

## DATA SONIFICATION FOR URBAN WAYFINDING

*How can we assist people's wayfinding process to be safer and more efficient?*

P. TALALAK,  
University of New South Wales, Sydney, Australia  
talalakpenny@hotmail.com

**Abstract.** In the twenty-first century, the everyday use of digital technologies has influenced people's wayfinding process in the urban environment. Technologies such as Google maps and dynamic forms of digital signage are now implicated in the decisions people make about their journey. While these ubiquitous tools are efficient and beneficial in navigation performance, they are vision centric which reduces situation awareness. According to the Centre for Road Safety – Pedestrian Trauma Trends Report 2017, pedestrian fatality rates increase by 15% every 5 years due to mobile use. Previous studies on wayfinding using auditory cues for the vision impaired have suggested that audio feedbacks are an efficient and productive way to communicate information about the surrounding urban environment (McQueen, 1995). In this paper, non-speech audio, known as data sonification, is explored as an assistant to current urban wayfinding processes. This research investigation is explored through public transport environments in Sydney, NSW where real-time data is transformed into an acoustic signal for facilitating knowledge acquisition about a point of interest POI. It is speculated that while data sonification may not have the ability to replace the current wayfinding process, it can rather enhance existing visually orientated wayfinding system.

**Keywords.** Data sonification; wayfinding; real-time data; navigation process.

## 1. Introduction: Research context and motivations

In a complex urban system, wayfinding and spatial knowledge acquisition have become essential factors in helping individuals solve spatial problems experienced in their everyday lives. Wayfinding can be defined as “how well people are able to find their way to a particular destination without delay or undue anxiety” (Peponis 1990). Thus, people rely on the availability of their surroundings and environment in the decision-making process to create a mental model of the surrounding in order to find a place. This process is known as cognitive mapping and is essential in a person's memory storage of urban elements. As stated by Kevin Lynch's *Image of the city* (1960), it is argued that the five urban elements consist of landmarks, paths, nodes, edges and districts are major contribution to the interaction between urban navigators and the environment (Vaez et al 2016). Wayfinding has become integrated in various disciplines such as Transport, Buildings, Architecture and Tourism, yet, the current method of wayfinding such as physical maps, GPS and street signage can be a challenge to reach for the destination in a real-time environment. Visual indicators for landmarks and destinations are still present as an individual's every day spatial problem. This could be due to its lack of opportunity for a serendipitous discovery of places, shifting the focus to visual maps that can potentially lead to higher risk in navigation and does not promote accessibility to all types of people. While visual cues play an important part in recognising and interacting within the space, auditory cues have shown to contribute in assisting the identification of components in a public space as well as the type of activity within the space. This has enabled people to explore the unfamiliar and complex urban environments with greater ease. By providing a system with path planning and self-localisation, wayfinding seems to be an effortless and automatic for a navigational tool. Audio feedback in navigation systems has been investigated to allow a fully immersive experience within the surrounding environments whilst facilitating wayfinding in order to locate the point of interest (McGookin et al 2009; Betsworth et al 2013; Ankolekar et al 2013). In an experiment conducted by Holland et al (2002), Audio GPS systems were experimented with sighted users using non-speech audio as a navigational feedback. The research has suggested its effectiveness to represent the distance while finding location irrespective of musical training. When the audio is mapped to a provided data or information, a process called data sonification is introduced. Data sonification can be defined as “the transformation of data relations into perceived relations in an acoustic signal for the purposes of facilitating communication or interpretation.” (Kramer et al. 1999).

This paper will explore the possibilities of data sonification for spatial knowledge acquisition in assisting with the creation of cognitive mapping used during the wayfinding process. The research is divided into three phases. The first section of the research studies the behaviour of the user by collecting

quantitative data from interviewing 20 participants. This enhances the understanding of how efficiently the users of digital visual maps build spatial knowledge and the risks involved. The second part of the research outlines the functionality of data sonification with real-time data in a web application. Finally, the device is tested and evaluated with participants against the current visual navigational device. The paper concludes with a summary of implications on data sonification and future research for audio as a navigational feedback to enhance spatial knowledge acquisition.

## **2. Research Aims**

This research aims to explore the possibilities of data sonification for wayfinding in an urban space. An example of data will be derived from the open data source of NSW Transport Data API which will be combined with GPS data to provide a real-time environment. A Data Sonification prototype will be produced as an end product to test and validate this research. In addition, the research can further contribute to the current research and the practice of wayfinding such that an improvement to cognitive mapping, wayfinding plan development and physical movement (Arthur and Passini, 2002) can be proposed. Ultimately, the research aims to demonstrate the perception of soundscape as a way to improve wayfinding such as spatial knowledge acquisition but can also be potentially relevant for visually impaired people.

## **3. Research Questions**

There are multiple ways audio can be used as a navigational feedback in wayfinding process. This includes Geiger Muller method (beeps and click), text-to-speech audio, and non-speech audio such as music or sound effect. In data sonification, non-speech audio is used to convey information but is very rare in an urban environment. As real-time data becomes readily and publicly available, this research aims to answer two related questions about data sonification in urban wayfinding:

1. Can data sonification assist and enhance spatial knowledge acquisition about a specific point of interest?
2. How can data sonification influence the process of wayfinding?

## **4. Methodology**

This research will follow design research methodology approaches from information system. Design research promotes innovation through rapid prototyping and frequent iterations to match the problem identified by the user and accommodate their needs (Iivari & Venable 2009). The first part of this project explores the empathy towards the user in order to collectively identify the problem and their needs. This is achieved through user interviews, user

personas and user journey. The outcome delivered will be a digital artefact which consists of multiple iterations from low fidelity through to high fidelity prototyping design. The prototype is then tested with participants where further design iterations and improvement will be made to align with the user's end goal.

According to Goldkuhl in *Action Research VS Design Research: Using Practice Research as a lens for comparison and integration*, 2013, Design Research aims to achieve new means for general goal that demands innovation and novel technology or cutting-edge technology (Goldkuhl 2013, pp. 5). Thus, this project introduces a new approach to wayfinding by developing a technological intervention for a navigational device that integrates real-time data through data sonification process to assist urban wayfinding.

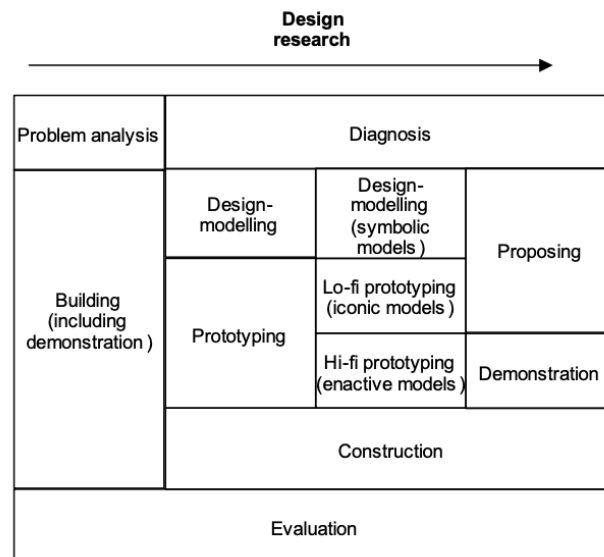


Figure 1. Flow chart of design research methodology

## 5. Background Research

Multiple studies of wayfinding have summarised the process to be “a person's ability to successfully reach one's destination by dealing with the environmental restrictions and uncertainties” (Vaez Eslami et al. 2016). In order to gain a comprehensive study of human behaviour and the environment, researchers investigated spatial cognition to understand the relationship between people and place. This leads to the study by Kevin Lynch in 1960, *The Image of the City*, where he identified the five elements (Paths, Edges, Nodes, Districts and Landmarks) that contribute to spatial cognition (Lynch

1984). In support of Lynch's theory, further identification of factors that influence human's navigation process include visual access, differentiation, layout configuration and signage (Weisman, 1981). As visual elements play a vital role in facilitating the navigation process, Lynch later argued that the location of landmarks and arrangement of pathways in a strong hierarchical pattern is what makes the image of a city recognisable (Lynch 1984). In contrast to Lynch's theory, Walter Benjamin investigated the urban relationship of humans with a stroller in order to narrate the story of different parts and events in terms of city's layout and social relations (Vaez Eslami et. Al 2016). This allows the human to conceive the image of the city and absorb the visual cues which is responsible for the creation of a mental urban image in a post-modern city. In summary, these studies and theories are the foundation established to understand the human's behaviour in an urban environment. Using their spatial cognition and perception, humans can create a mental image or cognitive map that influences their wayfinding process such that their everyday life decisions are simplified.

While wayfinding heavily relies on semiotic interpretations, audio has been the prime tool for urban identification of elements in public space in addition to aiding those with visual impairments. Types of audio such as text-to-speech and non-speech audio is commonly used for notifying events or indicating directions to support wayfinding in a complex urban space. However, as the complexity of the space increases, there is a demand for a mapping tool to better represent a multivariate data for the urban environment. Defined by Barrass in 1997, data sonification is the process of "mapping information to perceptual relations in the acoustic domain to meet the information requirements of an information processing activity." (Barrass 1997, pp 29-30). Although, auditory characteristics such as pitch, rhythm, articulation and duration are all present in both speech and non-speech audio, this study has shown that human brains are more capable to conceive music and speech simultaneously without any challenges. Supported by cognition research conducted by Zatorre (2002), "the auditory cortices in the two hemispheres of the brain are relatively specialised enough to be able to exploit the temporal and spectral differences between speech and musical sounds." (Worrall 2011, pp. 2). Data sonification is applied to multiple industries such as in the medical industry for monitoring, economics for stock market analysis, device for visually impaired as well as seismology for analysing voluminous data source. As the availability of data increases such as live traffic updates and transport systems, there are many potentials that data sonification can offer to improve everyday live activity.

Recently, there has been a rise in research to particularly focus on improving wayfinding in unfamiliar place both indoor and outdoor location. Audio Bubbles is an example in which a non-speech audio is implemented to support wayfinding for tourists. Developed by McGoodkin et al in 2009,

Audio Bubbles seek to challenge the information present on a visual map that limit serendipitous discovery and homing behaviour (McGoodkin et al 2009, pp. 41). When the user approaches the point of interest (POI), a mobile device will amplify as the “beep” sound similar to the Geiger counter metaphor to signify the proximity of that POI. Upon the success of wayfinding, a trumpet sound is played as a user feedback within 10m of the landmark. The project demonstrates success in using Audio Bubbles as a navigation aid for users to locate a specific POI, however, it is still unclear whether Audio Bubbles can dominate visual only maps. It was evident that using monaural sound (without headphones) has allowed the user to fully immerse with the surrounding environment which in turns enhances the interaction between the people and the place. On the other hand, there is still a gap for future work to implement social points of interest for activity identification relating to that POI. This leads to a study conducted by Audvert, which operates similarly to Audio Bubbles but has been designed for large, complex and unfamiliar indoor environments. (Betsworth et al 2013). A different approach to auditory feedback was used for determination of the proximity to a POI by integrating amplitude properties to mimic the natural hearing functions. The project extends its aim for POI discovery by providing a short shop description as an additional feature in a text-to-speech format in order to facilitate the user’s decision-making process. The problem with a text-to-speech audio system for wayfinding can be evident to increase the cognitive load as stated by Zatorre (2002). As a result, Audvert offers a shaking gesture feature to combat multi-audio streaming and allowing users to play one spatial audio stream at a time. While these works aim to assist users to direct themselves in a fast and efficient way to their desired destination using auditory icons and speech as a system feedback signals, music cues have not been systematically explored for POI discovery (Ankolekar et al 2013). Musicons are used to provide a better user experience due to its ability to provide an emotional connection that better represents a specific the place. However, when used as a navigation tool, musicons are reportedly harder to interpret due to ambiguous cues that causes uncertainties in the correct POI identification (Ankolekar et al 2013, pp. 2966).

By evaluating existing projects and theories, this project aims to build upon a similar aim to use audio as an assistant to the navigation process for POI identification. An alternative approach to audio feedback system has been developed and will employ instrumental music to convey meaningful information. Whilst musicon are snippets of modern and popular music, instrumental music eliminates the lyrics which does not interfere the user’s interaction with the environment. According to Denora in 2000, *Music in everyday life*, people are actively listening to music as part of their daily routine. This project will also extend beyond the navigation process to successfully locate the POI by offering a user a sense of the activity within the

located place. This is achieved by accessing real-time data provided as a public API which can be translated into sound through sonification technique. Similarly, to the Audio Bubble, a mobile device allows access to GPS systems such that the user and the POI can be located. Arguably, Audio Bubble's decision in outputting the audio feedback through loudspeaker minimises social isolation, this project aims to build upon creating a sense of place by representing activities that typically occur within that area. Likewise, the Audvert project provides the user with the POI description and hence headphones are more appropriate and effective in order to inhibit the audio feedback from integrating with other external sounds. Overall, the project targets more towards the activities related to the POI by collecting real-time data of that POI and sonified the data with urban soundscape.

## 6. Case Study

Following the design research methodology, it is crucial for this research to gain an insight from a human-centred design approach. Insights into the current processes of navigation and emotional responses from the user can contribute to the first iteration of the prototype to be more curated towards the users need and its problem. A survey was conducted in open-ended questions format that enable the participants to provide qualitative feedbacks. These feedbacks were analysed into user personas and user journey with emotion mapping to further extract an insight from the users and identified their pain points. Following the comprehensive user research, a first iteration of the prototype is built using a web development framework called React.js.

### 6.1. RESEARCH

A total of 12 participants (8 males and 4 females) were mainly recruited from the University of New South Wales Bachelor of Computational Design discipline. The average age of the participants ranged from 20 – 26 years whom all had access to mobile phone and navigational tools.

#### 6.1.2. Interviews

The interview questions were divided into two sections: the current navigational process and the current audio experience within daily journey.

The interviews were set out to test and validate the following assumptions:

- People are relying on visual navigation tool to identify the point of interest (POI) as well as to acquire knowledge about it
- People are listening to music on their daily commute or during their navigation process
- People are often at higher risk when using visual navigation tool for wayfinding

### *6.1.3. Interviews Findings*

According to the interview result, 41.6 % commute via train as their daily mode of transport. This is followed by 33.3% via bus, 16.6% via car and 8.3% via walking. It is important to acknowledge the status and occupation of the participants who are predominantly students or working within the city area where public transports is easily accessible. The age of the participants is taken into the account as most participants were students and have a different budget range to contribute to their commute. In conjunction with the findings, all participants used visual navigational device specifically Google Maps app to assist with locating the destination. It was further analysed that the Google Maps app played a very crucial role in every day lives of the participant's decision- making process. More than 50% of the participants used Google Map to check train timetable and real-time update of the journey such as traffic, delays, emergency/accidents. Google Maps were also evidently used during the exploration phase to flag the point of interest (POI) for past or future visits, acting as a journal. While visual navigational tools became embedded into the participant's life, more than 50% were prone to hazards and were at higher risk during the use of the visual maps. Although, no major accidents were reported during the interview session, the participants claimed to have confronted minor accidents such as bumping into people or walking into a pole. The main risk encountered by one of the participants were crossing the road during red lights due to shifting in focus on the device rather than the surroundings. Some challenges of these devices were disorientation of the GPS point with delayed updates during navigation process. Moreover, there were multiple touch points and alternating apps for knowledge acquisition about the POI such that the repetition during the planning phase and revisiting the route and train timetable multiple times during navigation process. In a situation for wayfinding in an unfamiliar place, the difficulties lie within aligning the representative visual map with the outside real-time environment.

### *6.1.4. User Personas and Journey*

In order to get a deeper insight into the participants and identifying their pain points realistically several techniques were utilised. For example, user personas and user journey are techniques utilised to view the problem from a user's perspective when designing and introducing any technological intervention. A male participant will be used as an example in this case.

Participant A is a full-time electrician and runs an electrical business over the last 10 years. The nature of his work requires him to drive in an unfamiliar area with given addresses to inspect and monitor electricity at different properties. Thus, a visual navigation tool is required at all times during driving and getting to the location on time. Participant A occasionally uses public transport to travel but when required, planning and checking the train



[illegible]

y outlined the pain points and mapped

The user journey outlined the pain points and mapped out the emotional journey of Participant A travelling to an unfamiliar place. The navigation process can be seen divided into three phases: Planning phase (usually the day or night before leaving the origin), Leaving Phase (a moment before leaving the starting location) and During Navigation Phase (the phase where a user travels from one place to another destination). Throughout the three stages, Google Maps was the only prime tool used to assist in the journey and decision-making process. The main problem extracted from this analysis demonstrated multiple touchpoints throughout the planning phase to check the time, the route, the location and the traffic. Although Participant A displayed no frustrations or feelings of unsatisfied as the goals were achieved, however the process was long and tedious. The middle section, i.e. the Leaving Phase, is a repetitive task from the planning phase due to the re-checking of the Google Maps for real-time data such as traffic. Pain points can be identified during the navigation process towards the end which was due to difficulties in locating the destination. According to Participant A, it was challenging to align landmarks and streets number/name with the visual navigation device

while driving. This could cause a major hazard such as not only missing the destination, but people are higher risk for mobile use when driving. As such, there is a gap in assisting users to draw their focus away from the visual navigation device and concentrate on the surrounding environment so that users are less prone to risk.

#### *6.1.6. Problem Statement*

User experience research such as interviews, user persona and user journey enable this paper to centerlise the solution based on the user's pain point and their goals. Thus, problem statement is established.

How might we assist the navigation process in the urban environment so that commuters have an efficient and safer journey?

### 6.2. PROTOTYPE

This project application heavily relies on real-time data which can be gathered from Transport NSW Open Data website. This free open data source contains NSW urban data such as transportation, fare, traffic live update and speed cameras. This project used real-time data from Trip Planner API catered towards building a transport trip planning app. This allowed users to search for trips, stops, service alerts, places of interest and access to the train arrival and departure time. In conjunction with the Trip Planner API, another API called Stop Finder API was used to match the stop ID with the stop name and output the stop name instead of the ID for the user.

#### *6.2.1. Cross-Origin Request and Proxy*

To access the data, an API key was required to call the data from the website to the project application which was freely accessible from signing-up to the website. Although, the API keys were correct and did fetch the data, the application ran into cross-origin request (CORS) error which denied the access to the data from the TransportNSW Website.

The error displayed was "401: Application calling the API has not been authenticated". Despite the API key disallowing the authorisation process, TransportNSW website is a protected resource and needs authorisation. Authentication is a process to verify and proves the identity of the application. However, authorisation allows that entity the right to access the API. Due to this, API keys can be accessed easily by the entire network if become insecure and thus, TransprotNSW website required a configuration to have the right access to the data and prevent leaked data to fraud network. The application was hosted on a localhost by default, which was not a browser but instead a server. This caused CORS error because the localhost was trying to send

request to another origin and failed to authorise trying to consume API running on a different host and port.

To avoid CORS error, a proxy was configured to allow the access of resources from other servers. Proxy acts as a gateway between the client side (the web application) and the internet. The request to fetch the API will be made through the proxy server which was then forwarded to the web application to receive the data.

```
1 module.exports = function(app) {  
2   app.use(  
3     "/v1/tp/",  
4     proxy({  
5       target: "https://api.transport.nsw.gov.au/",  
6       changeOrigin: true,  
7       headers: {  
8         Authorization: "apikey " + API_KEY  
9       }  
10    })  
11  );  
12  };
```

*Figure 3. Configuring a proxy*

The default API proxy from the web application does not forward headers, thus Authorization header was used which contained credentials to authenticate a user agent with a server.

#### *6.2.2. Environment Variable*

API keys are private and should not be shared publicly. Environment variable allows variable in code to be set outside the program which can then be used within the program. To set up the environment, a node was installed to access the library called dotenv. A new file was created and saved as a .env file to contain the API keys. By making sure that this file did not get released, the file was added to .gitignore file to prevent any activation with git command.

#### *6.2.3. User Interface*

This web application was created with React as a front-end to handle large data input and rendered any data on a designed user interface (UI). React is based on UI components and requires *props* to pass data between components. A Class Component in React allows the state to be updated.

```
1  class App extends Component {  
2    constructor(props) {  
3      super(props);  
4      this.state = {  
5        destination: undefined  
6      };  
7    }  
8  
9    render() {  
10     return ();  
11   }  
12 }
```

Figure 4. React class component

#### 6.2.4. API Fetch

The initial state of the destination is undefined due to no data displayed before the API is fetch. To fetch the API, a method within a Class Component is needed where the destination variable can be updated once the API was called. The API data output as an object where we can easily access the value of each object. A *promise* was used during the API fetch to store and supply the value when needed instead of immediately return the final value.

```
1  const [isSubmitting, setIsSubmitting] = useState(false);  
2  
3  const doApiRequest = () => {  
4    setIsSubmitting(true);  
5    stop_finder()  
6      .then(data => {  
7        const stopID = data.locations[0].id;  
8        return departure_mon(stopID);  
9      })  
10     .then(data => {  
11       onRequestComplete(data);  
12       setIsSubmitting(false);  
13     });  
14  };
```

Figure 5. API Fetch

In the above figure, Stop Finder API returns a promise which will then return the Stop ID to match in the Trip Planner API.

#### 6.2.5. Users Geolocation

For the web application to gain access to the current user's location by coordinates, another type of API called MDN Geolocation API was used in conjunction with React application. The method within the API "initiates an asynchronous request to detect the user's position and queries the positioning hardware to get up-to-date information" (Mozilla Contributors 2019).

```
1  getGeolocation = () => {  
2    if ("geolocation" in navigator) {  
3      navigator.geolocation.getCurrentPosition(position => {  
4        const latlng = position.coords;  
5  
6        //view it on the console  
7        console.log(latlng, "LATLONG");  
8  
9      });  
10   } else {  
11     console.log("GeoLocation is not possible in this browser");  
12   }  
13 };
```

Figure 6. Geolocation API

#### 6.2.5. Train Timetable

The Trip Planner API outputs the train timetable in Coordinated Universal Time (UTC) format which was difficult to read and match with the local time. UTC is the primary time standard by which the world regulates clocks and time (Panfillo 2016).

```
▼ destination:  
  arrivalTimeEstimated: "2019-11-03T03:38:36Z"  
  arrivalTimePlanned: "2019-11-03T03:38:36Z"
```

Figure 7. UTC Time

To convert UTC time to Australian Eastern Standard Time (AEST), a JavaScript library called moment.js was used to allow the parsing of time for future manipulation.

```

1  var countdownInterval = setInterval(() => {
2      const { countdown } = this.state; //this.state.countdown
3
4      let newCountdown = countdown - 1; //countdown is in seconds
5
6      // UPDATE STATE
7      this.setState({
8          countdown: newCountdown
9      });
10
11     const volumeTime = 480; //5 mins
12
13     if (newCountdown < 0) {
14         clearInterval(countdownInterval);
15         this.setState({ arrived: true });
16     } else if (newCountdown < volumeTime) {
17         const xNumber = 100 / volumeTime; //xNumber = factor
18         const volume = (volumeTime - newCountdown) * xNumber;
19
20         this.setState({ playAudio: true, volumeAudio: volume });
21     }
22 }, 1000); //end setInterval function
23 this.setState({ countdownInterval });

```

Figure 8. Countdown Function

In the code above the countdown function was created to return the time of how many minutes left until the train had reached the stop. The time was calculated in seconds where the state of the countdown got updated every one second. When the countdown hit 5 minutes, the volume of the train sound was introduced in an ascending manner until the countdown reached zero where full volume will be played.

#### 6.2.5. Audio

Sound was chosen based on the urban soundscape of the train. The sound effect of the train was downloaded from *soundbible.com*. The decision-making of this phase was risky for finding the most user-friendly sound that will not cause an emotional distress when hearing the sound of the train approaching. A formula was used to map the sound train with the volume and countdown altogether.

$$x = 100/volumeTime \quad (1A)$$

$$volume = (volumeTime - newCountdown) * x \quad (2A)$$

where *volumeTime* is the countdown number in which the audio will start playing and *newCountdown* is the new countdown time left from the train.

## 7. Discussion

The prototype was tested against 10 participants age between 20-22 years (8 male and 2 female). Two investigations were performed to test out the prototype. The first study was used to time the efficiency of the participants' current navigation process dictated by both familiar and unfamiliar

destination. The second study gave the participants the full access to be familiar with the prototype without prior instructions as they would apply in a real-life situation. Both studies were conducted in a workplace (Sydney CBD) and an educational institution (Randwick).

Prior to testing, limitations of the prototype were outlined to the participants due to various technical incompleteness. Not all of the information was displayed on the user interface of the prototype which can caused confusion to the participant confusion. The user did not comprehend the intention of the prototype and acknowledged it as another visual navigational device. The first iteration of the prototype focused on acquiring knowledge about NSW Transport train timetable. Due to the time limitation, the timetable data had not been filtered to specifically achieve the output of the train details. As a result, the prototype additionally output other unnecessary information such as street name and bus stop name. The location of the experiment also played a vital role in functioning the prototype. The starting location depended on the current location of the participants via GPS signal. This had an effect on the output of the transport data for example, if the participant was located in Randwick, the closest stop would be a bus stop rather than a train station and thus, the output did not match the user interface as programmed.

#### 7.1. FIRST STUDY: EFFICIENCY OF THE CURRENT WAYFINDING METHOD

Eight Participants were asked to plan their navigation process spontaneously given familiar destination with the navigation tool of their choice. This process is then followed by participants using the prototype, Data Sonification App (DSA), to receive the transport timetable in assisting their planning. The audio was set to 8 minutes timeframe for all destination in the DSA. The origin location of the participants started at University of New South Wales so that the origin location was controlled and consistent.

Overall, more than 90% of the participants used Google Maps as their tool to achieve their planning phase with the remaining using TripView App or NSW Transport App. When given a familiar place, the duration of the process took approximately 30s. Multiple interaction of touch points were noted but was not considered an interference to the process as participants navigate the visual device with ease. On the other hand, when given an unfamiliar place, the duration extended up to an average of 50s due to multiple screen switching for information acquisition about that place such as mode of transport, timetable and the location of the destination.

#### 7.2. SECOND STUDY: UNDERSTANDING DATA SONIFICATION APP

The prototype, Data Sonification App (DSA) was given to the participants without prior description on what the prototype does. Initially, the audio of the train was set to 8 mins so that This technique allowed the collection of the user's emotional response to the prototype and analysing the user behaviour

whether the intention of the prototype can be clearly communicated. According to the test, more than 90% comprehended the purpose of the prototype but acquired more information on the destination and the process of reaching that destination. Interestingly, the one participant was unable to identify the sound of the train and misunderstood to be something else. Although majority have identified the audio to be mimicking the train effect, the interpretation was unclear what increasing in volume meant. They were also unsure of the action upon completing the interaction with the prototype. When hearing the sound of the train rising in volume, many participants reported the feeling of stress and intensity due to the urge of being under pressure to catch the train.

## **8. Evaluation**

Whilst the process of wayfinding during the planning phase for the familiar and known destination appears to be the most efficient when using a visual navigational device, DSA aims to investigate the potential of audio and its changing parameters to convey data related to that destination. Another objective of this project is to demonstrate an alternate method of spatial knowledge acquisition about that place without physically being there. Additionally, this method should act as an exploratory alert system for when the user is in contact with the data based from the user's location. In alignment with the research question, DSA has successfully demonstrated the potential of conveying real-time data for spatial knowledge acquisition on a specific location by sonifying the train timetable. However, there is a huge learning curve for the user to understand and translate the meaning of the audio in order to apply in a real-world situation. Data sonification could not accurately translate quantitative data but rather provides an emotional feel of audio to raise awareness of the place. As a result, the participants were able to recognise the train approaching the platform but could not identify the exact arrival time.

### **8.1. FUTURE WORK**

This research can contribute to the study of wayfinding in a digital urban space as technology becomes a part of our everyday decision-making. Further improvement to the current prototype includes an addition of detailed information on the journey and correct information of the stop. A more responsive design needs to be developed in order to independently test the app in a different location and device. Finally, a more customisable user interface should enable the user to select their own origin, stops, specific time of the vehicle or different path of navigating.

Further research to sound and its composition are crucial within this research. Sound can be interpreted in multiple ways and thus, the prototype can be manipulated to align with different user's intention. Music composition



of classical instrument or electronic beat could be synthesised for a more pleasing audio feedback. Music composition could replicate and express emotions to convey the data effectively and accurately. However, this scope plays a major contribution to the field of music psychology as their own discipline itself.

This research hopes to highlight the immense opportunities and benefits of using audio for wayfinding process. An integration of audio could be implemented to the current wayfinding process with a visual navigational tool such as Google Maps or TripView. While providing enough information required from the user, audio is embedded as an additional feature to assist the journey. Further prototypes can be built upon different urban data sources such as Crime data, Live Traffic updates or congestion rates of a specific place to assist in raising awareness to the user during the physical journey. Industry such as Architecture could improve the wayfinding process in complex indoor environment such as airport or shopping centre with audio to assist people with exploratory journey. Data sonification can be used to raised awareness of the urban environment used in Security discipline within an Engineering industry to enhance a safer and secure place.

## 10. Conclusions

In conclusion, this research has illustrated the potential of data sonification as an assistance for spatial knowledge acquisition during the process of wayfinding in an urban environment. This is crucial for users to develop a cognitive map or a mental model to understand the relationship between the urban environment and the navigational device. By introducing the Data Sonification Prototype, users can feel the real-time urban data, and utilise sound as an exploratory piece to develop an emotional connection to the place either by raising an awareness or by guiding through the journey. The paper provides an alternative method for spatial knowledge acquisition through audio and reinforces the current wayfinding process in a digital space for future research. Although, audio as a navigational feedback cannot completely replace visual navigational tool for sighted users, audio feedback is currently being utilized for users with visual impairments. Sighted users are becoming comfortable with their current navigation device, thus, users are less aware of the higher risk associated with the physical navigation process i.e. higher fatalities each year. Audio has been a source of feedback for announcements and warnings but is not subjected to being sonified by data or real-time data. Therefore, there is a need for further research into sound and music to provide a user-friendly sonifying audio.

Wayfinding is an individual's every day problem solving where mapping tool has become integrated into human everyday life. Interpretation of these maps plays a key role in people's safety, time and exploration.

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**Appendix A: Equations****A.1. VOLUME FACTOR**

$$x = 100/volumeTime$$

**A.2. FINAL VOLUME**

$$volume = (volumeTime - newCountdown) * x$$