HeartBeat

An interactive installation to reflect the sentiments of Canadians during pandemics like Covid-19

by

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Abstract

Social media has given citizens an avenue to express their views on various subjects in their personal lives, policies, and even a way to communicate with each other about their sentiments and emotions. This is key during a pandemic such as Covid-19 where the world is facing a global impact and the need for a pandemic-related public art framework has been sought globally by art societies and researchers to revitalize the society. However, due to the pace of this pandemic, most city art strategy papers require a framework for pandemic related public art especially in Toronto which has an agenda of moving towards becoming a smart city and public art should reflect that. This thesis investigates how might public art installations reflect the sentiment of smart communities in a pandemic. I designed 'HeartBeat', an interactive installation and visualization to reflect the emotions of citizens during the pandemic using Research Through Design and user-centered design approaches. The goal is to reflect the sentiment of Canadians during the current pandemic. HeartBeat uses tweets from Canada and visualizes the popular emotion groups during the pandemic period in an interactive installation. To evaluate HeartBeat, I conducted case study evaluation for various time periods and semi-structured interviews by selecting experts such as artists, designers, curators, policymakers, and data journalists. The contributions from HeartBeat could provide designers and artists exploring the pandemic to consider these design choices and methodologies; discussion shows the ways available to understand emotions of citizens during a pandemic in a smart city; detailed process design and technology stack architecture for pandemic related public art which could be used as public art frameworks during pandemics.

Keywords: pandemics, sentiment visualization, interactive installation, Internet of Things, public art

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Chapter 1- Introduction

1.1 Personal Motivation

I was born in Pakistan where public art as a whole was limited. Whenever we would go for vacations to the US or Canada, I would get inspired by their use of public art - especially interactive art and how artists would take topics such as women empowerment, poverty etc. to impact change in the society using their displays. As I grew up, the inspiration turned deeper with the use of social media tools to work in digital campaigns. As a digital marketing and advertising professional, I have worked on digital campaigns and themes that utilize social media sentiments of the public on key subjects that matter to them most and use an iterative methodology to create interactive visualization and tell a story.

I observed that there is a dominant need today, as well as in the near future, for interactive public art installations to support and revitalize the inclusion of community and civic engagement in the cities. Naturally, when I joined this Master's in Digital Futures program, my focus was empowered by the use of these tools. For example, my past projects (Figure 1) included using an interactive installation for a Women Empowerment campaign. Another example (Figure 2), is about using a canvas to bring nature to life using interactivity.

Figure 1: Interactive installation: Using tweets to reflect women empowerment.

Figure 2: Interactive installation (Healing hands) – Micro interactions on the canvas to display video.

Covid-19 has impacted millions of citizens around the world. I came across a discussion about this between seasoned experts Franco Mormando and Thomas Worcestor in Ryan Sirju (n.d) and got completely inspired where they described "in times of crisis, people like to see their experience mirrored through another medium, especially art, which is visually striking, which moves to the heart. We also find comfort in having our emotions validated — especially at a safe distance (Ryan Sirju, n.d, para. 8).

It suggests an imperative need to reflect the sentiments of communities in Covid-19 and the use of public art to revitalize society. The impact of Covid-19 got deepened for me personally as my whole family in Pakistan got infected with Covid-19. This further motivated me to explore this impact. The current academic thesis is part of my long-term personal and academic pursuit to create frameworks of public art engagement that resonate with the sentiments of citizens, whether it is for times like Covid-19 which is my current pursuit followed by government policies, tourism, and women empowerment in the future. I hope to practice various methodologies and create insights by unifying different dimensions or factors to create knowledge for artists as well as governments engaged in public art. Public art has undisputed benefits to revitalize societies and with the impact of Covid-19, reflecting sentiments of

communities using artistic forms becomes paramount. Thus, a pandemic related public art installation which reflects sentiment could potentially address issues facing societies due to Covid-19.

1.2 Research Goals

For the current thesis, my goal is to understand a framework of public art during a pandemic using the vision of the City of Toronto's Public art strategy paper (City of Toronto, 2019). Currently, the city of Toronto has a 10-year public art strategy paper from 2020-2030 with a strong vision however, it is missing a pandemic or crisis-related framework for public art. This is an important and urgent problem to focus on. Thus, my goal is to use their vision and to investigate a pandemic related public art framework. Smart Cities are urban areas that exploit operational data, such as that arising from traffic congestion, power consumption statistics, and public safety events, to optimize the operation of city services (Harrison et al., 2010). There is a fundamental weakness, especially in these times, when the objective is to have smart cities such as Toronto, and how sentiment might be visualized in smart cities. Toronto has an agenda of becoming a smart city with the goal to improve access to information and data (City of Toronto, n.d). This also includes a program by City of Toronto such as Open Data (City Of Toronto, n.d-a). A smart city's main objective is to increase the quality of life for its citizens and to make the city more attractive, lively and greener (Ben Ahmed et al., 2016).

I began my research by understanding the conversations about the pandemic related public art around the world which are surfacing such as public art needs, use of Twitter in Covid-19, and the need for sentiment reflection during a pandemic.

1.2.1 Twitter during past pandemics

Lessons drawn from past studies and pandemics, such as H1N1, show that Twitter can be a useful source of opinions and experiences (Chew et al., 2010). Tweets can be used for real-time content analysis and knowledge translation research, allowing health authorities to respond to public concerns.

A recent study found that social media, especially Twitter, can guide public pandemic policy in Australia (Yigitcanlar et al., 2020). Further research pertaining to sentiment analysis has also been used in Covid-19, such as Twitter sentiment analysis on worldwide COVID-19 outbreaks, and public sentiment analysis for various topics pertaining to Covid-19 (Samuel et al., 2020; Hussain et al., 2020).

This could be because more than 15 million Canadians use Twitter every month (Slater, 2018). The author also shows that this translates to 49.7% of Canada's online population. Of this group, close to half (44%) check Twitter constantly, meaning they check-in, consume and engage multiple times a day. In addition to this, 9% of Twitter users in Canada are older than 65+ age (Statista, 2015).

1.2.2 Understanding sentiments during a pandemic

The need for civic engagement is urgent. There are strong lessons drawn from the response of Covid-19 which further highlights the significance of understanding the sentiments of citizens. Lessons drawn from the current response to the COVID-19 pandemic show one of the underlying issues is the lack of transparency (Chamola et al., 2020). Moreover, Maluj & Zaluski (2017) support the emotional and social potential of art in a city, as they found in Poland, where art was capable of evoking emotions and have a particular impact on both their attitudes and engagement in the process of city revitalization.

Thus, there is an urgency and gap to fill and my goal is to investigate the framework for pandemic related public art in smart cities and how an interactive installation can reflect the sentiments of communities in crisis such as Covid-19.

Several conversations around the urgency and need for pandemic related public art have taken the center stage. According to The City of Fredericton (2020), they called for 'pandemic-related' art proposals in response to the province's collective feelings of the circumstances created by COVID-19. In a recent conversation, a group of UC Berkeley scholars examined what arts and culture mean in times of a crisis where they discussed how the community is changing during Covid-19, and what arts and culture

can offer worried, lonely individuals fearful of an invisible virus (UC Berkeley, 2020). Furthermore, a recent interview of the CEO of The Creative Coalition published in The Chronicle Of Philanthropy highlights the value of arts as a resource, both spiritually and economically which cannot be overlooked in this crisis (Mento, 2020). In addition to this, a recent study by American For The Arts showed that 89% of organizations suggest have been delivering artistic content to raise community spirits and morale during social distancing/quarantine (Cohen, 2020). In addition to this, the CEO of Creative Coalition in a recent interview describes the urgency of pandemic related public art and its long term impact on culture and societies as "While a lack of arts in this nation is not going to kill us immediately, a slow painful death of culture will negatively affect our citizenry and its survival" (Mento, 2020, para. 8).

1.3 Research Scope: Toronto Art Strategy Paper 2020-2030

I discovered the local landscape of pandemic related public art in Toronto. After reviewing the Toronto Art Strategy Paper 2020-2030 by the City Of Toronto (2019), I observed that there is a potential of including a framework for pandemic and crisis-related public art engagement as currently pandemic or crisis-related themes are absent. This paper was drafted with the direction from the Economic Development Committee to consider the recommendations of Redefining Public Art in Toronto, a study led by OCAD University and the University of Toronto (City Of Toronto, 2019). The Toronto Art Strategy paper 2020-2030 has a vision – the city will deliver on the Toronto Public Art Strategy's vision of creativity and community, everywhere through 21 actions (Figure 51 in Appendix A), underpinned by a commitment to advancing truth and reconciliation with Indigenous communities through public art. Their purpose is to benefit citizens and visitors by focusing on three key principles- creativity, community, and everywhere. However, the framework could include pandemics (Covid-19) which is currently missing from the strategy and is mandatory due to the long-lasting impact that Covid-19 is or will leave on Canadians. And according to the Toronto Arts Council, 90% of Torontonians believe that the arts make Toronto a better place to live (Toronto Arts Council, 2020). Due to the gap of a pandemic

related framework from the Toronto art strategy paper, my current pursuit requires urgent attention in filling this gap.

1.4 Research Motivation - Bridging Goal and Scope

This thesis lies in the intersection of a pandemic (Covid-19) and the vision published by the Toronto Art Strategy Paper. As a result, the findings from this thesis will contribute towards making a public art framework for pandemic or crisis. As shown in Figure 3, I have explored the vision of the Toronto Art Strategy Paper which is creativity, community, and everywhere, and discovered potential opportunities and technology stack to investigate the intersection of themes for this thesis. In this thesis, "creativity" is mapped with "sentiment visualization & interactive installation" because during a pandemic there is a need for interactive work. "Everywhere" is mapped with "Smart cities - Internet Of Things (IoT) & Context-Awareness" because of Toronto's smart city vision as well as making public art available online. "Community" is mapped with "sentiment analysis of citizens" because understanding community emotions and their reflection are key due to societal impact from Covid-19. The vision of the Toronto Art Strategy Paper is mapped on the themes of my research and are the areas of investigation for HeartBeat. Figure 4 defines the intersection of the aforementioned themes. Sentiment analysis and opinion mining is the field of study that analyzes people's opinions, sentiments, evaluations, attitudes, and emotions from written language. It is one of the most active research areas in Natural Language Processing and is also widely studied in data mining, web mining, and text mining (Liu, 2012). Mbryonic Ltd (2019), however, suggests an interactive installation is an exciting way to activate a physical space through technology, sound, and light that responds to you. They consequently turn people from passive audiences to engaged active participators.

It is important to consider that creating a pandemic related public framework is a diversified space. Each community or municipality has its own space, audiences, priorities, and backgrounds. Some

might require a large sample of diversified data along with multiple sources of data to conduct sentiment analysis. However, they all share the societal impact of the pandemic in different ways. For example, communities where the pandemic had limited impact as compared to those worse affected. In this thesis, I have focused on using the vision of the Toronto art strategy paper (Figure 4) to explore a pandemic by focusing on English speaking Twitter population in Canada to understand the sentiments of the community during the pandemic period, and use timeline case study and selected expert interviews for evaluation.

Toronto Art Strategy Paper – three pillars of Vision (City Of Toronto, 2019)	**Intersection of Thesis Keywords**	**Problems from pandemic**
Creativity: Public art transforms the City's urban fabric, telling stories about who we are and where we live	Interactive sentiment visualization & Interactive Installation	Need for interactive and engaging public art during the pandemic
Everywhere: Public art can provide opportunities for residents to engage with the city's diversity and creativity on an everyday basis, no matter where they live	Smart Cities - Internet Of Things & Context Awareness	Adapt Toronto's smart city vision while making public art accessible online due to lockdown situation
Community: Through creative, savvy digital tools, and engaging educational and interpretive programming, the strategy charts a course to better connect the public to public art.	Sentiment analysis of citizens	The Societal impact of Covid-19 leading to the need of understanding and reflecting what society is feeling

Figure 3: Intersection of research themes with the vision in the Toronto Art Strategy Paper.

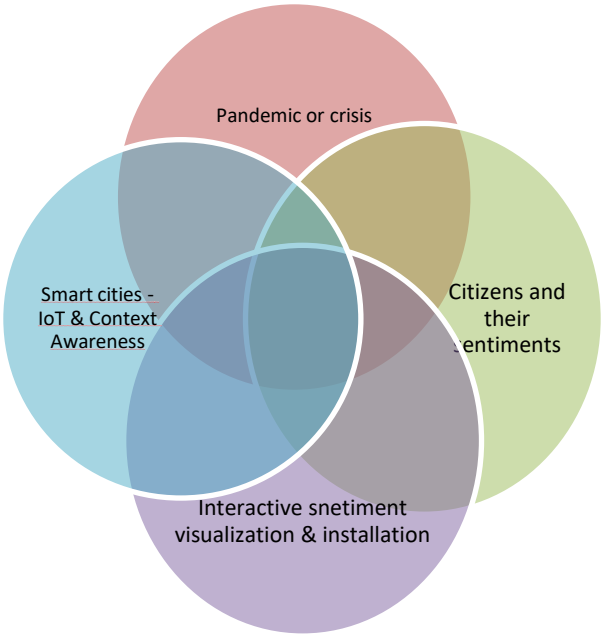


Figure 4: This thesis lies in the intersection of pandemic, community (citizens and their sentiments, everywhere (smart cities, IoT & context awareness) and creativity (interactive sentiment visualization and installation)

1.5 Research Questions

As a result of my personal and long-term motivation for pursuing civic engagement projects as mentioned earlier, I have taken the endeavor to bridge interactive public art and emotions of citizens during Covid-19. I am investigating how might an interactive installation reflect the sentiment of a city (using Twitter) during a pandemic such as Covid-19. This has two layers. Firstly, create an installation(virtual/physical) to reflect the sentiment and emotions of Canada during the Covid-19 pandemic. Secondly, understand the dynamics and methodologies to explore research questions. My research questions are as follows:

- How might public art installations reflect the sentiment of communities in a pandemic?
- How can an Internet Of Things (IoT) enabled interactive installation reflect the sentiment of a city (using Twitter) during a pandemic such as Covid-19?

- How can I strengthen the relationship between creativity, community, and everywhere to create a pandemic related framework?
- In what ways IoT, context-aware design, and technology stack can be used to showcase and create interactive installation during a pandemic?
- How can a pandemic related interactive installation be evaluated using experts to understand the meaningfulness of the framework and interactive installation?

1.6 Contribution & Significance Of The Overall Project

This thesis will contribute towards the pandemic related public art in several ways.

1. It provides a deep horizon scan of the literature covering various disciplines such as sentiment analysis, pandemic related public art, sentiment visualization in smart cities using IoT, design methodologies, and interactive art. This thorough discussion highlights the methods available to understand the emotions of citizens during a pandemic, and the role of IoT to make public art available everywhere and explore interactive and context-driven opportunities.
2. It contributes a detailed process design and technology stack architecture for an IoT-enabled interactive installation to reflect the sentiments of citizens during a pandemic. The installation uses sentiment analysis tools, IoT, context awareness and interactive visualization for both online and hybrid versions for exploration by using the technical documentation provided in this thesis. Moreover, HeartBeat could be embedded into third-party (as it's HTML-based) websites such as news publications. The entire process encapsulates a user-center designed approach which is discussed in this thesis.

3. It has many advantages for using the pandemic related public art framework such as community building during crisis described in this thesis for various cities and countries who are keen to bring the civic engagement back in their communities due to Covid-19.
4. HeatBeat, which is an interactive installation to reflect the sentiments of citizens during the pandemic, offers new avenues for artists exploring the pandemic to consider these design choices and methodologies. The goal of HeartBeat is to present a pandemic related public art framework by using the vision of the Toronto Art Strategy Paper (community, creativity and everywhere). It further allows artists to take Heartbeat and add-on more tools and nuances to create an engaging interactive public art for pandemics within their localities.
5. Finally, a recent study by Ceron and Negri (2015) showed that policymakers could significantly beneficiate from data freely available from social media, thereby enhancing institutional responsiveness, accountability, and learning. As a result, this interactive installation reflecting the sentiments of citizens during a pandemic could contribute towards richer policies.

1.7 Chapter Overview

This chapter gave the orientation of the HeartBeat research project and showcases the motivation, rationale, goals, gaps, urgency, and the contribution and significance of this project.

Chapter 2 is a contextual literature review of several important themes of this research topic. It commences with describing the pandemic and its societal impact; how public art in crisis has helped cities in the past; And also the gap in the current Toronto Art Strategy Papers to offer a framework for pandemic related public art. These discussions then link with how the concepts within the vision of community, creativity, and everywhere might be transformed to understand sentiments on the Twitter, technology stack, use of IoT and context awareness, and interactive installations pertinent to HeartBeat.

Then, I discuss the related public artwork and its strengths and weaknesses. I later summarize the chapter by narrowing down the opportunities available to create an IoT-enabled interactive installation to reflect the sentiments of citizens during Covid-19.

Chapter 3 shows the methodology practiced to create HeartBeat. It illustrates and discusses the human-centered design method, research through design, and the various phases within that method. At the onset of the chapter, I discuss the need-finding for the pandemic related public art which directed the initial and final phases of HeartBeat design. Followed by a detailed discussion on the development, technology stack, and process design that was adopted to create HeartBeat. I conclude the chapter by discussing the selected evaluation criteria for HeartBeat which is based on a case study evaluation of a pandemic timeline and semi-structured interviews with selected experts in the field of design, public art, data journalism, and advertising.

Chapter 4 discusses the results of the timeline case study evaluation along with quantitative and qualitative findings from the experts using the evaluation methodology adopted for HeartBeat. Later, these outcomes are discussed to explore the pros and cons of the HeartBeat design.

Chapter 5 summarizes the HeartBeat project by revisiting its rationale, goals, and contributions. It covers what I have learned from this project and highlights potential future work for potential creators following the evaluation findings.

Chapter 2- Context and Literature Review

The need for a pandemic related public art and its intersection with an interactive installation, to reflect the sentiments of Canadians is intricate and requires thorough research on various fronts. In this chapter, I cover the pertinent literature to my research along with past and on-going related works. First, I define the concept of pandemics, Covid-19, and public art as described in various literature sources as well as the impact of the Covid-19 on societies. I also call attention to the issues arising due to Covid-19 such as social and cultural and why societies around the world are showing an urgent need for public art in these times to curb these effects. I also highlight gaps from the Toronto Art Strategy paper when it comes to a pandemic related framework and provide selected works of public art from past pandemics. I cover cases on how public art has benefited cities.

Then I use the vision of the Toronto Art Strategy Paper which is community, everywhere, creativity, and discuss how I have mapped each of those elements to review literature for HeartBeat. I start with community and review the research in the field of sentiment analysis of users from Twitter during Covid-19 and various emotion models to reflect the sentiments and emotions of Canadians. I, then use everywhere to discuss how the Internet of Things (IoT), Context-Awareness, and frameworks of smart cities could be utilized to create public art that could potentially be available everywhere. Following this, I discuss creativity and the use of interactivity in sentiment visualization and interactive installation.

Lastly, I cover related work pertaining to Covid-19 in Toronto and discuss potential gaps. I also discuss other non-pandemic related work within sentiment visualization and interactive installation to learn about the pulse of citizens in various applications, such as sentiments, proximity etc. As a result of this theoretical literature review, I was able to evaluate potential streams made accessible using

interactive digital media to reflect the sentiments during a pandemic using an Internet of Things (IoT) enabled interactive installation.

2.1 Pandemic & Public Art

This section sets out to discuss the main definitions of pandemics, crisis, public art and highlights the impact of Covid-19 on societies. Finally, it shows the need from art societies around the world for pandemic related public artwork to curb the impact.

2.1.1 Definitions

According to (World Health Organization, 2010, para. 1), "a pandemic is the worldwide spread of a new disease." The outbreak Covid-19 is defined as "Coronavirus disease (COVID-19) is an infectious disease caused by a newly discovered Coronavirus" (World Health Organization, 2020b, para. 1). Moreover, on March 11, 2020, the Director-General of the World Health Organization (WHO) declared Covid-19 as a pandemic by stating "We have therefore made the assessment that COVID-19 can be characterized as a pandemic" (World Health Organization, 2020d, para. 4). There were many pandemics before WHO existed. WHO's Constitution came into force on 7th April 1948 (World Health Organization, n.d. -a). There were various pandemics in the past as highlighted by the Centers for Disease Control and Prevention(CDC). These include the 1918 Pandemic (H1N1 virus), 1957-1958 Pandemic (H2N2 virus), 1968 Pandemic (H3N2 virus), and 2009 H1N1 Pandemic (H1N1pdm09 virus) (Centers For Disease Control And Prevention, 2018). In addition to that, the crisis is described as follows:

> "A situation that is perceived as difficult. Its greatest value is that it implies the possibility of an insidious process that cannot be defined in time, and that even spatially can recognize different layers/levels of intensity. A crisis may not be evident, and it demands analysis be recognized." (World Health Organization, n.d. -b, para. 30).

According to the City of Toronto (2019), public art is work in any medium that has been produced by an artist, installed in a publicly-accessible space. This includes digital spaces such as web-based media. This also includes several elements (a) public art can take many forms; (b) public art can be permanent or temporary; (c) public art is a platform for artists and (d) public art is designed for publicly accessible spaces and is intended to the public (p.4)

2.1.2 Covid-19 Societal Impact and Urgency of Public Art

In this subsection, I first discuss the societal impact from Covid-19 and the need for reflecting sentiments during the current pandemic followed by urgency shown by global art societies to create pandemic related public art.

The impact of Covid-19 on societies around the world has created an immediate need for pandemic related public art. The lessons drawn from the current response to the Covid-19 pandemic strengthens the need for pandemic related public artwork frameworks and the gap in understanding the sentiments of citizens during the pandemic. For example, a recent study found sentiments from Twitter, such as misinformation about COVID-19, are circulated more on Twitter as compared to traditional media (Bridgman et al., 2020). Furthermore, the lessons drawn from the response on Covid-19 are below which also shows similar data (Chamola et al., 2020). Each of these lessons was a result of the pandemic related interventions proposed by Chamola et al. (2020). This influences the time period I chose for analyzing tweets.

- Lack of transparency
- Delayed travel restrictions
- Delayed lockdown measures

- Public misinformation
- Announcement delays
- Cognitive bias
- Insufficient stock of Personal Protective Equipment (PPE)

On another platform, a gap in understanding the sentiments of citizens was highlighted during Covid-19. Devine et al., (2020) points out lack of trust, after key analysis of case studies during Covid-19 and the government, and describes "trust is going to be critical for the path out of the current crisis. It shapes, and is shaped by, policy responses in complex ways. And after the crisis, governments will need to rebuild trust in what will likely be a very different policy landscape both nationally and internationally" (p. 9).

Moreover, the importance of reflecting voices and sentiments of Canadians from the impact of Covid-19 is pointed out by the Government Of Canada (2020) where the president of Social Sciences and Humanities Research Council (SSHRC) of the Government of Canada highlights solving the impact of Covid-19 from the lens of social sciences and humanities. Moreover, Kozlowski et al. (2020) also highlights the scarring effects from Covid-19 on societies which may include a change in beliefs towards negativity.

> “SSHRC takes a deeper look at the research response to the COVID-19 pandemic through a social sciences and humanities lens. Our first theme explores the social inequalities created and exacerbated during this pandemic. We’ve curated content from voices within Canada’s social science and humanities research community that are bringing to light the differentiated impacts of the pandemic. This research is vital to ensuring that Canada emerges from this period with

more insight into the problems and solutions facing many segments of our population." (Government Of Canada, n.d. p.1)

On the other hand, there has been an urgency around the world to create pandemic related public art to minimize the impact on societies from Covid-19. In a recent expert panel discussion by UC Berkley (2020) on art during a crisis, experts highlighted the following:

> "During a crisis, the normal structures of our life which we take to be determined, and necessities, suddenly fall away. You find you can live life artistically, you can create a different way to live, you can create yourself. Your life is not path-dependent, the way you thought it was. During the COVID-19 pandemic, We understand that communality is a necessity. We can hope that this ability to reshape life will be something that is taken away from this crisis. … We will see new ways of relating to one another that won't be determined by the crisis, but will be a result of the creativity we can see that is possible in our (new) ways of living." (UC Berkley, 2020, para. 6-7)

As a result of this impact, there are multiple calls being made to create public art during a pandemic. Such as the UK gallery curator calls for a public art project in response to Covid-19 (Guardian News & Media Limited, 2020). According to the joint statements of Italian, German, and Spanish Ministers, there is an urgent need for all kinds of art during this crisis:

> "We are still unable to imagine the repercussions on our economy. We still don't know how many of us will lose loved ones, people we know or are acquainted with, with whom we share this earth. Full of dismay and pain we commemorate together those who have lost their lives as a result of the virus. What would become of us in a time like this, without books, films and music in which to find refuge and support? What would our societies be without those who created

them? Without artists. We are therefore even more determined to protect our most precious asset: our faith in solidarity and the power of culture" (Franceschini et al., 2020, para. 8).

Furthermore, another urgent need for public artwork was highlighted in Charlotte during a recent interview by Barb MacLeod, chairwoman of Charlottetown's arts advisory board, stressing the need for public art during these times (Stewart, 2020). Several benefits of art during quarantine and crisis were suggested by Guzman (2020):

> “Artists are explorers, healers, activists, and visionaries. Making art is essential to speak truthfully to power, to dream with new realities, and ultimately to change the world. It is possible, even in quarantine. I think about Frida Kahlo, who made her first portraits confined in her bed, recovering from that tragic bus accident in which her body was severely injured. I think about the indigenous traditions of telling stories, I think about media arts, so contemporary not only in their message, but also in their medium; and the thousands of ways in which humans trust in artistic representations to make sense of changes and crisis.” (para. 12)

With the impact of Covid-19 on various fronts in the society such as sentiments, inequalities, etc. I agree with the suggestion about the urgent need for a pandemic related public framework as discussed above in detail. In the following subsection, we review the local landscape of Toronto and scan Toronto Art Strategy Paper, its mission, and challenges.

2.1.3 Gap in Toronto Public Art Strategy Paper 2020-2030

This section highlights the importance of public art through the lens of the Toronto Art Strategy Paper and the gap that is observed when it comes to a pandemic related public art framework.

The rise of public art in Toronto has been driven by key collaboration between various stakeholders such as the City of Toronto and various councils. This helped them to deliver three core

public art programs, namely, City of Toronto Public Art and Monuments Collection, the Percent for Public Art Program, and StreetARToronto((StART) (City Of Toronto, 2019). These programs have escalated and generated a huge impact on the city's local scale, as well as internationally. However, it has been further highlighted in the Toronto Art Strategy Paper about the potential for Toronto to be a leader in global public art by focusing on priorities such as equity and inclusion amongst many others. There are many successful programs currently running such as the (StART) which supports graffiti and street art and its issues.

This strategy paper was a joint collaboration of the Economic Development Committee, OCAD University, and the University of Toronto to set the vision categorized into creativity and community, everywhere. Firstly, creativity is focused on telling stories about the citizens and where they live and their discovery through art. This includes work such as the interactive sound installation: Public Studio with Anna Friz, called the 120 Mirrors. Secondly, the community is focused on a continued commitment to public art to better connect the public through art. Thirdly, everywhere empowers the thought that citizens should have accessibility to the art from anywhere (City Of Toronto, 2019).

During my investigation, I discovered that there is no coverage of pandemic related public art frameworks within the paper. Thus, I have used the strong and inspiring vision of the paper (creativity, community, and everywhere) to investigate opportunities that could contribute to the missing gap of a pandemic related framework for public art which could make the smart city even more inclusive by improving access to information and data (Figure 1).

The gaps I have highlighted above is further strengthened by how the City of Vancouver's cultural services stresses the urgency for an immediate need for art and culture, due to the current pandemic, to support the society as they suggest "now is a time where arts and culture are needed more than ever" (City Of Vancouver, 2020, para. 1)

2.1.4 Public Art During Past Pandemics & Crisis

Public art has been used during various pandemics and crises in history. The role of public art during past pandemics is strongly discussed and described in the following excerpt during an interview where the author also pleads for a quicker and immediate urgency during Covid-19. (Sirju, n.d)

> "I have the catalog from our show sitting on my desk. I find the cover image, which I referred to earlier, especially engaging now: Saint Charles Borromeo among the Plague-Stricken of Milan. It's by a French painter, Pierre Mignard, a work he did in Rome. It's a very engaging painting of the sacrament of the Eucharist, bringing it to plague victims —who are being portrayed, probably quite realistically, as in pretty bad shape —reaching out to him. He's bringing some kind of hope to them. Above them is incense; people thought the plague was easily transmitted through the air — actually the bubonic plague was not, but they didn't know that; turns out it was transported by infected fleas. But they thought "bad air" was the main problem, so incense was thought of as a way of fighting it. So that's all part of it, too: There are things we don't understand [about COVID-19] and future generations might think, Boy, were they naïve in 2020 and slow to understand." (Sirju, n.d, para.17)

Smallpox of 1884 was a major pandemic. Figure 9 shows an illustration depicting quarantine (State Library Victory, 1884). The Spanish flue holds an important era in the scope of pandemics, as popular artist such as Egon Schiele was paramount. The painting (Figure 10) "the Family" is one of the most quiet and sad Schiele. It depicts the artist himself, his wife Edith harms, and their unborn child. According to Sidelnikova (n.d.), it reflects the emotions of doom, terror, and pain that they were going through.

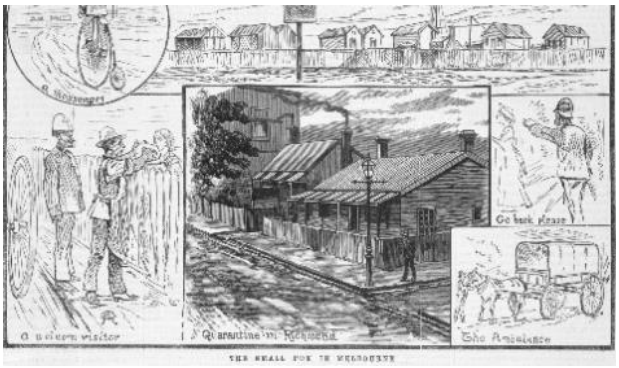


Figure 9: Sketch of a scene from Smallpox(1884), Australia.

Note. Quarantine in Richmond (State Library Victory, 1884)

Figure 10: Self-portrait and reflection of sentiments during Spanish flue, Egon Schiele (Austrian Gallery Belvedere, n.d.).

According to the U.S. Department Of Health & Human Services. (n.d), the timeline reflects the history of the domestic HIV/AIDS epidemic from the first reported cases in 1981 to the present. Several public arts have been installed in this domain such as the installation (Figure 11a) which shows the word

“LOVE” replaced with “AIDS" to change the sentiment around AIDS. On the similar subject, a Canadian artist Andy Fabo (Figure 12) began documenting LGBTQ+ community for AIDS (Dupuis, 2019).

Figure 11a: Love sculpture for AIDS (Smith, n.d.).

Note. Attracted by the fluidity of this image, which travelled internationally, General Idea made a visually similar painting, but replaced the word “LOVE” with “AIDS” (Figure 11b). (Smith, n.d.)

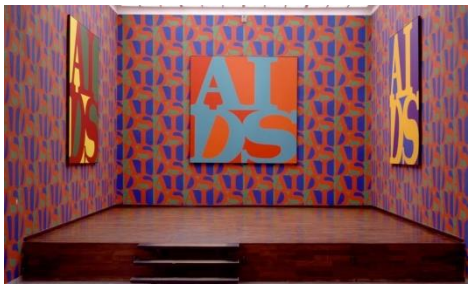


Figure 11b: General idea’s artwork for AIDS and how it was used in Figure 11 for the Love sculpture for AIDS (Smith, n.d.).

Figure 12: Andy Fabo's Delirious at the Borderlines. (Dupuis, 2019)

This signifies that public art during past pandemics has played a huge role in reflecting sentiments in various ways and thus there is an immediate gap to be filled for a pandemic related public art framework. Moreover, the U.S is creating national research and strategy initiatives to help strengthen communities around the U.S., during and after COVID-19. Culture + Community has highlighted that leading with empathy is key through cultural sites, which could help bring positive experiences back to the society (Culture + Community In A Time Of Crisis, 2020). In the next subsection, I cover cases where public art has benefited cities.

2.1.5 Role of Public Art In Benefiting Cities

There are various cases of how public art has benefited cities at the right time. I have covered some cases below. Zitcer and Salina (2020) suggest three key elements for public art, which are time, place, and voice of artwork. This reinforces the timing of a pandemic such as Covid-19 and public art. Lessoff (2000) has covered various cases on effects of permanent public art after reviewing Malcolm Miles's Art, Space, and the City: Public Art and Urban Futures. Furthermore, benefits are well described for urban regeneration including the 'Barcelona model' which focuses on the design and quality of public urban space as success stories (Sharp et al., 2005). The role of public art during pandemics could

be further supported by Betsy Damon (2021) where the author describes using public art with, for, and by the public and describes it as the heartbeat of the community.

Case 1. The regeneration of the Northern Quarter (NQ) near Manchester, U.K, has been through a partnership between local traders, residents, and the City Council. The NQ had declined economically, and the physical environment had worsened. In 1993, Manchester City Council rendered a study from the arts consultancy Projects Environment, which recommended that the NQ would benefit from a local community artist who could help initiate and focus creative activity within NQ. As a result, Projects Environment jointly sponsored with the City Council the appointment of an artist-in-residence for a duration of 6 months to recommend policy shifts and co-ordinate individual projects. This appointment escalated the overall regeneration of NQ which made this regeneration project in the NQ unique. The leading outcome of the project has been the development of the positive sense of NQ in the Manchester region, enhanced image and perception, and major regeneration (Wansborough & Andrea, 2000).

Case 2. Katara Cultural Village is a tourism development project located in Doha, near West Bay. The findings reveal the main advantages and disadvantages of introducing public art to an urban space, namely in regard to acceptance, culture, and social behavior. In addition, the study helps identify new ways to use public art to enhance public interactions and participation in new urban environments (Suwaidi & Furlan, 2017).

In the subsections ahead, I discuss the vision concepts of community, everywhere, and creativity which is the vision of the Toronto Art Strategy Paper, and map it with the themes of HeartBeat. I commence with discussing pandemic and non-pandemic related digital approaches for sentiment analysis and point out several psychological emotion models that form the premise for those approaches. I also highlight potential gaps that could assist in exploring opportunities for my research

goals. Then I discuss the use of the Internet Of Things and Context Awareness by using the goals of smart cities and how it could be beneficial for HeartBeat. Lastly, I cover the dynamics of interactivity in sentiment visualization and interactive installations in order to explore options and avenues in technology and design stacks for the HeartBeat and its design system.

2.2 Community: Sentiment analysis

2.2.1 Approaches

"Sentiment analysis" is a key attribute of my thesis as this is mapped with "community" which is one of the key visions of the Toronto Art Strategy Paper as mentioned earlier (Figure 1). Understanding the sentiments of an individual has been studied for a long period of time. However, with the advent of human-computer interaction, newer computer-based models have come to the global marketplace to help understand emotions even more. This offers a great premise to survey approaches, methods, and applications to be used for HeartBeat. Sentiment analysis and opinion mining is the field of study that analyzes people's opinions, sentiments, evaluations, attitudes, and emotions from written language (Liu, 2012). In this thesis, I have used sentiment and emotions interchangeably. The term sentiment analysis is widely interchanged with emotion analysis and others due to their related fields (Ahmed et al., 2016).

Most commonly, there are two approaches that are practiced. Firstly, subjectivity, which Pang & Lee (2008) describe as opinions, evaluations, emotions, and speculations all fall into this category. Secondly, polarity, which the authors describe as classifying either positive, neutral, or negative from the text. Furthermore, comparison of these two approaches has been complex, and finding improvements in subjectivity classification can have a better impact on sentiment classification (Mihalcea et al., 2007).

Within these approaches, there are several ways of classification which are highlighted by Sailunaz (2018) for Twitter: Firstly, the keyword-based model matches words from a tweet, based on the dictionary provided by the researcher. The dictionary varies for various researchers. Moreover, the

author used synonyms for each emotion and words were collected from various online English dictionaries. In addition to this, Strapparava & Valitutti (2004) used a WordNet-Affect library in a similar study. Other ways of classification summarized by Sailunaz (2018) show a Lexicon-based method where emotion lexicon is used as opposed to the prior approach where words are matched from a dictionary. Also, the machine learning model involves training the classifier model for training the data. Lastly, there are hybrid approaches that utilizes the mixed approaches. It also investigates the complexity of understanding emotions, even after using complex machine learning models, and the gaps in learning sarcasm. Moreover, Sailunaz also concluded that text analysis performs better than other mediums of expression and also found that text keyword-based and lexicon-based performed better but machine-learning models appeared far more accurate with larger datasets.

2.2.2 Emotion Models

To perform emotion analysis, there are several models in practice today. This includes Ekman's 'Big Six' basic emotions: anger, fear, happiness, surprise, disgust, and sadness; Dimensional models describe emotions in terms of continuous spaces along axes such as valence/pleasure, arousal, and dominance; Plutchik's wheel of emotions (Kucher et al., 2018) and Johnson-laird and Oatley model (Sailunaz, 2018). Various models offer several limitations and are used by researchers based on their own requirements. For example, Ekman's model, Johnson-laird and Oatley model, and Shaver's emotion model offer a limited range of emotions (Figure 52). But the limitation of these models is that it focuses on only selected basic emotions. On the other hand, the Circumplex model is the most used emotion classification model. For example, the circumplex model of affect (Russel, 1980) and Plutichk's wheel of emotions both offer a wide range of emotions (Figure 52). Moreover, Plutchik's wheel of emotions performs better than Mehrabian-Russel 's three-dimensional Pleasure-Arousal and Dominance (PAD) paradigm, in predicting verbal descriptions such as words rather than deeds (Havlena et al., 1989). In line with Havlena et al. (1989) research, this thesis is also using words for sentiment analysis, thus

Plutchik's wheel of emotion serves as an optimal model. Similarly, in another study, Plutchik's color wheel provided the authors to clearly perceive the "closeness" between arbitrary pairs of emotion categories (Benini et al., 2011).

Model	Emotions
Ekman[38]	Anger, Disgust, Fear, Joy, Sadness, Surprise
Shaver[39]	Anger, Fear, Joy, Love, Sadness, Surprise
Oatley[40]	Anger, Anxiety, Disgust, Happiness, Sadness
Plutchik[41]	Acceptance, Admiration, Aggressiveness, Amazement, Anger, Annoyance, Anticipation, Apprehension, Awe, Boredom, Contempt, Disapproval, Disgust, Distraction, Ecstasy, Fear, Grief, Interest, Joy, Loathing, Love, Optimism, Pensiveness, Rage, Remorse, Sadness, Serenity, Submission, Surprise, Terror, Trust, Vigilance
Circumplex[42]	Afraid, Alarmed, Angry, Annoyed, Aroused, Astonished, At ease, Bored, Calm, Content, Delighted, Depressed, Distressed, Droopy, Excited, Frustrated, Glad, Gloomy, Happy, Miserable, Pleased, Relaxed, Sad, Satisfied, Serene, Sleepy, Tense, Tired

Figure 52: Comparison of number of emotions for various emotion models showing a wider range of emotions for Plutchik and Circumplex model of affect (Sailunaz, 2018).

Plutchik's wheel of emotions has a wide set of emotions derived from basic emotions that can be combined to offer various other emotions. There are 8 primary emotions and with their high and low intensity, totaling 24 emotions. Chafale & Pimpalkar (2014) describe Plutchik's wheel of emotions as a model with eight primary emotions with four opposite emotion pairs, showing the 8 basic emotions, while

primary emotions can also be expressed at different degrees of their intensities, for each emotion, there are three degrees. The basics are grouped into polar opposites (Figure 5): Joy and sadness; Acceptance and disgust; Fear and anger; Surprise and anticipation. Combinations of two primary emotions are called "secondary" emotions. The remaining 8 emotions on the topmost layer such as love etc. are the combinations. Moreover, Plutchik adopted the color metaphor to describe that emotions closer to each other are easier to fuse than the ones further apart, which may cause conflict when combined (Fritz, 2009). Furthermore, Jarymowicz & Imbir (2014) describe the same model in psychological terms that mixing basic emotions with their appraisals results in new emotional qualities, feelings, and consequences. According to TenHouten (2005), one of the reasons for considering primary emotions is that they can be found in a wide range of human cultures, and they examined that Plutchik's wheel provides stronger reasoning for using this emotion model. This is key for Canada which has an inter-cultural population.

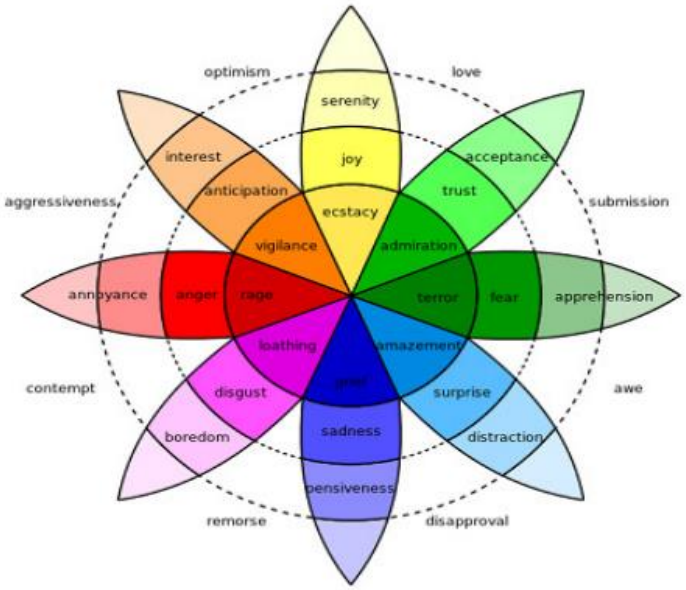


Figure 5: Plutchik's wheel of emotions (Chafale & Pimpalkar, 2014).

Note: Due to the vast library of words available in Plutchik's wheel, it could be used for sentiment analysis using Twitter to count these words from Tweets but also provide opportunities for intensity of emotions

2.2.3 Related Applications

Several applications are using similar approaches and models. Twitter has been used by several studies for pandemics such as H1N1 (Signorini et al., 2011). Tomp & Pechenizkiy (2014) used Tweets in English, German and Dutch to discuss current methods of sentiment analysis, ranging from advanced neural networks to simply polarity-based analysis, such as sentiments being positive, negative, or neutral. They proposed to use Plutchik's Wheel of emotions for three reasons: complete, compact, and displays emotions as opposites of each other. Various pertinent studies have used filtered Covid-19 related tweets such as Corona etc. to find the popular topics for analysis. For example, Kabir & Madria (2020) created a module to listen to the stream of tweets and try to check if a tweet contains the word 'Covid-19', or 'coronavirus' in it by using Python's Tweepy (Tweepy, n.d) package. While checking the module, they converted all the text to lower case and attempted to find out sub-string within the text. By doing this, the module identified a qualified tweet and saved any tweet that contained words like 'Covid-19' as a single word or as a part of the word. Similarly, another recent study focused on a textual corpus consisting of Tweets filtered by "Coronavirus" as the keyword which showed resulted in fear sentiment and negative sentiment (Samuel et al., 2020). According to Manguri et al. (2020), COVID-19 and #coronavirus related tweets showed sentiment percentages of 13% and 7% of the tweeters involved who felt the feeling of content and hopefulness, respectively. Sanders et al. (2020) analyzed sentiments about Covid-19 and the usage of masks, and one of the key findings from their work was that people have been reacting to news about the shortage of N95 respirator masks in the US. Furthermore, another study showed sentiments during Covid-19 with 11 topics using Plutchik's wheel of emotions and Twitter after cleaning the tweets such as URLs, etc. (Xue et al., 2020).

The above studies show that when tweets are filtered for Covid-19 related tweets, the results are usually negative and only related to Covid-19, and are deprived of the overall sentiment during the

pandemic period which is fundamental for HeartBeat. This is key because we are living in a diversified community, where the pandemic is different for various regions and the interventions implemented by the government also vary. This results in varied sentiment amongst the communities and will be reflected in HeartBeat.

As mentioned earlier, researchers use emotion libraries widely. Pertaining to the use of emotion dictionaries, Nemes & Kiss (2020) in their recent Covid-19 related study used classical dictionary-based analysis, and had a pre-set vocabulary where each word was assigned a value. Moreover, Sailunaz (2018) used synonyms for each emotion, collected from various online English dictionaries for their study on emotion detection using Plutchik's wheel of emotions.

There also several non-Covid related sentiment analysis studies which helped shape the sentiment model for HeartBeat. Arunachalam & Sarkar (2013) investigated Twitter sentiment analysis to understand the views of citizens with respect to government programs in the UK. Their research was divided into defining the analysis model which included topic modeling (selection of the tweets for one pertinent program), sentiment lexicon, and Hotword. Hotwords are the parameters that are common across the defined topics of interest such as income support for government programs. Secondly, they performed an analysis with Hotword and sentiment of citizens for the selected program. The result was sentiment placement (positive, negative, neutral, and ambivalent) with respect to various topics such as employment, education, home loans, pension insurance, disability compensation, and dependent's assistance. Moreover, Grandi & Neri (2014) used opinion mining and sentiment analysis through Twitter for the city of Bologna to provide actionable insights about the city's tangible and intangible features.

Several similar applications are found related to politics and finance such as what voters are thinking (Pang & Lee 2008). Bollen et al. (2011) investigated the sentiments of users on Twitter and how it relates to cultural, social, and other events happening in 2008, using a six-dimensional model of mood.

This model constituted of tension, depression, anger, vigor, fatigue, and confusion. This commenced by using two data sources and overlapping them on each other from August to December in 2008. They used the Profile of Mood States (POMS) which is an abbreviated form of the emotional model. To clean the data, they formatted by removing numbers or other characters. The function they developed matches with the same work within the Tweets. Moreover, since time series was important to their research, they then overlapped with a timing function to lay down root and cause. The result showed a wide variety of mood shifts as the period under discussion was marked with important events such as elections and the stock market.

2.2.4 Summary on Emotion Analysis and Twitter

In this subsection, several sentiment analysis approaches, their emotion models, and related applications were discussed. Moreover, I also discussed pragmatic digital approaches used across various fields and their shortcomings. We can summarize from their work several process design guidelines for sentiment analysis that formed the premise of HeartBeat's sentiment analysis engine:

1. Use Plutchik's wheel of emotions, amongst others, due to its wide range of emotions, earlier applications, and its closeness to multi-cultural society such as Canada.
2. Use a text-based approach for analyzing tweets using a library of synonyms for emotions (of the chosen emotion model) from verified online dictionaries – one of the approaches for Keyword based approach
3. Use Twitter streaming API (such as Tweepy) for extracting tweets as it's the most popular and commonly used approach
4. Clean the tweets with URL's, usernames, etc. before analyzing
5. Avoid topic modeling of tweets pertaining to Covid-19 as it may result in negative emotions as highlighted above and ignores overall sentiment of the citizens during the pandemic period

Following my discussion on the community aspect of the vision which provides a thorough base of sentiment analysis engine, I apply key concepts of sentiment analysis in smart cities, use of IoT, and context awareness in HeartBeat which is covered in the next section.

2.3 Everywhere: Smart Cities - IoT and Context Aware

We earlier discussed how "IoT and Context awareness" is a key translation of "everywhere", one of the key visions of the Toronto Art Strategy Paper, and a growing demand for smart cities (Figure 1). Moreover, the City of Toronto further stresses on marching towards a smart city by building a more connected community. Using information and data, which a city needs to help it become an economically, socially, and environmentally-connected community (City Of Toronto, n.d).

Firstly, I examine some definitions in depth. "The Internet of Things allows people and things to be connected anytime, anyplace, with anything and anyone, ideally using any path/network and any service" (Perera et al., 2014, p.3). Another key concept is Context which is described as an entity that is relevant to the audience. “An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves." (Perera et al., 2014, p.7).

Another key contributor for designing interactive applications is about context-awareness. It is defined as "a system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user’s task." (Dey & Abwood, 2000, p.7). Furthermore, during a pandemic such as Covid-19, IoT is assisting the world with fighting the Covid-19 epidemic. This includes 5G epidemic monitoring platforms in telemedicine, Robots/UAVs, Medical Sending (Chamola et al., 2020). Within smart cities, Ahmed et al. (2016) highlights sentiment visualization and real-time sentiment analysis as key opportunities amongst others after surveying various tool and techniques in

sentiment analysis. Moreover, they suggest a robust framework for sentiment analysis applications in smart cities (Figure 16) which could also be a user-friendly interface complemented with interactive graphical visualization capabilities that will permit the use of this system by managers and civic leaders who have no technical programming and statistical background. This assisted me later in applying various pieces highlighted in Figure 16 such as interfaces, libraries, tools, compute engines, data engines, and data sources that form the foundation of HeartBeat.

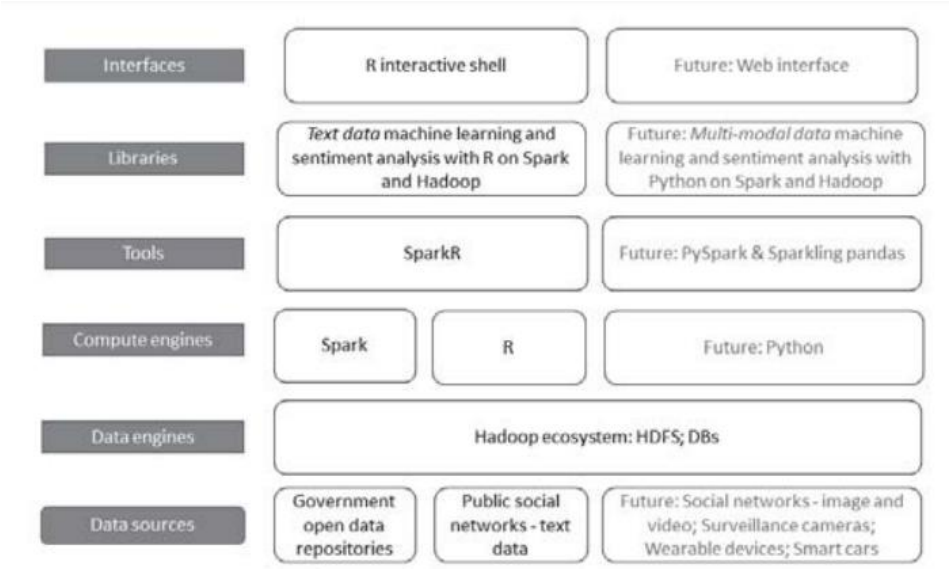


Figure 16: System architecture explaining the backend and frontend tools, data sources, interfaces, technologies etc. that apply when working on sentiment analysis applications for smart cities (Ahmed et al., 2016).

Moreover, Schmidt (2000) further offers design guidelines for context aware systems such as context should be linked with the events or changes that occur in the applications. Moreover, Perera et al. (2014) suggested a context life cycle (Figure 17) which shows context acquisition could be conducted via physical or virtual sensors (such as Twitter) which are then converted into meaningful information (context modeling), deriving high-level context information (context reasoning) and then distributing it

to audiences of that context (context dissemination). This became key for HeartBeat where I used the time period of a pandemic and showed sentiments using Twitter and converted raw tweet data to create meaningful representation using an interactive installation for sentiment visualization.

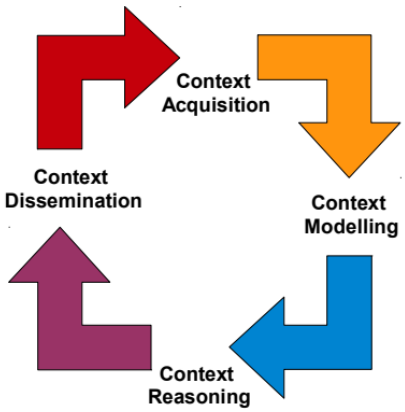


Figure 17: Steps to follow for making an application context aware (Perera et al., 2014).

Both the aforementioned frameworks, context life cycle (Figure 17), and system architecture of sentiment analysis applications for smart cities (Figure 16) provided a robust design framework for HeartBeat which I later used and summarized principles for my design framework. A similar approach was covered by Plomion (2019) during an interview with Niki Selken, creative development lead at Gray Area, who discussed how smart cities could develop incredible public artworks by using open-source data such as APIs.

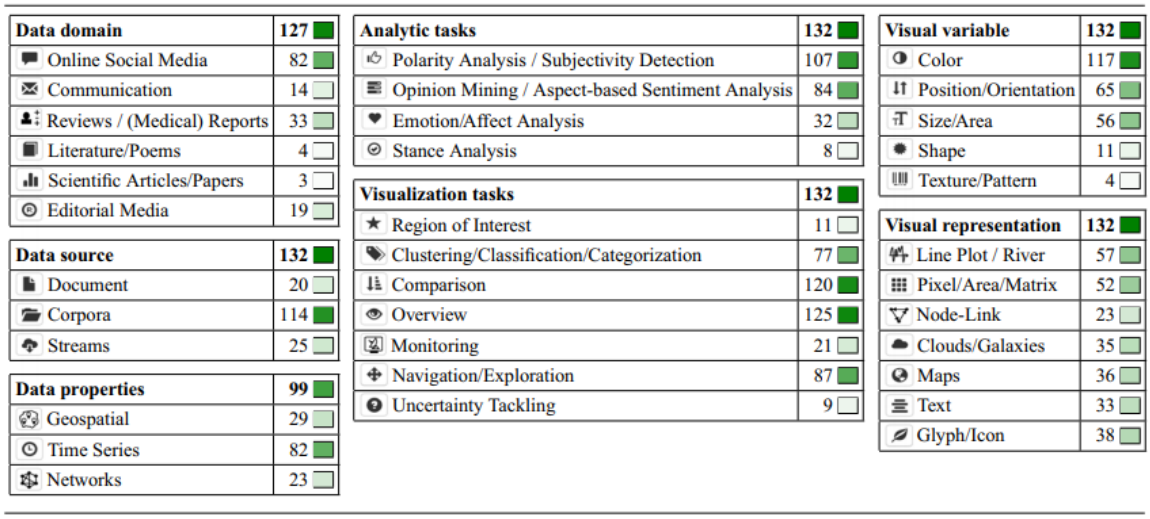
In the next section, I discuss the third and final part of the Toronto Art Strategy Paper's vision creativity using the interactive and visualization opportunities, frameworks, and related examples to tie the aforementioned summaries from sentiment analysis, smart cities, and context-awareness that would later contribute towards HeartBeat's design space.

2.4 Creativity: Interactive sentiment visualization and Interactive Installation

In this section, we survey and discuss the various sentiment visualization techniques practiced today, and their gaps and how an interactive installation can contribute as a technique. This explores the third and final part of the Toronto Art Strategy Paper's vision which is creativity but in relation to the opportunities that I envision to use to complete the pandemic related framework.

Kucher et al. (2018) conducted a detailed analysis of 132 sentiment visualization techniques and offered a comparison of various types and general properties within them such as data domains, data source, data properties, analytic tasks, visualization tasks, visual variable, and visual representation (Figure 18). They found the following key aspects which we later informed HeartBeat's design system:

- The most popular task supported by these techniques was concentrated on offering the audience an overview of the data being analyzed (aggregated or major portion of the data) followed by a technique that compares data sets as opposed to providing the big picture.
- Interpolating colors and position/orientation (counts) were the two most widely used as visualization variables to show different pieces of data
- Basic line plot/river-like-representation and pixel/area/matrix such as pie charts were most popular to make the final visualization.



Data domain	127
Online Social Media	82
Communication	14
Reviews / (Medical) Reports	33
Literature/Poems	4
Scientific Articles/Papers	3
Editorial Media	19

Data source	132
Document	20
Corpora	114
Streams	25

Data properties	99
Geospatial	29
Time Series	82
Networks	23

Analytic tasks	132
Polarity Analysis / Subjectivity Detection	107
Opinion Mining / Aspect-based Sentiment Analysis	84
Emotion/Affect Analysis	32
Stance Analysis	8

Visualization tasks	132
Region of Interest	11
Clustering/Classification/Categorization	77
Comparison	120
Overview	125
Monitoring	21
Navigation/Exploration	87
Uncertainty Tackling	9

Visual variable	132
Color	117
Position/Orientation	65
Size/Area	56
Shape	11
Texture/Pattern	4

Visual representation	132
Line Plot / River	57
Pixel/Area/Matrix	52
Node-Link	23
Clouds/Galaxies	35
Maps	36
Text	33
Glyph/Icon	38

Figure 18: Widely used sentiment visualization techniques such as visual variable, visualization tasks and data properties, amongst others. Some of these were used for HeartBeat such as online social media, color etc. (Kucher et al., 2018).

Furthermore, since the scope of this research includes emotion analysis, key literature is available within sentiment visualization:

- Subasic & Huettner (2000) created a sentiment visualization application which draws star plots to visualizing the affect profiles of web-based content
- The application titled, IN-SPIRE, used a rose plot visualization technique to show affect for various categories such as customer reviews (Gregory et al., 2006)
- Zhao et al. (2014a) visualizes using river-like graphs (Figure 19) by using Plutchik's wheel of emotions along with VAD model to create a visualization system titled PEARL.

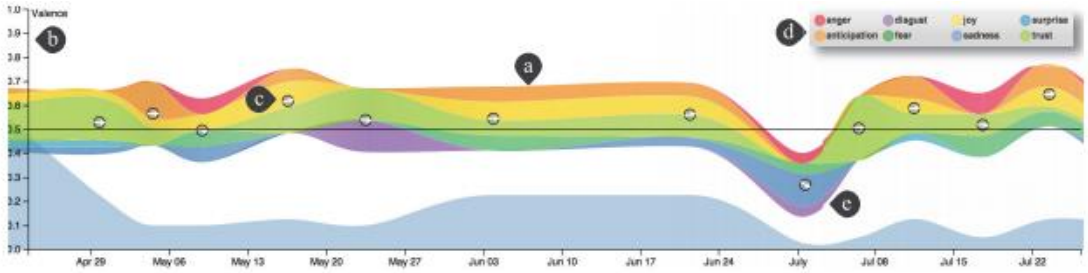


Figure 19: Visualization technique showing river-like graphs to reflect emotions from the Plutchik's wheel of emotions (Zhao et al., 2014a).

While the above sets the basic premise for sentiment visualization but it introduces some challenges. Calderon et al. (2014) suggested that while monitoring social media data in an emergency management situation, there is a need to do more than just automated analysis methods. They suggested the need for merging various visual representations for monitoring tasks including interactions with visual interfaces such as the inclusion of interactive capabilities to explore the streaming information space within the design space. Moreover, Tversky et al. (2002) suggest interactivity facilitates cognitive performance. The importance of interactivity is key here as HeartBeat later developed as an interactive installation with sentiment visualization.

The increasing growth in various forms of media such as sentiment visualization and computer-based art has evolved the meaning of interactivity. According to Smuts (2009), interactivity is defined as mutual responsiveness that has two key aspects: unpredictability but without being random. However, Smuts further suggests that the system would not be called interactive if it becomes unpredictable. This implies that when the user is fully aware of the system and is likely to know what actions will trigger events, such a system is not interactive. Although, I would argue that mutual responsiveness from the above definition is key which is also highlighted as "the fact of allowing information to be passed continuously and in both directions between a computer or other device and the person who uses it"

(Oxford University Press, n.d.). But I slightly disagree with the mandatory condition of a system being unpredictable to be labeled as interactive. For example, in an event of sentiment visualization, data updates every few minutes with the same interactive buttons or actions, which makes the system predictable.

From a Human-Computer Interaction (HCI) and data visualization lens, "interaction for visualization is the interplay between a person and a data interface involving a data-related intent, at least one action from the person and an interface reaction that is perceived as such (Dimara & Perin, 2020, p.9). In their definition, the authors point out key aspects of an interactive visualization such as interplay which is defined as a dialogue; a person could be a human or non-human entity; data interface is the visualization system; data-related intent (explicit or implicit) is described as the interaction that happens in the visualization system with content from a data source. Moreover, this is a key aspect for HeartBeat which is centered around sentiment visualization and later follows this definition and key values for design guidelines.

According to Kim et al. (2009), the interactive installation is used to compile and muster the new forms of technology media and aesthetic representation practiced by the artist using their own aesthetic. This was a key attribute for my research linking interactive visualization such as sentiment visualization with the interactive system that forms the HeartBeat. Kim et al. suggest three key elements that form an interactive installation:

- Bridging spectator and artist's work through an interactive communication medium such as a display device
- Detecting input or reaction from the spectator
- Change in the visualization from an interactive reaction

This greatly assisted in understanding and finding opportunities for designing HeartBeat, pertaining to its design and structure, for both interactive sentiment visualization and then encompassing the system with an interactive installation. Moreover, it showed how interactivity has transformed and the key elements of the interactive system and their usage.

2.5 Related Work

The pandemic related public artwork and installations around Canada has so far focused on murals and digital screens with powerful textual messages to reflect the sentiments. In Toronto, The Bentway invited the artists to form a public art campaign to capture perspectives, experiences, and understanding of life in Covid-19 (The Bentway, 2020). This campaign included work from various artists such as Ani Casitillo (Figure 20) who created a visual graphic with the words "We All Meet Again" that was shown on digital billboards in Toronto (The Bentway et al., 2020). Similarly, according to Davis (2020), the City Of Toronto's StreetArtToronto program invited artists to create murals pertaining to the Frontline Heroes Art Project such as shown in Figure 21. While this campaign focused more on a static digital art visualization, others focused more on physical interaction such as the artist, Michel Dumont, who made an installation (Figure 13) of the Covid-19 cell in Vancouver (The Chronicle-Journal, 2020).

Figure 20: Pandemic related public art in Toronto where artists reflected their sentiments using words and graphics - We all meet again (The Bentway et al., 2020).

Figure 21: Pandemic related public art in Toronto where artists drew a mural to reflect the sentiments of front-line workers - Covid-19 mural (Davis, 2020).

Figure 13: Pandemic related public art where the artist curated a physical installation of a Covid-19 cell (The Chronicle-Journal, 2020).

The above Covid-19 related public art make great effective strides to reflect selected sentiments from the artist's view during covid-19 such as social distance, frontline workers, etc, however, there is a potential gap as discussed in earlier chapters, about the need for reflection of sentiments of citizens in public art during Covid-19 due to various reasons, such as lack of trust (Chamola et al., 2020), the emotional and social potential (Maluj & Zaluski (2017) and the need for public art where people would be at comfort having their emotions validated (Sirju, n.d). In addition to this, Codell (1992) suggests sentiment as the highest quality of the art. However, Sharp et al. (2005) believe it is complex to list measures of a successful intervention or the claims made about public art's social impact. On the other hand, besides the gap of representing the sentiments, there are potential weaknesses in the above

public art such as the technology tools suggested in earlier chapters in the areas of community, creativity, and everywhere: sentiment visualization frameworks for smart cities, interactivity, and context-awareness. This is key for a city like Toronto which is moving towards being a smart city.

In the non-pandemic public art space, significant work is available in sentiment visualization and interactive installation which could render insights for the opportunities available to create work for Covid-19 and which later shaped the design framework for HeartBeat, such as its physical component of light display of emotions along with the interactive visualization of sentiments on online browser along with new avenues, models and aesthetics. For example, ARCH+ART, a group of Egyptian artists, created an interactive installation (Figure 22) that focuses on social interactive installation to address global issues in which visitors are urged to walk closer and away from the lights to interact with the installation (Welch, 2020).

Figure 22: Interactive installation in Egypt about social interaction where visitors interacted with the screen (Welch, 2020).

The Atlas Of Emotions is an online interactive visualization using colored circles with an overlay button for interaction, to visualize universal emotions from the Paul Ekman's model: sadness, fear, enjoyment, anger, and disgust (Montañez, 2016). While this work uses popular sentiment visualization techniques such as color and online interactions, others are more context-aware and use the key elements of interactive installation. One such interactive installation is Times Square Alliance, a physical

10 feet heart which pulsates and changes 400 LED lights to brighter red and beats faster by pressing a button in front of the display with the goal to show the pulse of the city (Rosenfield, 2012). Moreover, Markus Kison (2012) created an interactive installation by inducing pressure on a physical heart to visualize the primary emotions from Plutchik's wheel of emotion by extracting text from a blog that mentioned the primary emotion or their symposiums. This is a key highlight of sentiment visualization and also being context-aware with physical visualization but lacks a web interface. A web interface is a key piece of sentiment visualization architecture in smart cities (Ahmed et al., 2016). A similar project is "mood cloud" which is an interactive installation that captures mood from visitors using a tablet and displays combined emotion on a light display, made for Bill & Melinda Gates Hall (Cornell University, n.d.).

2.6 Literature Summary

In this thesis, I endeavor to create an IoT enabled interactive installation to reflect the sentiment of Canadians during Covid-19. The purpose is to extract the benefits of this public art framework during the times like these for smart cities such as Toronto. In the first part of this chapter, I highlighted the main problems in the current Covid-19 related public art space and its impact. Firstly, I defined the impact of Covid-19 on societies and how art councils are requesting for a pandemic related public art, and the need for reflection of sentiments in the public art. Secondly, I discussed the domestic scene of the public art framework in Toronto and the missing opportunities for a pandemic related framework within it. And, how the three main pieces of the Toronto's public art strategy paper: community, everywhere, and creativity might be utilized for the pandemic related public art. Thirdly, I share how public art has played a vital role to revitalize cities.

In the second part of this chapter, I mapped community, everywhere and creativity to discuss various sentiment analysis models, usage, and comparison. Followed by its relevance and analyzing the

framework for sentiment visualization in smart cities. Then, I discuss the importance and frameworks for interactivity, interactive installation, and context-awareness. Finally, I discuss the related work and how the current pandemic related public art has gaps that I intend to fill with HeartBeat.

As we see the missing opportunities from the current public art in response to Covid-19, I have briefly taken into consideration the guidelines, as earlier discussed and compared, about building sentiment visualization for smart cities which will be inside an interactive installation and is context aware. This connection would later help me with the tools learned in this contextual review to form the design structure. I aim to create an experience that could be utilized online as well as offline when admission to museums is opened again after Covid-19 restrictions. I will explore process design and Plutchik's wheel of emotion model to reflect the sentiment followed by interactive installation.

In the following chapter, I build and design HeartBeat - an interactive installation to reflect the sentiments during Covid-19 - by adopting a user-centered process. Firstly, I introduce research through design methodology and related methods and how it will be used to build and evaluate HeartBeat. I follow various frameworks and learnings from this chapter to define goals and reasoning as I build the HeartBeat system through this methodology. The primary focus is to discover how HeartBeat as an interactive public art installation can reflect the sentiments of citizens living in smart cities such as Toronto during covid-19 - especially in the time when all public museums are closed off for visitors.

Chapter 3- Research Methods And Methodologies

The focal point of my research is to explore how an IoT-enabled interactive installation can reflect the sentiments of Canadians during the ongoing pandemic by creating a tool (HeartBeat) that could be utilized in the current state of pandemic related public art. HeartBeat is an interactive installation and a public artwork that reflects the sentiments and emotions of Canadians during the ongoing Covid-19 pandemic. I commenced with Research Through Design (RtD) methodology and linked the knowledge from the earlier detailed background literature and frameworks such as sentiment visualization for smart cities, interactivity elements, and context-aware system to move towards interaction and sentiment visualization methods of HeartBeat. For the validation of my overall interactive installation, I adopted a user-centered design methodology of semi-structured interviews with selected experts from the fields of art, data journalism, and public art policymakers in Canada, and a timeline case study method. While my professional practice in interactivity and literature review influenced my methods and choices for HeartBeat along the way, this chapter lays out the methodology for HeartBeat's creation, development, and evaluation.

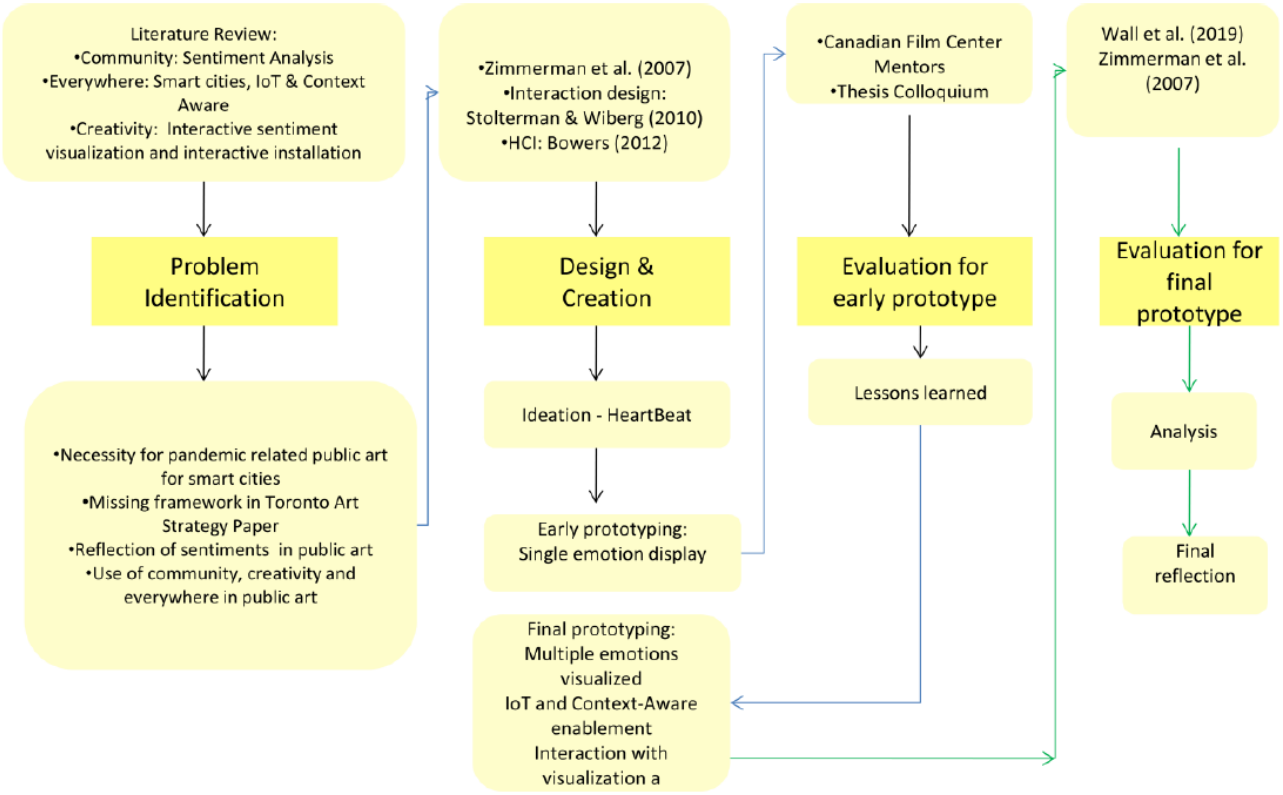


Figure 28: Research Through Design process map for designing HeartBeat.

Research Through Design is widely popular in Human Computer Interaction (HCI) and interaction design domains. Zimmerman et al., (2010) define Research Through Design as an iterative method and process adapted as a designer's method of inquiry to create artifacts to achieve a societal goal. Moreover, the authors also stress that the contribution from such a process could also be the implicit knowledge acquired through the creation of artifacts. Several studies in (HCI) and interaction design have based their method on Research Through Design. This includes works from Stolterman & Wiberg (2010) who based their approach on Zimmerman's Research Through Design within interaction design. Moreover, Bowers (2012) also applied Research Through Design within the field of HCI to work on their interactive installation. Furthermore, Bayazit (2004) pointed out that one key role of research through

art and design is the common knowledge that is extracted from observing an artist's practices while making the artifact or art.

These papers assisted to critically evaluate and create the design framework through Research Through Design. According to Zimmerman et al. (2007), this approach to interaction design research can transform the world from its current state to a preferred state. This strengthens my vision where the aim of HeartBeat is to contribute as public art - helping citizens restore, or try to restore, from Covid-19's impact. I followed three proposed steps of Research Through Design as suggested by Zimmerman et al. They are as follows.

- Recognizing new technological opportunities that could bridge the problem space and offers a robust impact on the world
- Design artifacts which are also the vision of a preferred state
- Holistic evaluation of the contribution

By adopting the above steps, I framed my Research Through Design methodology for HeartBeat. The three steps are (a) problem identification; (b) designing and prototyping; (c) user-centered evaluation. In addition to this, Zimmerman et al. (2007) suggest a four-tier formal criteria for evaluating contributions arising from Research Through Design which I later adapted for HeartBeat. These include (a) documentation of HeartBeat throughout the process; (b) show how HeartBeat is inventive in addressing the specific problem situation; (c) relevance of HeartBeat in achieving the preferred state; and (d) extensibility, so the arts community can leverage the knowledge or outcomes derived from HeartBeat. According to Fralyling (1993), the Research Through Design method is less straightforward but still identifiable and visible. In addition to this, while designing and evaluating HeartBeat, I also adopted a user-centered design approach.

According to Nielsen (1994), heuristics are defined as 10 general principles for interaction design such as the visibility of system status, etc. However, according to Tory & Moller (2005), expert interviews could render valuable feedback and evaluation strategy for such visualization and offered a modified HCI guideline of Nielson's Usability Inspection methods where they suggested using a selection of experts to conduct an evaluation with them without emphasis on heuristics. Such a method of using expert interviews was also practiced by Kucher et al. (2020) using the framework suggested by Wall et al. (2019). In addition to this, for our visualization evaluation I also adopted the similar framework suggested by Wall et al., 2019 that includes (a) insight, which includes incidental or accidental insights; (b) time, which is focused on the quickness of understanding visualization, more efficient understanding of data; (c) essence, it relates to overview and context of data and (d) confidence, which refers to how confident users feel about the quality of the data. In addition to this, I also evaluated the HeartBeat through a case study method over a pandemic timeline. A similar visualization evaluation method was suggested by Elmqvist & Yi (2013) by using a case study over an extended time, as it reveals results that are more factual especially when done with event timelines.

HeartBeat follows three steps (Figure 28) which are discussed in the subsections of this chapter. Firstly, problem identification helps defines the wicked problem which Rittel & Webber (1973) describes as a social problem where one of the characteristics of this problem is that their solutions are not true-or-false, but good-or-bad. This step was commenced by my virtual residency focused on creative and artistic presentations from Covid-19 co-hosted by Toronto Biennial of Art and OCAD U Graduate Studies and in-depth analysis of literature review of interviews from art societies and the gaps in the Toronto Art Strategy paper. The second step is designing and creating HeartBeat which goes through various iterations and early prototype (Version 1) evaluation to respond to the earlier step of problem identification. This step used various frameworks and my experience to create an artifact that could be evaluated. Finally, the third step is evaluation of HeartBeat where I do timeline case study evaluation

and semi-structured interviews with artists, policymakers etc. and loop back to my original goals and to provide reflection, critique, and discussion on my finding and contribution towards a pandemic related public art for smart cities.

3.1 Problem Identification

In this step, I followed observation, horizon scanning, and case study as my main methods through (a) virtual residency; (b) analysis of interviews by art societies and (c) reflecting on Toronto Art Strategy paper to understand the problem and (d) my personal motivation as mentioned in the introduction chapter.

The impact of Covid-19 has impacted everyone. The virtual residency (https://contingenciesofcare.com/) I attended in Summer'20 allowed me to interact, observe and understand different social impacts from Covid-19 from the perspective of art. This included observation, attending workshops, and note-taking from various artists and facilitators who reflected the impact of the pandemic in various art forms. One of the sessions from this residency that stood out for me was Post-pandemic studio: emergent frontiers of the new normal, where there were talks about the new normal, sustainable art practices etc. This helped me to understand the pandemic and that its impact is long term, along with the current lockdown situation for artists and citizens, where the lack of public art engagement is an issue.

I started scanning the current conversation and in-depth analysis in the literature review mentioned in the earlier chapter where interviews from art societies are urging for the need of a pandemic related public art, a reflection of sentiment in public art, and highlighting potential gaps of Toronto Art Strategy Paper for a missing framework for a pandemic - this helped me solidify the problem and technological gaps. This was further strengthened after evaluating pandemic related public

art in Canada as mentioned in the earlier chapter, and the need to build a digital bridge during Covid-19 between audiences, creators etc. (Culture + Community In A Time Of Crisis. (2020).

To summarize, these methods assisted in discovering key pain points such as the urgent need for a pandemic related public art, a reflection of sentiments in public art for smart cities, and the missing technological opportunities in the current pandemic related public art. These opportunities included the use of interactivity and context-aware system, interactivity in sentiment visualization, and interactive installation. The subsection ahead shows the creation and design of HeartBeat.

3.2 Design and Creation

This stage covers the ideation, early prototyping (Version 1) for visual design and interactivity, and final prototyping (Version 2) for HeartBeat. These are described in the subsequent sections.

3.2.1 Ideation

The first stage highlighted the problems and issues about creating public art that should reflect the sentiments of citizens living in smart cities such as Toronto using interactivity and context-aware systems. Using these queues, and understanding the current context where we are living in an uncertain lockdown with limited production resources, as well as for citizens who cannot go to museums, I commenced contemplating and design thinking about various digital solutions that could fit this brief. Thereafter, I was able to set-up the attributes of this system, titled HeartBeat. The name is inspired by the thought of reflecting the emotions or pulse during the ongoing pandemic. The goal of HeartBeat is to serve as a public art that citizens can engage with during the lockdown and at the same time reflect the sentiments of Canadians during Covid-19. However, the key solutions that HeartBeat should provide are based on the aforementioned pain points are (a) reflect sentiments of citizens; (b) sentiment visualization for smart cities; (c) context-aware and interactivity and (d) act as public art, and be virtually available everywhere even during a lockdown.

To further support my idea development phase, I conducted a workshop with students of an ongoing virtual class at OCAD of 10-15 participants who responded with how they would reflect their sentiments and emotions during Covid-19. Almost all responses showed a description of emotions with a word followed by a visual to describe it. This helped me to further understand how the HeartBeat could take a shape to reflect textual and visual emotions.

3.2.2 Early Prototyping (Version 1)

I focused on two overarching attributes of HeartBeat. These are that HeartBeat should have an interactive online web version accessible to anyone but with physical visualization in case the lockdown eases down. I later evaluated my early prototype (Version 1) to take leanings to the final prototype (Version 2). However, I tried to adapt the sentiment analysis architecture for smart cities from Figure 16 to create my architecture shown in Figure 23 and Figure 24 which I will discuss next. It shows how there are two front-facing sides: the web interface and the physical visualization.

3.2.2.1 Creation

Thus, the HeartBeat has two parts: online sentiment visualization and physical visualization. At this point, I created a process design for physical visualization (Figure 23) from earlier learnings to discover the tools and communication between them. The original idea for physical installation was to create a large interactive heart with sensors. However, due to limitations in accessing labs due to the lockdown, I pivoted. The process designing follows sentiment analysis, where I used the learnings from the earlier chapter about extracting Tweets using Tweepy (Tweepy, n.d), which is a Python programming language library to extract Tweets from Canada and then count them based on limited keywords from Plutchik's wheel of emotions to test the system. Moreover, I cleaned the Tweets for username, URLs, and spacing to only read the text. The next step in my early prototype (Version 1) for the physical visualization was to connect this with Arduino through a serial port to enable different lights that could

be controlled using the serial monitor from Python to Arduino. The early results are presented in Figure 6 which shows changing LED lights based on emotions. This was to create an early test about the coding and analysis. This was linked with Arduino and the LEDs to reflect the emotions in various colors. This helped in testing the physical component of HeartBeat. Later the early prototype (Version 1) architecture for physical installation (Figure 23) gets extended into the final prototype (Version 2) of physical installation.

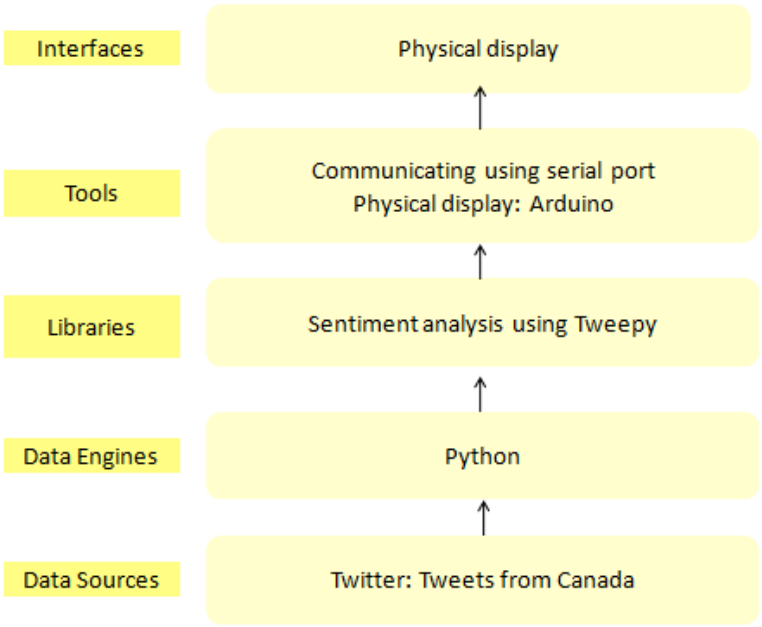


Figure 23: Early prototype (Version 1) architecture for physical installation showing the process design.

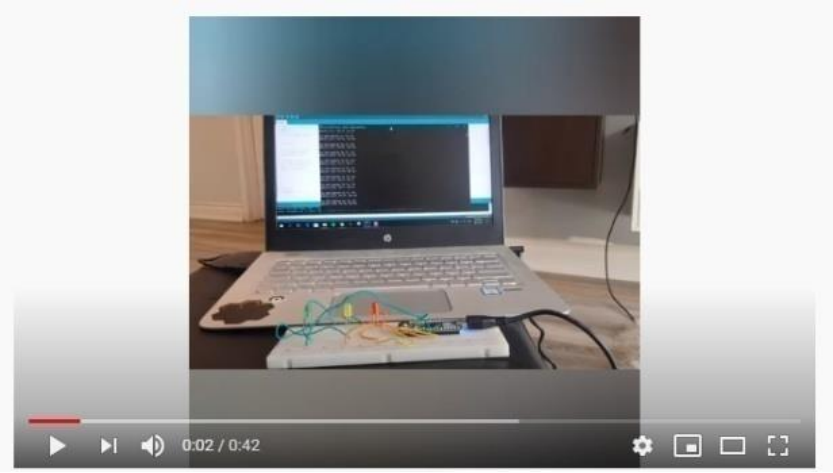


Figure 6: Early prototype (Version 1) for Physical installation showing changing lights based on Tweet sentiments.

On the other hand, for early prototyping (Version 1) for the web interface (Figure 24), I used the same Python code and connected with p5.js (p5.js, n.d) which is a JavaScript language that I learned and used in the earlier part of my graduate program) to create a heart that changes colors based on the receiving emotion from Python using a serial port. Several studies investigated the attractiveness of interactive public art installations. A study by Hu et al. (2013) discussed the attractiveness of interactive public art installation and found colorful appearance as a key factor. Moreover, a year later another study also suggested connectedness in public art as a key quantitative measure for evaluation (Hu et al., 2014). This became key during my prototyping phase while I was devising the visualization. In addition to this, Nielsen (2002) indicated "Using meaningful graphics" as one of the key attributes in homepage web design. Thus, the exploration of heart-shaped visualization was key. I used a heart shape icon that is connected with the same Python code and sends data to p5.js through a serial monitor as shown in Figure 7. The use of the heart as a shape was inspired by the thought that the heart is a symbol of emotions and relates to strong emotions (Yalom, 2019).

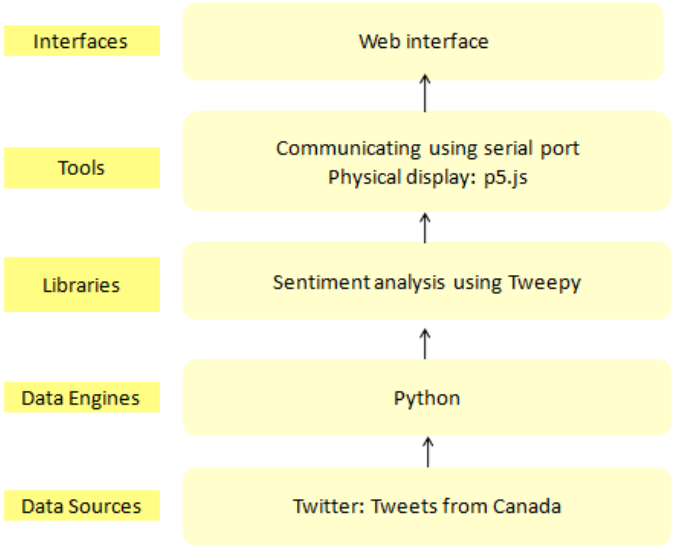


Figure 24: Early prototype (Version 1) architecture for web interface showing the process design.

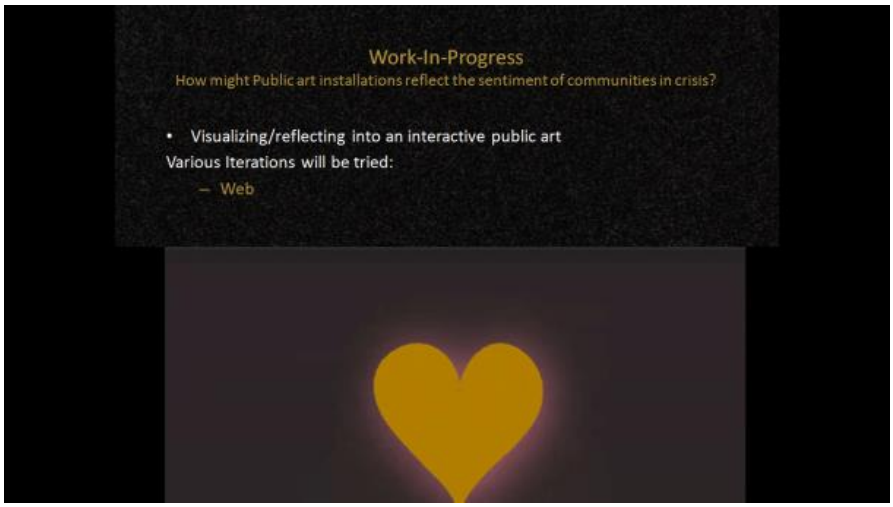


Figure 7: Early prototype (Version 1) for web visualization showing a single color reflecting single emotion while Version 2 and Version 3 show various emotions.

3.2.2.2 Early Prototype (Version 1) - Evaluation and Challenges

I evaluated these two versions with two different classes in my graduate program. This included the CFC Media Lab which has mentors from the Canadian Film Center and the Thesis Colloquium where there are public presentations of the ongoing work to students, faculty, and external guests. These resulted in understanding challenges and solutions along the way to make the final prototype (Version 2) more robust. Some of the highlights from this evaluation included solving issues of understanding sarcasm within tweet analysis. Moreover, the audience appreciated using the heart as a visual to reflect sentiments but pointed out the use of more emotions in the same heart so various feelings could be identified. Lastly, in terms of communication, various ways were discussed to avoid using serial port and use cloud protocols to send data that could be available for both web and physical display.

3.2.3 Final Prototyping (Version 2)

I started with understanding the key challenges and evaluation conducted earlier to solve those issues. The problem identification remained unchanged.

3.2.3.1 Creation

I moved toward design and creation from the lessons learned. The Figure 25 displays the final architecture that was derived as a result. It includes using Ably (Ably,n.d) which offers a real time functionality to send and receive data and is essential for HeartBeat which is built for smart cities. I replaced the serial port with Ably which assisted in sending the data from Ably to both the web interface and physical display at the same time.

The second challenge was to minimize the involvement of sarcasm in tweets which I tried to solve with Python by adding a dictionary of 30 synonyms (Appendix B) using for each of the emotions from the Pluthick's wheel of emotions. This technique is popular and has been discussed in the earlier

related applications section. I used 24 emotions from the Plutchik's wheel of emotions as opposed to 32 as the remaining 8 words such as love, submission etc. are derived after combining other primary keywords (Figure 8). This gave a vast library of around 720 words to run sentiment analysis.

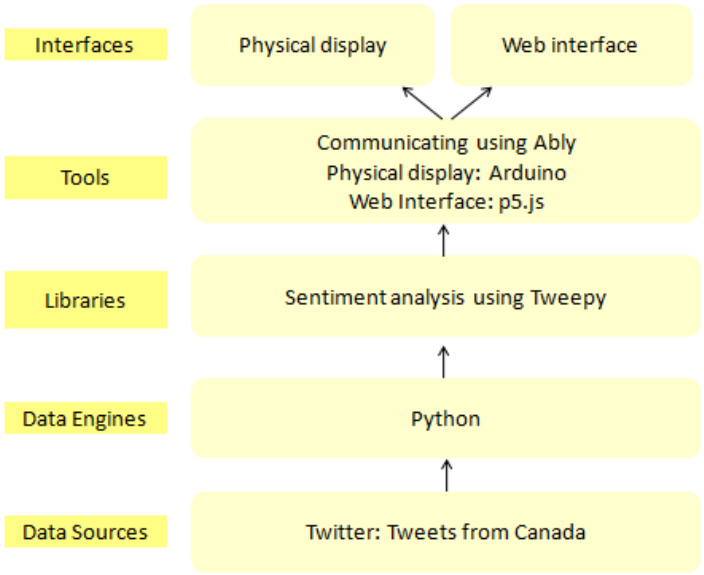


Figure 25: Final prototype (Version 2) architecture showing renewed process design to combine physical display and web interface.

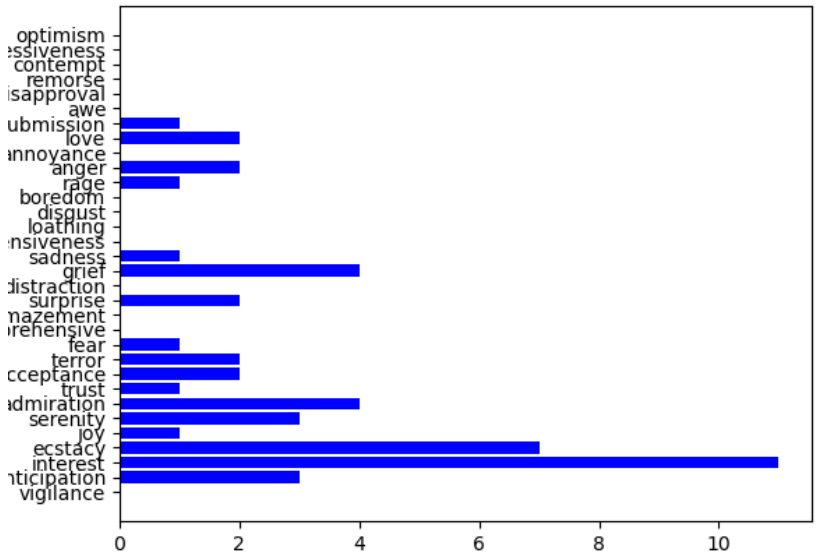


Figure 8: Output from Python shows popularity of different emotions from tweets. For example, interest shows the highest count. These results are then input into p5.js.

Moreover, in terms of displaying more emotions into the heart, I changed the technique in the web interface. I earlier displayed only one popular emotion but from the evaluation earlier, I changed it to display more emotions so users can connect with multiple emotions due to wide array of emotions experienced during the pandemic, and display text on the right side of the heart. I created a visual scene (Figure 14) of a museum that shows a wall and bench which reflects a setting where the visitor can sit and watch the heart beating, reflecting emotions. The heart beats through animation on a heartbeat sound to add a multisensory layer of sound (Ablart et al., 2017). Pertaining to the display of emotions, I used a technique called circle packing where each circle or combination of circles of similar colors highlights similar emotions. While the quantity of those circles shows how popular that emotion is. Circle packing has been used to visualize large hierarchical data by several studies such as by Wang et al. (2006) and Paulovich & Mighim (2008). Similarly, Zhao et al. (2014b) adapted circle packing to visualize

tweets for the 2012 Hurricane Sandy. There are 350 circles inside the heart which are allotted a share of dots from the percentage of the emotion. There is no overlapping between circles to ensure each dot or circle is visible and each dot has a random radius. Wang et al. (2016) followed a similar approach of packing 1000 circles with random radii. Furthermore, Moreover, Mylavarapu et al. (2019) used bubble charts, which are similar to circle packing, where the placement of each bubble on the chart did not mean anything.

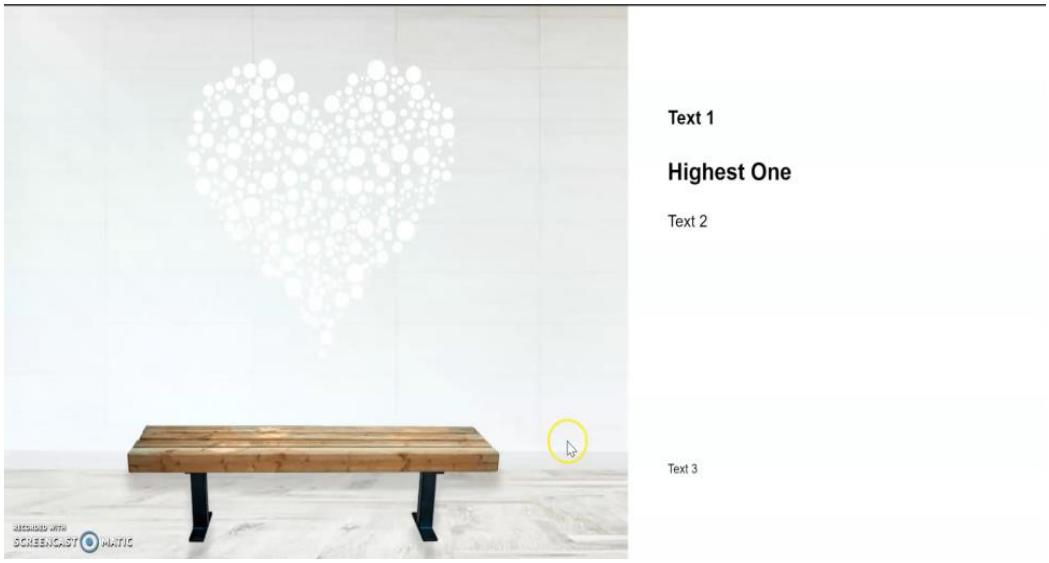


Figure 14: Final prototype (Version 2) - work in progress showing structure of heart and text placement.

The Figure 26 shows that how the colored dots inside the heart display different emotions and are more in quantity than others such as "Interest" which is currently orange and has more dots. Upon hovering on the dot (Figure 27), the user can see the name of the emotion such as "admiration" as shown. A similar approach was used by Riechert (2018) who provided detailed information when hovering over a node. Moreover, these dots are interactive (Figure 27) to display more hearts which makes the user feel that they endorse that emotion which is visible with various green hearts around

the mouse cursor. Moreover, the legend shows the colors of primary emotions and all other emotions of high and low intensity are shades of the same colors. In addition to that, on the right side of the heart, I also present a context in a textual form which updates approximately every 1.5 minutes. However, on certain occasions, if there are more than one dominant emotion, only one of them would be displayed on text but all of them will be visualized through dots. The heart animates on a heartbeat sound creating an animation of beating and dots change around every 1.5 minutes in their places. This highlights the principle of congruence and principle of apprehension where there should be a natural correspondence between change over time and must be slow respectively (Tversky et al., 2002).

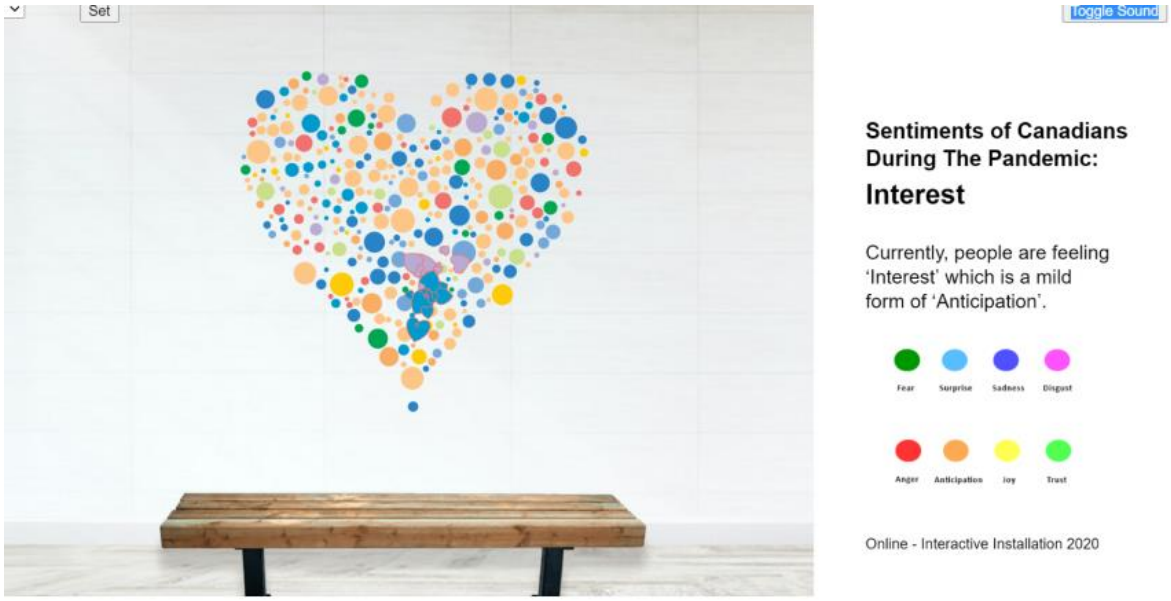


Figure 26: Final prototype (Version 2) - Sentiment visualization showing a mouse click interaction where the blue colored hearts are flying upon click.

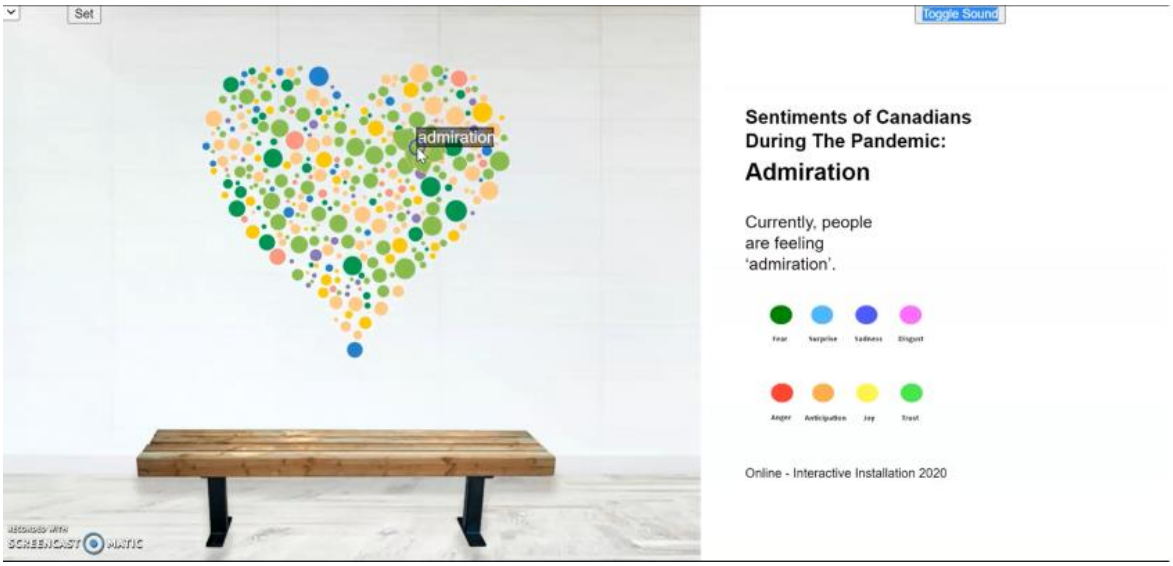


Figure 27: Final prototype (Version 2) - mouse hover on the green dot showing admiration in a label.

3.2.3.2 Reflections on prototype

The physical visualization shown in Figure 15 showcases the change of light visualization at the same time when the web interface is updated. This is a great extension for HeartBeat where lights could take shape of any mold such as a heart shape as shown in Figure 29 which can be placed in any outdoor setting. Initially, I picked the data range of Tweets from March 1st, 2020 to September 31st, 2020 to understand data and reading on average 55 tweets on every update. Although, the ongoing pandemic has taken many turns from the first wave to second wave. Thus, I broke the timeline into various chunks to reflect the sentiments. These are shown in the next chapter where I evaluated HeartBeat through a timeline case study. These tweets are extracted from Canada and are random in nature to highlight the raw sentiment of the country without focusing on one particular topic such as Covid-19 related tweets. As earlier studies shown in the above chapter that it leads to negative sentiment and related emotions. The visualization on LEDs updates every 1.5 minutes when the heart on the browser updates. Finally, the Figure 48 shows that HeartBeat addresses the sentiments through a physical installation, web version,

and also the visualization could be embedded in third-party websites such as digital publications.

Figure 15: Physical visualization of sentiments showing color on LEDs to reflect the emotion.

Figure 29: Heart shape mold is enclosed with LEDs to reflect the color of the popular emotion.

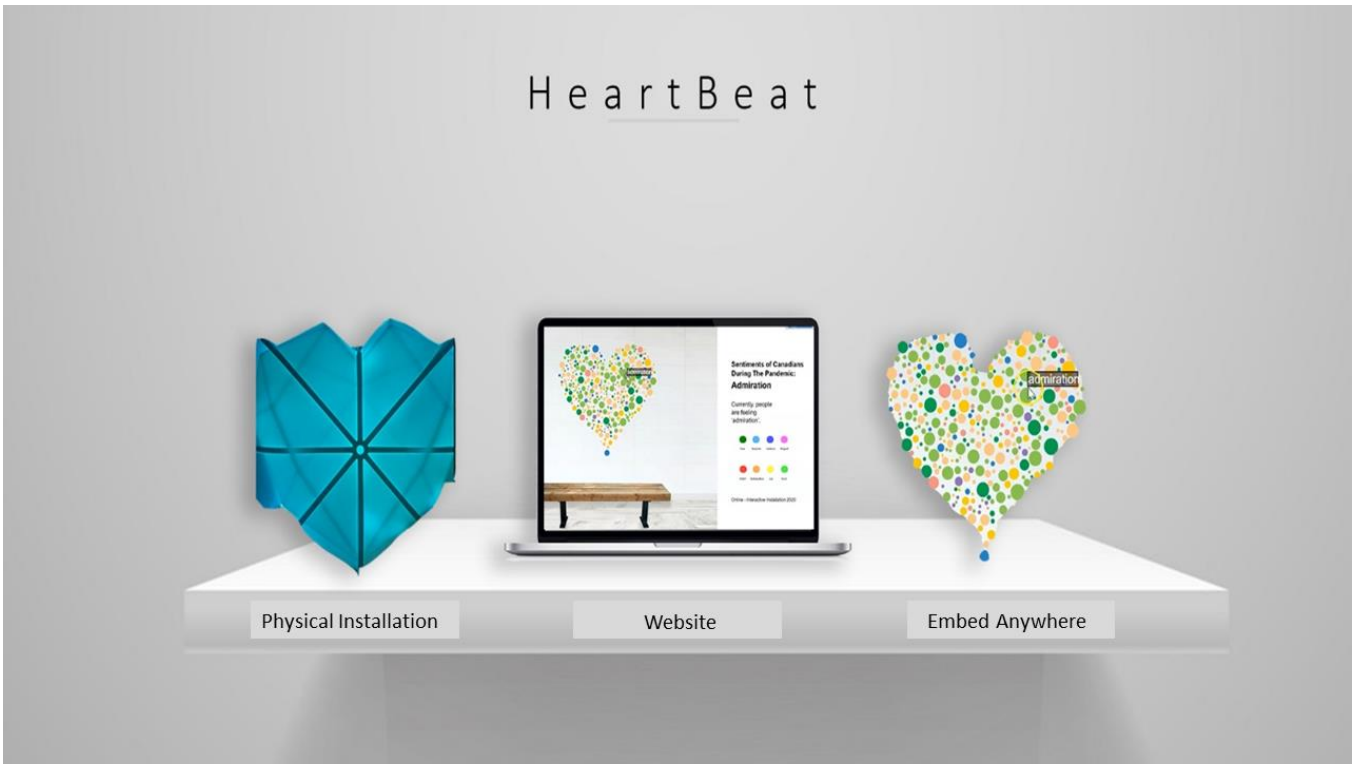


Figure 48: The HeartBeat could be used for Physical installation, website, and the heart could be embedded on any third-party website.

3.2.3.3 Technical process flow

The Figure 49 shows the technical process flow explaining how Tweets are analyzed using Python, percentages of emotions are sent to Ably which are received by p5.js (p5.js, n.d) for computation of website visualization, which is then connected with the physical installation so both versions (website and physical) update together. It commences with getting access tokens from Ably (Ably, n.d) and Twitter (Twitter, n.d). These are inserted into Python programming language to get tweets using Tweepy (Tweepy, n.d). The incoming tweets from Canada are appended and formatted, counts the appearance of words from the emotion library, and calculates the percentage of each emotion group. These percentages are sent to Ably which are pushed to p5.Js. The website visualization is built using p5.js which assigns a quantity of dots to each emotion based on the incoming percentage of Tweets. For example, the percentage of anticipation is multiplied by the total available dots in the heart to populate dots. After the assignment of dots until the heart is filled with available dots, the emotions are allotted their assigned color along with dynamic text description. Simultaneously, for the physical installation, Arduino is connected to p5 serial control and LEDs to reflect the color of the popular emotion in the physical heart which is orange for the anticipation emotion.

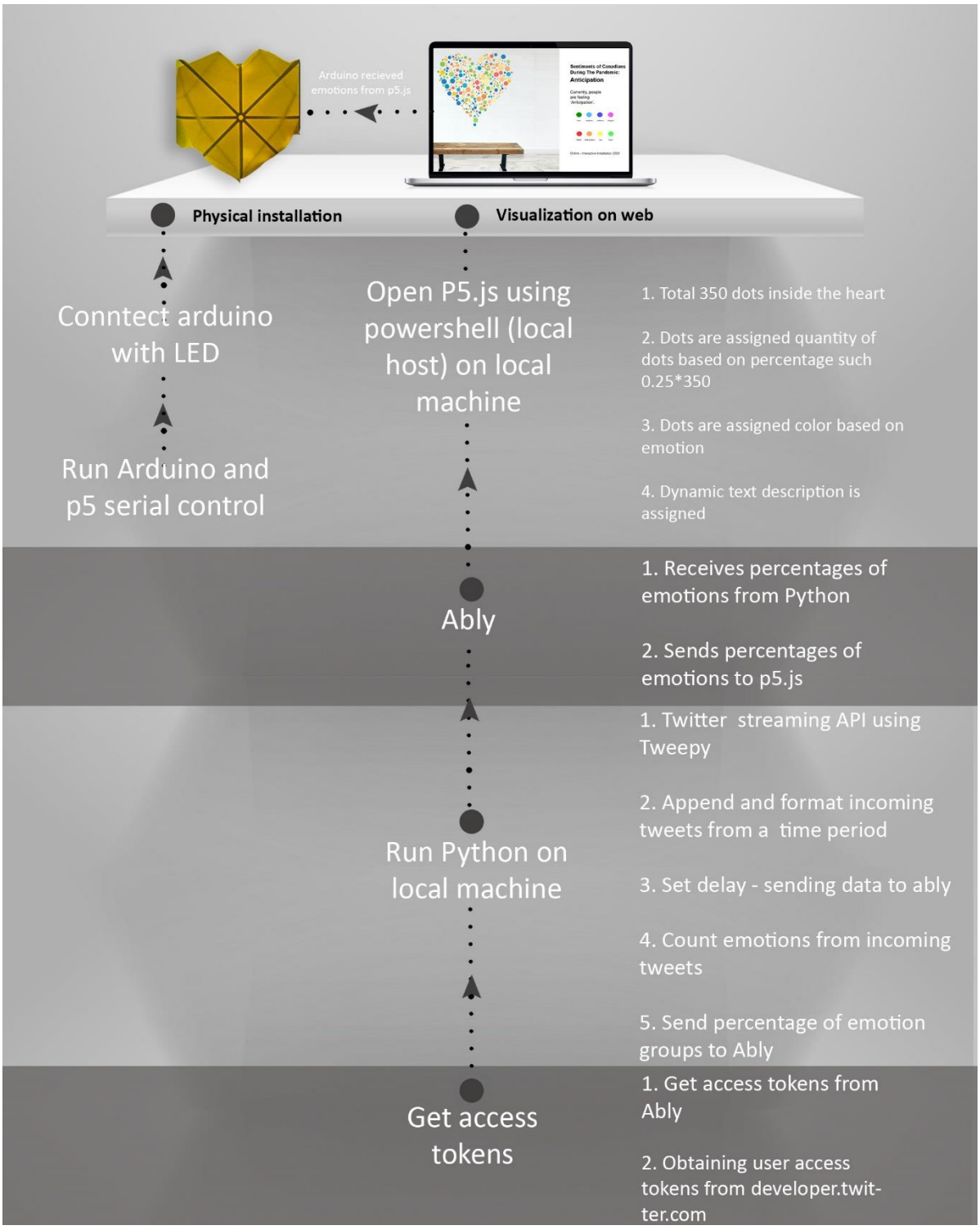


Figure 49: Technical process flow showing steps of how website visualization and physical installation read, reflect and update the visualization of emotions.

3.2.3.4 The framework

The framework for HeartBeat explains details of each phase highlighted in sentiment analysis applications for smart cities (Figure 25) such as data sources, data engines etc. The framework for HeartBeat (Figure 53 and Figure 54) shows how each phase of understanding sentiments (Figure 53) and visualization (Figure 54) is meant to be iterative. Figure 53 connects with Figure 54 using the green arrow shown in both figures. Each box is modular and could be replaced with other tools and sources. In order to approach the formation of the pandemic related public art framework, using the concepts of Toronto art strategy paper's vision of creativity, community and everywhere, it needed a formal framework with variables that could suit scalability and flexibility for future work. The framework follows an overall flow of linking the sentiment analysis section through red arrows (Figure 53) with the visualization of sentiments shown through blue and yellow arrows (Figure 54) using a publish-subscribe (Pub/Sub) service such as Ably (the green arrow is shown in Figure 53 and Figure 54).

The Figure 53 shows 9 larger buckets (connected with red arrows) that could be tuned, modified, or replaced to understand the sentiments in different ways. This begins with ensuring extraction of access tokens, selection of coding tools such as Python, data sources such as Twitter, cleansing, and running the code in backend to send sentiment data to a pub/sub service. Thereafter, the pub/sub service connects Figure 53 with Figure 54 with a green arrow on both figures. Figure 54 shows how the 11 larger blocks could be linked with a web visualization (blue arrows) and physical installation (yellow arrows). At the onset of Figure 54, the programming language, dots assignment, and color assignment blocks are key as they define how sentiments are converted into a quantity of dots and their color allotment for HeartBeat. Furthermore, in the micro-interaction block, I have used mouse hover and click events. Upon execution, visualization is reflected on the website as shown in Figure 54. At the same time, out of the 11 large blocks in Figure 54, 5 blocks (yellow arrows) on the top left are involved

with physical installation where the LED color assignment block and physical mold are reflecting the color of the popular emotion on a physical heart shape mold.

All the blocks described above are flexible and scalable. The blocks could be repeatable as well as the outcome of each block could define the block ahead. This is to ensure that each phase is robust enough to guide the rest of the process in the framework and ensure that the goal is always in focus. The modular attributes of this framework make it scalable and could be utilized regardless of levels of expertise in the technical or design field. Moreover, the technology stack blocks could be replaced to suit large exhibition requirements.

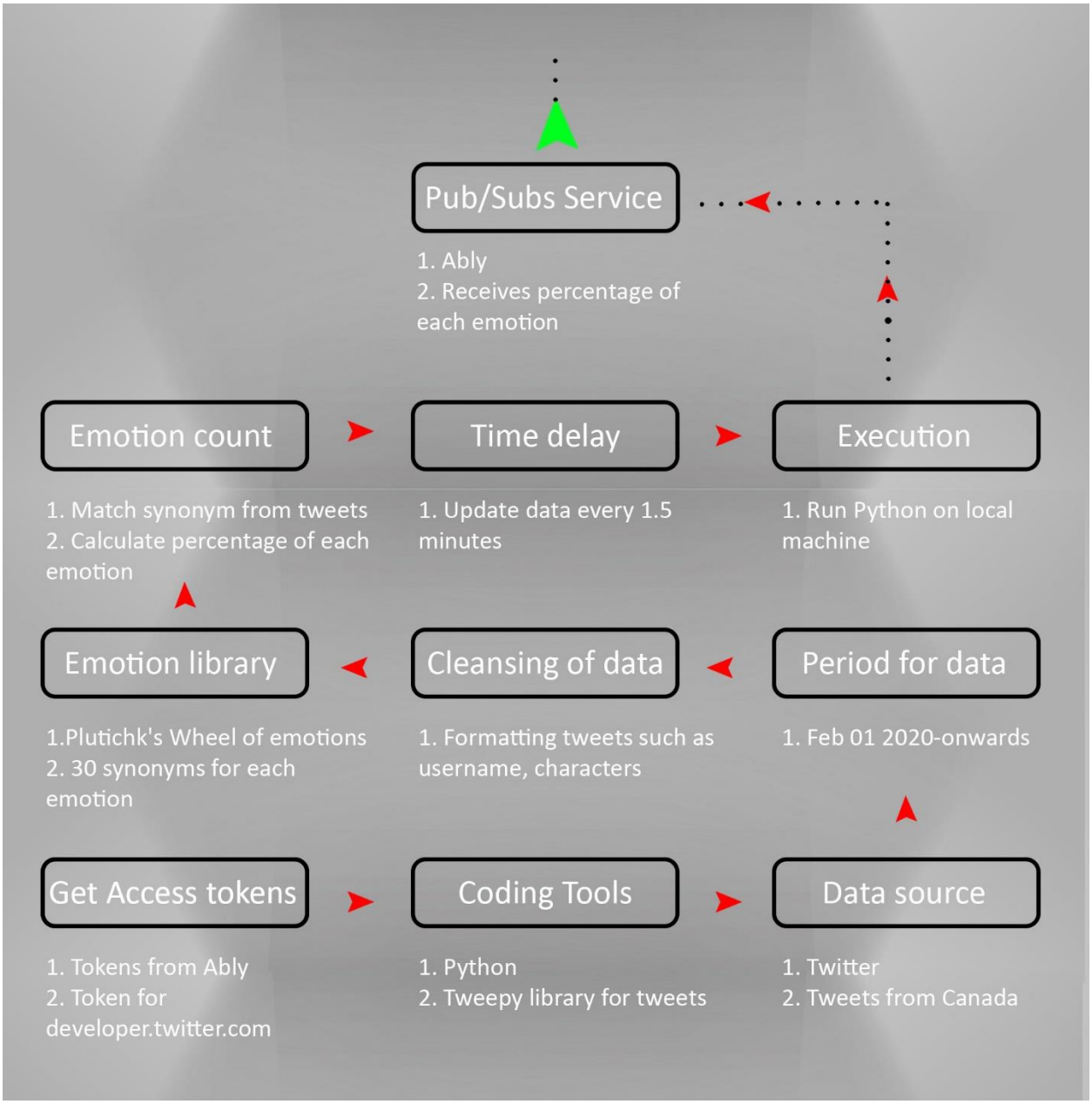


Figure 53: Framework of HeartBeat showing the sentiment analysis blocks and their linkage by using red arrows. It connects with Figure 54 using the green arrow.

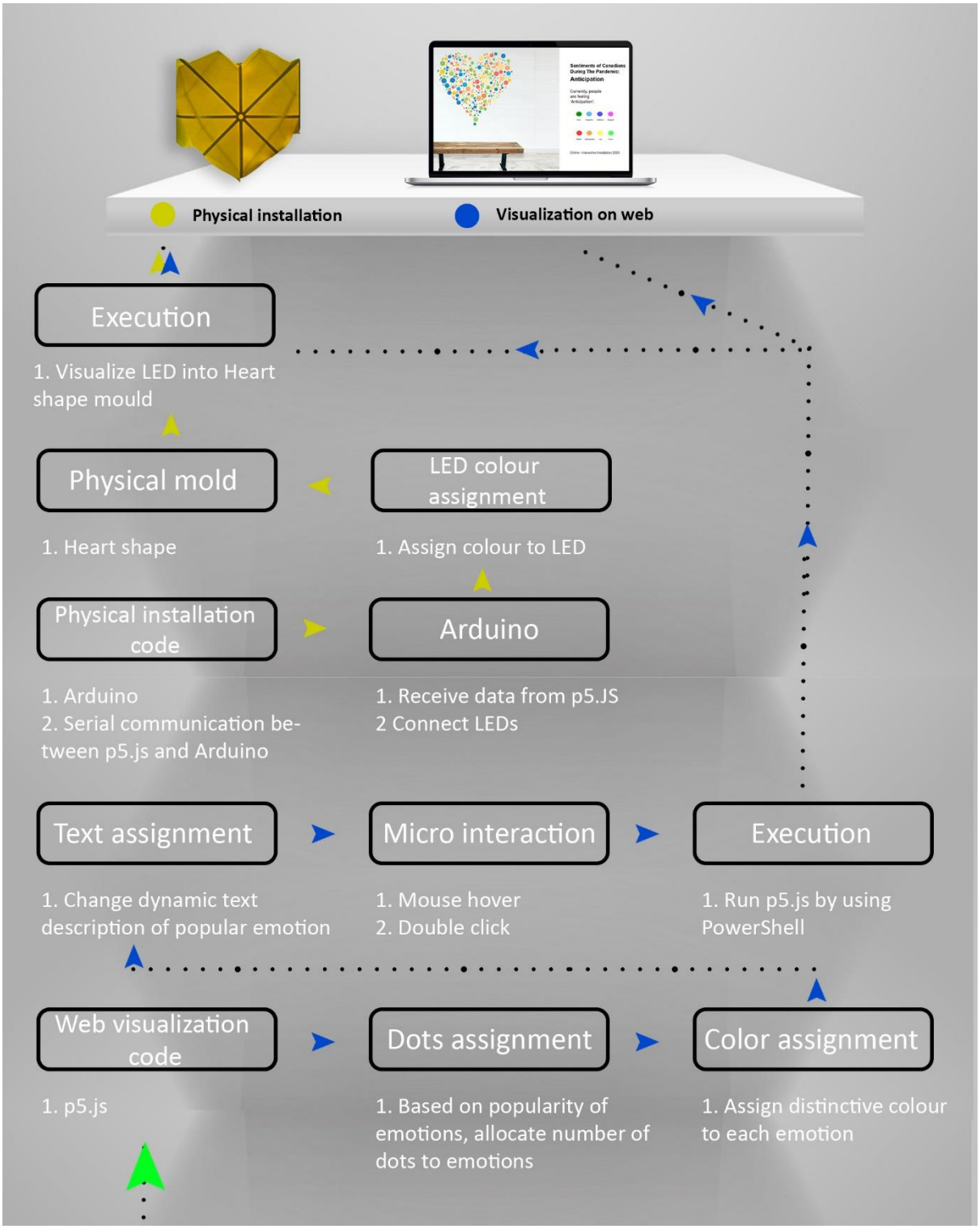


Figure 54: The green arrow from Figure 53 links with current figure. The framework of HeartBeat showing the visualization blocks for web and physical visualization, using blue and yellow arrows, respectively.

3.3 Chapter Summary

Following the Research Through Design approach suggested by Zimmerman et al. (2007), I tried to follow four-tier criteria earlier mentioned which are (a) process; (b) invention; (c) relevance, and (d) extensibility along with Wall et al. (2019)'s evaluation for visualization. Within this process, I recorded and presented the rationale of various methods and frameworks that I adapted, including the creation and evaluation phase. This also includes using the python and p5.js code, which could allow artists and public art designers working in this domain, especially in the pandemic, to create more novel work or use different visualization models based on their needs. Within invention, I highlighted various gaps from the current pandemic related public art and the potential use of technologies and architecture for smart cities that could serve the purpose of public art, especially in Toronto. This included using both web interface as well as physical display that could be used by policymakers or digital media outlets to showcase HeartBeat, where citizens could relate to various sentiments. Within relevance, I used the web interface and interactive sentiment visualization techniques as the citizens are unable to visit public spaces due to lockdown, however, they need an avenue to get their emotions reflected which could serve the benefits of public art as discussed in earlier chapters. This is key during the pandemic as everybody is suffering on different levels and it is key to reflect various emotions within the HeartBeat. Finally, the extensibility factor from this criterion offers an opportunity for artists and organizations to use more hearts based on their subject of interest and sentiment analysis such as about vaccination etc. Moreover, artists may also adopt the physical display of lights and create their own mold shapes to use Heartbeat. Due to web-based functionality, data journalists could utilize the HeartBeat as a Covid-19 sentiment tracker to embed on their digital news websites. In the following chapter, I present results from the evaluation of HeartBeat.

Chapter 4 - HeartBeat Findings and Discussions

4.1 Evaluation Group

I concluded chapter 3 by discussing the two kinds of evaluation methods that I have conducted. To evaluate HeartBeat, I use a case study approach to evaluate HeartBeat on a pandemic timeline as suggested by Elmqvist & Yi (2013), along with combining two other approaches. I combined Zimmerman et al. (2007) criteria of process, inventions, relevance, and extensibility along with Wall et al. (2019) visualization framework of insight, time, essence, and confidence. Also, I selected experts to evaluate based on these two criteria. Therefore, after the final prototype (Version 2) stage, I recruited experts who are artists, data journalists, public art policymakers to evaluate HeartBeat. The evaluation comprises of qualitative and quantitative survey questionnaires and expert interviews to help evaluate the main goals of HeartBeat. The results were collected quantitatively using a Likert scale and along with open-ended questions to gather critical feedback and review the goals of HeartBeat. I followed the guidelines suggested by Saunders et al. (2015) for anonymizing interview data. We would reach anonymity for names using pseudonyms such as 001. For their place of work, we will use pseudonyms such as Company 1 etc. For their occupation, we will use phrases such as a job in the field of arts.

Firstly, the case study evaluation method, where I chose different time periods of the pandemic and how HeartBeat reflects the emotions of Canadians in those periods using the web version and physical installation through Plutchik's wheel of emotions. Secondly, I engaged in the qualitative and quantitative evaluation of HeartBeat by interviewing 11 selected experts from the fields of public art, data journalism, advertising, and public art policy from Toronto. Both these approaches gave me a critical context to compare the efficacy and usability of HeartBeat, which is based on a dynamic reflection of sentiments, interactivity and IoT, with current pandemic related public art.

In the current chapter, I discuss results from both evaluation methods which includes the case study as well as the interviews of selected experts. In the case study method, I present a timeline of five periods and how the HeartBeat reflects sentiments of Canadians in each of those periods in juxtaposition with a key pandemic intervention that happened during those selected periods. The key takeaway was the overarching emotions observed by HeartBeat in that timeline. For the second evaluation with selected experts, I chose 11 experts for quantitative and qualitative evaluation. The sample size used by Kucher et al. (2020) was a single expert interview, however, Caine (2016) suggests a sample size of 12 participants for HCI studies. Although the sample size I used is small, these expert reviews unveiled important reflections on visualization tools (Tom & Moller, 2005). For the quantitative data, I presented findings through a bar graph and compared results whereas, for the qualitative survey, I observed and noted critical feedback and responses from the experts to follow a reflective process and discussed commonalities and trends from their responses.

Furthermore, I also confer about the achievements and drawbacks of HeartBeat's design and its impact on understanding the sentiments of Canadians during the pandemic. The results from the case study approach and expert interviews showed that HeartBeat reflected appropriate or expected emotions during various periods and is a beneficial toolkit for a pandemic related public art. In addition to this, the study also revealed potential enhancements in sentiment visualization and interaction to improve the engagement and experience of HeartBeat. On the other hand, HeartBeat faced various limitations in the areas of technology, time, access, and current lockdown times along with a smaller survey size which I discuss at the end of this chapter.

4.2 Results

4.2.1 Results from case study evaluation.

In this section, I evaluate 5 periods in time (one before the pandemic and others during the current pandemic) and reflect how the web version and physical version of HeartBeat reflect the sentiments. These periods resonate with key Covid-19 interventions that occurred such as travel ban, vaccine etc.

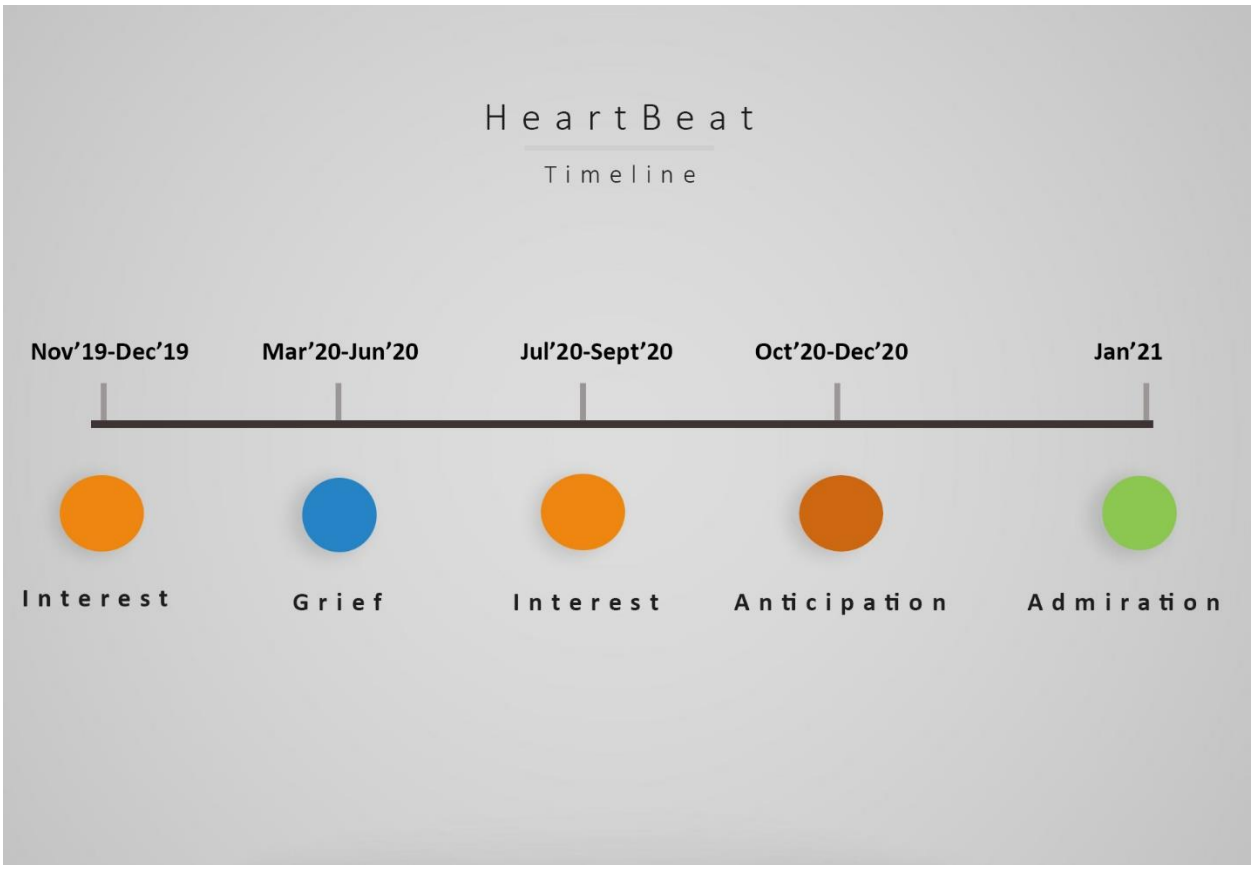


Figure 44: HeartBeat showing different popular emotions based on timeline evaluation from pre-Covid-19 until January 2021.

Nov'19-Dec'19

This is the period when a pandemic had not yet been declared in Canada. Figure 42 shows the graph of emotions that resulted from the sentiment engine of HeartBeat during this period, showing the emotion "interest" as the leading emotion from the sample tweets amongst other emotions. Figure 43 shows a snippet of a few tweets and how they were classified into groups of emotions. The results from Figure 42 were reflected on the web version of HeartBeat (Figure 41) with interest as the dominant emotion with a larger population of the orange dots inside the heart. Similarly, the same orange color is displayed on the physical installation of the heart (Figure 41). The use of color orange and interest is in line with the Plutchik's wheel of emotions (Figure 5). The key takeaway from this period shows that people are feeling interest which is a mild form of anticipation.

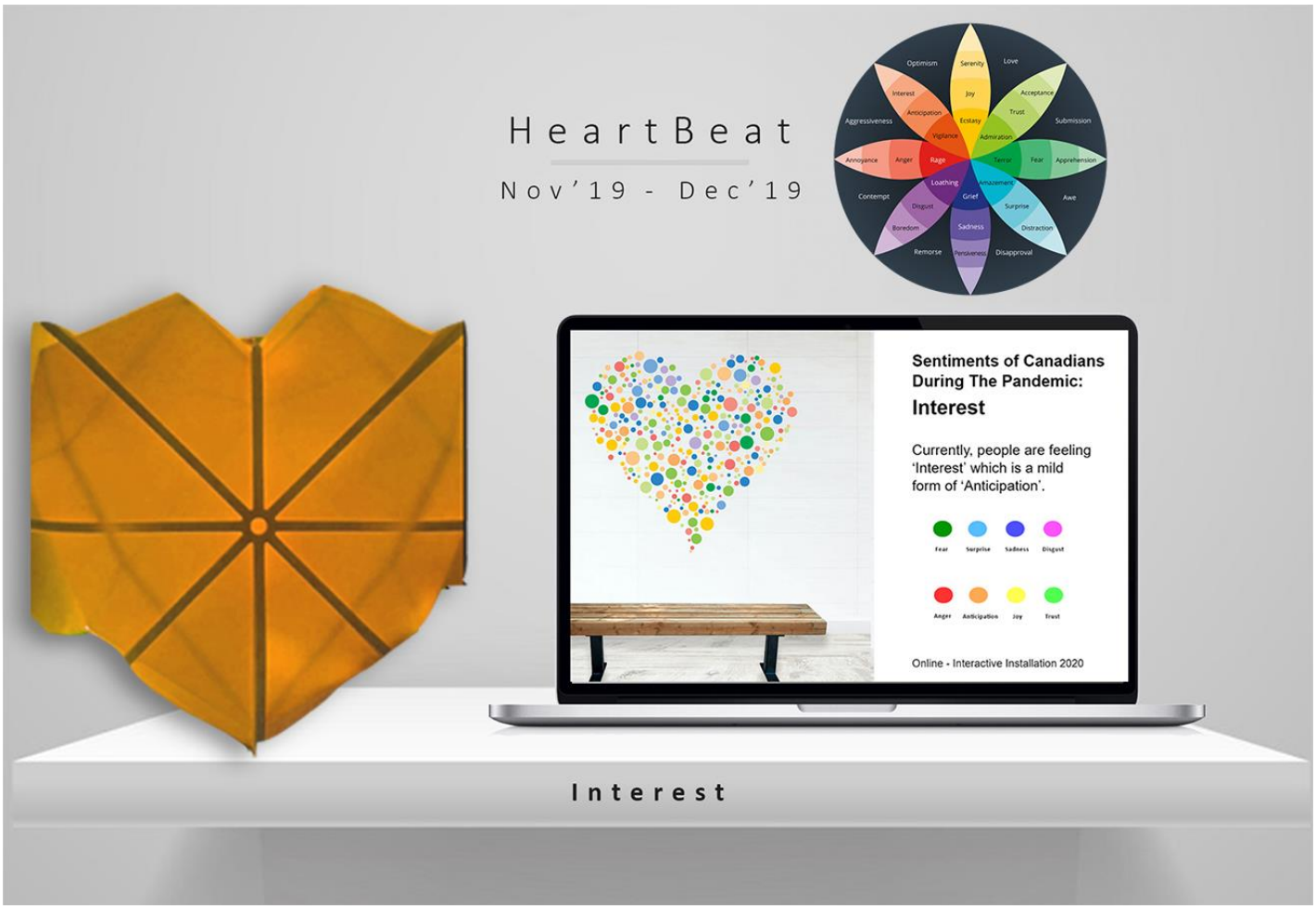


Figure 41: HeartBeat – Interest (orange shade) shown during Nov'19-Dec'19 on both physical installation and website visualization. Plutchik's wheel of emotions is shown on top right of the image.

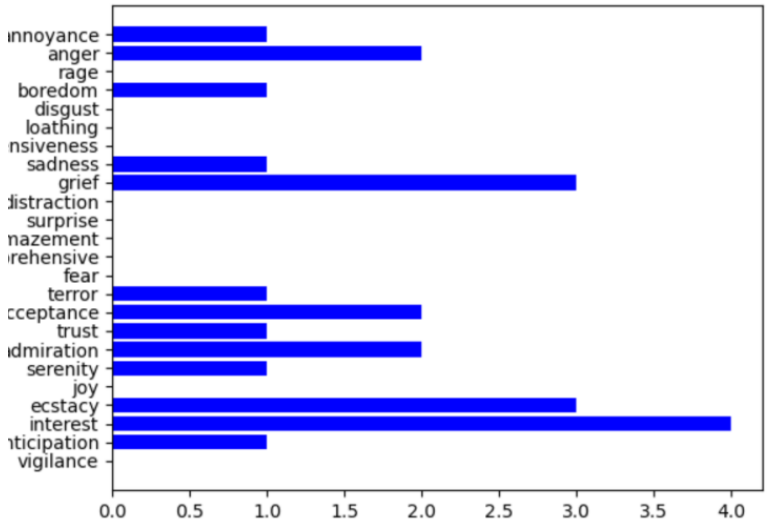


Figure 42: Graphs showing emotions during Nov'19-Dec'19 with interest as dominant while other emotions with equal percentages are displayed using equal number of dots on the visualization.

```
Tweet: Awesome. At least you're rolling up your sleeve to focus on the economy and job creation… https://t.co/kOHy4auoCq

Group Found:  admiration
```

Figure 43: Sample of tweets classified in the admiration group.

March'20-June'20

This is the period when Canada's national lockdown was announced, and Canadians witnessed their first wave. The Figure 32 shows a snippet of this period and how various Covid-19 interventions were conducted including a national travel ban (Canadian Institute for Heath Information, 2020a). Figure 31 shows the graph of emotions that resulted from the sentiment engine of the HeartBeat during

this period, showing the emotion "grief" as the leading emotion from the sample tweets amongst other emotions. Figure 50 shows a snippet of a few tweets and how they were classified into groups of emotions. The results from Figure 31 were reflected on the web version of HeartBeat (Figure 30) with grief as the dominant emotion with a larger population of the blue-indigo shade dots inside the heart. Similarly, the same blue-indigo color is displayed on the physical installation of the heart (Figure 30). The use of blue-indigo color and grief is in line with the Plutchik's wheel of emotions (Figure 5). The key take away from this period shows that people are in grief.

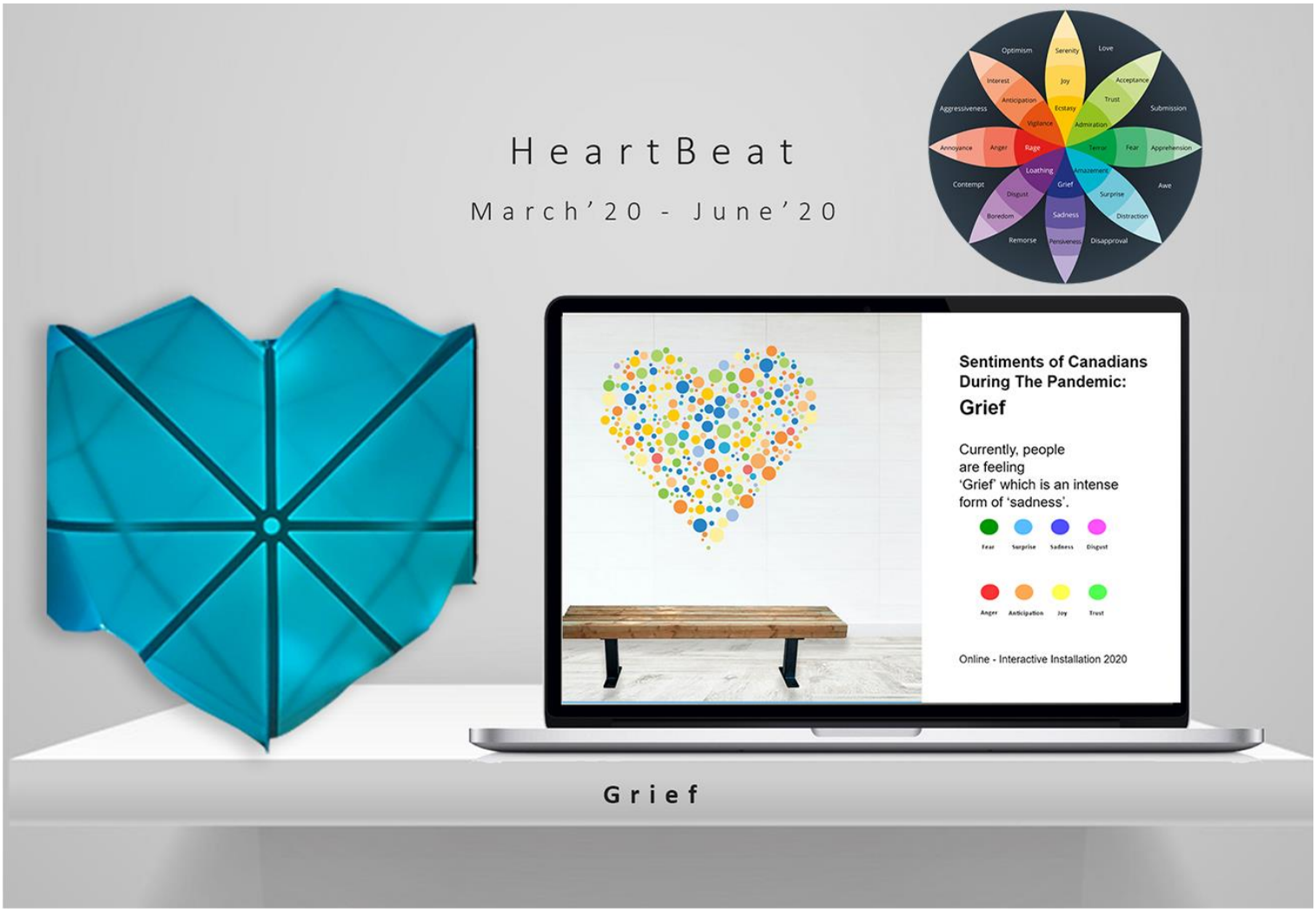


Figure 30: HeartBeat - Grief (blue-indigo shade) shown during March'20-June'20 *on both physical installation and website visualization. Plutchik's wheel of emotions is shown on top right of the image.*

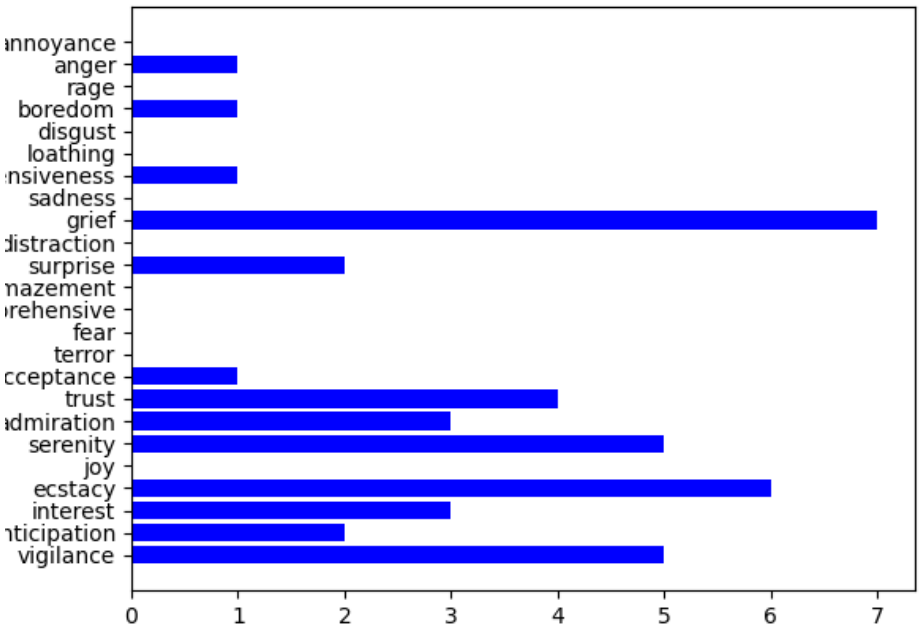


Figure 31: Graph showing emotions during March'20-June'20 with grief as dominant.

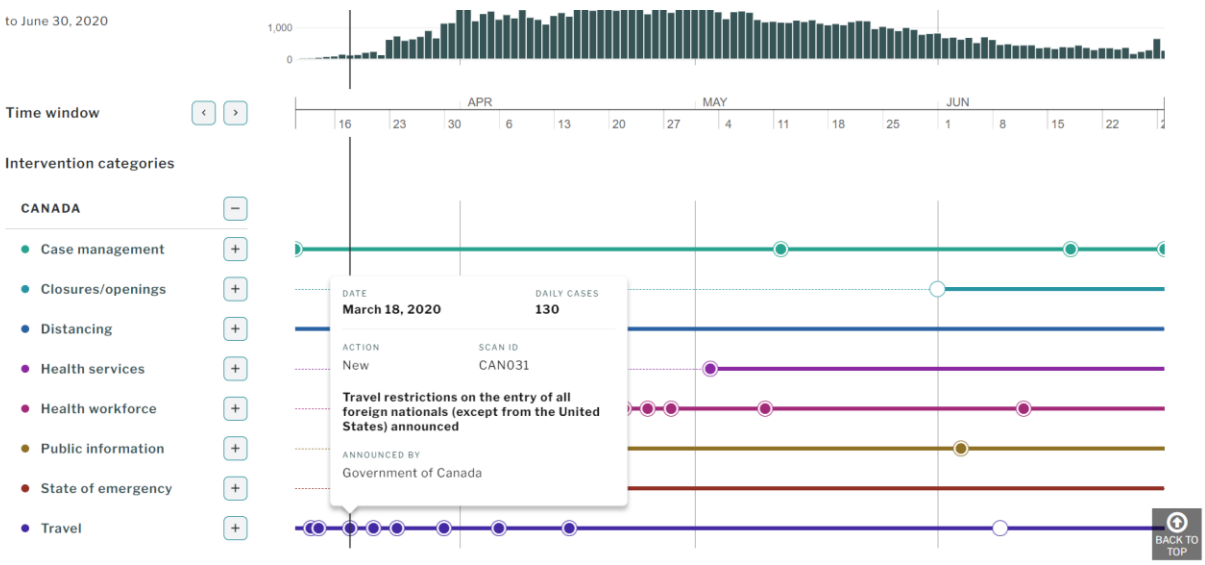


Figure 32: Timeline -Travel restriction imposed during March. (Canadian Institute for Health Information, 2020a).

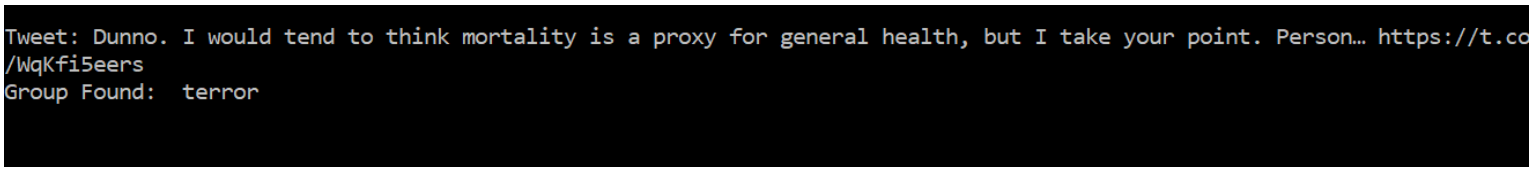


Figure 50: Sample of tweets classified in the terror group.

July'20-Sept'20

The Figure 35 shows a snippet of this period and along with Covid-19 interventions including limited travel permissions (Canadian Institute for Heath Information, 2020b). In addition to this, during the same period, Covid-19 mobile app was made available for contact tracing (Prime Minister Of Canada, 2020). Figure 34 shows the graph of emotions that resulted from the sentiment engine of the HeartBeat during this period, showing the emotion "interest" as the leading emotion from the sample tweets amongst other emotions. The results from Figure 34 were reflected on the web version of HeartBeat (Figure 33) with interest as the dominant emotion, with a larger population of the orange dots inside the heart. Similarly, the same orange color is displayed on the physical installation of the heart (Figure 33). The use of color orange and interest is in line with the Plutchik's wheel of emotions (Figure 5). The key takeaway from this period shows that people are feeling interest which is a mild form of anticipation.

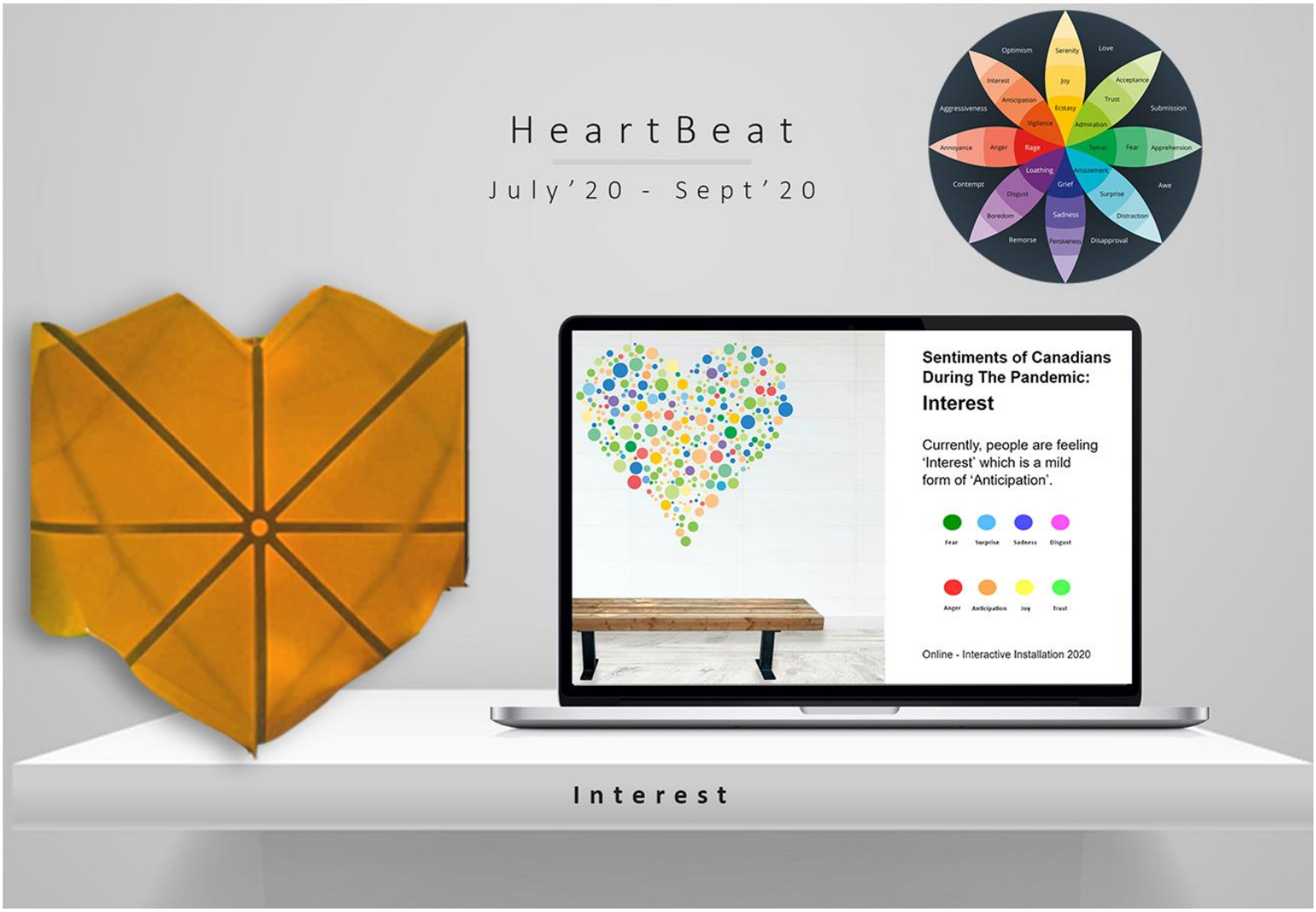


Figure 33: HeartBeat - Interest (orange shade) shown during July'20-Sept'20 on both physical installation and website visualization. Plutchik's wheel of emotions is shown on top right of the image.

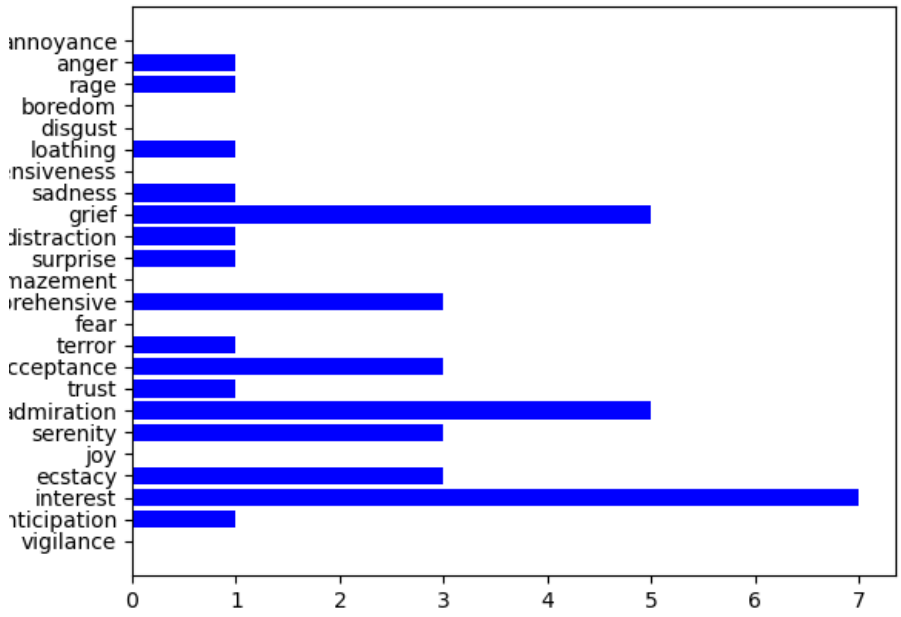


Figure 34: Graph showing emotions during July'20-Sept'20 with interest as dominant.

Figure 35: Timeline -Limited travel restriction permitted during August, 2020 (Canadian Institute for Health Information, 2020b).

Oct'20-Dec'20

During this period, three key events took place (a) second wave in October; (b) vaccine news in November, and (c) provinces plan rollout for vaccination in December along with the Christmas holidays (Healthing, 2020). Figure 37 shows the graph of emotions that resulted from the sentiment engine of the HeartBeat during this period, showing the emotion "anticipation" as one of the leading emotions from the sample tweets amongst other emotions. The results from Figure 37 were reflected on the web version of HeartBeat (Figure 36) with anticipation as one of the dominant emotions with a larger population of the orange dots inside the heart amongst other dominant emotions. Similarly, the same orange color is displayed on the physical installation of the heart (Figure 36). The use of the color orange and anticipation is in line with the Plutchik's wheel of emotions (Figure 5). The key takeaway from this period shows that people are feeling anticipation amongst other dominant emotions.

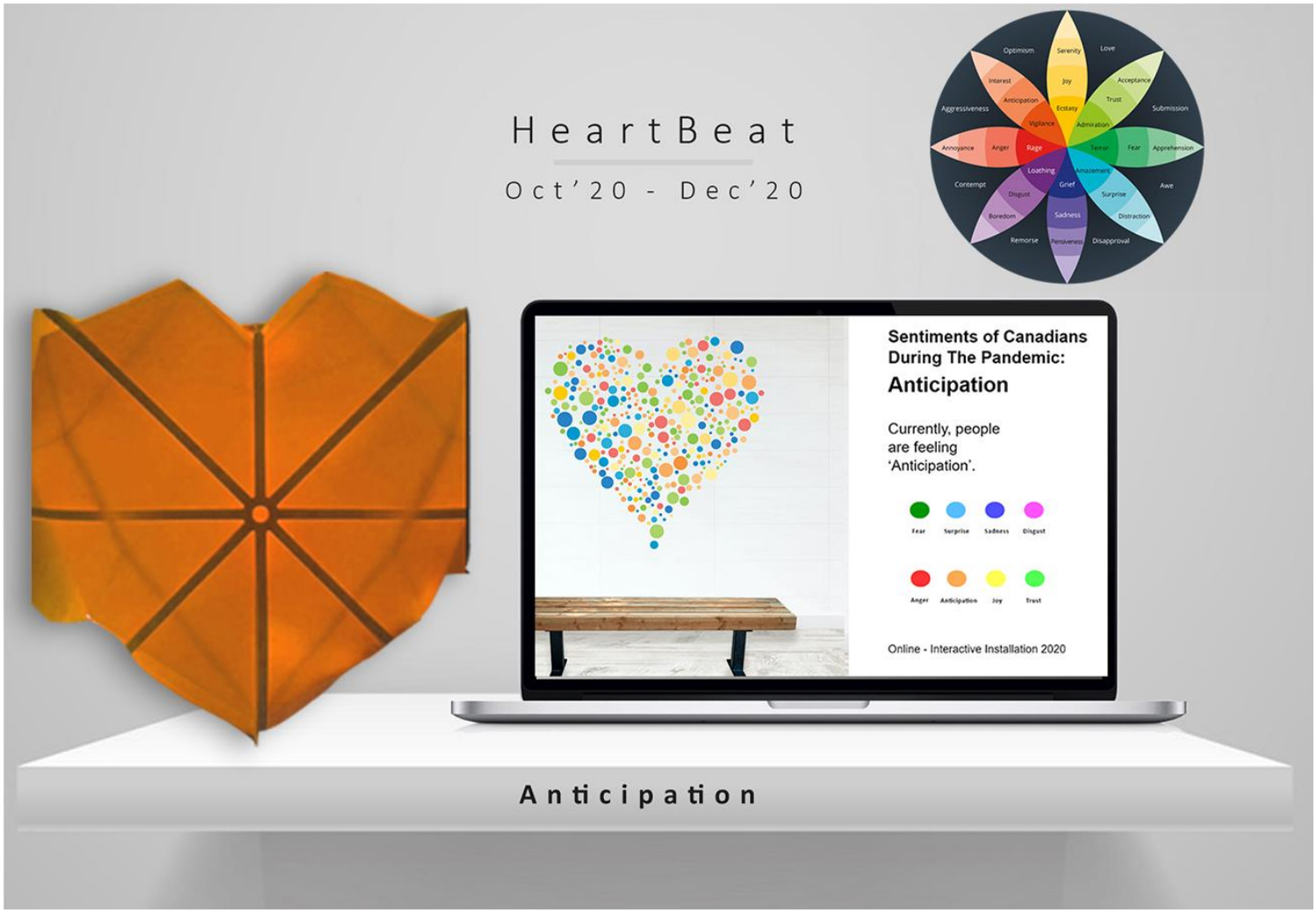


Figure 36: HeartBeat – Anticipation (orange shade) shown during Oct'20-Dec'20 on both physical installation and website visualization. Plutchik's wheel of emotions is shown on top right of the image.

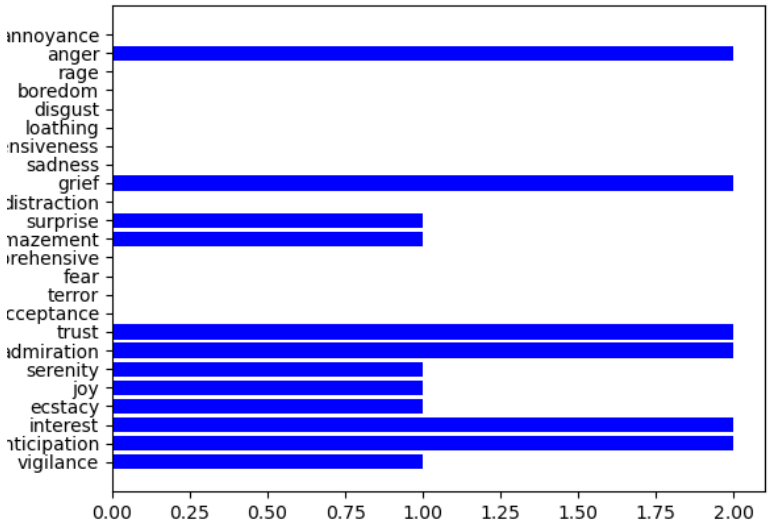


Figure 37: *Graph showing emotions during Oct'20-Dec'20 with anticipation as one of the dominant amongst others. All other dominant emotions are reflected in Figure 36 using equal number of dots.*

Jan'21

During this period, several events took place such as the wider rollout of vaccines, province-wide curfew/stay-at-home orders, and approval of rapid COVID-19 test from Spartan Bioscience (CityNews, 2021). Figure 39 shows the graph of emotions that resulted from the sentiment engine of the HeartBeat during this period, showing the emotion "admiration" as the leading emotion from the sample tweets amongst other emotions. Figure 40 shows a snippet of a few tweets and how they were classified into groups of emotions. The results from Figure 39 were reflected on the web version of HeartBeat (Figure 38) with admiration as the dominant emotion with a larger population of the green dots inside the heart. Similarly, the same green shade is displayed on the physical installation of the heart (Figure 38). The use of the color green and admiration is in line with the Plutchik's wheel of

emotions (Figure 5). The key takeaway from this period shows that people are feeling admiration which is an intense form of trust.

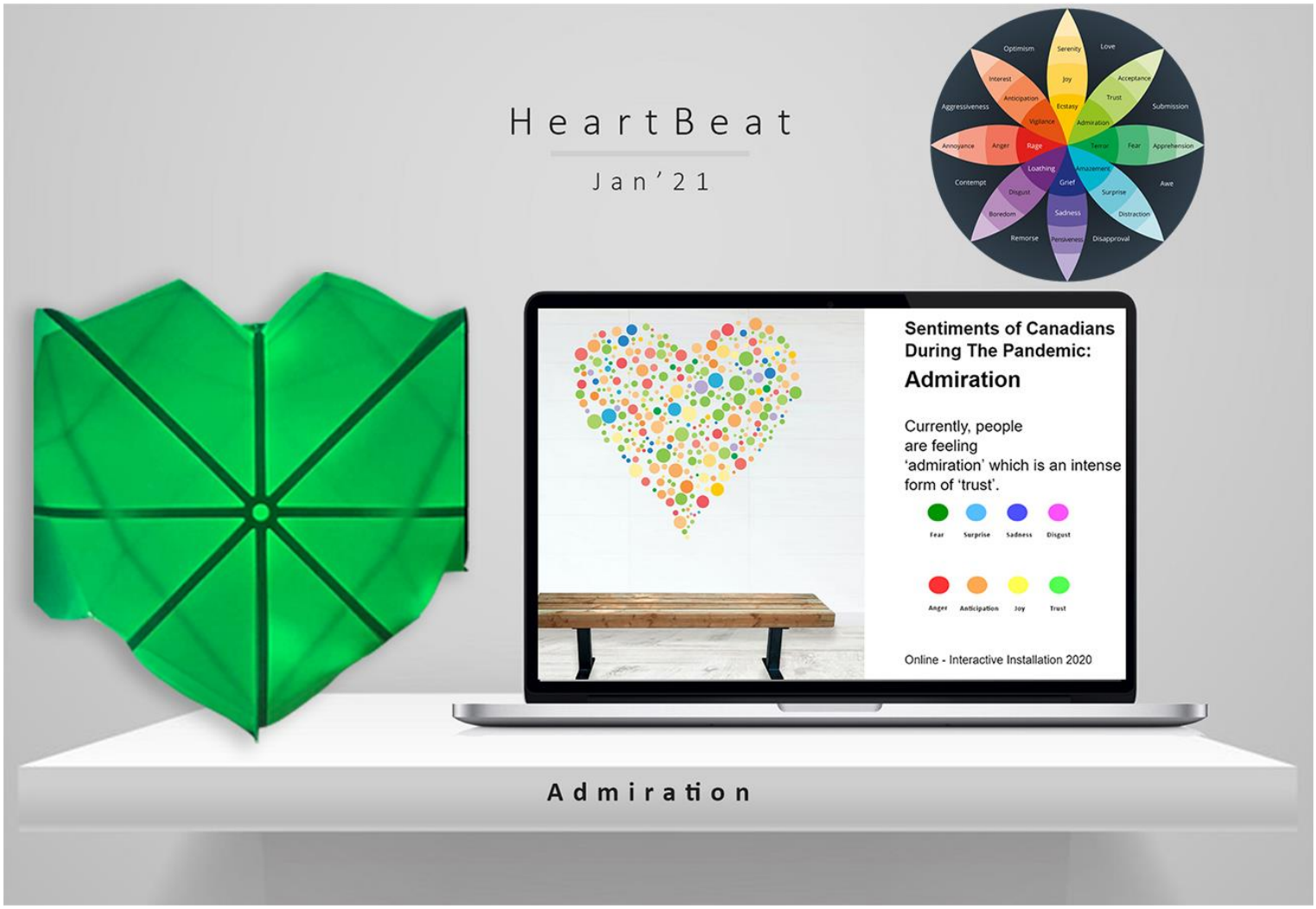


Figure 38: HeartBeat – Admiration (green shade) shown during Jan'21 on both physical installation and website visualization. Plutchik's wheel of emotions is shown on top right of the image.

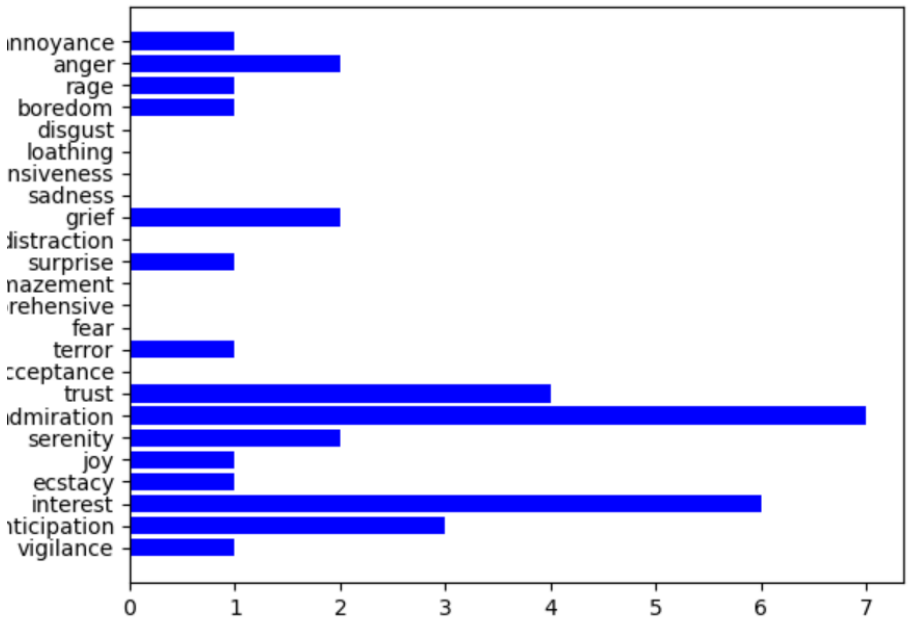


Figure 39: Graph showing emotions during Jan'21 with admiration as dominant.

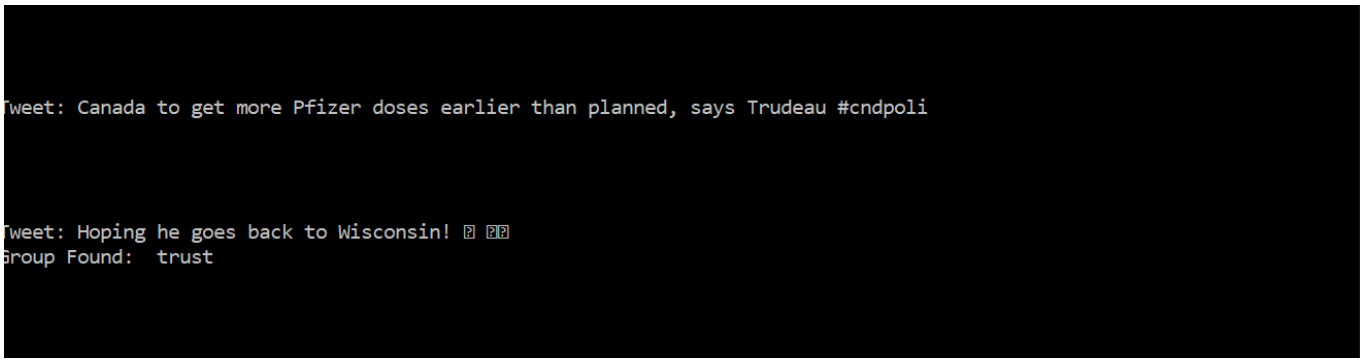


Figure 40: Sample of tweets classified in the trust group.

4.2.1.1 Case study evaluation summary

To summarize, the above timeline (pre-Covid-19 & pandemic) reflects emotions for various time periods and how HeartBeat reflects the sentiments of Canadians in the web version as well as the physical installation. The Figure 44 summarizes these various shifts of emotions in juxtaposition with time periods such as how Canadians began feeling grief during the first wave, followed by interest, anticipation, and finally admiration in January 2021.

4.2.2 Results from Interviews with selected experts

I chose 11 experts in Canada from various fields who are involved in public art, curators, policy-making for cities, artists, data journalism, and art direction. This group of professionals have high levels of interest both professionally and personally in public art, aesthetics, and how a pandemic related public art could be beneficial. Although, I had a choice to just select artists but due to the goals of HeartBeat, it was imperative to evaluate how HeartBeat as a framework for a pandemic related public art could impact stakeholders. The evaluation took place remotely due to the current lockdown measures in Toronto. The participants were shown a pre-recorded video of the web version of HeartBeat and also shown the process of how HeartBeat was created as a pandemic related framework using the vision of community, creativity, and everywhere. Thereafter, participants were shown a 5-point Likert scale based questionnaire with 8 questions as shown in Appendix C. As discussed in the previous chapter, I combined four questions of Zimmerman et al. (2007) evaluation criteria from research through design with four questions from Wall et al. (2019)'s evaluation for visualization. This helped me evaluate HeartBeat from a wider context. Each question had two parts: scoring quantitatively followed by a reflection on the same question where the experts could share a reflective response about the visualization, experience, and the overall HeartBeat system. The overall interview lasted 30-40 minutes.

The first part of this section discusses the quantitative results from both Zimmerman's evaluation criteria (Figure 45) for research through design and Wall et al. (2019)'s criteria for visualization (Figure 46). The questionnaire is presented in Appendix C. Then, I discuss qualitative reflective responses for each of the evaluation criteria.

Figure 45 shows the results when 11 experts were asked to rate and reflect on process, invention, relevance, and extensibility on a five-point scale. The majority of the experts seemed to strongly agree (55%) and agree (35%) about HeartBeat's framework process and documentation utilization in their own practice while approximately 20% of participants disagreed with the usage. For the invention criteria, almost 60% of the evaluation group agreed while 30% strongly agreed with HeartBeat's framework (sentiment visualization, physical display, and web version) to have the potential of filling the gap in the current pandemic related public art. Only 10% disagreed with the same. In terms of relevance, none of the participants disagreed with the relevance of HeartBeat in current times such as the pandemic and lockdown and close to 51% strongly agreed with its suitability in the present times. Regarding the extensibility of HeartBeat, in terms of reusing or repurposing the HeartBeat by artists, designers, and curators to create more such work, 45% agreed with its extensibility while 18% strongly agreed. However, close to 40% either disagreed or took a neutral stance about repurposing HeartBeat for their personal art practice.

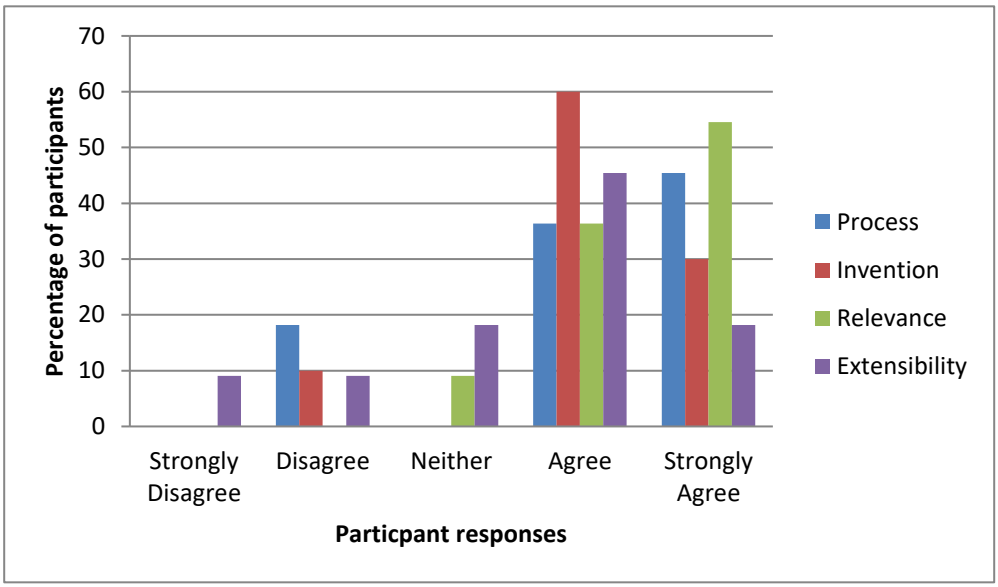


Figure 45: Quantitative results from evaluations (Q1-Q4) show that majority of participants strongly agreed with the process and invention of HeartBeat. While the larger part of the evaluation group agreed with invention and extensibility.

Figure 46 shows the results when the evaluation group of experts were asked to rate and reflect on insight, time, essence, and confidence on a five-point scale. In terms of insights gained from the HeartBeat visualization for both obvious and implicit trends, 54% of the group agreed and strongly agreed with the insights while 45% neither agreed nor disagreed with the insights. When surveyed about the time in terms of how quickly participants were able to understand the visualization, 55% agreed that this visualization made the understanding faster. Whereas 27% strongly agreed and 18% marked as neither. When exploring the overview and context of visualization (essence), 45% agreed to have a sound understanding of both. While 36% scored as neither. Pertaining to the participant's confidence about the quality of data, 27% of responses fell into the category of agree/strongly agree and 18% disagreed.

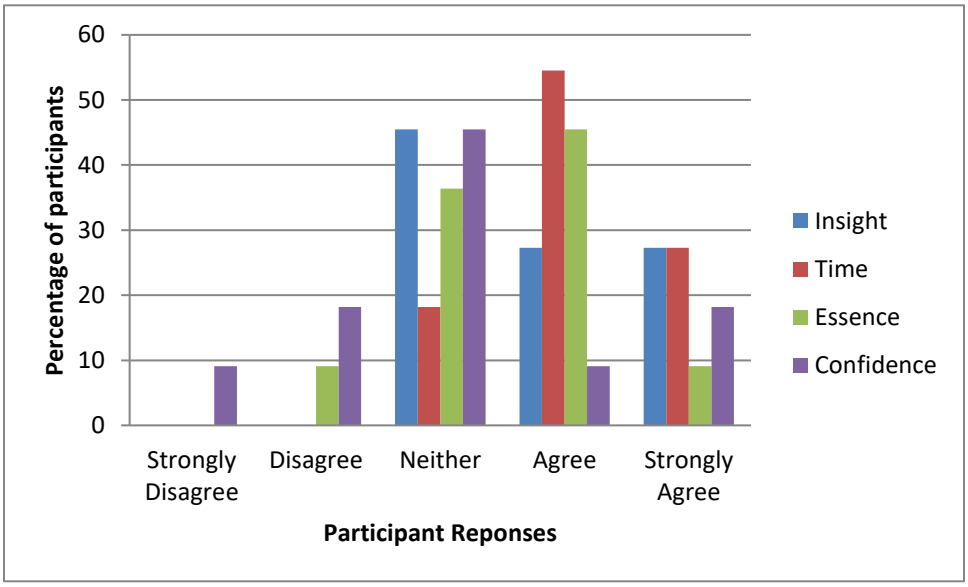


Figure 46: Quantitative results from evaluation (Q5-Q8) show that majority of participants agreed with the essence and the ability of understanding visualization quickly. While with regards to the insights reflected on HeartBeat, 54% agreed and strongly agreed, accumulatively.

I now discuss the qualitative responses and reflections from the participants, which I collected during these interviews. The responses included in-depth insights, trends, and opinions which inspired me for future iterations. The summary of all the distinctive points discussed in this subsection is summarized in Appendix D. Most participants enjoyed the HeartBeat experience. One of the participants described HeartBeat as "a necessary step into the new world" while another expressed it as a reminder that our lives are interconnected. One participant mentioned that reflection of multiple emotions is necessary and also "a need to commemorate what we have been through" while another participant said, " It does help people question how others are feeling – and sparks conversation". One individual shared that HeartBeat is very responsive to the current times and it's necessary to be responsive to the community's emotions and not just being positive and negative through art. Another participant shared

similar thoughts about HeartBeat stating it as a current community need. One participant detailed HeartBeat as "wonderful, human and urgent " while another individual surveyed suggested getting " too many ideas" when asked about the extensibility of HeartBeat. And it's relevant with the current stay-at-home order. In addition to this, one artist suggested HeartBeat has nature to be malleable where artists can play with it to share whichever sentiment while another participant described that to a certain degree, it's another element in relation to public art. One participant described that HeartBeat has Identified an area and there is room to create art in this way. And, outside a pandemic – there will be a desire not to see public art on computers – thus needs of people will change after a pandemic and the physical installation of the HeartBeat could be useful.

In terms of impact on policy-making, one participant described HeartBeat's data might help sense of the communication but changing public policy might be unreliable and described it as one of the tools in the toolbox by saying "HeartBeat is a temperature check". Another participant marked HeartBeat as being in an interesting place as policymakers are more likely to use a matrix that could combine source, month. percentage to connect with emotions. One individual expressed his reflection by suggesting that due to the limitation of HeartBeat of just using one source (Twitter) for information it will not impact policy. On the contrary, another participant outlined HeartBeat's framework, the structure provides great utility. The pandemic related framework allows us to address the context of the pandemic. There is no public art because there is no framework. The notion of everywhere becomes paramount due to mobility. Another participant described HeartBeat as a useful framework going forward for crisis strategy as people in the industry are beginning to think about it.

One participant narrated that HeartBeat's simplicity is what makes it effective. It offers strong insights like trends that are obvious from colors. However, one participant suggested mentioning a time period or a time-based trend or trajectory could make it more contextual. Similarly using a time filter

button could further make it engaging, according to one participant. Another participant suggested HeartBeat could be more interactive by using sensors that could help user's true reflection of emotions demonstrated live. Similar thoughts were shared by another participant about accessibility for public art for addressing communities inclusively such as vision impairment and also suggested to discover ways to have interaction without hover mouse. Also, the visualization could be supported with more context such as socially and culturally. Another participant described using happenings, events, time or a reason behind emotions could improve HeartBeat further. These thoughts were shared by another participant who described that HeartBeat offers a clear depiction of sentiment but not stronger insights. Similarly, another contributor suggested that using context could add more trust factor to the visualization. The engagement with HeartBeat was acknowledged as one interviewee suggested how the current pandemic related public work is only one-way and not engaging enough.

Another artist critiqued that the physical installation of HeartBeat could have more information such as a title, linking it to the website (live physical heart and then the website could deliver more information). However, one individual from the evaluation group highlighted the physical installation has potential for light festivals.

Seeing emotions through color selection is an important decision for HeartBeat that makes it easy to understand, narrated by one participant. On the use of color, another individual spoke that It's a very emotional time and colors help people feelings while HeartBeat is simple and reflective. A participant also suggested that colors of legends could be better such as similar shades of green for fear and trust. However, the size of the circle size could be improved. Another participant suggested that although visualization reflects very clearly the overview of data but using the size of the dot to signal emotions groups could make it better. Another contributor to the evaluation suggested using the position of dots of similar colors near each other to add further clarity. Also, the frequency of dots

marked some confusion for this participant. One participant reflected on how HeartBeat could represent more real-time information and suggested If tweets are coming live and links with dots (to represent live – or a progress bar). One participant noted that the transition or update could be slower. On the other hand, another interviewee marked HeartBeat as ever-changing and dynamic - It's not frozen in time (even in non-pandemic) for readers – and brings a sense of connectivity.

One participant suggested using sound more inclusively such as a percentage shift of the beating sound. Another participant also described changing the tempo of the heart such as intensity of heart beat during the reflection of an emotion such as admiration. Also, using more hearts and overlapping heartbeats of different emotions as currently the heart seems to be too perfect. Another participant also suggested using multiple hearts that could be filled with colors and morph into current data – a more indicative approach.

On using the heart as a shape, one participant suggested that using a design of a biological heart would be better as an animated heart shape is always casual. However, another participant acknowledged the use of the heart as "Heart is such an iconic image". Another individual critiqued on using the heart as a shape by endorsing that the visual shape connects with the data and HeartBeat, reinforcing the data using a symbolic image. One participant suggested that they would want to transform the shape based on their own installation such as using community consultation and would also trying different sources in addition to Twitter.

One participant also shared how Twitter as a data source could be seen as untrustworthy as Twitter has banned specific individuals and their voices are unheard. Another individual interviewed recommended showing more info on the dataset for the visualization. However, one participant described that Covid-19 related emotion and mental health is still being investigated, but HeartBeat is an interesting add-on to how data is collected using Twitter. Another individual was against the use of

Twitter, especially when using social media for Covid-19 related news. Moreover, one participant described that more than the source of data, the objective of the HeartBeat is towards emotions and art which is more important. Another participant illustrated this notion even more by endorsing that although Twitter represents one part of the segment, art is not about offering scientific accuracy but inspiration. There is an emotional feeling outside the body and HeartBeat reflects the temperature of the city to provoke conversation. Another interviewee shared that sometimes from simple charts you can understand data quicker, but you care less about it.

One participant suggested that HeartBeat has the potential to participate in in an exhibition such as Arte Util (https://www.arte-util.org/). Another individual expressed that HeartBeat could be disp layed at storefronts and also be reflected at city halls. While another interviewee suggested the potentia l for embedding HeartBeat for digital publications.

Several participants also suggested the future work potential of HeartBeat, such as focusing on comparing tweets from popular media outlets and their sentiments with what members of the public are tweeting and their emotions. Moreover, another participant was curious to explore changing the color of HeartBeat using its physical installation in public space – such as every week is a different color for the neighborhood of that public space. A similar notion was suggested by another participant about using HeartBeat to investigate emotions for each neighborhood as "We are in a society – other people are feeling the same thing and collective experience is key". HeartBeat is reflecting certain emotions from twitter and it could use more content, such as non-public data from internet social media groups. Another contributor suggested that a lot could be built using HeartBeat, such as complex algorithms for the backend as well as more adjectives or emotions on the visualization. One participant suggested that HeartBeat being open-sourced, should be shared with artists of different countries so they can visualize their emotions, and offer a comparison between countries such as New Zealand versus the rest of the world.

The results from both kinds of evaluation methods, case study evaluation through timeline and interviews (quantitative and qualitative) with selected experts, showed robust findings from a wide context. This includes understanding a clearer pathway to success from various stakeholders, interests, and critiques of interviewees for different criteria of HeartBeat, limitations of the design and visualization of HeartBeat, and suggestions on future direction. This indicates, that to be more successful, various lessons should be integrated for future iterations of the design and creation of the prototype or artifact.

4.3 Lessons Learned

HeartBeat was evaluated using case study evaluation for various time periods, Zimmerman et al. (2007) evaluation criteria from research through design, and Wall et al. (2019)'s evaluation for visualization. Firstly, the timeline evaluation showed how the emotions varied in different time periods which is key to understanding the overall sentiment in different periods of the pandemic. Secondly, Zimmerman et al. (2007) evaluation revealed salient features of research through design in the areas of the process, invention, relevance, and extensibility of HeartBeat. Thirdly, Wall et al. (2019)’s evaluation showed the strengths and weaknesses of the visualization itself in the areas of insight, time, confidence, and essence. The outcome of the study revealed compelling insights into interviewees' interaction, use of the HeartBeat framework, and experiences with the overall system. Being consistent with the above evaluation criteria and my personal expectations, I have gathered and extracted lessons about HeartBeat's achievements and limitations. Using the same criteria (Zimmerman et al. (2007) and Wall et al. (2019), I have created a comparison table (Figure 47) of how HeartBeat and other pandemic related public art in Canada, discussed in the related work section of Chapter 2, follows these eight evaluation points. The Canadian works selected to compare with HeartBeat are (a) We all meet again, this is a Covid-19 focused public art to reflect the sentiment of artists on digital screens; (b) Frontline hero arts projects, this is also focused on Covid-19 and reflects the sentiment on one community which is

frontline workers, and (c) Covid-19 cell, this is a physical installation focused on Covid-19. These all are focused on the pandemic, reflection of sentiment, and physical installation. Thus, they are relevant to the HeartBeat.

Evaluation criteria	**HeartBeat(Version 3)**	**We all meet again (Figure 20)**	**Frontline hero arts project (Figure 21)**	**Covid-19 cell (Figure 13)**
Process and documentation	√	√	×	×
Invention of artifact	√	√	√	√
Relevance in current times	√	√	√	√
Extensibility of project to be repurposed	√	√	√	×
Insight - obvious and implicit trends	√	√	×	×
Time in understanding visualization	√	×	×	×
Essence - overview and context of data	×	×	×	×
Confidence about quality of data	√	√	×	×

Figure 47: Evaluation of HeartBeat with pandemic related work in Canada. The projects compared are focused on the pandemic, reflects sentiment of communities and physical installation, thus relevant to HeartBeat.

Reflecting sentiments of Canadians during Covid-19 using HeartBeat was dynamic, with accessibility online during the lockdown. The interaction of HeartBeat was simple with mouse hover however engaging enough to spark conversation about the current community needs and offers a tool for the pandemic related public art. Although the sample size of the evaluation was limited, HeartBeat allows an efficient medium when looking for current sentiments. The quantitative results also showed that participants felt that visualization was quick to understand. Although HeartBeat is extensible due to

its modular design and physical and online features, it requires more context to impact policymaking for the pandemic related framework as well as policy decision based on emotions. There would need to be more than Twitter as a data source and context such as timestamps, or social and cultural data to inform or impact policies. It is imperative to mention that the HeartBeat's simplicity in interaction was acknowledged, however, it would be important in the future to make it more interactive in the areas of offering time filter buttons for users to view various time periods upon their discretion - one of the features of HeartBeat that limited the interaction along with selection of own tweets vs national.

Another lesson learned is about HeartBeat being less multi-sensory and more visual. The use of varying sounds based on the intensity of emotions could make it more appealing to the senses. However, in the current state, HeartBeat could be made even more interactive by creating a unique hashtag for HeartBeat asking users to tweet their emotions which could make HeartBeat more context-aware. Similarly, for the physical installation, the interactivity could be extended using sensors. In general, HeartBeat rendered users with a quicker take way of the sentiments with obvious trends using both text and visualization side by side, to make comprehension simpler. However, the use of colored dots caused some confusion for participants which could be reframed in the future by using size of dots and their position to make multiple emotions more visible and intuitive to understand. Another interesting learning was of the shape of the heart itself. Although, there was a solid connection of data with an icon-like heart shape, some participants reflected that a dynamic design of the heart could be explored as it evolves with time and emotions.

HeartBeat encouraged and created curiosity amongst users to learn more about the emotions and care for the heart. As one participant summarizes, HeartBeat makes it possible to care more for the art. Most pandemic related public art was only available on outdoor billboards and situated in public space such as murals on walls, and it was not possible to engage or learn about them during the current

lockdown situation. Thus, the novelty of HeartBeat in using community, everywhere, and creativity from a pandemic view makes the benefits of public art during these times more crucial. The emotions and content being reflected become a concern as Twitter is the only source for HeartBeat which limits sentiments to only one segment of the society which needs to be addressed by using more layers of open-source data (City of Toronto, n.d.-a) available by the City of Toronto. These issues were not addressed in HeartBeat as they were not part of the scope but present an opportunity in the future for HeartBeat to be multilayered with a robust mix of data sources.

Overall, I have learned that HeartBeat has many visual and interaction opportunities that could make it more interactive and context-aware in addition to creating more interaction options for users in the visualization itself. It is also clear that more pandemic related public art needs to be produced within sentiment visualization, IoT, and interactivity to reap the benefits of public art during a crisis time. Furthermore, for the next crisis or a pandemic, HeartBeat presents a framework and tools to create more work within the intersection of community, creativity, and everywhere. Lastly, the lessons also gave a more meaningful direction for the future direction of HeartBeat as it could be made more inclusive for more communities, and municipalities to create an impact such as understanding Tweets from languages other than English including variety of data sources that could be an optimum strategy.

4.4 Version 3 - Refining HeartBeat based on evaluation: Exhibition design

Following the evaluation from experts, several suggestions were made, along with critique, and ways for iteration were suggested to improve the HeartBeat. Within the web visualization, one key area of improvement was the quantity of dots, colors, and showcasing the time period. I reduced the quantity of dots from 350 to 100 and then also reviewed the visualization for 600 dots. However, 350 dots seemed to present a better shape of the heart by filling dots. On the other hand, currently, the current iteration of visualization shows a different color for primary emotions, and their pertinent high and low intensity emotions show different shades of the same primary color, thus showing too wide a range of colors. To simplify this, I allotted the primary color to each of its high and low-intensity emotions as opposed to different colors for each of the high or low intensity word. For example, Figure 55 (Version 3) shows that sadness (primary emotion) will have the same color as grief (high-intensity emotion of sadness). However, when users would hover on the dot, they will still see all the emotions which makes it simple to learn about primary emotions and their high and low-intensity emotions through the same color. This was achieved by changing the dot and color assignment buckets from the framework (Figure 54). Similarly, I focused on a specific time-period for reflecting sentiments (Figure 55) which is Feb'21 until March'21. This was achieved by changing the period of the data block from the framework Figure 53 and text assignment block from Figure 54. The snapshots showing prototype for Version 3 is shown in Appendix E.

On the other hand, for physical installation, several suggestions were presented to show the meaning of color. One of them was to use a text label to show the meaning of color when the heart is placed in a public space. Thus, for an outdoor experience, I would create a label as shown in Figure 56 (Version 3) which is a representation to showcase the meaning. The snapshots showing production for physical installation are show in Appendix E. However, the physical installation

(Version 3) has several opportunities with sound, haptic feedback and which are discussed in the Future Work chapter ahead.

Lastly, Figure 57 shows a representation of how the website visualization of Heartbeat could be embedded into any third-party websites such as digital news. This is possible as the website visualization is based on HTML.

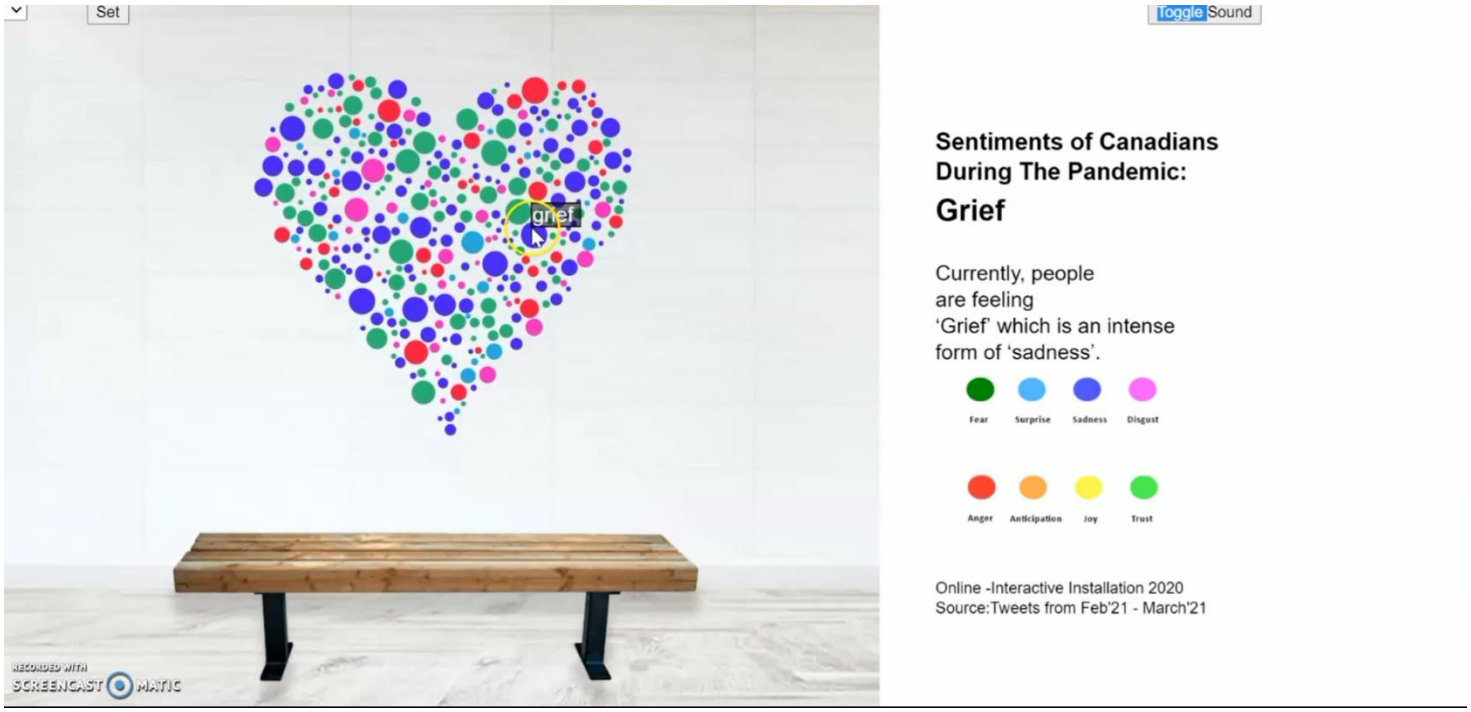


Figure 55: HeartBeat (Version 3) showing grief as a dominant emotion with blue-indigo colored dots for the Feb'21-March'21 period. The primary color of sadness is reflected on all its high and low intensity emotions such as grief.

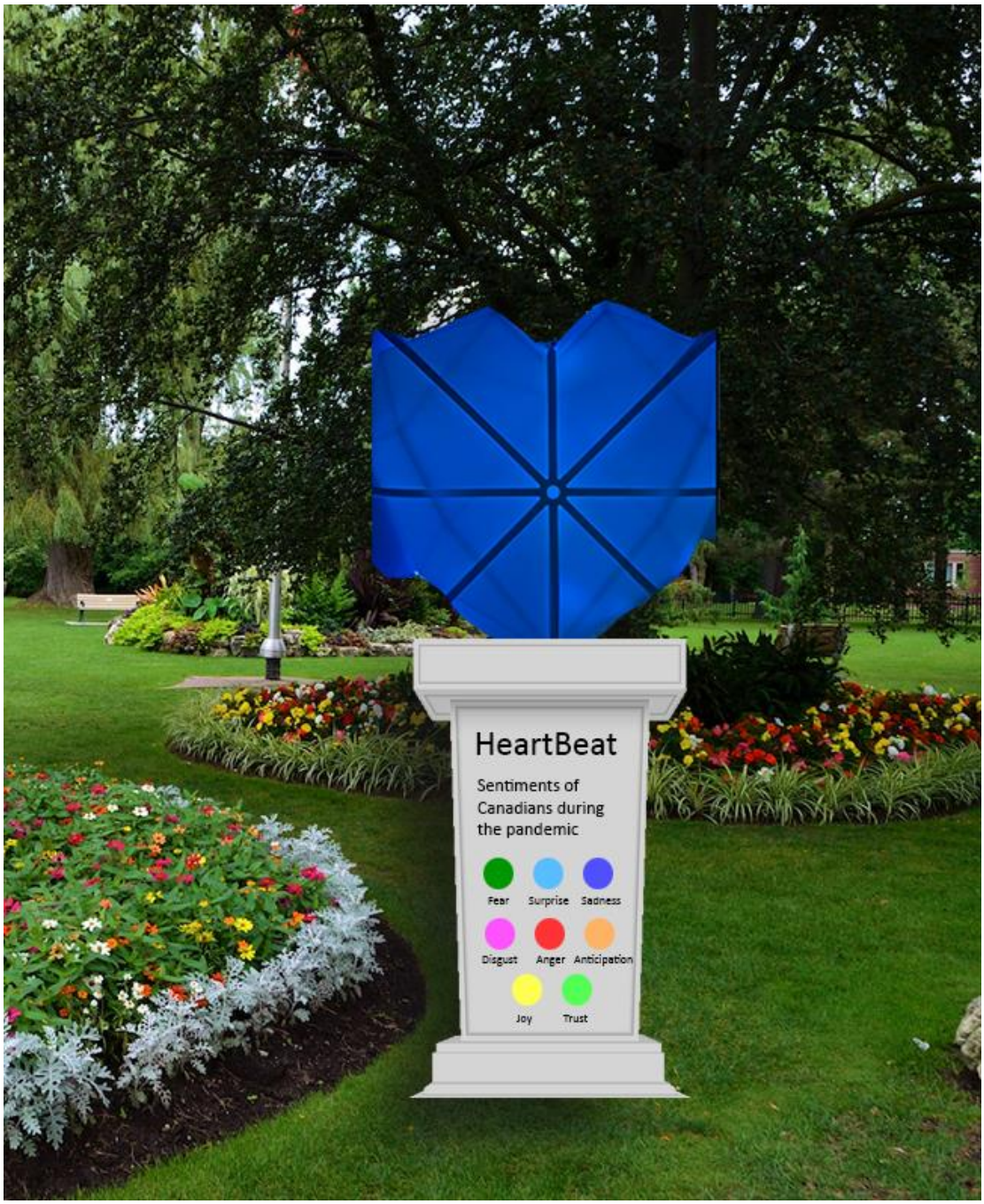


Figure 56: Physical installation (Version 3) showing blue-indigo color on the heart. It shows the physical installation could be placed in public space to guide with the meaning of colors. This is a representation of how the physical installation could be presented.

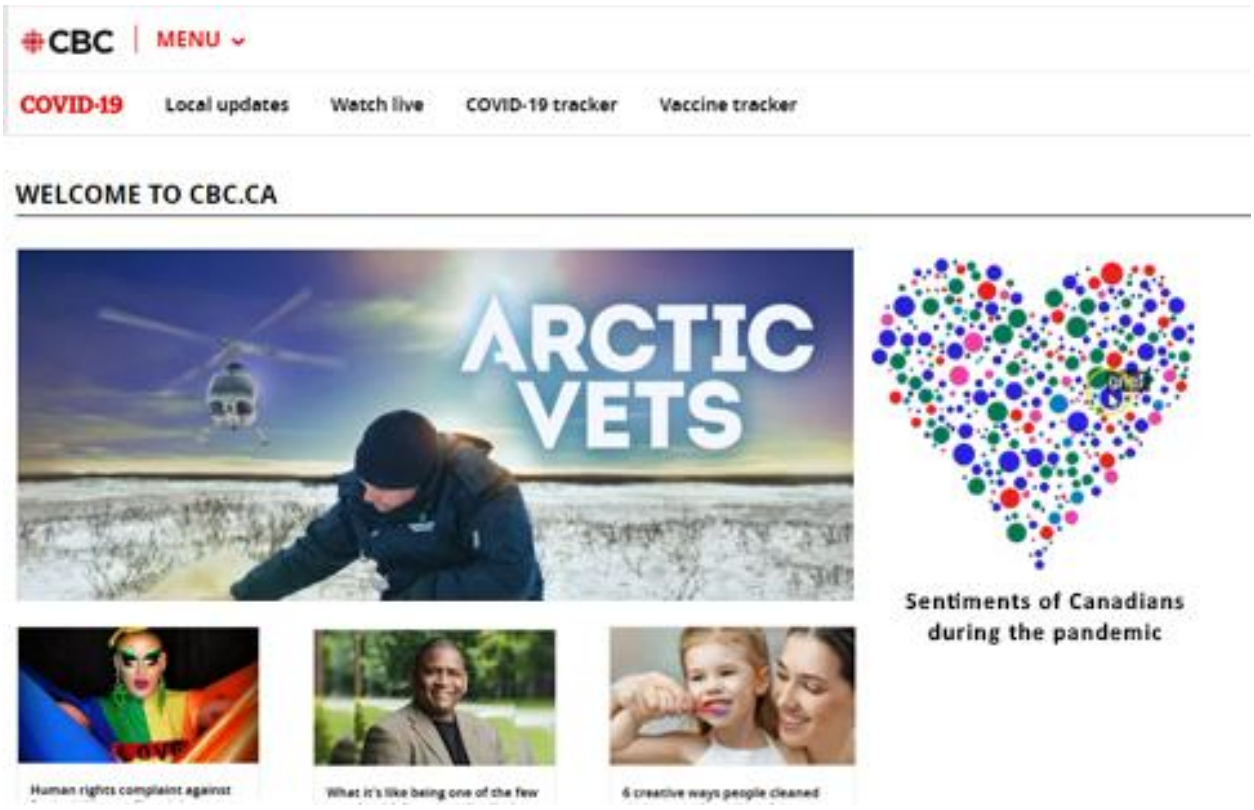


Figure 57: This is a representation of how the website version (such as cbc.ca) of the HeartBeat could be embedded into third-party websites such as digital news publications to show sentiments.

4.5 Limitations: Covid-19, Technological and Skills

Various limitations were encountered from the onset for HeartBeat's initial vision. Several of these limitations were Covid-19 and lockdown related, others were due to time, resources, and technological challenges.

Firstly, due to the ongoing Covid-19 pandemic, the situation has been uncertain throughout the project period. This includes remote learning including design and creation from inside the home, inaccessibility to stores or labs due to the lockdown, Covid-19 fatigue and stress, lack of physical engagement during need identification process till evaluation, and finally management of time to create work during a stay-at-home lockdown. These are further enveloped by a concern of keeping yourself and your family safe. Moreover, during the same time, my family back home in Pakistan had contracted Covid-19.

During the need identification phase of my virtual residency (Contingencies of care), although the programs were greatly insightful, but due to the remote delivery of programs and lack of physical engagement with stakeholders it made the gathering of important insights difficult. Similarly, during the evaluation of the early prototype (Version 1) by Canadian Film Center mentors, discussions were remote, limiting actionable feedback that I could work on. Although, the mentors delivered robust feedback to steer the project to suit the current pandemic times.

The results from evaluation methods including a critique from selected experts showed significant insights in terms of avenues of improvements, but due to the limited sample size, it is difficult to prove the reliability and consistency of results. Unfortunately, due to the challenges of time and scope of HeartBeat, it was difficult to recruit more interviewees who were also managing a challenging schedule. Moreover, using a Likert scale posed challenges during the evaluation with selected experts such as participants avoiding choosing maximum options on the scale because of the effect of choosing

extreme options even though if it was the right choice. This sometimes creates problems in the subjective understanding of the responses. However, due to the nature of participants, who were experts, the findings from this evaluation method showed a clear direction of positives and limitations. Nonetheless, statistics act as a tool to help think about the extracted data but for the future iterations of HeartBeat, one should be aware of such challenges while evaluating their prototype and its sample size.

Most of my professional skills lie in the areas of digital marketing. However, HeartBeat required various programming skills even within p5.js, Arduino, and IoT. The skill advancements within these areas were challenging during the current lockdown times as I was working solo to improve the HeartBeat as much as I can within the time and scope of this project. However, there were many times where hurdles from lack of technical skills were faced in order to grow and improve HeartBeat such as its visualization.

In addition to the above, the original idea of the HeartBeat framework, as mentioned in an earlier chapter, was to have a robust physical installation with a large fabrication of Heart by using sensors to make it more interactive. However, during the evaluation of the early prototype (Version 1) and lack of access to labs and after consultation with mentors from the CFC lab, I pivoted to purchasing a small mold of a heart shape. The intention was to make a physical display more interactive. However, that also required more powerful systems including microcontrollers and several apparatuses to fabricate the system. But these were inaccessible due to current times.

Chapter 5 – Conclusion and Future Work

At the onset of the thesis (Chapter 1), I laid down the contribution, significance, and desired goals of HeartBeat. In the current chapter, I revisit these research goals and discuss their accomplishments. This is followed by deliberation of the contributions of HeartBeat to research and reviewing the potential road map for future work.

5.1 Revisiting thesis goals

The goal of HeartBeat is to create a pandemic related public art and framework by researching into three areas of vision from the Toronto Art Strategy Paper which are (a) community; (b)creativity and (c) everywhere. Each of these three areas was discussed in relation to the pandemic such as Covid-19. Much of the literature in the community section was about the rationale and ways of understanding the emotions of citizens, while, within the everywhere section, I reviewed the use of smart city features such as IoT, context awareness, and sentiment visualization architecture for smart cities. Thirdly, within the creativity part of the literature, I examine interactivity and interactive installation from the lens of a pandemic. The primary goal of this thesis is to create, design, and evaluate HeartBeat, an IoT enabled interactive installation to reflect the sentiments of Canadians during a pandemic. Within this primary goal, several secondary goals were achieved by evaluating a technology framework to serve the web version, physical installation and embed everywhere features to assist(a) reflection sentiments of citizens; (b) sentiment visualization for smart cities; (c) IoT, context awareness and interactivity, and (d) act as public art and be virtually available everywhere even during the lockdown.

5.2 Revising thesis contributions

The HeartBeat fulfills several contributions towards the research of a pandemic related public art framework and the future of public art practices during crisis or pandemic times.

1. Detailed literature intersecting three areas: community, everywhere, and creativity and how they are mapped with various disciplines such as sentiment analysis, pandemic related public art, sentiment visualization in smart cities using IoT, context awareness and interactivity. These three areas were the backbone of the thesis. Chapter 2 examines each of these three areas in detail and ties them together in a knowledge resource to commence HeartBeat.

2. Detailed process design and technology stack architecture and a framework for an IoT enabled interactive installation to reflect the sentiments of citizens during a pandemic by creating HeartBeat. Chapter 3 conducts a thorough investigation and offers a robust process architecture of HeartBeat, which uses a web version, physical installation, and embed anywhere functionality. The chapter provides the methodology starting from ideation to prototyping and evaluation using multiple criteria along with technical diagrams.

3. Validation through findings of evaluation in Chapter 4 about advantages for using the pandemic related public art framework described in this thesis for various cities and countries.

4. Confirmation through findings from Chapter 4 of how selected experts believe that HeartBeat could allow artists to take the Heartbeat and add-on more tools and nuances to create an engaging interactive public art for a pandemic within their localities.

5. Attribution through findings from Chapter 4 of HeartBeat, showing an interactive installation reflecting the sentiments of citizens during a pandemic could contribute towards richer policies.

5.3 Future Work

HeartBeat examines how might an IoT enabled interactive installation reflects the sentiments of Canadians during a pandemic. This pandemic related public art framework opened windows to several opportunities for me as well as others who would like to use it for future investigation. I could classify them into (a) short-term, whereby the focus would be on the visualization itself; (b) medium-term goals, focused on examining newer web and physical prototypes of HeartBeat and (c) long-term goals which are focused on reaching out to various other communities such as local neighborhoods or even other countries.

5.3.1 Short-term future work

The web visualization has various areas for enhancement as most of the short-term iteration are focused on the design of visualization itself. Various suggestions about the design emerged from experts as well as stakeholders. The use of the size of dots to add clarity, time filter to give the user more control, display of live tweets to build more confidence, and using sound as part of emotions to make the visualization more immersive, are some of the areas where the user experience of the sentiment visualization could be widely improved and make it more interactive. In addition to this, digital news publishers or data journalists could use any of these iterations to embed it as a Covid-19 sentiment tracker based on their news story.

5.3.2 Medium-term future work

One of the original visions of the HeartBeat was to make a physical visualization more immersive. And I also learned during the evaluation about reflecting the sentiments through different means. One method that also offers a blend of physical and digital is mixed reality. The future version of HeartBeat could use a mixed reality such as A-frame (web framework for building virtual reality experiences) on one side and on the other hand by fabricating an interactive heart with sensors to reflect the sentiments of Canadians. Such a study could investigate how mixed reality and physical

installation could reflect the sentiments during future pandemics or crises and can offer users of public art more interactivity. With this approach, users could seamlessly transition between physical or virtual interaction and be more engaged with mixed reality during future lockdowns. In addition to this, the future of HeartBeat could be more social by using various mixed reality tools such as Facebook's AR Studio(https://sparkar.facebook.com/ar-studio/) that would add great social connectivity to HeartBeat.

5.3.3 Long-term future work

In the long run, HeartBeat has a wide array of opportunities to reach out to more communities. This includes being more localized as well as being global. Due to the nature of HeartBeat, the sentiment engine, web visualization, or physical visualization could all be tweaked separately due to its modular design. Thus, the future study relating to using neighborhoods and using municipal-related sentiments to launch and drive more citywide programs (or national vs global) seems a strong area of investigation. On the other hand, HeartBeat needs to be more inclusive in society. Since it encompasses sound and color, there is a potential for using sound creatively such as haptic feedback as well as physical sensors to distinguish various sentiments.

5.4 Final Remarks

The world is witnessing a long-lasting impact of Covid-19 on societies. With this urgency, researchers and designers should investigate how community, creativity, and everywhere could be further explored to create public art that revitalizes societies from Covid-19 and future-proof societies from an upcoming crisis or a pandemic. HeartBeat presents its contributions by exploring sentiment visualization, IoT, context awareness, and interactivity and learning lessons along the way. These lessons learned from various evaluation criteria and seasoned experts render novel possibilities to transition HeartBeat into new avenues. One of the possibilities was discussed in this thesis about how

HeartBeat as a system could be utilized as a pandemic related public art framework for a smart city such as Toronto.

As examined in the future work section, there are three potential timelines for creating more engaging work. I hope that the contribution of HeartBeat will assist artists, designers, policymakers, data journalists, and researchers to investigate more frameworks that could solidify countries against future pandemics like Covid-19, and develop similar tools such as HeartBeat or build on top of its modular design to create public art that is sustainable for future crises or pandemic times.

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Appendix A: 21 actions of Toronto art strategy paper

1	Issue open calls to artists and curators for project ideas
2	Animate Toronto with temporary public art
3	Identify public art opportunities and engage artists as early as possible in all projects
4	Champion career-launching platforms for the next generation of public artists
5	Create new skills development and leadership opportunities for Indigenous artists, curators and art consultants in the field of public art
6	Deliver a range of competition types and opportunities
7	Encourage new methods of community-engaged public art works in a variety of media
8	Enable the public to discover and interact with public art through creative online resource
9	Activate public art through community-focused educational and interpretive programming
10	Create more public art opportunities for artists from equity-seeking communities
11	Engage Indigenous communities to identify sites of significance across Toronto for Indigenous public art projects
12	Ensure that juries and advisory committees are reflective of the diversity of the arts sector, and the population of the City of Toronto
13	Engage artists and communities city-wide in decision-making related to public art through meaningful consultation processes
14	Establish an artist-in-residence program in City divisions
15	Pursue new opportunities for destination public art
16	Develop City-wide standards to consistently apply the “Percent for Public Art” policy to municipal capital projects
17	Produce public art master plans on a city-wide basis to provide strategic direction on future project plans
18	Pool public art funds to produce new works in underserved areas of the city
19	Advance Indigenous place-making city-wide through public art
20	Integrate public art in a variety of media into a broader range of public realm improvements
21	Protect public art works city-wide through proactive maintenance and conservation

Figure 51: 21 actions from Toronto art strategy paper (City of Toronto, 2019)

Appendix B: Emotions Library

The following are the emotions used in the HeartBeat. The synonyms of each of the emotions are extracted from standard dictionaries listed below:

Emo1= ["**vigilance**", 'Cautious', 'vigilant', 'askance', 'attentive', 'attentively', 'attentiveness', 'belt', 'braces', 'conservative', 'conservatively', 'diligence', 'diligent', 'discreet', 'methodically', 'meticulous', 'meticulously', 'meticulousness', 'mindful', 'risk-averse', 'safe', 'scrupulous', 'sedulous', 'watchfulness', 'wakefulness', 'alertness', 'alertness', 'caution', 'diligence', 'surveillance', 'attentiveness', 'circumspection', 'lookout']

Cambridge: https://dictionary.cambridge.org/dictionary/english/vigilance

WordNet: http://wordnetweb.princeton.edu/perl/webwn?s=vigilance&sub=Search+WordNet&o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&h=0000

Thesaurus: https://www.thesaurus.com/browse/vigilance?s=t

emo2 = ["**anticipation**", 'Planning', 'expecting', 'arranging', 'accidentally', 'accidentally on purpose ', 'advertent', 'advisedly', 'aim at bargain', 'in the pipeline ', 'planner', 'provident', 'providently', 'provision', 'purpose', 'purposefully', 'purposely', 'prevision', 'apprehension', 'hope', 'joy', 'prospect', 'contemplation', 'expectancy', 'foresight', 'foretaste', 'impatience', 'outlook', 'game', 'hobby', 'interestedness']

Cambridge: https://dictionary.cambridge.org/dictionary/english/anticipation

WordNet: http://wordnetweb.princeton.edu/perl/webwn?s=anticipation&sub=Search+WordNet&o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&h=0000000000

Thesaurus: https://www.thesaurus.com/browse/anticipation?s=t

emo3 = [**'interest'**, 'excitement','energy','buzz', 'alacrity', 'animation', 'ardour', 'avidity', 'commotion', 'fascination','elation', 'eagerness', 'frenzy', 'friskiness', 'frolic', 'dynamism', 'stake', 'pursuit', 'concern ', 'matter', 'activity', 'concern', 'enthusiasm', 'importance', 'passion', 'significance', 'sympathy', 'affection', 'attentiveness', 'care', 'case', 'consequence', 'diversion']

Cambridge: https://dictionary.cambridge.org/dictionary/english/interest

WordNet:
http://wordnetweb.princeton.edu/perl/webwn?s=interest&sub=Search+WordNet&o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&h=000

Thesaurus: https://www.thesaurus.com/browse/interest?s=t

emo4 = ["**ecstasy**", Pleasure', 'happiness', 'afterglow', 'beatitude', 'bed', 'bed of roses ', 'delirium', 'exaltation', 'exultation', 'feast', 'fulfilment', 'fun', 'gaiety', 'joviality', 'joy', 'joyfulness', 'joyousness', 'jubilation', 'savour', 'sensuousness', 'stardust', 'rejoice', 'gladden', 'elation', 'euphoria', 'happiness', 'joy', 'rapture', 'beatitude', 'blessedness']

Cambridge: https://dictionary.cambridge.org/dictionary/english/ecstasy

WordNet:
http://wordnetweb.princeton.edu/perl/webwn?s=joy&sub=Search+WordNet&o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&h=00

Thesaurus: https://www.thesaurus.com/browse/ecstasy?s=t

emo5 = ["**joy**", 'afterglow', 'beatitude', 'bed of roses ', 'delirium', 'exaltation', 'exultation', 'feast', 'fulfilment', 'fun', 'gaiety', 'goody', 'joviality', 'joyfulness', 'jubilation', 'like a dog with two tails ', 'rejoice', 'stardust', 'delight', 'pleasure', 'amusement', 'bliss', 'charm', 'cheer', 'comfort', 'delight', 'elation', 'glee', 'humor', 'satisfaction', 'wonder']

Cambridge: https://dictionary.cambridge.org/dictionary/english/joy

WordNet:
http://wordnetweb.princeton.edu/perl/webwn?s=joy&sub=Search+WordNet&o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&h=00

Thesaurus: https://www.thesaurus.com/browse/joy?s=t

emo6 = ["**serenity**", Calm', 'relaxed', 'cool as a cucumber', 'at your leisure ', 'be at peace with the world ', 'calmly', 'calmness', 'easy', 'easy come', 'easy go ', 'easy-going', 'free-flowing', 'mellow', 'nerveless', 'nervelessly', 'peaceably', 'peacefully', 'sedate', 'unstressed', 'without a care in the world', 'repose', 'quiet', 'placidity', 'calmness', 'composure', 'patience', 'peace','mind', 'stillness', 'tranquillity', 'cool', 'peace']

Cambridge: https://dictionary.cambridge.org/dictionary/english/serenity

WordNet:
http://wordnetweb.princeton.edu/perl/webwn?s=serenity&sub=Search+WordNet&o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&h=00

Thesaurus: https://www.thesaurus.com/browse/serenity?s=t

emo7 = ["**admiration**",'admire', 'admiring', 'admiringly', 'approving', 'approvingly', 'awe', 'glorify', 'hallow', 'hero worship', 'honorific', 'idolater', 'pay your respects ', 'respectful', 'revere', 'reverence', 'appreciation', 'adoration', 'affection', 'applause', 'appreciation', 'delight', 'esteem', 'fondness', 'love', 'pleasure', 'praise', 'recognition', 'reverence', 'wonder', 'wonderment']

Cambridge: https://dictionary.cambridge.org/dictionary/english/admiration

WordNet:
http://wordnetweb.princeton.edu/perl/webwn?s=admiration&sub=Search+WordNet&o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&h=000000000000

Thesaurus: https://www.thesaurus.com/browse/admiration?s=t

emo8 = ["**trust**",'Hoping', 'hopefulness', 'appealingly', 'cautious', 'cautiously', 'cross','fingers','dream', 'hopefully', 'hopefulness', 'faith', 'confidence', 'confidence', 'expectation', 'faith', 'hope', 'assurance', 'certainty', 'certitude', 'conviction', 'assurance', 'certainty', 'certitude', 'conviction', 'credence', 'credit', 'dependence', 'positiveness', 'reliance', 'stock', 'sureness', 'entrustment']

Cambridge: https://dictionary.cambridge.org/dictionary/english/trust

WordNet:
http://wordnetweb.princeton.edu/perl/webwn?s=trust&sub=Search+WordNet&o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&h=

Thesaurus: https://www.thesaurus.com/browse/trust?s=t

emo9 = ["**acceptance**",'accepting', 'accommodation', 'accreditation', 'agree to', 'agree with', 'approve', 'approver', 'buy-in', 'consensus', 'court', 'internalize', 'middle ground', 'reach', 'roll', 'strike a chord', 'sympathy', 'traction', 'unquestioned', 'validate', 'acknowledgment', 'admission', 'approval', 'compliance', 'consent', 'cooperation', 'recognition', 'recognition', 'acquiring', 'permission']

Cambridge: https://dictionary.cambridge.org/dictionary/english/acceptance

WordNet:
http://wordnetweb.princeton.edu/perl/webwn?c=8&sub=Change&o2=&o0=&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&i=-1&h=0000000&s=acceptance

Thesaurus: https://www.thesaurus.com/browse/acceptance?s=t

emo10 = ["**terror**", 'acrophobia', 'aerophobia', 'agoraphobia', 'catastrophize', 'chill', 'claustrophobia', 'claustrophobic', 'coulrophobia', 'dread', 'fearfulness', 'hydrophobia', 'Islamophobia', 'misophonia', 'mortal', 'nomophobia', 'phobic', 'scare', 'transphobia', 'willie', 'xenophobia', 'scourge', 'threat', 'anxiety', 'awe', 'dread', 'horror', 'intimidation', 'panic', 'shock', 'fright']

Cambridge: https://dictionary.cambridge.org/dictionary/english/terror

WordNet:
http://wordnetweb.princeton.edu/perl/webwn?s=terror&sub=Search+WordNet&o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&h=00000000

Thesaurus: https://www.thesaurus.com/browse/terror?s=t

emo11 = ["**fear**", 'phobias', 'acrophobia', 'aerophobia', 'agoraphobia', 'catastrophize', 'chill', 'claustrophobia', 'claustrophobic', 'coulrophobia', 'dread', 'fearfulness', 'hydrophobia', 'Islamophobia', 'misophonic', 'mortal', 'nomophobia', 'phobic', 'scare', 'transphobia', 'xenophobia', 'reverence', 'revere', 'anxiety', 'despair', 'dismay', 'jitters', 'panic', 'scare', 'suspicion']

Cambridge: https://dictionary.cambridge.org/dictionary/english/fear

WordNet:
http://wordnetweb.princeton.edu/perl/webwn?s=fear&sub=Search+WordNet&o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&h=0000

Thesaurus: https://www.thesaurus.com/browse/fear?s=t

emo12 = ["**apprehensive**", 'Anxiety', 'worry ', 'agitation', 'angst', 'anxiety', 'consternation', 'discomfiture', 'nerve', 'nervousness', 'oppression', 'overwork', 'panic attack', 'perturbation', 'preoccupation', 'strain', 'tizzy', 'apprehensiveness', 'dread', 'discernment', 'alarm', 'disquiet', 'doubt', 'dread', 'foreboding', 'misgiving', 'mistrust', 'suspicion', 'trepidation', 'uneasiness', 'worry']

Cambridge: https://dictionary.cambridge.org/dictionary/english/apprehension

WordNet:
http://wordnetweb.princeton.edu/perl/webwn?s=apprehension&sub=Search+WordNet&o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&h=000

Thesaurus: https://www.thesaurus.com/browse/apprehension?s=t

emo13 = ["**amazement**", 'astonishment', 'bewilderment', 'future shock', 'incredulity', 'shock', 'stupefaction', 'surprise', 'wonder', 'wonderment', 'astonishment', 'admiration', 'awe', 'bewilderment', 'confusion', 'perplexity', 'marvel', 'shock', 'stopper', 'stunner', 'stupefaction', 'wonder', 'confoundment', 'one for the books', 'something else', 'sensationalist', 'sensationalize', 'shock', 'shock tactics', 'shocking', 'raise a few eyebrows']

Cambridge: https://dictionary.cambridge.org/dictionary/english/amazement

WordNet:
http://wordnetweb.princeton.edu/perl/webwn?s=amazement&sub=Search+WordNet&o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&h=000000

Thesaurus: https://www.thesaurus.com/browse/amazement?s=t

emo14 = ["**surprise**", 'Surprising ', 'shocking', 'a blinding flash ', 'a bolt from the blue ', 'a bolt out of the blue', 'amaze', 'amazing', 'amazingly', 'blinding', 'darn', 'dynamite', 'earth-shattering', 'expectation', 'sensationalize', 'shock tactics', 'shocking', 'stagger', 'staggering', 'stun', 'the darnedest thing ', 'world-shattering', 'astonishment', 'awe', 'bewilderment', 'consternation', 'disappointment', 'jolt', 'miracle', 'revelation', 'shock']

Cambridge: https://dictionary.cambridge.org/dictionary/english/surprise

WordNet:
http://wordnetweb.princeton.edu/perl/webwn?s=surprise&sub=Search+WordNet&o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&h=0000

Thesaurus: https://www.thesaurus.com/browse/surprise?s=t

emo15 = ["**distraction**", 'Confusion', 'feeling confused', 'a chicken and egg situation ', 'addled', 'all of a doodah', 'all over the place', 'alphabet soup', 'discombobulation', 'disordered', 'disorganization', 'disorganized', 'disorientating', 'muzzily', 'muzziness', 'mysterious', 'mysteriously', 'mystification', 'unaccountably', 'unexplained', 'woolliness', 'woolly', 'beguilement', 'aberration', 'complication', 'confusion', 'disturbance', 'diversion', 'interference', 'interruption', 'abstraction',"corrupt"]

Cambridge: https://dictionary.cambridge.org/dictionary/english/distraction

WordNet:
http://wordnetweb.princeton.edu/perl/webwn?s=distraction&sub=Search+WordNet&o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&h=0000

Thesaurus: https://www.thesaurus.com/browse/distraction?s=t

emo16 = ["**grief**", 'bereavement', 'grieve', 'grieving', 'memorial card','Memorial', ' Day', 'mourn', 'obituary', 'remembrance', 'Remembrance Day', 'rest in peace ', 'rip', 'shrine', 'heartache', 'heartbreak', 'agony', 'anguish', 'despair', 'discomfort', 'heartache', 'heartbreak', 'misery', 'mourning', 'pain', 'regret', 'remorse', 'sadness', 'sorrow', 'trouble', 'unhappiness', 'worry']

Cambridge: https://dictionary.cambridge.org/dictionary/english/grief

WordNet:
http://wordnetweb.princeton.edu/perl/webwn?s=grief&sub=Search+WordNet&o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&h=00

Thesaurus: https://www.thesaurus.com/browse/grief?s=t

emo17 = ["**sadness**", 'be not on ', 'intolerable', 'intolerably', 'lame', 'lamely', 'lameness', 'leave a lot to be desired ', 'pathetically', 'sad', 'second-rate', 'substandard', 'that will never do!', 'unsatisfying', 'unsound', 'unworthy', 'sorrow', 'sorrowfulness', 'anguish', 'grief', 'heartache', 'heartbreak', 'hopelessness', 'melancholy', 'misery', 'mourning', 'poignancy', 'sorrow', 'blahs', 'bleakness', 'bummer']

Cambridge: https://dictionary.cambridge.org/dictionary/english/sadness

WordNet:
http://wordnetweb.princeton.edu/perl/webwn?s=sadness&sub=Search+WordNet&o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&h=00

Thesaurus: https://www.thesaurus.com/browse/sadness?s=t

emo18 = ["**pensiveness**", 'pensive', 'Deep in thought', 'considerate', 'contemplative', 'contemplatively', 'deep', 'deep in thought', 'introspective', 'introspectively', 'meditative', 'pensively', 'reflective', 'reflectively', 'ruminative', 'sink', 'sunk', 'sunk in thought', 'thoughtful', 'thoughtfully', 'thoughtfulness', 'brooding', 'broody', 'contemplative', 'meditative', 'musing', 'contemplative', 'dreamy', 'sober', 'thoughtful', 'wistful']

Cambridge: https://dictionary.cambridge.org/dictionary/english/pensive

WordNet:
http://wordnetweb.princeton.edu/perl/webwn?s=pensive+&sub=Search+WordNet&o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&h=0

Thesaurus: https://www.thesaurus.com/browse/pensive?s=t

emo19 = ["**loathing**", 'dislike ', 'hatred', 'abhorrence', 'abomination', 'anathema', 'animosity', 'animus', 'disgust', 'dislike', 'distaste', 'distastefully', 'enmity', 'ill will', 'misandrist', 'misandry', 'misanthrope', 'misanthropy', 'repulsion', 'sore point', 'technophobe', 'transmisogyny', 'loathe', 'abominate', 'execrate', 'contempt', 'disgust', 'dislike', 'enmity', 'hatred', 'revulsion']

Cambridge: https://dictionary.cambridge.org/dictionary/english/loathing

WordNet:
http://wordnetweb.princeton.edu/perl/webwn?s=loathing&sub=Search+WordNet&o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&h=000

Thesaurus: https://www.thesaurus.com/browse/loathing?s=t

emo20 = ["**disgust**", 'dislike', 'hatred', 'abhorrence', 'abomination', 'anathema', 'animosity', 'animus', 'dislike', 'distaste', 'distastefully', 'enmity', 'execrate', 'loathing', 'misandrist', 'misandry', 'misanthrope', 'misanthropy', 'repulsion', 'sore point', 'technophobe', 'transmisogyny', 'vitriol', 'gross out', 'revolt', 'repel', 'antipathy', 'dislike', 'distaste', 'hatred', 'loathing']

Cambridge: https://dictionary.cambridge.org/dictionary/english/disgust

WordNet:
http://wordnetweb.princeton.edu/perl/webwn?s=disgust&sub=Search+WordNet&o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&h=0

Thesaurus: https://www.thesaurus.com/browse/disgust?s=t

emo21 = ["**boredom**", 'tedium', 'boring things', 'a wet weekend ', 'banality', 'blandness', 'bromide', 'cabin fever', 'commonplace', 'ennui', 'flatness', 'frustration', 'insipidness', 'jejune', 'same', 'screed', 'snooze', 'snoozefest', 'sterility', 'stodginess', 'the same old thing ', 'turgid', 'yawn', 'ennui', 'apathy', 'disgust', 'ennui', 'fatigue', 'indifference', 'lethargy', 'monotony']

Cambridge: https://dictionary.cambridge.org/dictionary/english/boredom

WordNet:
http://wordnetweb.princeton.edu/perl/webwn?s=boredom&sub=Search+WordNet&o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&h=0000

Thesaurus: https://www.thesaurus.com/browse/boredom?s=t

emo22 = ["**rage**", 'Anger', 'displeasure', 'acrimony', 'anger', 'animus', 'annoyance', 'bad feeling', 'irritation', 'rancour', 'red mist', 'reprehension', 'resentfulness', 'resentment', 'road rage', 'madness', 'bitterness', 'exasperation', 'frenzy', 'furor', 'fury', 'indignation', 'irritation', 'madness', 'mania', 'obsession', 'outburst', 'passion', 'resentment', 'temper', 'violence']

Cambridge: https://dictionary.cambridge.org/dictionary/english/rage

WordNet:
http://wordnetweb.princeton.edu/perl/webwn?s=rage&sub=Search+WordNet&o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&h=00000

Thesaurus: https://www.thesaurus.com/browse/rage?s=t

emo23 = ["**anger**", 'grit', 'grit your teeth ', 'grudge', 'hard feelings ', 'have a face like thunder ', 'irritation', 'bother', 'botheration', 'pain', 'pain in the neck', 'pain in the ass', 'acrimony', 'animosity', 'annoyance', 'antagonism', 'displeasure', 'enmity', 'exasperation', 'fury', 'hatred', 'impatience', 'indignation', 'ire', 'irritation', 'outrage', 'passion', 'rage', 'resentment', 'temper', 'violence']

Cambridge: https://dictionary.cambridge.org/dictionary/english/anger

WordNet:
http://wordnetweb.princeton.edu/perl/webwn?s=annoyance&sub=Search+WordNet&o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&h=00

Thesaurus: https://www.thesaurus.com/browse/anger?s=t

emo24 = ["**annoyance**", 'Anger', 'displeasure', 'acrimony', 'anger', 'animus', 'bad feeling', 'benny', 'flap', 'get the hump', 'gorge', 'grit', 'grit your teeth ', 'grudge', 'hard feelings ', 'have a face like thunder ', 'irritation', 'red mist', 'reprehension', 'resentfulness', 'resentment', 'botheration', 'anger', 'discontent', 'displeasure', 'exasperation', 'frustration', 'indignation', 'irritation', 'pique', 'unhappiness']

Cambridge: https://dictionary.cambridge.org/dictionary/english/annoyance

WordNet:
http://wordnetweb.princeton.edu/perl/webwn?s=annoyance&sub=Search+WordNet&o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&h=00

Thesaurus: https://www.thesaurus.com/browse/annoyance?s=t

Appendix C: Survey questionnaire for expert interviews

	Questions	Strongly disagree	Disagree	Neither	Agree	Strongly Agree
		1	2	3	4	5
1	Process: Will the pandemic related framework process and documentation of using creativity, community and everywhere help artists, policy makers, curators and data journalists?					
1.1	Follow up: Reflective response					
2	Invention: Will the resultant toolkit of HeartBeat (sentiment visualization, physical display and web version) fill the gap in the current pandemic related public art?					
2.1	Follow up: Reflective response					
3	Relevance: Will the HeartBeat be relevant in the current times such as pandemic and lockdown?					
3.1	Follow up: Reflective response					
4	Extensibility: Does the HeartBeat has a nature to be extended, reused or repurposed by artists, designers and curators to create more such work?					
4.1	Follow up: Reflective response					
5	Insight: Does the visualization offers strong insights in terms of obvious and implicit trends?					
5.1	Follow up: Reflective response					
6	Time: Does the HeartBeat facilitates faster (time) visualization in terms of understanding the data?					
6.1	Follow up: Reflective response					

7	Essence: Does the visualization reflects an overview and context of data?					
7.1	Follow up: Reflective response					
8	Confidence: Does the visualization offers you confidence about the quality of the data?					
8.1	Follow up: Reflective response					

Appendix D: Summary of key responses from participants during evaluation

Category of responses while evaluating HeartBeat	Key Responses
Process, Relevance, Extensibility, and Invention	The necessity of reflection of emotions during Covid-19
	Addresses the current need of community
	HeartBeat reflects the temperature of the country
	Relevancy of HeartBeat in the current stay-at-home order
	Sparks conversation about interconnected feelings
	Extensibility of HeartBeat as it is malleable for artists to iterate different sentiments
	Physical installation could be used even after a pandemic when gatherings are permitted
Policy impact	HeartBeat is one of the tools to impact policies
	Combining other sources of data could make HeartBeat stronger to impact policies
	Currently, there is no pandemic related public art framework, and HeartBeat allows us to address it
Insights, Context, and time	HeartBeat offers strong insights using colors as cues
	HeartBeat is interactive as compared to current public art which is mostly one-way communication
	Inclusion of time-period, time filter, or social attributes could provide more context
	The use of physical sensors in physical installation could be more interactive
	Inclusion of title or label for physical installation to understand the color
	Accessibility of HeartBeat as individuals with vision impairment could find colors difficult to read
Use of color and dots	The use of colors for HeartBeat creates an emotional connection in these pandemic times
	The size of circle and its position could reflect more clarity
	Showing live tweets on web interface could add more interactivity
Use of sound	The sound and tempo of heart beating could reflect changes in emotions
	Using multiple hearts for each emotion and bringing them closer in visualization could be beneficial

Shape of Heart	Use of heart is strong as it's an iconic image
	Using a real biological heart could be better than an illustrated heart shape
Confidence in Twitter as a source of data	HeartBeat offers an interesting investigation about using Twitter to reflect mental health from Covid-19 as it is still being investigated.
	Twitter bans opinion from certain individuals such as people with strong opinions, therefore could be unreliable
	HeartBeat is not about accuracy but inspiration
Exhibition avenues	Potential to participate in https://www.arte-util.org
	Storefronts displays
	Embed Heart in news publications
Future work recommendations	Comparing tweets from popular media outlets and their sentiments with what members of the public are tweeting and their emotions
	Physical installation for each community or neighborhood to reflect what others in proximity are feeling
	Overlay Twitter data with non-public data such as social media groups
	The emotion library could be extended with complex algorithms
	HeartBeat could be open source to see what other countries are feeling such as Australia or New Zealand

Figure 58: Summary of key responses from participants during evaluation.

Appendix E: HeartBeat technical snapshots from production

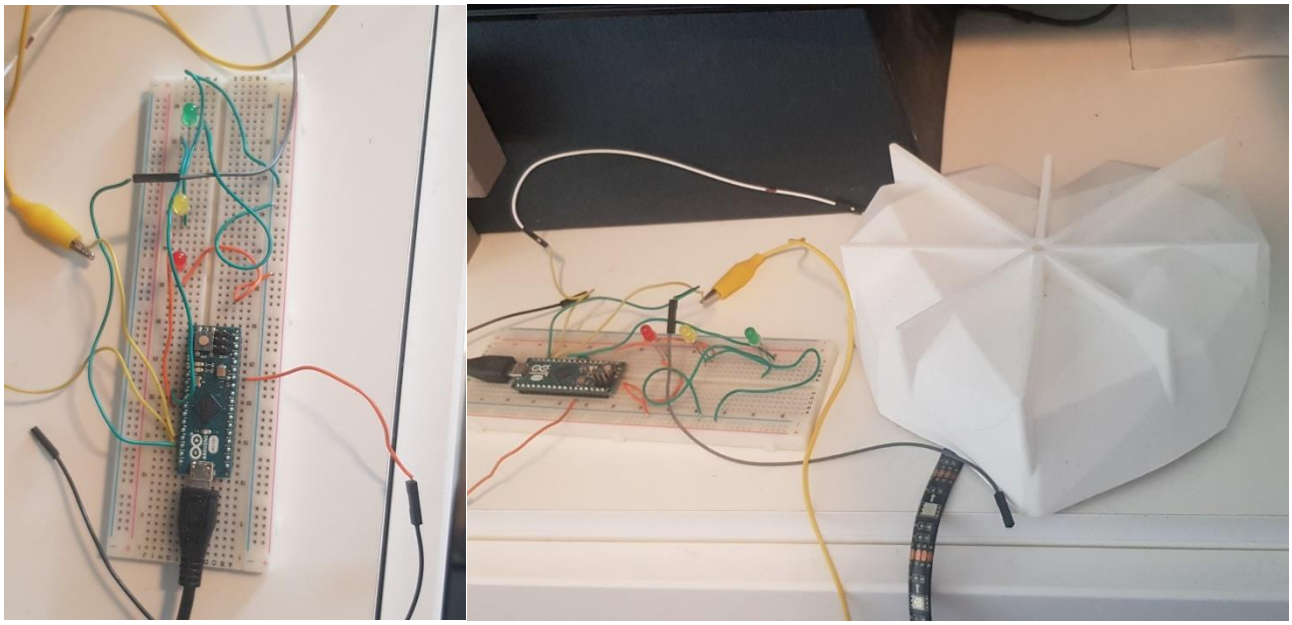

Figure 59: Arduino is connected with LED strips enclosed in a heart mold to reflect the visualization through changing colors.

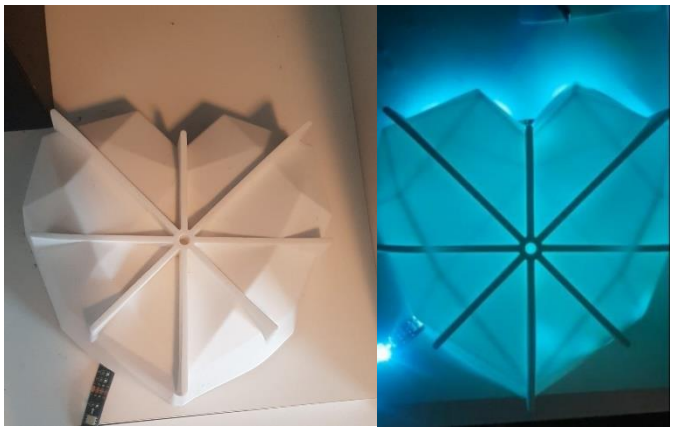

Figure 60: Heart shape mold is enclosed with LEDs to reflect the color of the popular emotion.