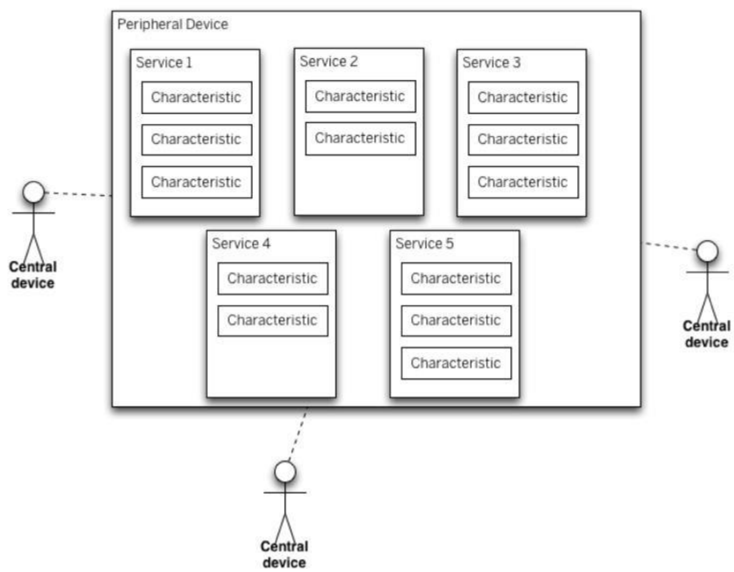


Figure 22: Diagram of Bluetooth (BLE) network. (Sanal)

Arduino Nano BLE uses a BLE library which allows an easy connection from peripheral to client. The board only allows a one-to-one relationship between the peripherals and client which is an issue for broadcasting bench states to multiple benches which is a limitation of the hardware. If the benches were in a one to one relationship, there would not be a full network for the benches to communicate within. The limitations of one to one do not allow for the complex sharing of information sought in this iteration.

The design of the benches requires a consistent broadcast of state of the bench, but also the ability to read multiple devices at once. Mesh networks allow for many-to-many connections, rather than BLE which is a one-to-one connection. XBee radios have the ability to create automatic mesh networks that self-heal if one of the radios is moved out of range or temporarily loses its power. There is no prolonged lag time because there are no server requests.

Ultimately the interactions were not fully able to be tested in Prototype 3a. The issues with networking did not offer the ability to develop the communication to be in line with the previous interaction discoveries. Networking brings challenges of wireless communication that can alter the behaviours of the benches and result in confusion for the users if not implemented properly.

Prototype 3a Overview Table

	Not Good	Good	Very Good
Inputs			
Outputs			
Networking	Both Wi-Fi and BLE are not suitable for this project.		
Construction			The wheels allow for easy mobility around the space.
Interaction	Unable to test		

5.5.2. *Prototype 3b: Wired Network*

Figure 23: Installation of Prototype 3b with the benches wired together.

The interaction between three benches is more complex than the interaction amongst two benches. This iteration does not address the networking but focuses on the interaction in order to develop the different patterns that arise amongst the three benches.

**** All Vacant: Flashing white light and even solenoid tempo ****	Bench #1 Vacant	Bench #2 Vacant	Bench #3 Vacant
Bench #1 Occupied		#1 Occupied: Solid LED colour, no solenoid tapping #2 Vacant Bright red lights, uneven solenoid tempo hitting the bench	#1 Occupied: Solid LED colour, no solenoid tapping #3 Vacant Bright red lights, uneven solenoid tempo hitting the bench
Bench #2 Occupied	#2 Occupied: Solid LED colour, no solenoid tapping #1 Vacant Bright red lights, uneven solenoid tempo hitting the bench		#2 Occupied: Solid LED colour, no solenoid tapping #3 Vacant Bright red lights, uneven solenoid tempo hitting the bench
Bench #3 Occupied	#3 Occupied: Solid LED colour, no solenoid tapping #1 Vacant Bright red lights, uneven solenoid tempo hitting the bench	#3 Occupied: Solid LED colour, no solenoid tapping #2 Vacant Bright red lights, uneven solenoid tempo hitting the bench	

Figure 24: Chart of behaviours for Prototype 3b.

The interaction patterns address how each bench responds if they are vacant or occupied, in relation to how many other benches are vacant or occupied. Because networking is not a part of this iteration, the benches will be wired together. The interaction in this case forces the benches to be closer together and they cannot be moved, even though one of the benches has wheels for mobility.

This iteration was displayed in a classroom setting, with approximately fifteen people participating in the critique. When interacted with in quick succession, it was difficult to understand that the benches were changing states. In previous test sessions, the interaction rate was not as frequent. This poses interesting interaction challenges, such as how long does it take for someone to understand a state is changing? Multiple people were sitting on a bench at once and were confused as to whether or not multiple people on a bench would affect the behaviour. If a single person was on a bench, they would slide around the seat to see if different spots provoked different reactions from the bench. In this iteration the bench sensors use the entire seat as a single sensor and have no ability to differentiate if multiple users are interacting with the bench, or if a single user is changing position on the bench. This high load testing provided insights on how the interactions can be immediate but also missed by the users.

The patterns used for the outputs are similar and not very diverse. Some users noted that the flashing lights and rhythmic clicking of the solenoids resembled a bomb. This sound could cause apprehension in users and prevent them from approaching the benches.

This testing session provided further information that would help to enrich the user experience of interacting with the benches. During a high frequency load change it is challenging to understand different states and reactions even with the intended immediateness of feedback. Multiple users sitting on a bench expect something different to happen than when a single person is on the bench.

Prototype 3b Overview Table

	Not Good	Good	Very Good
Inputs			
Outputs			
Networking			
Construction			.
Interaction	Confused about the interaction due to high volume load. Users were unsure if the bench was changing states when interacting.		

5.5.3. *PROTOTYPE 3C: WIRELESS EXPLORATION WITH RADIOS*

Figure 25: Installation of Prototype 3c, wireless benches using radio communication

This final iteration of Prototype 3 combines the findings from Prototypes 3a & 3b and shares the focus between networking and interaction. Through the use of XBee radios, this iteration looks at radio networks for quick transfer of data amongst the benches. New e-textile sensors were fabricated for this iteration so that the seats could detect up to two people sitting on bench. Audio feedback through the solenoids is used to provide cues when distinct actions happen within the network, such as when someone else sits on a different bench or if two people sit on a bench. The network broadcasts a ranking of the benches which the benches then receive and change their behaviour. The ranking is solely determined by how many interactions the benches receive. The interactions in this prototype are defined by a “session” of a user sitting.

Figure 26: Image of an XBee Radio used in Prototype 3c.

The network structure implemented with the XBees in this iteration is not a mesh network but a star topology. This paradigm allows for a central node to be a coordinator for the network. The coordinator receives and transmits information from all the nodes (other radios). This paradigm does not allow for a many-to-many relationship but instead a one-to-many. The benches communicate to each other through the coordinator node. This change of paradigm allows the benches to manage less because the only information they transmit is if they are vacant or occupied. The information they receive is a message detailing if another bench has just been occupied or the ranking order of the benches. Ultimately, the coordinator is the manager of the benches. In this prototype the coordinator took the form of an XBee connected to a microcontroller on a breadboard and distanced from the installed benches.

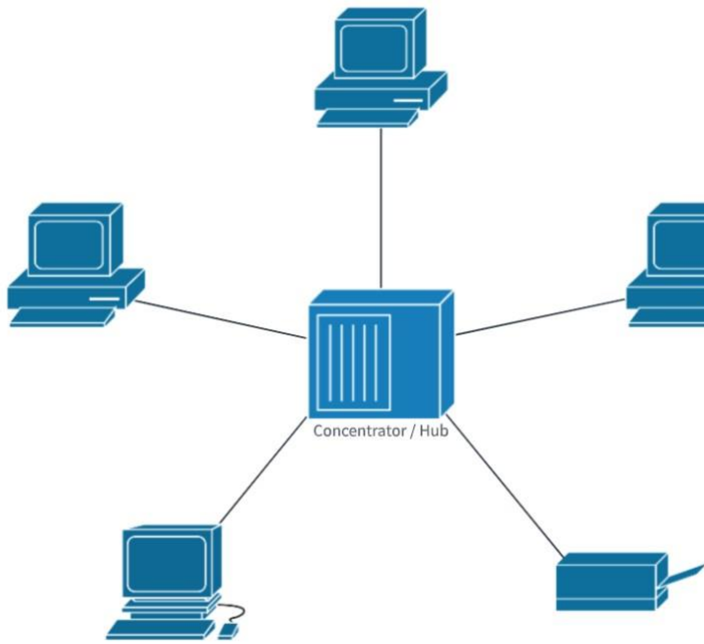


Figure 27: Image of Star Topology Network Diagram. (Lucid Chart)

The benches used the input of vacancy and occupancy of two seats on each bench to determine how many times a user engaged with them. Every time a user sat on either side of a bench, the radio would send a message to the coordinator indicating that the particular bench had experienced as a “sit”. The “sits” were used as a unit of measurement. The coordinator would keep a tally of the “sits” to change the behaviours of the bench.

During the feedback session the networking of the benches was challenging to understand immediately. The benches responded to the different states of the others in the network but did not give a large variety of feedback for the users to understand. The immediacy of sitting down and standing up was understandable by the users, but the challenge was communicating that the user affected the entire network. This session showed that the interactions need to be very didactic for the users to understand that they affect the other benches. Overall the hardware for networking and the communication between the benches was working well, but the interaction needed to be further improved.

Prototype 3c Overview Table

	Not Good	Good	Very Good
Input			
Outputs			
Networking			Successfully and quickly communicated the varying states to all the benches involved in the network.
Construction			.
Interaction	Users were confused as to how they are able to affect the network	The immediacy of state change when users sit up and down was effective at communicating a state change.	

5.6 Prototypes Summary

Across these three major iterations, the sensing, actuation, and networking were developed. The interaction needs further refinement for consistency and the construction also needs to be more stable. These iterations were critiqued primarily by the research team. A formal user testing session is essential to progress the interaction and further the iterative process.

6. FINAL PROTOTYPE & USER TESTING

6.1. FINAL PROTOTYPE OVERVIEW

Figure 28: Images of the new prototypes assembled for user testing.

Throughout the previous iterations, nearly all areas evaluated eventually were assessed as “very good.” However, the interaction with the benches still remained confusing and the benches were not yet able to reliably communicate states or purpose. The input, output, networking, and construction made so far were done through comparison of materials and function.

	Not Good	Good	Very Good
Input			Analog textile sensor
Outputs			Solenoids and Lights
Networking			Radios
Construction			Wheels, size for two people to sit
Interaction	Confusing		

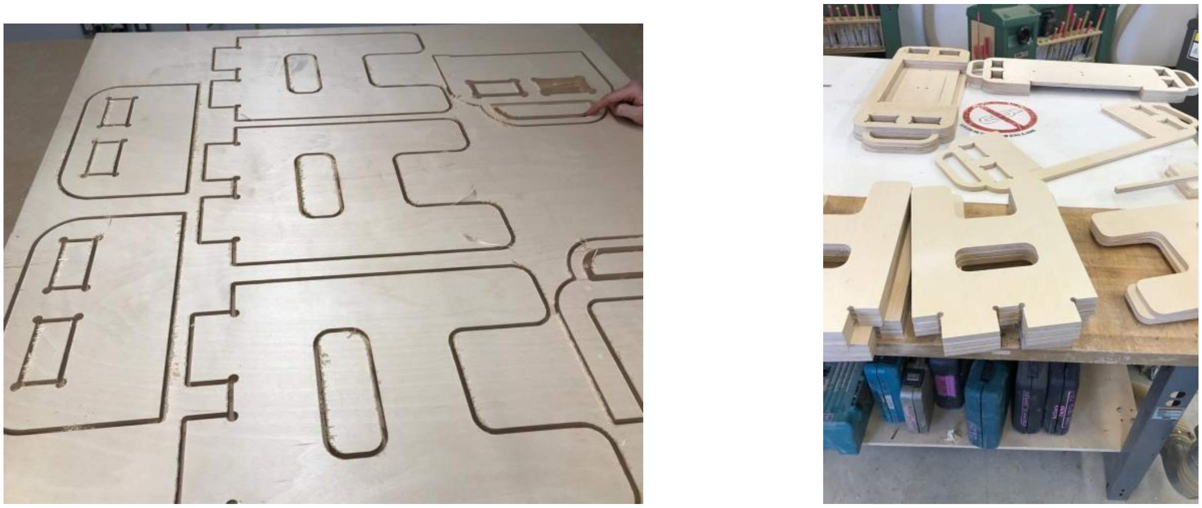


Figure 29: Process images of the benches including pieces milled on plywood (left) and cut plywood (right) laminated together to make the bench legs.

The final prototype takes into consideration the construction critiques and concerns brought up in response to the previous iterations. To create a visual cohesiveness amongst the group, three entirely new, nearly identical, benches were fabricated. These benches were produced en masse with a CNC Mill using plywood to make individual pieces that would then be laminated together. This method was chosen for precision and the ability to quickly and reliably manufacture multiple prototypes of the same design.

Figure 30: Images of the assembled benches, the bench pieces placed together without the frame and upholstery (left), and the bench fully finished with the top frame and two-tone felt (right).

The new benches are topped with three different hues of felt, with each bench combining two hues, and none of the benches having the same pair. The difference in tones was intended to help communicate to users that the benches can respond to two people sitting on the seats.

Each bench also has a sliding shelf which holds all electrical components beneath the seat which allows ease for servicing the benches.


Figure 31: Detail images of the bench shelf. Up close image of the shelf closed (left) and above view image of the shelf open (right).

Most notably, this design includes handles as a part of the frame. During the feedback sessions, handles were discussed as signifiers that the benches could be moved around the space and offer agency for the user. To heighten the notion of movement, casters were added to the bench legs so that the user could move them easily within the space. The inclusion of these assets would further inform the interactions of participants.

The benches continue to use radios to broadcast and receive states within the network. The states are reflected through solenoids and LED lights. They are changed by the vacancy and occupancy measured through two textile pressure sensors.

6.2. User Testing

This user testing study has been reviewed and received ethics clearance through the Research Ethics Board at OCAD University, file #101715.

- Three user testing sessions were conducted with fifteen participants: eight in the first, five in the second, and two in the third. The sessions were structured as a fifteen minute interaction period that was filmed followed by a twenty-minute group interview which was audio recorded. The participants were given no direct instruction during the interaction period except to enter the room. During the interview period, the following questions were asked of the group:

- Question 1: What was your first thought when you walked into the room?
- Question 2: What was the thing that stood out most about your experience?
- Question 3: What kinds of interactions did you have with other people while sitting on or playing with the benches?
- Question 4: Did you notice how other benches were responding when you were sitting down?
- Question 5: Did you move the benches? And if so, in what way?
- Question 6: What do you think the benches were responding to?
- Question 7: How would you describe these benches to someone else?
- Question 8: Are there any ways in which you can imagine the benches responding differently?

Figure 32: Image of the benches turned on and arranged prior to the start user testing.

The observation and discussion that took place during the interaction period and the group interview period highlighted multiple interactions. Many experiences and descriptors were echoed across all three of the user testing sessions. From this data, the themes identified that were most common and necessary to address were: Bench Design, Movement, Contextual Awareness, and Sound + Light Interaction.

6.2.1. Bench Design

From initial interaction to how the participants would describe the benches, parts of the bench design strongly informed the experience and interactions from the participants. Upon entering the room, many users noted that seeing the wheels and the handles were the first thing they noticed. Since these features are not commonly integrated into public bench designs, it informed the users that these benches may be interacted with differently.

> *The design of the benches, it makes you kind of ask, in what ways is this a conventional bench and in what ways is it something else that is supposed to upset my ideas of benchyness? How I use a bench? All that kind of stuff*.

Another tester noted:

> *They're very approachable. It's not like if you see a really fancy designer chair, you're like: 'Oh, I don't know if I want to sit on that.' These ones are like, I'm definitely going to sit on that and move it around and I'm okay. I'm maybe a little concerned, I guess the durability about it, but I'm not trying to be careful about everything…I feel I can play around. Be myself.*

Figure 33: A user observing another user laying on two benches.

The bench design prompted this next comment and particular action as a result of the application of two-tone felt on the seats.

> *I think the two color of the felt really indicates that it's kind of made for two people. So, if it was just one color, I think I would have just taken the whole space to myself, just to sit in the middle. But the color is just like, oh I should sit on it with other people.*

Figure 34: Users testing out different types of seating patterns.

Overall, the new bench design heavily influenced the affordances and interactions through the signifiers of wheels, handles, and two-tone felt upholstery. This elevated familiarity with these aspects of the benches allowed for further interactions to be explored during the testing session.

6.2.2. MOVEMENT

Since the handles and wheels signified movement, users were comfortable in moving and arranging the benches in different configurations. Many types of movement were observed and discussed. In particular, it was observed that users would absentmindedly move the bench with their feet as they were observing the interactions of others.


Figure 35: A user tilting the bench to test responses.

Users were also curious about tilting the benches to see if this provoked any type of response. Users would drag the bench by the handle to transport it within the space, but would also lift the bench to experiment with the reactions.


Figure 36: User pushing one another on a bench.

Pulling and pushing others on the benches as a form of play was also observed. Users did not mention if they expected a reaction from the bench during this interaction. A common configuration that arose was when users started talking to one another to bring the benches closer together. Referring to other participants, one individual commented:

“They were talking to each other, but the benches were facing the same direction. So, they moved their benches to face each other.”

6.2.3. Contextual Awareness

Participants were very keen on understanding if proximity affected the interactions of the benches. As a result, many different arrangements were tried and tested to see if the benches would react in a new way.

Figure 37: User testing group placing the benches near each other to test the proximity responses.

> *People wanted them to link together somehow physically. Like make an actual train or for them to link on the sides or something like that. There were a lot of engaging interactions with them... They're not too heavy. You could move them if you needed to. They're really easy to push.*

Figure 38: A user testing group arranging the benches by the colour of the felt.

Another expectation of contextual awareness was surrounding co-occupancy and timed movements. Participants often tried to do the same action in sync to see if it triggered an in-sync reaction.

Figure 39: Users testing if the benches respond to their sitting in the same position.

Participants would also try new seating patterns to see how the benches responded. In the figures above and below, the participants moved back and forth from sitting together to sitting in separate seats to see how their positions affected the benches.

Figure 40: Users comparing the response to two people sitting on a bench versus each sitting on their own bench.

However, it was unclear to the users if a single or two users affected the bench responses.

> *I was curious… does the left side matter versus the right side or versus, or just like any pressure from level. So, I was watching it... If I sit on the left does it change? If I sit on the right does it change?*

In another session a different participant noted:

> *We spent a lot of time, so we sat on either side to figure out whether it changed color. Then I was trying to check how heavy it was and if I could put it on the other one would it change the color.*

Figure 41: Users investigating what happens to the vacant bench of the group when the other two are occupied.

The desire for contextual awareness regarding entities other than bodies was also brought forward: "[If I] just left my phone and then went away, it would be nice if it would make a sound." This suggested that the benches could possibly have a deeper understanding of an occupant's "body" and also be able to understand the difference between an object sitting on the bench versus an individual.

Participants were expecting the reactions of the benches to be aware of the position of the users and also the position of the other benches. This expectation drove much of the experimentation in the sessions, from configurations, to seating patterns.

6.2.4. Sound + Light Interaction

When discussing with users what was the most memorable interaction during the testing session, both the sound and light feedback came up frequently. The light changing was apparent to users but was also confusing at times. Participants were keen on trying to understand the lighting pattern. Noted by one participant that it was challenging to see their own light, because they were focused on others instead.

> *I would notice the other benches light up. When you're sitting you actually don't see the light on your bench but you could always see what other benches are doing.*

Figure 42: A user trying to see how their bench is reacting compared to the others.

Initially I was going down and trying to look at if the lights change and then after some time I gave up and I was like, I'm going to sit and see if that light changes when that person does something with the bench.

Yeah, I would look at if other people's benches are lighting up and is it ending up differently than mine? And what are people doing to make them light up and then I'd try to do it.

Figure 43: The user testing group trying to see underneath the bench.

Participants were very curious about the construction and working of the benches. Every so often a participant would try to see what was going on underneath the bench due to the light emitting from that location.

Figure 44: A user crouching to see underneath the benches as they respond to an interaction.

The light and sound combination was described as creating personalities for the benches. The colour of the light and speed of the tapping sound mimicking different emotions. “I think it was interesting that all of us just kind of immediately assigned personality and emotion. Like, oh it's angry.” However, when the bench was vacant and making noise the sounds were confusing. “I don't know if they were meant to be friendly, or happy, or sad from the speed.”

Overall, the sound and light patterns were noticed and observed but were not directly communicating the impact of their interactions to the users. It prompted users to continue to test the benches, but the challenges with the consistency of the colour and sounds were roadblocks for users feeling like they fully understood the interaction.

6.2.5. *Feedback*

Primarily the response when asking how the experience of testing the benches went was that it was “fun” and “positive.” The confusion from the bench interactions was not necessarily a deterrent and did not create a frustrating experience for the participants.

If you have an interactive thing and it's real simple and obvious what it does, then are these interesting? If there doesn't seem to be a connection between what you do and what it does, then you also lose interest. So are we in the middle? I think we probably were... But the possibilities of interacting with the people on the benches left it quite open ended.

The sound interaction was most apparent in the session with the least number of participants. When asking participants about what stood out most in the session their responses were “I definitely noticed them, and they were the main indicator of interaction to me.”

The benches’ behaviour of “competing” for the attention of individuals primarily occurs when they are in a vacant state. Because participants were drawn to sitting down almost immediately, the users did not perceive that the benches were competing with each other. Instead, users described the benches as having their own personality and emotions, and that they were playful.

A single participant voiced that they were colour blind and that the changing light colours were challenging to understand. They recommended using a variety of light patterns and sounds to enhance the experience to be more accessible.

In this iteration, the height of the benches was taller than a typical bench. This caused many of the users’ feet to dangle from the seat. When discussed in the group interview, many participants noted that this heightened the playfulness of the benches.

Feet dangling reminded one participant of childhood, while another participant said it made moving benches with others sitting on them easier.

When asked about what responses could be added to the benches, proximity feedback, differences in audio, and haptics were suggested. The participants were most concerned with the proximity of the benches and wanted to understand if moving the benches in different configurations had any effect on the behaviours. Different types of audio tones were also recommended to give the benches more unique voices. Haptics were mentioned as a way to alleviate the confusion of not easily being able to see the colours underneath your bench.

6.3. User Testing Reflection

Overall, the user testing session brought forth many important key points for consideration in the final interaction iteration. The affordances of the handles and wheels prompted users to play with the benches and communicated that these benches were not “typical” benches. The lights and sounds created personalities for these benches that allowed users to create identities for each bench in the group. The lights and sounds were necessary for feedback but became confusing as the session carried on. With larger groups of users, the vacant state of the benches was not common, and more often than not users would occupy the benches and observe others. This caused some confusion and challenges with the bench behaviours as they are programmed to attract users when they are vacant but do not frequently interact with users while they are occupied. In smaller groups the users tested different in-sync configurations to explore the interactions of the benches. These observations offer key considerations to refine the experience of the benches and to work towards the goal of communicating the competition amongst the benches.

7. Reflection & Conclusion

7.1. Reflection: The Middle Ground

As a culmination of the iterative process, user testing, and foundational theory, these benches did prove to be "smart" benches in the denotative sense that they sense and respond to an interaction. The users' recognized that they were able to impact the behaviours of the benches, however, the grouping of multiple benches together made the interaction experience more about the group of the users, rather than the group of the benches. This was because the benches promoted playfulness.

Several users commented on the in-between aspects of the work, that the prototypes did not look like indoor chairs but also did not resemble park benches. This highlights the current state of the work. The benches themselves are not intentionally designed to be covert if placed in public places but are also not refined enough in comfort or aesthetic to be suitable within the home environment. The in-betweenness of the bench design succeeds in piquing enough interest to elicit the necessary "sitting" data from users, but the design does not position itself as primarily for the users or for the benches.

This middle ground prevents the benches from fully becoming a piece of infrastructure that could blend into the known environment but does not communicate fully that the benches are tools for the users. The behaviours also support this middle ground. The states that the benches "fall" into during use do not dictate the behaviors of the users, but similarly the users do not dictate the behaviours of the benches. The control of the interaction does not fully lie with either the bench or the users.

This middle ground status allows for two possible approaches of continued development: bench for the benches and bench for the people. The "Bench for Benches" approach looks at the autonomy of the bench, while the "Bench for the People" approach looks at the agency of the user. The majority of other smart bench technologies can be considered to fall into the category of "Bench for the Owners" as the data-set produced from these products is only viewed by and collected for the owners. This current middle ground position of "Very Good Benches" allows for more conversation regarding the other two, less prominent, stakeholders that can hold agency and autonomy in the interaction paradigm of owner, user, and object. A Bench for (Benches | People | Owners) shows who interprets and optimizes the contextual awareness collected by the group of benches.

The “Bench for Owners” approach has already been thoroughly explored, implemented and optimized to provide data to the owner. In exchange for this data, the benches offer a perceived convenience for users. Possible next steps for “Very Good Benches” are to look at how the research collected through the Research through Design process, iteratively developed prototypes, and user testing results can be used towards creating “A Bench for Benches” and “A Bench for the People”.

The following overviews contain possible next steps for each of these provocations as derived from user testing feedback. They address the optimization of data for each approach and how the current iteration “Very Good Benches” can be further iterated to arrive at the desired result.

7.1.1. A Bench for Benches

Optimization Approach: For the Benches to use the contextual data of where human agents are invited or manipulated to respond and react to their environments in order to help the benches achieve their goals.

Currently Developed Items

- The personalities that are developed between the benches which anthropomorphize them as entities within the space

Design Additions

- Further develop each bench’s contextual awareness of other bench locations and the human entities around them
- Awareness of being moved
- Develop a stronger individual voice amongst the benches that responds to contextual awareness

Design Reconsiderations

- Change the current furniture-like aesthetic (the use of felt and curves) to a more immediately recognizable traditional utilitarian design
- Modify the casters to be better suited for outdoor purposes to increase durability

- Implement a more didactic visual and audio language that communicates the states of the benches

7.1.2. *A Bench for the People*

Optimization Approach: For the benches to understand where the other benches are to optimize the ability to offer seats for users, and inform users of other available benches.

Currently Developed Items

- Functional handles and wheels that allow for agency in arrangements
- Lights which respond to sitting and standing and can evoke a sense of play amongst the groups

Design Additions

- Provide a more comfortable sitting experience through the use of padding
- Add proximity awareness to the benches
- Have the benches respond when they are touching each other
- Implement haptic feedback
- Change the positioning of the lights to one that is more visible for the user

Design Reconsiderations

- Audio feedback as it could be disruptive in smaller spaces

This division of purpose provides next steps for two sub-projects that would relate to the greater concept of “Very Good Benches.” Both of these projects centre around networked, interactive seating, but the direction and control of the interaction come from different drivers.

7.2. Conclusion: Not Bad

This work explores, prototypes, and evaluates alternative approaches to smart technologies. Through Research through Design, Prototyping, and Speculative Design new stakeholders for smart infrastructure placed in public spaces are imagined.

Optimization typically relates to who benefits from the interpretation and application of data collected in smart technology. This research shows that there are stakeholders other than the owners. Through iterative design, this work takes a DIY Urbanism approach to exploring interactions that could be possible in the public realm. Though this work did not truly reach an uncontrolled public space, it was able to look at what signifiers can be used to communicate with the stakeholders of each interaction.

Infrastructure is long lasting and plays an important role in our communities. Looking at stakeholders other than the "owner" and goals other than "optimization" allows for a different future of smart infrastructure for communities. This alternative agency and autonomy over space and movement can be in the uses of smart objects or it could be in the digital entity itself. The middle ground that this research eventually falls into allows for alternate paths of continuing alternate interactions in a techno-imaginary urban environment.

DIY Urbanism looks at how communities can take agency over space by crafting solutions to neglected concerns of neighbourhoods. While this project does not wholly employ this method of intervention it does adopt the philosophy of looking at disruptive interventions to challenge our understanding of the space and interactions.

Ubiquitous computing is becoming pervasive in many of our interactions in public spaces. Adding sensing and a network to an object creates new interactions, either passively or actively, from users. The benches produced in this research elicit play by responding to sitting and standing but would also benefit from further refined behaviours and through responding to proximity of other benches. As gathered from the user testing results and noted in the research reflection, the utilization of proximity data is one such possibility which could ultimately drive the desire to create smart benches for the user, rather than smart benches for the "owner".

Overall, this research shows that prototyping through iterative design, speculative design, and research through design combined together can create an artifact that provides information on how we respond and discover the interactions and affordances of ubiquitous computing placed in a familiar everyday object. Designers can design smart objects that work towards alternative futures by designing for different more inclusive publics. Ultimately, the results of user testing and the state of the prototypes need not be categorized as "Not Good," "Good," or "Very Good," as all of these designators show that when developing for alternative interactions the stakeholder must be considered to avoid confusion. These benches do not necessarily "optimize" the act of sitting on a bench, but rather the work piques interest and play which can change and enhance an urban environment and that’s “not bad.”

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9. APPENDIX A: ACCOMPANYING MATERIALS

9.1. IMAGES

1) Benches1.png

Title: “Very Good Benches”
Description: – Image of all three final prototypes placed together.
Date: April 1, 2020

2) Benches2.png

Title: “Very Good Benches - Detail”
Description: – Detail image of the bench handles.
Date: April 1, 2020

3) Benches3.png

Title: “Very Good Benches - Activated”
Description: User sitting on one of the benches, activating the seat, while the other bench responds.
Date: April 1, 2020

4) Benches4.png

Title: “Very Good Benches - Lifted”
Description: User lifting one of the benches using the handle.
Date: April 1, 2020

9.2. VIDEOS

1) Video-1.mov

Title: “User Testing Introduction”
Description: Video of the beginning of the user testing session with all benches vacant.
Date: March 4, 2020

2) Video-2.mov

Title: “User Testing – In Session”
Description: Video of users interacting with the benches.
Date: March 4, 2020

3) Video-3.mov

Title: “User Testing – In Session”
Description: Video of users investigating how the benches work.
Date: March 4, 2020

4) Video-4.mov

Title: “User Testing – In Session”
Description: Video of users moving around on the benches.
Date: March 5, 2020