University of Glasgow | School of Computing Science

Honours Individual Project Dissertation

Interactive Water Feature for Public Squares

Kerry Johnstone

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Abstract

Water fountains are commonplace in public spaces, and people are drawn to them by a natural urge to play with, and splash around in, the water. However, this play is often restricted by the safety concerns of public authorities and the inconvenience of getting wet in public with no way to dry off. Therefore, a water feature was built that uses proxemic interaction to enable users to engage with the water without getting wet. The fountain was evaluated by potential users in an experience prototype session to assess the potential impact of the fountain on their use of public spaces. It was found that the addition of interactive water features has the potential to increase usage of public spaces, though significant further work will be necessary before this is realised. While users enjoyed being able to create their own aims and challenges, even this was not enough to satiate their urge to splash in the water. Future fountain development should focus on encouraging and facilitating group interaction to enhance the user experience.

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1 Introduction

We see fountains in parks, squares, and public places around the world, and are naturally drawn to them. There is a primal urge to reach out and touch the water, and to splash. However, due to safety concerns and general inconvenience, we are often unable to follow these natural desires.

We believe there is the potential to facilitate play within these boundaries by adding novel interaction techniques to water fountains. This project explores how the addition of interactivity to water fountains could change the way in which we use public spaces. We will present existing research relevant to our aims, and outline the process of building an interactive water fountain including the project requirements, the design of the fountain, and how it was implemented.

We then present an evaluation using an experience prototype, which addresses a series of research questions relating to the wider topic. The results of this evaluation are discussed with relation to the literature, and a number of conclusions are drawn relating to the impact such interactive fountains may have on the behaviour of the public.

In this chapter, we outline the motivation for adding interactivity to water fountains, and will present a series of research aims that this project will address.

1.1 Motivation

The topic of how everyday objects, such as benches and steps, influence the usage of and behaviour within public spaces is well explored and understood, and has informed city planning for many years as seen in the work of Whyte (2012). As technology has become part of everyday life, it too has found a place within our public spaces alongside the benches and fountains. However, little is understood about the effects of technology on our public spaces, particularly when we deliberately incorporate interactive technology into these spaces and the objects within them.

Water fountains make for a particularly interesting area of study because of the potential benefits of adding interactivity to them, and the effects this could have on the space around them. When the public encounter a fountain in a public space, they are often compelled to touch the water, put their hands in the jets, and in warmer weather some may even feel the need to enter the water (Whyte 2012).

Whyte (2012) demonstrates that authorities who are responsible for the fountains will often prevent or discourage access to the water due to perceived health and safety risks associated with allowing members of the public to play with or enter the water. For example, Doulton Fountain in Glasgow Green, pictured in Figure 1.1, has had a fence erected to prevent the public from being able to touch or enter the fountain.

Additionally, it can be inconvenient for people to actually touch the water, despite their compulsion, as it will leave them with wet hands in public with no way to dry them, an issue discussed by Dietz et al. (2014). These restrictions and inconveniences often lead to people restraining themselves, and not interacting with the fountain in the way they desire.

There is the potential to add playful interactivity to water fountains which would allow the public to play with the water similarly to how they desire, without requiring any direct physical contact

__Figure 1.1:__ Doulton Fountain, Glasgow Green, is fenced off to prevent the public accessing the fountain.

with the fountain itself. This would likely alter how people behave in response to the fountain, as well as how people behave within and relate to the space surrounding the fountain.

1.2 Aims

In light of the above motivations, we will build an interactive fountain which will enable us to explore how playful interactivity can allow users to engage with the fountain as they desire, without requiring direct contact with the water.

An evaluation will then be conducted using the fountain which will aim to address the question: How does adding interactivity to water fountains change the way people use public spaces?

Due to the broad nature of this question, it is unlikely it can be answered in a single evaluation, and certainly not one of this scale. As such, we present three key areas we will address, which will help towards answering the broader question:

- Could the addition of an interactive water feature increase the usage levels of a public place?
- How do members of the public utilise the interactive capabilities of these water features?
- Finally we wish to establish how interacting as part of a group changes the experience, with particular regard to how the relationships between participants affects this.

2 Background

In this chapter we will discuss a series of research topics, examining how current research in these areas relates to what we aim to achieve, and identify areas to build on and any gaps in current research.

2.1 The Social Life of Small Urban Spaces

'The Social Life of Small Urban Spaces' by William H. Whyte (2012) discusses a range of topics relating to the design of public spaces. Of particular relevance to our aims are the discussions of the role of water in public spaces and the concept of triangulation.

Whyte (2012) discusses how water fountains contribute to a public space, and it is clear from his examples that the public want to touch and interact with the water. For example at the Seagram's Building people often splash around in the fountain, dipping their hands and feet in, meanwhile they would swim in a reflection pool at the Christian Science Headquarters (Whyte 2012). However, the public were soon prevented from entering the reflection pool, as is common in public spaces around the world. Public safety is often cited as the reason for preventing access, with authorities fearing slips, falls, and drownings should the public access the water (Whyte 2012).

There is potential for an interactive fountain to bridge the gap between the public and the authorities. A fountain could use interaction techniques such as gesture recognition or proxemic interaction to allow the public to interact with the water without requiring any physical contact with the fountain. This would satiate the public appetite to play with fountains while easing the authority's concerns.

Whyte (2012) also discusses the concept of triangulation, where a miscellaneous aspect of a public space sparks a friendly interaction between strangers. This third party that causes the interaction can be anything from a sculpture to a person, or could potentially be a fountain. He describes triangulation as one of "the principal factors that make a place work" (Whyte 2012) and therefore it is a key concept to consider when designing a fountain with the aim of positively influencing how people use a space.

A fountain can act as a vehicle for triangulation in two ways. It can become a discussion point, where participants and spectators can together chatter about the merits of the fountain. However, by adding interactivity we create a much more interesting opportunity for triangulation to occur, whereby multiple users might interact with the fountain together. This could potentially encourage more use of the public space, by creating a friendly and welcoming atmosphere and providing opportunities for socialising.

2.2 Proxemic Interaction

Ballendat et al. (2010) describes the concept of proxemics as "how we interpret spatial relationships", and goes on to explain that our interactions with both other people and the world around us are underpinned by our understanding of such spatial relationships. This concept has seen limited applications so far, and has been confined to research systems which use a greatly simplified model (Ballendat et al. 2010). In their paper, Ballendat et al. (2010) developed a media player system which was controlled entirely through the interpretation of proxemics. There is the potential to exploit proxemics in a similar way as a method of controlling an interactive water feature without requiring physical contact with the fountain.

This could be implemented using "distance-dependent semantics" whereby the actions and behaviours open to a user are dictated by the distance between the user and the system (Ballendat et al. 2010). This is a flexible method, as no exact distance ranges are specified, and could be easily applied to the fountain. It makes sense that as a user comes closer to the fountain, and becomes more engaged in the system, new behaviour should reveal itself to them.

2.2.1 Proxemic Zones

Proxemics often maps distance to different types of interactions, with Ballendat et al. (2010) defining the following four mappings:

- "intimate": the closest zone, ranging from 6 to 18 inches
- "personal": ranging from 1.5 to 4 feet
- "social": ranging from 4 feet to 12 feet
- "public": the furthest zone, beginning at 12 feet and ranging to any distance over 25 feet

The interaction " becomes more private and explicit" the closer a person comes (Ballendat et al. 2010), knowledge which we can exploit in the fountain, tailoring the interactions offered to match the distance at which a user is situated.

In line with the four categories of distance-interaction mapping discussed by Ballendat et al. (2010), Vogel and Balakrishnan (2004) present a model of interaction that divides the space into four, correlating with the distance of the user from the system:

- First is the "Ambient Display Phase" where the system is in a "neutral state" and the user is at their furthest from the display and interaction is minimal
- In the "Implicit Interaction Phase" the system notifies a user as they enter the area immediately around the system, allowing the user to either engage with the system or terminate the interaction there
- During the "Subtle Interaction Phase" the user begins to come closer to the display, and may give a physical signal that they are open to interaction such a stopping in front of the display and so new modes of interaction open up to them, giving them more control of the system
- This leads into the "Personal Interaction Phase" where the user moves to their closest, and the interaction becomes more involved, revealing new interaction methods while still allowing the previous methods to be used

These phases could be used within the fountain to aid the transition from idle state to active user engagement. The first phase could facilitate an idle state, which the fountain would remain in when no users were within range. In the "Implicit Interaction Phase" the fountain could give some output in response to the user's presence, indicating that the system has some kind of interactivity and inviting the user to explore further, while still giving them the choice to ignore the system if they desire. The last two zones are where the bulk of the user-initiated interactions take place, and echo the distance-dependent semantics discussed earlier. Such techniques for revealing interactions could be used in the fountain, with new ways of controlling the fountain or new outputs from the fountain being revealed only when the user passes through certain distance thresholds.

2.2.2 Continuous and Discrete Interaction

There are numerous ways in which we can use proxemics to control interactions, but the most common methods are through discrete or continuous mappings (Ballendat et al. 2010).

Continuous movement takes input over a continuous range of input values, and maps this to a continuous range of output values, for example the number of thumbnails on the display increases as a user approaches, proportional to the decrease in distance between the user and the display (Ballendat et al. 2010). Such interaction can feel very responsive as every action a user takes will map to a change in output from the system.

The use of discrete zones causes a behaviour to be activated when a user enters or exits a zone, splitting the area around the system into distinct or overlapping sections which have different associated behaviours (Ballendat et al. 2010). These zones could easily be mapped to the distance ranges discussed earlier, however they are not without their drawbacks.

When a user is positioned on the boundary between zones, it can make the system think the user is switching between the zones despite the fact they are actually standing still (Ballendat et al. 2010). This can be jarring for the user, and can potentially cause confusion as it becomes unclear what behaviour the system is responding to.

This leads to us needing to deploy "hysteresis tolerance", where we place the exit point for a zone at a different distance to the entry point (Ballendat et al. 2010). This is one potential method for mitigating the switching which can occur at boundary points, as it becomes no longer possible for a user to be at both the entry and exit point at the same time. As such, the issue of confusing behaviour at boundaries is not an insurmountable problem, and when weighed against the benefits of mapping interaction zones to the distance ranges discussed earlier, there is a good case to be made for the use of discrete zones.

It is possible to use both continuous and discrete controls within a single system, as shown by the media player developed by Ballendat et al. (2010), where discrete zones are used to switch the system on and off when a user enters and exits the room, while continuous controls change the size of items on the display based on the distance of the user. The activation at a discrete zone is useful for giving the user control of the system, while the continuous controls allow for fluid usage of the system, and so combines the benefits of both models. This would benefit the fountain, which could use discrete zones to trigger the transition from idle state to the interactive state, and the continuous model to allow the user to exercise control once in this zone.

2.2.3 Designing for Shared Use

There is a need for public proxemic systems to gracefully handle multiple users interacting simultaneously. Ballendat et al. (2010) explains that different users may be interacting at different distances, and may be performing conflicting actions, and either the system needs to handle this consistently, perhaps preferring the action of whoever is closer, or rely on users to sort this out between themselves. Given that relying on users to resolve conflicts themselves, particularly in a public place where users are likely to be strangers, could lead to unintended consequences, it makes most sense that the fountain would simply respond to the person closest to it, to maintain consistency.

Vogel and Balakrishnan (2004) also stress the importance of designing for "Shared Use", allowing many users to simultaneously interact with the system "either individually or collaboratively". By placing the fountain in a public place, we surrender our ability to control how people use the system and how many people use it at once, and so we must design the system with the expectation that it will be used by many people all at once, and that they may be using it together as a single unit, or as a group of individual users. Failure to account for a multi-user scenario would lead to unsatisfying interactions for our end users, as the system would fail to meet their needs.

2.2.4 Design Recommendations for Proxemic Interaction

Vogel and Balakrishnan (2004) make a number of recommendations for the design of proxemic systems, some of which can be applied to the design of a proxemic water fountain.

The first applicable recommendation is that of "Comprehension", where users should be able to easily understand what is presented to them, though some ambiguity may be present to further entice the user (Vogel and Balakrishnan 2004). There must be some aspect of the fountain which is unclear in order to give the users something to explore, but this must be balanced against the need for them to understand how the system is responding and why, as too much confusion would make for an less pleasant user experience and potentially deter future visits to the fountain.

They also recommend optimising for "Short-Duration Fluid Interaction", by making it quick and easy to begin and end interaction, perhaps by just walking up to and away from the system (Vogel and Balakrishnan 2004). This would be of particular importance in a fountain should it be placed in a transitory space such as a public walkway, where users have little time to stop. A high barrier to entry may deter use, while making it difficult to exit an interaction would reduce the likelihood of someone coming back in future.

Similar to "Comprehension" is the recommendation of "Immediate Usability", by which a user can quickly discover how to use the system through trial and error, not requiring external guidance (Vogel and Balakrishnan 2004). The fountain will be placed in public unattended and with no instruction manual, so if the public cannot easily figure out how to control it then it will likely never be used at all. This ties in well with being easy to understand, as a system that is both easy to understand and easy to learn will provide a positive experience for the end user.

2.3 Playful Interaction

Dekel et al. (2005) defines playful interaction as "human computer interaction that has at its core no pragmatic goals [...] users are more interested in enjoying themselves than they are in achieving a specific task", and we will use this definition going forward. This kind of interaction has been utilised in many public spaces, and could be used in the fountain to fulfil the public desire to play with the water.

2.3.1 A Playful Waterfall

One public application of playful interactivity consisted of a waterfall which would play sound when the user put their hand through the stream of water, and was received well by the public with people queuing up to use it when it was placed in an art school corridor (Dekel et al. 2005). This installation demonstrates that it is feasible to build an interactive water feature, and gives the indication that such an item would be enjoyed by the public. However the results are discussed in superficial detail and so we must do further work if we wish to determine the full impact of such installations on public spaces.

2.3.2 Encouraging Collaboration

"Musical Chairs", a playful public installation, encourages collaboration by having some behaviours only be revealed when multiple people use the installation at the same time (Dekel et al. 2005). Having such hidden behaviours encourages people to work together to reveal what else the installation has to offer, and may lead to social interactions between strangers who happen to discover such features together. As such, if we wish strangers to use the fountain together, we should create some aspect of the fountain's behaviour which can only be activated by a group.

In addition to this, Bekker et al. (2010) state that by allowing the users to define their own goals and aims, we encourage them to interact with each other socially in order to negotiate these goals with the other users . Therefore, if we wish for users of the fountain to interact with each other we should refrain from setting any ultimate goal for the interactions, instead leaving this up to the users to define between and among themselves.

2.3.3 Learning the Controls

The functionality of the "Musical Chairs" installation was generally discovered by trial and error, a process which participants seemed to enjoy (Dekel et al. 2005). By making the process of discovering functionality easy yet gradual, it gives players a goal to work towards and gives them a sense of satisfaction when they discover new functionality.

We can take this idea forward into the fountain by not explicitly stating, through signage or other means, how to control the fountain. This then leaves it up to the user to tease out the controls, and may extend the length of time they spend with the fountain while giving them a sense of achievement when they figure out the controls. However, this must be balanced against the need for users to understand the system quickly and easily.

Dekel et al. (2005) underlines the importance of simplicity in public installations noting "a system that is too complicated to understand within a 30 second window will go unused", as participants may not have the time to try and figure out how a system works. Therefore if we wish to see any significant usage of our water feature we must ensure that the system we develop is self explanatory, and that the controls are clear to the user as there is no guarantee a user will dedicate much of their time to trying to figure it out themselves.

2.3.4 Encouraging Usage and Interaction

Bekker et al. (2010) developed a set of principles to guide the addition of playful interactivity, with the aim of encouraging physical activity and social interaction within the users of their systems. We can apply these principles to the creation of an interactive water feature to improve the user experience.

The first of these principles is "motivating feedback" where a user, seeing a system respond to their actions, is encouraged to engage in further behaviours as they explore the system more (Bekker et al. 2010). By having the fountain respond clearly and quickly to user behaviours we can encourage them to engage with the fountain more, and so this should guide us when designing the input-output relationship for the fountain.

Secondly, they note that the way in which an installation or item is designed changes the way in which it is used, specifically that an object designed for sharing will lead to more social interactions between users than one designed to be used by individuals (Bekker et al. 2010). By building a single fountain with the capability to handle multiple users at once, we encourage social interaction between the users of this shared installation, and so fulfil our goal of facilitating triangulation (Whyte 2012).

2.4 Spectator Experience and the Honeypot Effect

2.4.1 The Honeypot Effect

Wouters et al. (2016) defines the honeypot effect as "how people interacting with a system passively stimulate passers-by to observe, approach and engage in an interaction". For the fountain to alter how people use a public space, we need to encourage people to interact with the fountain itself, and utilising the honeypot effect could be one way of doing this.

An important aspect of utilising the honeypot effect is to advertise the system, either by having people hand out flyers or by making the system visible to potential users, while not giving too much away about what the system does or how it works (Wouters et al. 2016). It is important that we balance informing people of the fountain's presence with leaving some mystery around how it works as a degree of mystery or curiosity is required to turn the knowledge of its existence into a desire to interact.

Given it would be impractical to have people constantly handing out promotional material for the fountain, we should advertise the fountain by making it visible to potential users, perhaps using some form of idle state to draw the user in. Once these initial users have been drawn in, the honeypot effect can then take over the advertising of the system, drawing in spectators who then become users themselves.

2.4.2 Facilitating Learning

For any system to be well utilised it is important that people can understand and learn how to use it with ease. Therefore Wouters et al. (2016) suggest that users can learn how a system works by watching others interacting with it, and that both the system itself and the context in which it is deployed should facilitate this. We can achieve this by creating space around the fountain for spectators to sit and observe, and by making the method of controlling the fountain and all its outputs visible to the spectators. By allowing them to learn without having to directly interact, we increase the chances of spectators becoming involved participants.

Reeves et al. (2005) also discusses how the design of an interface changes the spectator experience, proposing a number of design strategies and outlining the impact these have. These strategies are discussed in terms of "manipulations" which are what the user does, and "effects" which are how the system responds to the user's actions (Reeves et al. 2005), with it being suggested that how a spectator experiences a system depends on the visibility of these effects and manipulations.

Some of the design strategies they outline, such as the "Suspenseful" and "Magical" strategies, hide either the effects or the manipulations from the spectators (Reeves et al. 2005). These strategies add mystery and excitement by not revealing all aspects of the interaction to the spectators, and may be quite entertaining. However, using these prevents the spectators learning the controls as they cannot see the interaction from start to finish, which may discourage them from making the transition to active user.

The "Expressive" strategy shows both the effects and manipulations, and is the best strategy for facilitating learning (Reeves et al. 2005). This strategy should be used in the case of the water fountain, as knowing the exact dynamics of the interaction before participating will ease some of the potential embarrassment of using such a system in front of others, making it more likely that a spectator will become a user.

However, Reeves et al. (2005) cautions that by making their actions so visible, the users may become nervous due to fear of making a mistake in front of others. Therefore, it is important that we finely balance the needs of both the spectator and the users to maximise the comfort of both.

Cox et al. (2016) also repeats the fact that spectators will learn by watching other people interact. Watching others is integral to how people learn to use interactive systems in public spaces, and so we should design the fountain in such a way that all controls can be easily observed. This will require an unambiguous design, with a clear relationship between its inputs and outputs.

2.4.3 The Importance of Common Goals

In order to get users to interact as a group, some aspect of the system must encourage them to team up, such as having a common goal that they can only achieve by working together (Wouters et al. 2016). The fountain could achieve this by having a state that can only be activated by a group, perhaps by placing buttons or sensors further apart than a single user could reach. This would help encourage triangulation as discussed by Whyte (2012).

Repeating this point, Cox et al. (2016) notes that participants interacting with each other most often occurs when there is some "common goal" for them to work towards. Therefore, in order to facilitate the concept of triangulation (Whyte 2012), we need to have some aspect of the fountain that can only be unlocked by a group. However, Cox et al. (2016) cautions that requiring direct interactions with another person to achieve a goal may be off-putting, and so we must be mindful of this when designing the common goal we wish for the participants to achieve.

2.4.4 Switching Roles

Combining two recommendations from Wouters et al. (2016) together, it is suggested to allow for people to easily switch between being a user and spectator, as well as facilitate those who decide to switch back from user to spectator sharing their knowledge and experience with other spectators.

It is important that no user feels trapped or forced into interacting, and that they can switch between roles as and when they feel comfortable. An easy way to achieve this in the fountain would be to allow users to return to a spectator state by simply walking away from the fountain, and vice versa. This ensures that users do not feel any pressure to continue interaction, and allows for easy transition between the roles.

To encourage the knowledge transfer between ex-users and spectators, we can create the fountain in such a way that the are likely to pass each other as they enter and leave the space around the fountain, a tactic suggested by Wouters et al. (2016), perhaps by having spectators congregate around the fountain, or by placing the fountain in a walkway or other space with high footfall such that those who are walking away from the fountain will walk past those who are coming towards the fountain and encountering it for the first time.

2.4.5 Social Embarrassment

One issue raised is that of "social embarassment", a feeling experienced by users which is born out of the potential that they may make a mistake in front of a crowd of spectators, or that they may be criticised by those watching them (Cox et al. 2016). It is possible that users of the fountain could feel embarrassed to use it in front of others, perhaps feeling they are drawing attention to themselves or appearing silly in front of others.

When designing the fountain we must mitigate this embarrassment and ensure that our users feel as comfortable as possible in the interaction. Cox et al. (2016) suggests this embarrassment may be alleviated by allowing them to freely switch between the roles of user and spectator. This echoes Wouters et al. (2016), who also highlighted the importance of allowing easy transition between roles, underlining the importance of ensuring the fountain is simple to engage with, but also just as simple to disengage from, so that users may switch, with ease, to whichever role they feel most comfortable in.

2.4.6 The Novelty Effect

One aspect raised by Cox et al. (2016) that we will not be able to evaluate in this study is the fact that the enjoyment and usage of a public installation will wane over time, and so short term studies may not be representative of the longer term impact of such an installation. We will not be deploying the fountain outside, or conducting the lab studies over protracted periods, and so will have no way of studying how participants feel about the fountain over the longer term. However, this would make for worthwhile future work, should the fountain be deployed in a public place.

3 Requirements

In this chapter we introduce the requirements the fountain must fulfil in order to be suitable for achieving the aims outlined in Chapter 1. These requirements are designed to build upon and utilise the prior research and relevant concepts discussed in Chapter 2.

3.1 Functional Requirements

The functional requirements state features that the fountain could have, and were decided based on the research discussed in the previous chapter in order to build on this, but also to fill in gaps which currently exist. These requirements have been prioritised using the MoSCow method to indicate how important they are in delivering a valuable product that we could use in our evaluation, splitting them into the categories below.

3.1.1 Must Have

These requirements are essential to the creation of a useful product and without them an evaluation will not be possible.

Play Without Contact: The fountain must allow users to interact with the water without necessarily having to touch the fountain or the water itself. This addresses the issues raised by Whyte (2012) and Dietz et al. (2014) where the public have a natural urge to touch the water and to play with it, despite the safety concerns and impracticality of doing so. This will allow the public to follow their urge to play with the water without the need for physical contact.

Distance-Dependant Semantics: The fountain should use the concept of distance-dependant semantics as discussed in Ballendat et al. (2010): as a user comes closer to the fountain, new forms of interaction should be revealed. This could be implemented using either a zone based proxemic model, as discussed in Vogel and Balakrishnan (2004), or could use a continuous model of interaction. This will encourage users to come closer to the fountain and to become more engaged in the interaction.

Supporting Multiple Users: We should allow for multiple users to interact with the fountain simultaneously, and to be at different levels of engagement to each other. The fountain will be designed for deployment in a public space, where we will be unable to control how many people try to interact with the fountain at any one time. The fountain should be able to graciously handle multiple users and respond in a pleasing way (Vogel and Balakrishnan 2004; Ballendat et al. 2010). This will help maximise the number of people who can interact during the evaluation, and ensure that users enjoy their interaction experience.

3.1.2 Should Have

The requirements in this section are not needed to run an evaluation, but do play a key role in ensuring that users have the best possible experience and that the evaluation yields good results.

Tolerance at Zone Edges: As mentioned in Ballendat et al. (2010), there will need to be a degree of tolerance at any zone edges to prevent rapid switching between the zones when a user stands at a boundary point. While a lack of tolerance would not prevent users from interacting, it would create an unpleasant experience and so the fountain should switch between zones smoothly.

3.2 Non-Functional Requirements

The non-functional requirements relate to general aspects of the fountain rather than specific features, but help to create an enjoyable interaction experience for the users during the evaluation. Like the functional requirements, these have been prioritised using the MoSCoW method.

3.2.1 Must Have

These non-functional requirements are essential to providing the best interaction experience to our users and to delivering a worthwhile evaluation.

Accessibility: We want all users to be able to enjoy interacting with the fountain equally, and it is vital to the success of the fountain that it is accessible to users with a range of sensory impairments. This can be achieved by combining different inputs and outputs that utilise different senses, such as having both visual and audio output.

3.2.2 Should Have

Here we introduce requirements which, while not essential to delivering the fountain, would be vital in producing the best results in the evaluation by improving the interaction experience.

Ease of Spectator/Participant Transition: To maximise the number of users interacting with the fountain during the evaluation we should make the process of switching from spectator to participant as easy as possible. It should also be easy for users to switch back from participant to spectator, and ensure that nobody feels trapped in an interaction they may not be comfortable with.

Visible Interaction: In order to minimise the social embarrassment discussed by Cox et al. (2016) and to facilitate spectators learning how to control the fountain, the method of interaction should be clearly visible. This will also advertise the fountain, helping to attract new participants, in addition to its role of teaching the interaction method to the spectators and helping them to feel confident enough to interact themselves.

3.2.3 Could Have

The requirements introduced here are not needed to create a pleasant interaction experience or to run an effective evaluation, but would help to further improve the experience.

Considered Context: Wouters et al. (2016) notes that the environment in which a system is situated should be considered when designing the interaction, and demonstrates how the area around an installation can be designed to encourage interaction between spectators and participants leaving the interaction space, which can lead to discussions which encourage spectators to become participants themselves. When placing the fountain in the location for the evaluation, care should be taken to ensure that the location is well suited to the needs of spectators, and that it supports the types of interactions between users that we desire.

4 Design

In this chapter we will first give an overview of the final design of the interactive water feature, and then discuss the reasoning behind a number of key design decisions which were made in order to meet the requirements laid out in the previous chapter.

4.1 Overview

The fountain will use the distance and position of its users as input to the system. A number of sensors will be spaced out around the perimeter of the fountain, allowing users to be detected on all sides. Initially, when no users are in range, the fountain will default to an idle state, as shown in Figure 4.1, where a small number of the pumps may be active, appearing as if it were any other fountain.

When a user comes within range of the fountain, the pump in front of them will activate. As the user comes closer to the fountain, the height of the water stream being produced by the pump will increase, and as they walk further away the height will decrease. While users will be able to activate multiple pumps simultaneously, because the pumps are spaced around the perimeter multiple users will be required to activate all of the pumps at the same time.

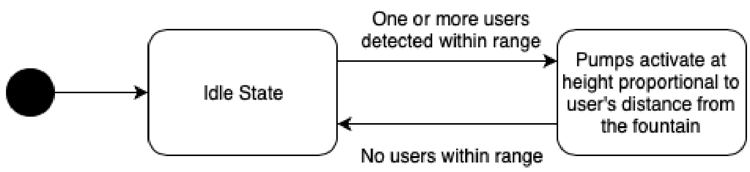


Figure 4.1: *When the fountain is switched on it begins in the idle state. When a user is detected in range the fountain switches states, activating the pump in front of the user at a height proportional to their distance from the fountain. If the user moves out of range, the fountain switches back to the idle state.*

4.2 Interaction Modality

Many decisions taken relate to the features the fountain should support, especially with respect to the interaction methods that should be provided to the user and how the system should respond to these. These can be divided into three main categories which are discussed below.

4.2.1 Proxemic vs Gesture Based Interaction

When deciding on the input method the fountain should support, two main methods were identified: gesture based, and proxemics based.

Gesture based interaction can be defined as "a coordinated and intended movement of body parts to achieve communication" (Stößel and Blessing 2009). That is a user may, for example, be required to move their hands or arms into a specific position that indicates to the system that they want to perform a specific action.

Using a method such as gesture controls would allow the user to control the fountain without any need for physical contact, as the gestures could be made in the air by the user. This is demonstrated in work by Vogel and Balakrishnan (2004) whereby users can control a public display by changing the position of their hand, but without the need for the hand to be in contact with the display.

However, there is difficulty in using gestures as it can be difficult to communicate to the user which gestures they need to perform. For example, Vogel and Balakrishnan (2004) found it necessary to occasionally display videos showing relevant gestures being performed.

While this issue can be easily tackled on a display where visual hints can be given, this would be much harder to do with a fountain. The fountain has no display on which to show clues, and it would be difficult for a user to discover gestures of their own accord as it would require them performing the gesture by chance. These difficulties in communicating the controls to the user make gesture based interaction unsuitable for our desired application.

Instead, we have chosen to use proxemic interaction, a concept introduced in Chapter 2. In our design, we will use a user's position and distance to control the fountain output.

Proximity sensors will be positioned around the perimeter of the fountain, so the user's position can be determined based upon which sensor they trigger, enabling us to turn on the pump nearest to them. The sensors will also allow us to measure the distance between the fountain and the user, so we can set the output of the pump based on this distance.

When the fountain is deployed in a public place, it is hoped there will be a high level of footfall in the area around the fountain. A user does not need to do anything explicit to activate the fountain, instead the pumps will activate in response to a user walking past which will signal to the user that this is not a normal fountain. It is no longer up to the user to discover that the fountain is interactive, instead the fountain will tell the user what it is capable of.

This initial signalling from the fountain will then give the user the opportunity to explore the fountain further if they desire, or to walk away should they wish to be left alone.

Overall, gesture based interaction would be difficult for a user to understand and discover when compared to proxemic interaction, as gestures require explicit actions that are unlikely to become obvious when observing the fountain or when walking past. Proxemic interaction does not require the user to do anything specific that they would not ordinarily do around a fountain. A user simply walking past the fountain, or perhaps walking up to the fountain to throw a coin in, will have the interaction revealed to them.

4.2.2 Discrete vs Continuous Interaction

In Chapter 2, we discussed the difference between continuous and discrete proxemic interaction.

Ballendat et al. (2010) introduced the concept of continuous interaction, whereby input is taken over a continuous range of values, and is then mapped to a continuous range of output values. They also introduced discrete interaction, where behaviours activate when a user enters and exits predefined zones (Ballendat et al. 2010).

The biggest issue in using discrete zones comes when a user reaches the boundary between two or more zones. As noted by Ballendat et al. (2010), when a user stands on the boundary, this can lead to the system thinking they are switching back and forth between zones, as they may be detected in multiple zones in quick succession.

While there are methods of mitigating this issue, such as “hysteresis tolerance” (Ballendat et al. 2010), the potential always remains that the switch from one zone to another could be jarring or unpleasant for the user, and so where zones are used it is perhaps wise for the number of zones, and therefore the number of boundaries, to be minimised.

This is supported by Reeves et al. (2005) who notes that hiding some aspects of how the system works can spark excitement for the user. Having very obvious zones delineating the space will make it clear to the user how the system is responding to their behaviour but also takes away from the mystery. While continuous interaction still makes it clear that the system is responding to their behaviour, the exact relationship remains more abstract and so will maintain more excitement than a zone based model.

However, a continuous model is not practical for use on its own, and so we will use a combined approach of both continuous and discrete interaction. Continuous interaction is constrained due to the limited capabilities of the sensors, and the space around the fountain, and so interaction cannot take place over an infinitely long distance. Therefore, there is by default a discrete distance at which the continuous interaction will begin and end.

This model, having a discrete zone within which continuous interaction takes place, is a well established model and was used by Ballendat et al. (2010) to control their media player. This approach minimises the number of discrete zones required, and maintains some mystery as to the exact input/output relationship while working with the natural constraints of continuous interaction, making this model most suitable for use in the fountain.

4.2.3 System Output

When designing the output of the system, our aim was to reflect the intensity of the interaction in the output. Ballendat et al. (2010) notes that a user’s interaction becomes more explicit the closer they get to the system, while Vogel and Balakrishnan (2004) makes note of interaction being minimal at larger distances, and then becoming more involved as the distance between the user and the system decreases. Therefore, we want the response from the system to be minimal at larger distances, and become more obvious and intense as the user gets closer to the fountain.

It was on this basis that we decided that the streams of water produced by the pumps should begin as small jets when the user is further away, and get taller as the user approaches the fountain. A small jet activating will still be distinct from the fountain’s idle state, while appropriately reflecting the user’s present engagement with the system. Then as the user approaches and the interaction becomes more explicit and involved, the height of the jet will increase, reflecting the heightened engagement being exhibited.

4.3 Encouraging Use

As well as the significant design decisions which dictate the functionality of the fountain, a number of decisions were made to improve the user’s experience without necessarily impacting the functionality.

4.3.1 Facilitating Collaboration

The topic of multiple users interacting with a system simultaneously was prominent in much of the work discussed in Chapter 2, and is an important factor to consider when designing a system for public deployment.

Ballendat et al. (2010) presents multiple users interacting as a problem to be handled, where their actions might conflict, however multiple users interacting together is actually a possibility we can capitalise on.

In Chapter 2 we introduced the concept of triangulation (Whyte 2012) where the fountain might prompt strangers to interact and socialise. Adding to the social life of a space is important if we wish the fountain to positively impact user behaviour. If we design the fountain in such a way that it encourages groups of people to interact with the fountain together, then we will be successful in supporting triangulation.

One method of encouraging users to interact together which is echoed across many works (Wouters et al. 2016; Cox et al. 2016) is to give users something to work towards, a reason to want to interact. Dekel et al. (2005) create this reason by having some behaviours of their "Musical Chairs" installation only accessible when multiple people use the system at the same time.

This is something we can easily achieve in the fountain by simply spacing the sensors out around the perimeter of the fountain. This will put some of the sensors out of reach for a single user, and so if they want to create a specific pattern or activate all of the pumps at once then they will require assistance from others. This then creates motivation for them to work with other users, and will successfully facilitate triangulation.

4.3.2 Improving the Spectator Experience

The two main strategies for improving the experience for spectators and to encourage them to become active participants is to make it easy to learn how the fountain works, and so make it easy to switch between roles.

Wouters et al. (2016) discusses how a spectator can learn how to control the system by watching the people currently interacting with it, but claims that the system must be designed to facilitate this. A spectator who feels they understand how the system works is much more likely to use the fountain than one who does not, so it is important we design the system in a way that supports this learning process.

One approach, suggested by Reeves et al. (2005), is the "expressive" model, where both how the user controls the system and the outcome of their actions are clearly visible to the spectators of the system. By making the entirety of the interaction visible it allows the spectators to develop understanding of the system, which will give them more confidence to join in themselves.

The fountain makes use of the expressive model, with both the actions of the participant and the response of the fountain clearly visible to all those within the vicinity of the fountain. This will allow spectators to learn how the fountain works before interacting themselves, hopefully giving them more confidence to interact.

One key barrier to spectators becoming participants is that they may feel embarrassed while using the fountain (Cox et al. 2016). This will be partially mitigated through learning, as users will likely be less embarrassed if they feel they are interacting correctly and understand what they are doing, however there is another key factor in minimising embarrassment.

Cox et al. (2016) mentioned that making it easy to switch back and forth between the role of participant and spectator may help alleviate some of this embarrassment. Wouters et al. (2016) also discusses the importance of allowing users to move between different roles within the system, and so we ensure this in our fountain by making the transition between roles as simple as walking away.

We mentioned previously that there will be a discrete boundary at which interaction with the fountain will begin, and so if a user wishes to cease interacting and return to a spectator state either permanently or temporarily then all they are required to do is walk to a point beyond that discrete distance.

This makes it easy for the users to stand and observe, interact, exit the interaction and observe some more with great ease, ensuring no user is trapped in an interaction that they may not feel completely comfortable with.

4.4 Idle State

While we have now established how the fountain will behave when a user or group of users is present, we must also establish how it will behave when no users are within the interaction zone. Given that the interaction becomes apparent when a user approaches the fountain, we need to develop an idle state which will draw users in.

Having the fountain do nothing at all when users are absent is not suitable, as it is likely people will assume the fountain is switched off or possibly even broken. Instead this must be an active state, perhaps mimicking a normal fountain, so that it grabs people's attention as they walk through a potentially busy space.

Of course the process of testing which idle states are most effective at drawing attention could be a research project in itself, and so it is unlikely that the idle state chosen here will be the optimal one. Instead we should choose a simple state which meets our needs, and forms the basis for future work on idle states.

A simple idle state consisting of a few pumps running at a static height is sufficient for the small, in-the-lab study that we will conduct where the fountain is not having to compete for the user's attention, however this would be an interesting area of further research should the fountain be deployed in a public space at a later date.

4.5 Accessibility

When designing a system to be deployed in a public space, it is important that we account for the varying abilities of our user population. Our users may have a range of issues affecting their mobility or their sensory systems, and it would be unfair to design a system which excluded them from interacting based on their disability.

The input techniques used in our system take into account the varying abilities our users may have. Gesture based controls such as those used by Vogel and Balakrishnan (2004) may pose difficulties for users with limited mobility as they may not be able to move their body into the required positions. For example some users may not be able to lift their arms, while Stößel and Blessing (2009) notes that the elderly may have some issues performing some gestures.

However, because the proxemic interaction that we have chosen to use requires only very coarse grained movements, the aim is that this can be achieved by users with a wide range of levels of mobility. For example, users in a wheelchair will be able to change their position and distance around the fountain in the same way an able bodied user can, allowing them to both experience the fountain in the same way.

The same level of consideration has been taken with regards to the outputs of the system. Not only does the height of the water create a visual change, it will lead to an audible change too. As the height of the water jet increases, the amount of force behind the water hitting the surface of the fountain will also increase, creating louder splashing sounds. Similarly, multiple users interacting simultaneously will create louder splashing sounds as more water hits the fountain surface at once.

There is also no constraint on the speed at which the user must move in order to see a response. The output from the fountain changes continuously in line with the users movements, so if users move quickly they will see quick changes, and if they move slowly they will see slow changes, essentially adapting the speed of the output to match the user's own speed, allowing them to take their time if necessary.

While we can design a system with accessibility in mind, the only way to know if a system is truly accessible is to test it with users of varying abilities. Given the convenience sample which will be used in our study, it is likely that this testing will fall outside of the scope of this project. However, future evaluations conducted in public spaces may be better placed to investigate this issue, and it is a worthwhile area for future work.

5 Implementation

In this chapter we will demonstrate how the design outlined in Chapter 4 was implemented, discussing the tools and techniques used in detail. This will involve discussion of both the hardware and software configurations of the system, and the decisions that led to these configurations being used.

5.1 Resources Used

In the course of the project we made use of preexisting code resources in order to speed up the development process and build on existing work. In particular we used the following:

- We used the Arduino sample code from the PumpSpark Fountain Development Kit github repository as a basis for our development. In particular, we made use of their method for actuating the pumps. [1]
- We modified code from a Medium tutorial for taking distance readings from ultrasonic sensors. The code inside their loop function was extracted as a separate function in our code, and was adapted to take in the pin values as parameters rather than using hard coded values. [2]

5.2 Hardware Configuration

The basis of the fountain is the PumpSpark Fountain Development Kit which includes a set of eight pumps, a control unit, and a collection of additional materials such as tubing, nozzles and a power supply (Dietz et al. 2014).

This kit abstracts away many of the issues involved in creating water features, such as moderating the supply of power to the pumps, with Dietz et al. (2014) noting the control unit acts as a "programmable power supply" with the pumps connecting to the control unit, which provides power to them in order to set their output.

We chose to use an Arduino Uno to mediate between our sensors and the fountain control unit, due to the extensive community forums[3] and the fact sample code was provided for use with the Arduino, as mentioned in the previous section.

The Arduino, as shown in Figure 5.1, activates and takes in readings from a set of eight ultrasonic sensors, and uses these readings to compute the appropriate output for the fountain. The Arduino then sends commands to the fountain control unit using serial communications. The control unit will then adjust the voltages of the relevant pumps to achieve the desired output (Dietz et al. 2014).

[1] https://github.com/greyesgt/PumpSpark/tree/master/Arduino Accessed: 20th March 2019

[2] https://medium.com/@seyoum14/using-a-hy-sr05-sensor-to-measure-distance-with-arduino-88e34d09c1c7 Accessed: 20th March 2019

[3] https://forum.arduino.cc Accessed: 20th March 2019

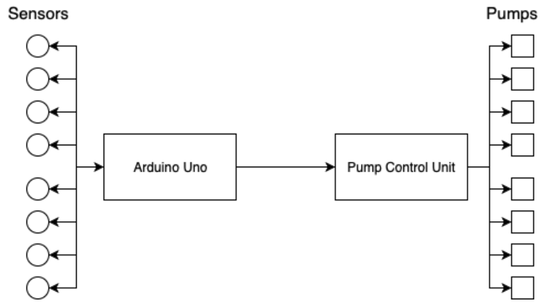


Figure 5.1: *The Arduino Uno sits between the sensors and control unit, and is responsible for activating the sensors, processing the returned readings, and sending commands to the control unit. The control unit uses the received commands to set the pump outputs.*

5.3 The Use of Ultrasonic Sensors

To detect the position of the users and their distance from the fountain we made use of eight ultrasonic sensors. In this section we will discuss why we chose to use ultrasonic sensors, explain how they were utilised in our system and outline the issues that arose as a result.

5.3.1 Ultrasonic vs Infrared Sensors

Upon searching for suitable proxemic sensors to use in the system, two types of sensor seemed to best suit our needs in terms of budget constraints and requirements for the maximum distance detected. These were ultrasonic and infrared proxemic sensors.

Ultrasonic sensors work by emitting sounds waves and calculating the time it takes for these sounds waves to be reflected back and received by the sensor[4]. Infrared sensors work in much the same way, emitting light in the infrared spectrum, and calculating how long it takes for this light to be reflected back[5].

Given the similar modes of operation, and the fact that both types of sensor met the requirements for use in the fountain, it was decided that the accuracy of measurements should be used as the deciding factor.

Adarsh et al. (2016) conducted an experiment comparing the accuracy of ultrasonic and infrared sensors when detecting objects of a variety of materials. Their work found that, for the majority of the surfaces they tested, ultrasonic sensors provided more accurate results (Adarsh et al. 2016). It is based on these results that we made the decision to use ultrasonic sensors rather than infrared. Accurate distance detection will be necessary to provide users precise control over the system, and large amounts of inaccuracy could be frustrating for the users.

5.3.2 Obtaining Distance Readings

In order to obtain distance readings we must cycle through each of the eight sensors in turn and activate them to generate a distance measurement. The sensors themselves connect directly to the digital pins on the Arduino, and the pin values that correspond to each sensor are stored in an array.

[4]http://www.farnell.com/datasheets/2630954.pdf Accessed: 20th March 2019

[5]http://www.farnell.com/datasheets/1386113.pdf?_ga=2.268676849.1441403269.1553111208-416252080.1538688134 Accessed: 20th March 2019

To obtain a reading from each sensor, we can iterate over this array of pins and for each pair of pins, where each sensor requires two pins to be stored in the array, we call a function that will activate the sensor connected on those pins.

The function for activating an individual sensor is a modified version of code found in an online tutorial[2]. The tutorial uses hard-coded pin values in the main loop of the program to obtain distance readings from a single sensor. In order to generalise this code to work for a system with multiple sensors, we extracted this code from the main program loop and instead placed it within a separate function. We also changed the code from using hard coded pins values to taking the pin values as a parameter. This means that each time the function is called we can specify which pins in should operate on, and therefore which sensor to obtain a distance reading from.

When the function returns a distance reading, this is stored in array for use later when we convert the distance readings to pump output values. After obtaining a reading, we require a short delay before taking the next reading. The ultrasonic sensors used all operate at the same frequency and so cannot differentiate between their own sound waves and waves produced by the sensors adjacent to them. Without a delay, this could lead to false readings as they detect waves from another sensor instead of their own. The short delay allows enough time for the sound waves to dissipate before activating the next sensor.

5.3.3 Filtering Noise

It was discovered while testing the prototype of the fountain that errors in the distance readings could lead to unexpected output from the pumps. For example, pumps would often activate despite no users being within range of the sensors, or may produce an intermittent stream rather than a constant stream. It was decided that to counteract these false readings we would need to either detect and remove false readings, or find a method to smooth them out.

Detecting and removing abnormal readings by checking for abnormally large jumps in value was quickly discounted due to it being impractical in our application. It is very difficult to define for the system what a normal change in sensor reading could be. For example, very large jumps in value could be valid, perhaps caused by a person running past very close to a sensor. The sensor may initially not detect anything in range, detect the person running past, then drop back to not detecting anything within range. Therefore, we cannot simply discard large jumps in sensor value as being errors, and so had to take a different approach.

Instead it was decided that an average should be taken across a series of sensor readings, by storing a set of previous sensor readings in an array. Each time a new distance reading was taken, the oldest reading in the array was replaced by the new reading and an average of the readings taken. This means that large jumps or drops in value would be smoothed out by being averaged with other, normal readings.

However, averaging readings together can introduce a delay in the system responding to the users movements, and so a fine balance has to to struck between smoothing out erroneous values while maintaining a responsive feel. The prototype was initially tested with the previous five sensor readings being averaged together, however this introduced a delay into the system that would be noticed by users. We then changed the system to averaging together three sensor readings and tested this, finding that it struck a good balance. Averaging three readings together smoothed out incorrect readings and so was an improvement compared to not performing any averaging, while not introducing noticeable delay into the system.

5.4 Converting Distance to Output

In order to obtain output values at which to set the pumps, it is necessary to establish a mathematical relationship between the distance values obtained and the range of possible output values.

The range of output values is constrained by the hardware in use. As seen in the sample code[1], the pumps can be set to values in the range of 0 to 254. However, when actually testing the pumps it was found that a value of less than around 70-75 would not generate any output. This decreased the number of possible output values that could be achieved using the equipment at hand.

The range of possible distance readings is limited both by the capabilities of the sensor and by the environment in which the fountain is deployed. The sensors we have used have a maximum range of 4 metres and minimum range of 2 centimetres [4], and so we could have sensor readings anywhere within this range. However, the room in which the evaluations took place was too small to make use of the full distance range, there was no way to position the fountain within the room without detecting the walls as being in range, and so the fountain would never reach an idle state. Instead it was decided that the maximum reading that should be accepted is 2.5 metres, to allow the fountain to be used in the room provided while still allowing for plenty of idle space around it. While this comes with the drawback of reducing the usable distance range, it is necessary for the purposes of our evaluation.

A polynomial relationship was initially considered to provide some variation in the mapping, perhaps having the change in height become more rapid as the user comes closer to the fountain. Initial testing with the prototype showed this could be confusing to users who may not understand why the fountain was not behaving in a consistent way. As a result of this it was decided that a linear relationship should be used instead. It was established that the linear relationship used should be defined as:

$$output = -0.725x + 255, \tag{5.1}$$

where x is the smoothed distance reading. Due to the pumps only accepting integer values, the output resulting from this equation would be rounded before being stored in an array for use later, when it would be transmitted to the pump control unit to generate output.

5.5 Idle State

As discussed in Chapter 4, it is necessary to establish an idle state within the fountain, a form of behaviour for the fountain to default to when no users are in range, for the purpose of generating interest and drawing people towards the fountain. In the interests of simplicity, it was decided to use an idle state in the form of the four corner pumps running at the constant value of 70 throughout the duration of the idle state. This low value minimises splashing and noise, while mimicking the appearance of a standard, non-interactive fountain.

To track whether the fountain is in an idle state we maintain a Boolean variable, which is set to true when the fountain is in the idle state, and false when one or more users are in range. When the system is switched on, the idle state variable is initialised to true, as we are assuming no users will be interacting with the fountain at this point. When generating the array of output values for the pumps, if a user has been detected as being within range by any of the sensors the idle state variable sets to false.

A conditional statement within the main loop of the program uses this variable to determine which one of two output states it should enter. If the idle state variable is false, the pumps will be set to the values contained in the output array, and if the idle state variable is true, the system will default to activating the four corner pumps at a value of 70.

Whenever we begin to retrieve new output values, we reset the idle state variable to true, essentially defaulting to that state. This means that the system will always enter the idle state unless a sensor value indicates a user is in range.

5.6 Fabrication

In addition to configuring the electrical hardware as discussed earlier, the fountain required the creation of a structure to contain both the hardware and the water in such a way that it would mimic the appearance of a normal fountain. The final form of the fountain structure can be seen in Figure 5.2b.

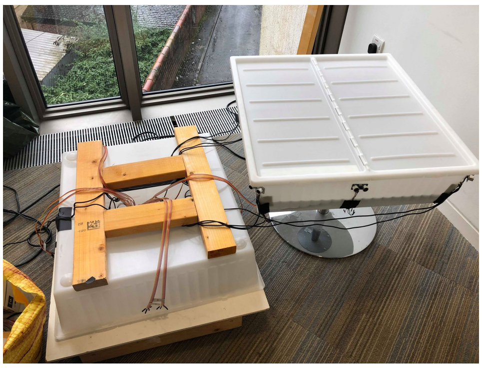
As can be seen in Figure 5.2, the basis for the structure is two large plastic storage boxes, with one upright box stacked on top of an upturned box.

The upturned box on the bottom holds the Arduino and the control unit for the pumps, keeping them separate from the water contained in the other box. A hole was cut in what would have been the base of this box to allow for wiring to be fed to the electronics contained within, as can be seen in Figure 5.2a.

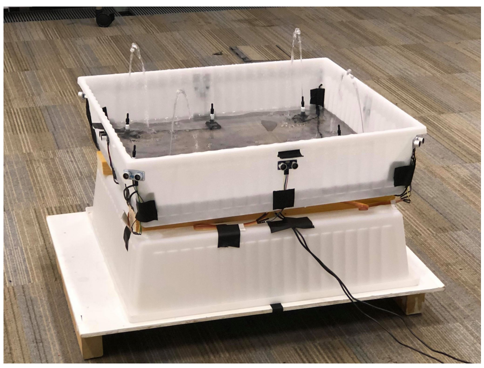
The upright box placed on top holds both the pumps and the water, with the wiring for the pumps being passed out through holes drilled in the sides of the box above the waterline. The sensors are glued around the outside perimeter of the box on the corners and the sides, while the pumps are glued inside the box in the corners and at the sides, so that for every sensor there is a corresponding pump. The wires for both the pumps and the sensors are passed between the two boxes and then through the hole in the bottom box where they connect with the rest of the electrical hardware.

One significant obstacle to the fabrication process was the flimsy nature of the plastic boxes. The top box in particular would bow due to the weight of the water, which would in turn alter the angle of the water streams such that the streams would overshoot the sides of the box, splashing water over the floor. To overcome this issue, a wooden support was constructed that would be positioned between the two boxes and stop the base of the top box bowing. This support can be seen in 5.2a, and was successful in solving this issue.

This entire structure was then placed on a dolly to allow for easy transportation between the rooms where the evaluations would be held and the area where it would be stored.



(a) Fountain structure during the assembly process.



(b) Final, completed fountain structure.

Figure 5.2: *Fountain during and after the fabrication process. (a) shows the structure partially complete, with the wooden supports and the hole for the wires clearly visible. (b) shows the completed structure, where we can see the sensors positioned around the perimeter of the structure, and the pumps situated within.*

6 Evaluation

In this chapter we outline the procedure used in evaluating the interactive water fountain with the aim of answering the research questions proposed in Chapter 1. We present the results of the experiment that was conducted and discuss how these answer our questions and relate to the wider literature in this area.

6.1 Aims

While our overall aim outlined in Chapter 1 was to try and answer the question "How does adding interactivity to water fountains change the way people use a public space?", this a a very broad question and it is unlikely this can be definitively answered by a single study. Instead we broke this aim down into a series of smaller research areas that will contribute toward the answering of this larger topic:

- We wish to establish whether or not interactive water features will encourage people to make more use of public spaces. For example, will people be more likely to visit spaces if they have an interactive water feature, and will they spend more time there when they do visit?
- We also wish to increase our understanding of how people make use of the novel features of interactive water fountains. Do they make use of the interactive capabilities in unusual ways? Do they favour these new interaction techniques over splashing in the water?
- Lastly we wish to establish how the people taking part in an interaction change the experience for others. For example, how does interacting as a group differ from interaction an an individual? And how would people feel interacting with a stranger compared to interacting with friends?

6.2 Experimental Design

While we are studying how interactive fountains affect behaviour in public spaces, the decision was taken to run the evaluation in a controlled lab setting rather than a public space. In its current state of development, the fountain is a high fidelity prototype not a finished, consumer-ready product, and so is not ready for deployment in a public space.

Additionally, any future study performed in a public space is likely to benefit from previous work having been conducted in laboratory settings. This laboratory evaluation may inform future development of interactive water features and provide a basis for evaluations to be conducted in public spaces.

The evaluation conducted involved two conditions: group and individual. In the individual condition, the participant interacted with the fountain alone, while in the group condition they interacted as part of a group of three. All groups consisted of people who knew each other prior to the study, ensuring consistency.

Having the two conditions allowed us to make comparisons between how participants experience the fountain alone and how they experience it when with people they know. However, limiting the groups to only participants with a preexisting relationship prevented us from evaluating how people use the fountain when around strangers. As such, we recommend future studies be conducted comparing groups comprised of friends with groups comprised of strangers.

6.2.1 Pre-Study Survey

In both conditions, participants were asked to fill in a short survey before interacting with the fountain. This asked questions about the demographics of our participants, specifically their age range, gender identity, and their technical background. The purpose of this was to establish how representative our sample is of the wider population.

We then asked participants a series of questions about their general opinion of interactive water features. First we asked if they knew of any other interactive water features, and asked them to give examples if they answered in the affirmative. We then asked participants if they would visit a public space to see an interactive water feature, if such a water feature would encourage them to spend longer in a public space, and if they would make a return visit to a public space with an interactive water feature.

Here we aimed to establish their baseline opinion of interactive water features, before their interaction with the one we developed. This allowed us to make comparisons with their opinion after the study, to see if exposure to an interactive water feature changed their opinion of them.

6.2.2 Experience Prototype

After completing the pre-study survey, participants then had the opportunity to interact with the fountain as an experience prototype. Studies involving experience prototypes differ from typical user studies due to the fact participants get hands on with the prototype as if they were using it for real, instead of just watching a demonstration or completing a preset list of tasks (Buchenau and Suri 2000). This gives a better understanding of how users would use the system in real life when compared with typical user studies which focus more on assessing the functionality than the experience, and where the experimental conditions rarely reflect the conditions in the real world (Buchenau and Suri 2000).

Buchenau and Suri (2000) discuss how experience prototypes were used to evaluate airplane interior configurations. In this example, the design team set up a room to mimic the interior of an airplane and then tested their proposed interior configurations in this room rather than in a real plane (Buchenau and Suri 2000). Testing in simulated environments often saves money when compared to testing in the real environment, and is more time efficient too (Buchenau and Suri 2000). While this is of course no substitute for testing a final design in a live environment, such an experimental setup can be beneficial when working with prototypes.

It was decided that our evaluation should follow a similar model to the airplane example, with a room being configured to mimic the layout of a public space. The fountain was placed in the centre of the room, to allow plenty of space around it for participants to move around, while seating was placed around the edges of the room facing in towards the fountain, mimicking public benches where participants could sit and watch the fountain.

Participants were allotted an amount of time in which they would be free to interact in this simulated public space: five minutes in the individual condition, and eight minutes in the group condition. This difference in time allocated was decided to account for the fact that in the group condition the fountain would be able to hold their attention for longer, and for the fact that because multiple people would be in the room at the same time the actual amount of time any one participant would get to interact with the fountain themselves would be reduced in comparison to the individual condition.

Before entering the room participants were instructed to imagine they were entering a public space such as a park or public square. Participants were not instructed to interact with the fountain, nor were they told anything about the functionality of the fountain. This reflects the conditions the participants would experience in a public place, where there would not be anybody present to tell them that the fountain is interactive or how the controls work.

Participants were asked to narrate their thoughts out loud for the duration of the time spent in the room. The narration of thoughts allowed any points of interest to be noted by the experimenter along with the participant's actions. These notes were then used during the interviews, where the experimenter would ask participants questions about actions or incidents of interest that occurred while they were interacting with the fountain.

6.2.3 Post-Study Survey

When their time with the fountain ended, participants in both conditions were then asked to fill in a post-study survey. The first two sections of the survey were identical between the two conditions, though these were followed by a third section in the group condition.

In the first section of the survey we asked the same questions about their general opinion of interactive water features as in the pre-study survey. This allowed us to compare the opinions held before and after interacting with our fountain to see if there was any change.

The second section of the survey then asked some questions about their experience interacting with our fountain. We wanted to establish their general feelings towards the fountain by asking how they found the experience, if they would like to visit the fountain again, and if they would recommend to their friends that they should visit the fountain. We also wished to understand how participants found the proxemic controls, asking how responsive they were and how easy it was to control the fountain, as well as how clear it was that their movements controlled the fountain. This enabled us to better understand how the participants felt during the study.

In the group condition, a third section asked participants questions about the experience of interacting with the fountain as part of a group, specifically if they found this to be a positive or negative experience, if they felt watching others helped them learn how to use the fountain, and if they enjoyed watching others use the fountain. From this we were able to establish if interacting as a group had any benefits to the participants that would not be experienced by individual users, such as increased enjoyment and enhanced learning.

6.2.4 Participant Interviews

After completing their post-study survey, each participant then took part in a short, individual interview. A semi-structured interview style was used, with the first portion of questions being asked of all participants in both conditions. The second stage of the interview was then devoted to discussing the participant's survey responses and the notes taken during their session interacting with the fountain.

The first of the preset questions focus on the general experience of the water fountain, asking participants what features should be added in future, what they enjoyed most about the fountain, what their first impression of the fountain was, and how they learned to control the fountain.

The last of the preset questions focus on how the presence of strangers would affect their experience, asking if they would interact in any way with a stranger who was also using the fountain, as well as specifically asking if they would work to achieve a common goal, such as activating all of the pumps, with a stranger.

The rest of the interview would then vary between each participant, asking questions specific to their survey answers, to gain some understanding of the reasons behind their survey responses, and discussing the thought processes behind the various actions and events that occurred while they were interacting with the fountain.

6.2.5 Limitations

While the design of our evaluation enabled us to answer the research questions we defined, there are a number of ways in which the study could be improved.

We discussed earlier that we would be conducting the study in controlled laboratory conditions rather than in a real public space. While this allows us to test the prototype at an earlier stage of development, this may affect the behaviour exhibited by the participants. For example, they may be less inhibited in the lab than they would in a public space as they are not being watched by other members of the public. Therefore, further studies should be conducted in public spaces to ensure that the behaviour seen is representative of the behaviour that would be exhibited should the fountain be permanently installed in a public setting.

Additionally, the participants came from a convenience sample of computing science students, flatmates, and friends. Therefore both the age range and technical backgrounds of the participants are not representative of the wider population. Future studies should take care to draw their sample from a more representative population to ensure that the results can be generalised.

6.3 Results

A total of 20 participants were gathered from a convenience sample, with 11 participants taking part in the individual condition. There were 9 participants in the group condition allowing for 3 groups of 3 participants.

The majority of participants were in the age range 18-24 years, with this range having 13 participants. There were 3 participants in the 25-34 range, and 1 participant aged 45-54 years.

One participant chose not to disclose their gender identity. A total of 9 participants identify as female, and 9 identify as male, with one participant responding that they identify as another gender identity not listed in the question.

Most participants had a strong technical background. A total of 12 of the participants have or are currently studying a university level qualification in computing, and 4 participants work in computing or IT. The remaining 4 participants had never studied a qualification in computing.

Full breakdowns of the Likert scale responses can be seen in the appendices.

6.3.1 Pre and Post-Study Surveys

Public Opinion

A total of 6 out to the 20 participants knew of an existing interactive water feature prior to commencing this study.

The Wilcoxon signed-rank test was used to test for differences in opinion pre and post-study due to the dependant nature of the results being compared.

Participants have a significantly greater likelihood ($p < 0.0088$, $w = -84$, $z = -2.62$) of visiting a public place to see an interactive water feature post-study (mean = 3.9, s= 1.17) than pre-study (mean = 3.0, s = 1.26). In this case we present the mean rather than median as, despite the test result, the median value was the same between both samples. A full breakdown of responses can be seen in Figure A.1.

Participants felt significantly more likely ($p < 0.0016$, $w = -91$, $z = -3.16$) to stay in a public place longer because of an interactive water feature post-study (median = 5) than they did pre-study (median = 4). A full breakdown of responses can be seen in Figure A.2.

There is a significant increase ($p < 0.0139$, $w = -79$, $z = -2.46$) in likelihood to make a return visit to see an interactive water feature between the pre-study (median = 3) and post-study (median = 4) surveys. A full breakdown of responses can be seen in Figure A.3.

Interaction Experience

The Mann-Whitney test was used to look for significant differences in Likert scale responses between our independent individual and group conditions, and the Fisher Exact test was used to look for the same difference in our multiple choice responses. In all cases of testing for differences between the individual and group conditions, we failed to reject the null hypothesis, and so no significant difference can be demonstrated.

Participants rated their experience with the fountain on a 5 point Likert scale, 1 being Very Boring and 5 Being Very Entertaining, and appeared to enjoy the experience giving a median of 5 and a mean of 4.55 (s = 0.60). A full breakdown of responses between both conditions can be seen in Figure A.4.

When asked if they would visit the fountain again, 13 participants responded yes, 1 responded no, and the remaining 6 participants said maybe, showing that the majority of participants would make a return visit to the fountain.

The majority of participants would recommend to a friend that they visit the fountain, with 18 participants responding that they would recommend, and the remaining 2 responded that they would not. Overall, participants would recommend that a friend should visit the fountain.

Participants found the fountain to be quite responsive, giving a median of 4 and a mean of 4.1 (s = 0.85) when rating on a 5 point Likert scale, 1 being Very Unresponsive and 5 being Very Responsive. A full breakdown of responses can be seen in Figure A.5.

Participants found the fountain quite easy to control, giving a median of 4 and a mean of 4.15 (s = 0.93) when rating on a 5 point Likert scale, 1 being Very Difficult and 5 being Very Easy. A full breakdown of responses can be seen in Figure A.6.

When asked if they understood how to control the fountain, all participants responded that yes they understood this.

Participants felt that it was very clear that their movements controlled the fountain, giving a median of 5 and a mean of 4.75 (s = 0.55) when rating on a 5 point Likert scale, 1 being Very Unclear and 5 being Very Clear. A full breakdown of responses can be seen in Figure A.7.

Group Interaction

Participants found the experience of interacting with the fountain in front of other people to be very positive, giving a median of 5 and a mean of 4.67 (s = 0.5) when rating on a 5 point Likert scale, 1 being Very Negative and 5 being Very Positive. A full breakdown of responses can be seen in Figure A.8.

When asked if watching others helped them learn how to control the fountain 5 participants responded yes, 3 said no, and the remaining participant responded maybe. While participants can learn from watching others, there are likely other factors that also contribute to their learning.

Participants enjoyed watching other participants interact with the fountain, giving a median of 5 and a mean of 4.78 ($s = 0.44$) when rating on a 5 point Likert scale, 1 being Very Boring and 5 being Very Entertaining. A full breakdown of responses can be seen in Figure A.9.

6.3.2 Interviews

The interviews with our participants were transcribed, and these transcriptions were analysed using open axial coding as outlined by Corbin and Strauss (1990). Codes were generated for each piece of information in the transcriptions, and related codes were grouped together to identify major themes. Too many themes were identified to discuss each individually, so we present only the most significant themes. Participants were given participant ID numbers to ensure the anonymity of the data collected. When referring to participant transcripts, we will refer to them by their ID number to maintain this anonymity.

Fountains as a Deciding Factor

When discussing the reasons why an interactive fountain would make them want to visit a public place, many participants described it as a deciding factor when choosing between public places to visit. Participant I3 noted in their interview "say you have two parks and you know that they're basically the same but one of them has the fountain, you will probably want to go there because there is like an activity to try", while participant G2 remarked "if I had an option between a park that didn't have a water feature and it just had like a regular fountain, and then I had like a fountain that was interactive, I'd probably go the interactive one".

Staying Longer

Participants overall felt that an interactive water fountain would make them spend more time in a public place because it would give them something to do. They could spend time playing with it and figuring out how it works. When asked why an interactive fountain would make them stay longer, participant I5 responded "I think it's just like figuring what it does and then that you can interact with it that kind of makes a difference", while G6 responded " I imagine me just like staying there for a while purely because of it rather than just like passing by".

Reasons to Return

When asked what their reasons would be for making a return visit to a place with an interactive fountain, many cited a desire to see or discover new features, and to introduce their friends to the fountain. Participant G3 said "I think I'd like to come back and then kind of see more things you can do with it" while participant I9 stated "I'd like to experience it with different people at different times so would definitely go back with a different group".

Improving the Idle State

Many participants expressed dissatisfaction with the idle state, feeling that it should have been dynamic or there should have been multiple of them, and that it did not draw them to the fountain. I7 stated "I felt like the idle state could have had a bit more going on" and later went on to say "the four central ones, maybe alternating those in height or something would have been a bit more interesting". Participant I6 suggested "the static setting was a bit boring, you could have multiple ones of those".

Novelty Factor

Participants also expressed concerns that the novelty factor of an interactive water feature could wear off over time, making subsequent visits less entertaining. G5 noted "I don't know how many times I could experience it the same way you know, if it's just a one time thing" while participant I8 said "you've seen it so now you know what it does, so you don't have the curiosity". It was suggested the addition of new features could mitigate this, with I4 stating "I feel like maybe there can be more features added and it would keep my attention for longer". Participants suggested a range of potential additional features they would like to see, but the most commonly suggested were the addition of lights and sounds.

Trial and Error

When discussing how they learned to control the fountain, it became clear that the majority of participants figured out the controls through trial and error, trying out different behaviours and seeing how the fountain would respond to them. When asked how they figured out the controls, I1 remarked "I got close to it, water jet sprung out there. When I moved to another one a different one sprung out." demonstrating how it was through trying different movements and positions that they came to understand the controls.

Setting a Goal

While there is no specific aim or goal when interacting with the fountain, a number of participants set themselves a goal or challenge. I1 tried to activate all the pumps, I6 tried to fire the pumps like water pistols, and I11 tried to hide in the sensor's blind spots. When asked how they felt while trying to find the blind spots, I11 stated "I could have just walked around it and watched all the pumps go and that would have been fine and that would be fun but it wasn't a challenge. It's just a thing I could do".

Pushing the Boundaries

When asked why they performed certain actions, some participants responded that they were trying to see how to the system responded to extreme behaviour, testing the the boundaries of the system. Participant I2 explained this behaviour saying "it's always interesting to see how a system will react to something like that" and that they were trying to "trick" the system, while G4 described this behaviour as "trying to, I guess, break it".

Splashing and Touching the Water

Despite being provided with a new way of playing with the water, most participants decided to put their hands through the streams, or splash each other regardless. Some participants couldn't explain why they did this, such as I5 who, when asked why they touched the water, said "I don't know I just wanted to see what happens basically". The splashing was even more prevalent in the group condition, spurred on by an urge to soak their friends, with G1 noting "it was just quite funny being able to play around, like soak each other with the water".

Interactions with Strangers

Participants seemed generally hesitant to interact with strangers, with most saying it would depend either on how they are feeling or an how friendly the stranger appeared. When asked if they would be willing to interact with any strangers, I9 responded "I think it would depend. Like if it was, like, a really scary looking one maybe I wouldn't". Meanwhile participant I4 said "it probably depends on my mood that day but if there's someone that seems nice yeah".

Despite this initial hesitancy, many said they would be happy to work with a stranger to achieve a common goal as long as this goal was preset or clearly stated. When asked if they would work with a stranger to achieve a common goal, G7 responded saying "yeah puzzle solving or something would be perfect", while I7 replied "if it wasn't like completely obvious that's what they were wanting to achieve I don't think I would".

Interactions with Friends

Participants in the group condition found that being able to watch friends being silly around the fountain improved their experience with the fountain. G8 noted "the fact that we, our experiment group was two friends it was entertaining just to see how we tried to get the other one to do something silly". Those in the individual condition expressed a desire to return to the fountain with their friends, to see how their friends would respond to playing with the system. Participant I3 said they would perhaps return to the fountain to "maybe bring friends to show them" while I11 said "it'd be fun to see if I could come back and [...] then also drag friends along with me".

Enhanced Learning

While we established earlier that the main way of learning how to control the fountain was trial and error, this learning could be enhanced by interacting as part of a group. Participants could discuss the controls with others to reinforce their understanding and could watch how the fountain responded to other people's movements. Participant G9 found their learning benefited from interacting with others saying "I think I'd understood but it definitely was solidified by the other people being there" while G5 said they learned from watching other participants stating "after seeing what they were doing it was pretty pretty obvious how it works".

6.4 Analysis and Discussion

Through combining the results of both the surveys and the interviews we can draw a number of conclusions about people's behaviours when using interactive water fountains in public spaces, allowing us to address the research aims previously outlined. We present our analysis in terms of three broad topics, aligning with our aims.

6.4.1 Encouraging use of Public Spaces

There is potential for interactive water features to increase usage of public spaces, attracting more visitors and encouraging visitors to stay for longer. However, in order for this to happen people need to become more aware of interactive water features.

The results of the surveys show that while participants seemed initially indifferent to interactive water features, this opinion became more positive after getting the chance to interact with one themselves.

After interacting, participants were quite likely to visit a public place to see an interactive water feature, with the interviews showing this was because they would prefer to visit a space with an interactive water feature than one without, as it gives them something to do during their visit.

The survey and interviews also showed that people would be quite likely to return to see new features or aspects of the fountain, and to share the experience with friends, further increasing visitor numbers.

Participants also said they would stay in a public space longer because of an interactive water feature, with the interviews demonstrating that people would spend time figuring out or playing with the fountain when previously they may have just walked through the space.

Therefore, we can see there is potential for interactive water features to increase usage rates of the spaces in which they are deployed, however the fact that the participants were indifferent before interacting with one themselves shows that to achieve this increased usage we must first make the public more aware of interactive water features. Therefore it is likely that initial deployments will not see the benefits, but that over time usage levels will increase as people gain more experience with this kind of technology.

In order to both achieve and maintain these increased usage rates, we must do more to attract users to the fountains and to sustain their engagement.

The interviews reveal that the simple idle state was not satisfying for users, who would have preferred to see multiple idle states, or at least a dynamic rather than static idle state. Changing the idle state in line with their comments would likely increase the number of people who use the fountain, as it will generate more interest and make more people likely to approach, revealing the interactive aspect.

It was also discovered during the interviews that users experienced a novelty effect, finding the fountain to be engaging at first, but quickly losing interest due to a lack of features and variation. This echoes the issues with interaction waning over time that were previously discussed by Cox et al. (2016). It was suggested by the interview results that interest could be better maintained if more features were added, with participants providing suggestions ranging from lights and sound, to networked fountains and puzzle games.

Overall, improvements are necessary to attract and maintain the user's attention. In order to draw users towards the fountain, we must find a more appealing idle state, or even a set of idle states, that will appear more interesting to prospective users than the current, static idle state. New features should be added to the fountain to supplement our proxemic interaction based model, as this would provide users with more opportunities to interact and explore, better facilitating both longer interactions and repeated visits. Without taking these factors into consideration, it would be difficult to achieve and sustain increased usage levels.

6.4.2 The Interaction Experience

While we did not set a specific goal or aim for the participants many set their own goal, often with the intention of pushing the boundaries of the system.

We aimed to harness the concept of playful interaction as defined by Dekel et al. (2005), where there is no set end goal for the interaction. Despite our fountain having no obvious or concrete aim, we see from participants' actions during the experience prototype session, and from their responses in the interviews, that many found it more entertaining to set themselves a challenge or goal to work towards.

Many of the goals participants set themselves seemed to be motivated by a desire to test the limits of the system, such as seeing if it was possible to activate all the pumps, or running around the system to see how well the jets of water could keep up with them.

We can conclude from our work that when presented with open ended interaction, such as a playfully interactive water feature, participants will establish their own goals along with motivations for these goals. However, what we cannot conclude is how this would compare to having a concrete or imposed goal to the fountain, such as having a built in game. It is possible that part of the fun is creating their own goals, and that having a goal set for them may limit their enjoyment. This motivates future work to see how having a preset aim impacts enjoyment and usage in comparison to when participants are free to set their own aims.

Additionally it seems that offering opportunities for playful interaction is not enough to stop users from splashing around and reaching out to touch the water.

The main motivation for adding interactivity to water features was to facilitate play without requiring users to touch the water. However, the events of the experience prototype sessions and the interview responses show that participants splashed each other and put their hands through the water streams even when presented with another way to play.

As shown by Whyte (2012), humans are naturally drawn to water, and it would appear from our work that playful interaction on its own is not enough to satisfy the urge to play with and splash in the water. Therefore, it would be misguided to build interactive fountains in the hope of preventing people touching the water. This does not mean we shouldn't build interactive water features, as we have seen they are very entertaining and can encourage usage of a public space, but we should reevaluate our motivations for doing so.

6.4.3 Effect of Interpersonal Relationships

If we wish to prompt interactions between strangers we need to provide them with a motivation for these interactions, such as a clear and concrete common goal.

When designing the fountain we intended to facilitate the concept of triangulation, an idea introduced by Whyte (2012) in which an object in a public space sparks interactions between strangers. While our participants seemed initially hesitant to interact with a stranger, as seen in their interviews, there was general agreement that they would be open to interacting if there was a clear and preset goal for them to work towards. This conflicts with Bekker et al. (2010), who suggested that it was allowing users to define their own goals that would encourage interactions.

While our initial results suggest that to facilitate triangulation we must provide users with a goal to work towards, this area will require further investigation. When discussing their interactions with strangers, our participants were discussing a hypothetical scenario, and so it is possible that their behaviour could be quite different if they were really in that situation. Therefore further studies should be conducted with groups of strangers interacting together rather than just groups of friends, to allow stronger conclusions to be drawn with regards to how strangers will interact with such fountains.

In addition, there are potential benefits to be gained from encouraging and facilitating group interactions, such as greater enjoyment for users and making it easier to learn how the fountain is controlled.

The survey results show that participants found using the fountain in a group to be a very positive experience, and that they found it very entertaining to watch others using the fountain. This is reflected in their interview results, where participants speak of being able to enjoy the fountain more as a group as there are more interaction possibilities. For example, groups were able to activate all of the sensors at once, a task that is almost impossible for an individual user due to the sensor configuration. Additionally, it was enjoyable to watch their friends running around the fountain, being silly and losing their inhibitions. Therefore it is apparent that being able to interact as part of a group added new dimensions to their interactions and enhanced their overall experience with the fountain.

While the majority of participants learned how to use the fountain through figuring it out on their own, the survey results show that some of those in the group condition learned by watching others using the fountain. The ability for users to learn from others is widely discussed in the literature (Wouters et al. 2016; Reeves et al. 2005; Cox et al. 2016), with many participants stating in their interviews that even if they figured out the controls by themselves, they appreciated being able to talk with others to confirm their understanding and they felt that they learned the controls faster in a group than they would have individually. By encouraging these group interactions, we could make it faster and easier for users to learn how the system works, giving them an overall better experience.

It is for these reasons that future work developing interactive water features should focus on capitalising on group interaction. By encouraging people to interact in groups, we can provide them with new ways of interacting, and make it easier for them to use our systems. Of course this should not come at the expense of individual interaction, which has its own merits, but should instead supplement it, giving users more possibilities and enhancing their overall experience.

7 Conclusion

7.1 Summary

Fountains are found in many public squares, parks, and plazas across the world, and for as long as they have existed people have had the urge to play with the water they contain. There is a primal urge to reach out and touch the water, to splash, and to play. However, due to safety concerns and the general inconvenience of getting soaked in public, such behaviours are often restricted and restrained.

In order to satiate this urge to play with the water within the boundaries of convenience and safety, we proposed the addition of interactivity to water features. We then created a water feature which uses proxemic interaction to facilitate playful experiences.

The fountain uses ultrasonic sensors placed around its perimeter to detect a user's relative position and distance from the fountain. The fountain will activate the jet of water in front of the user at a height dependant on the user's distance. As a user gets closer to the fountain, the jet gets higher, and as they get further away the jet gets smaller. The fountain also had an idle state, running the corner pumps at a static height when no users are in range.

We used the fountain to run an evaluation with the aim of answering the question: How does adding interactivity to water fountains change the way people use public spaces? However, due to the broad nature of this question and the scope of the project, we chose to focus on the following research aims which contribute to our understanding of the wider question:

- Could the addition of an interactive water feature increase the usage levels of a public place?
- How do members of the public utilise the interactive capabilities of these water features?
- How does interacting as part of a group change the experience, with particular regard to how the relationships between participants affects this?

In order to address these aims we ran an evaluation with an experience prototype in a controlled environment. The evaluation had two conditions, with participants interacting with the water feature either as an individual or as part of a group. Participants filled out short surveys before and after interacting with the water fountain, to gather data on their general opinion of interactive water features and their thoughts on their experience with our interactive water feature. At the end of their session, participants also took part in individual, semi-structured interviews to gather deeper insight into the reasons behind their survey answers and to discuss any interesting actions or incidents from their session interacting with the fountain.

From our results, it became clear that interactive water features have the potential to increase usage rates of public spaces, however significant work will be required to make this possible. First, the public must be made more aware of interactive water features as they are generally indifferent towards them until they gain experience and better understanding of them. Secondly, in order to better attract users and to hold their attention we must develop more interesting idle states and add additional forms of interactivity to the fountain, such as lights and sound.

Participants made use of the interactive elements to establish self created goals and challenges, often motivated by a desire to test the boundaries of the system. However, this playful interactivity was not enough to satiate the natural urge to touch and splash in the water, with many participants putting their hands through the streams and splashing each other regardless. This suggests a need to reevaluate the motivations behind developing interactive water features.

Finally, as we continue to develop interactive water features, we should focus on ways to encourage group interactions. The addition of concrete goals could help spark interactions between strangers, while facilitating more generic group interactions increases enjoyment of the fountain by adding new dimensions and possibilities to the interaction, and by enhancing the learning process.

7.2 Future Work

From our implementation and evaluation, we have identified a number of avenues for future exploration of this topic, which would enable studies to build on this work.

Our study was conducted in a controlled environment rather than in a real public space, and so it is possible that some of the participants' behaviors were not representative of how they would act if the fountain were actually deployed in public. As such, a reasonable next step would be to deploy the fountain in a public space, comparing the behaviour of those using the space before and after deployment of the fountain.

Additionally, while we asked our participants questions about how they would interact with strangers, these were purely hypothetical and so their answers may not accurately reflect how they would react in these situations. Therefore, studies should be conducted involving groups of strangers interacting with the fountain, so that comparisons can be made between interacting with a group of friends and interacting with a group of strangers.

Future work could also investigate the impact of having preset aims rather than allowing users to set these themselves. Currently our users seemed to enjoy being able to set their own goals, however it was suggested that having clear, preset goals would increase the likelihood of sparking interactions between strangers. As such, further study could focus on how both preset and user defined goals impact enjoyment and interaction types.

However, before conducting any further studies it would be advisable to develop the fountain itself further. Participants were dissatisfied with the static idle state, and so this should be replaced by either multiple idle states, or by a single but more dynamic idle state. Additionally, participants felt there were not enough features to hold their attention, so we should explore adding lights and sound to the fountain.

A | Likert Response Breakdowns

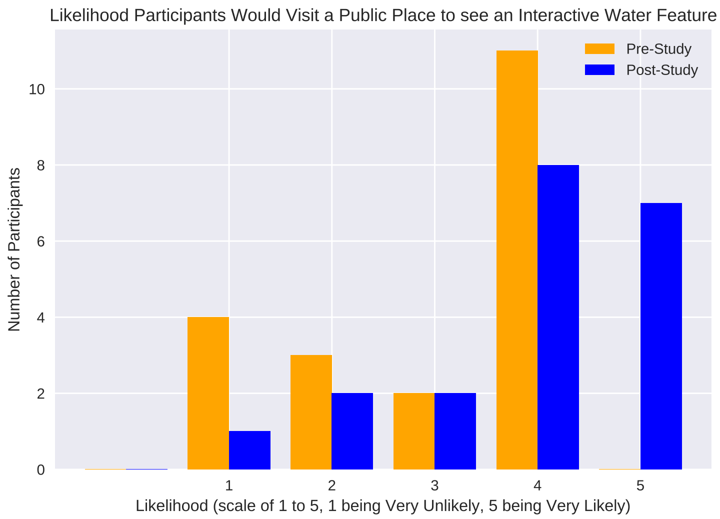


Figure A.1: *Breakdown of participants' responses to question "How likely are you to visit a public place (town, square, park) for the purpose of seeing an interactive water feature?"*

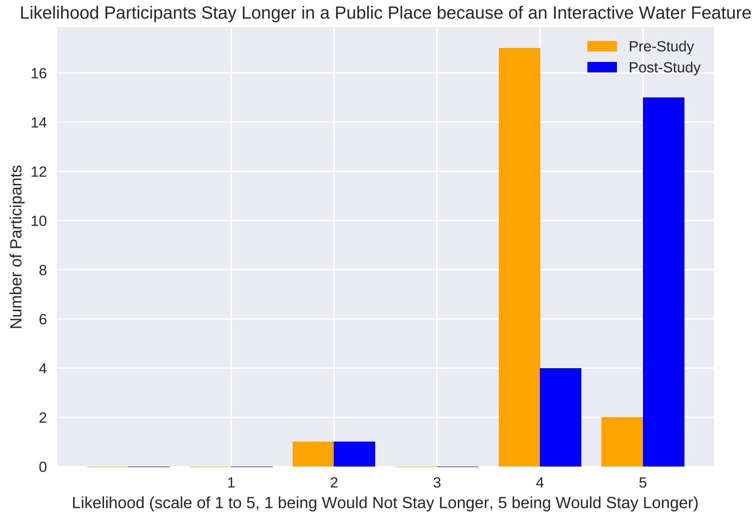


Figure A.2: *Breakdown of participants' responses to question "Would an interactive water feature make you spend longer in a park, square, or public place?"*

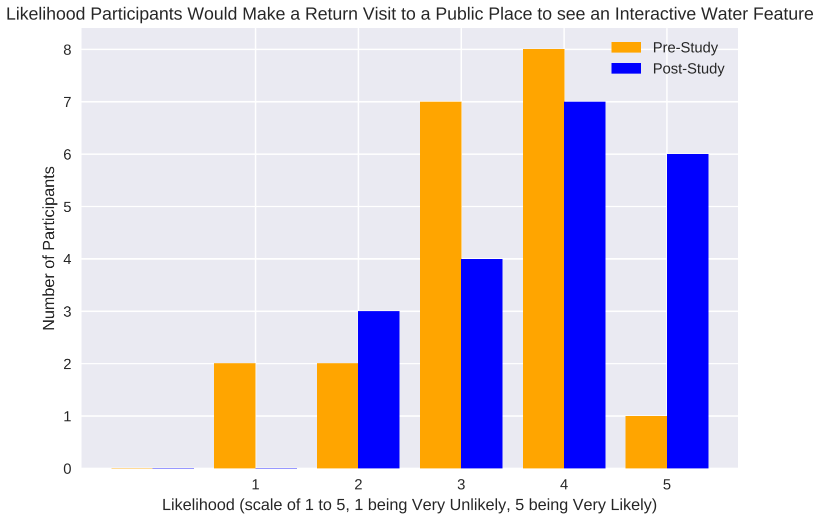


Figure A.3: *Breakdown of participants' responses to question "How likely are you to make a return visit a public place (town, square, park) which has an interactive water feature?"*

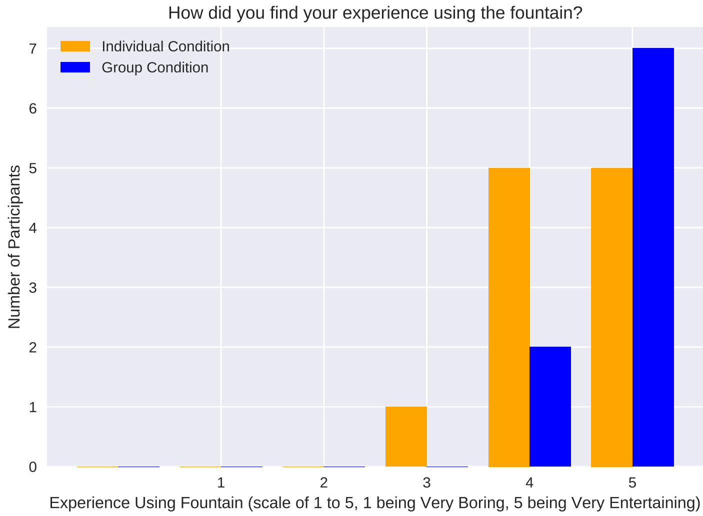


Figure A.4: *Breakdown of participants' responses to question "How did you find your experience using the fountain?"*

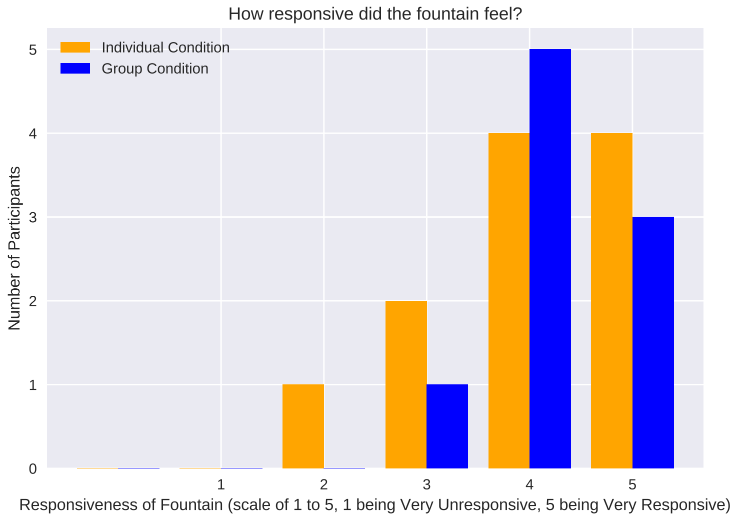


Figure A.5: *Breakdown of participants' responses to question "How responsive did the fountain feel?"*

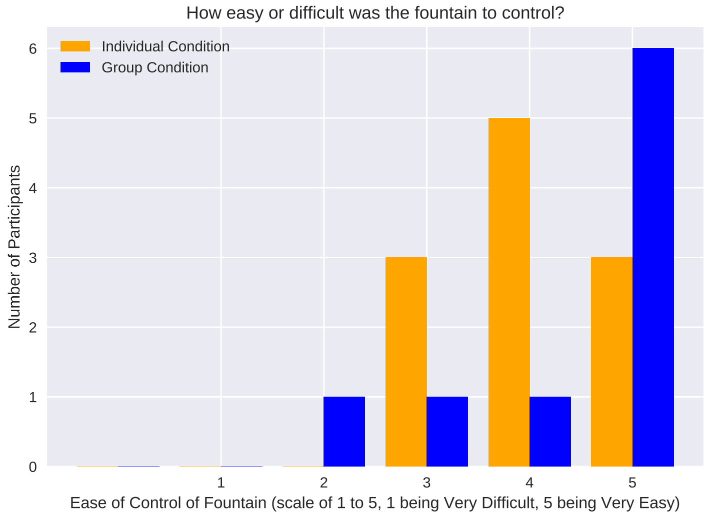


Figure A.6: *Breakdown of participants' responses to question "How easy or difficult was the fountain to control?"*

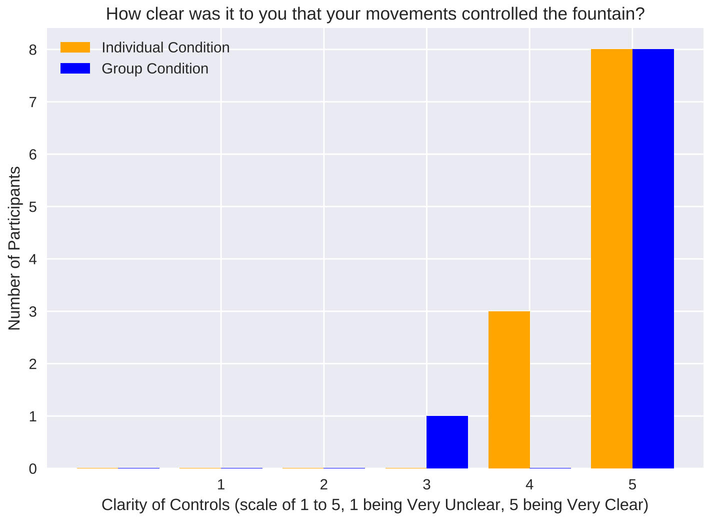


Figure A.7: *Breakdown of participants' responses to question "How clear was it to you that your movements controlled the fountain?"*

Figure A.8: *Breakdown of participants' responses to question "How was your experience interacting with the fountain in front of other people? "*

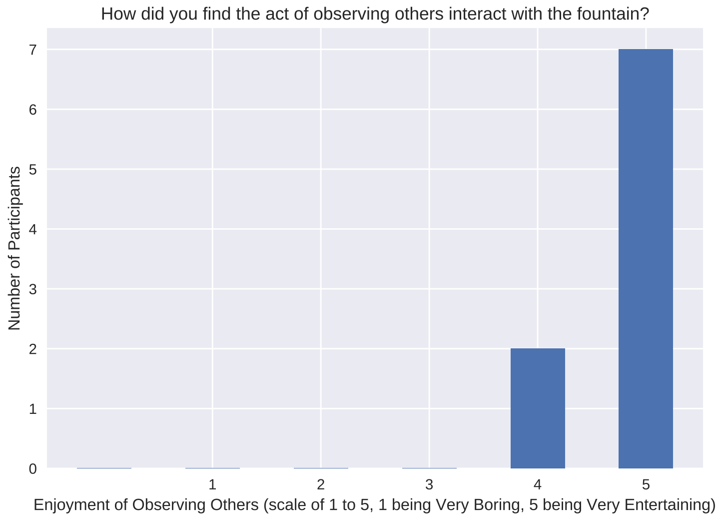


Figure A.9: *Breakdown of participants' responses to question "How did you find the act of observing others interact with the fountain?"*

B | Ethics Application

School of Computing Science Ethics Committee
University of Glasgow

Request for Ethical Approval

This form is to be used by 3rd year, 4th year, MSci, Mres, and taught MSc students in the Department of Computing Science whose projects entail human participation and which do not conform to any one of the criteria on the project ethics checklist form (http://www.dcs.gla.ac.uk/ethics/projects-form.pdf). Students enrolled for an MSc by Research or a PhD, and members of academic or research staff should submit their request for ethics approval to the Faculty Ethics Committee (see http://ethics.ims.gla.ac.uk/)

The form should be completed and returned by email to Prof Stephen Brewster (stephen@dcs.gla.ac.uk) to whom all enquires or requests for advice should be directed.

All sections of this form must be completed.

Before completing this form, please read the British Psychological Society's Code of Conduct (available on http://www.dcs.gla.ac.uk/ethics/). The relevant sections of the code are noted against questions in this form.

Copies of the participant information form and consent form should be submitted together with this form (BPS § 3&6).

Student's name: Kerry Johnstone

Registration/Matriculation Number: 2189152j

Email address: 2189152j@student.gla.ac.uk

Year level (3rd, 4th, MSci, MRes, MSc): 4th

Supervisor: Julie Williamson

Project title: Interactive Water Feature for Public Squares

1. Describe the basic purposes of the proposed research:

Through this project, we aim to gain better understanding of how the public's behaviour changes when technology is integrated into public spaces. Specifically, we wish to investigate the effects of adding playful interactivity to a water feature within a public space. We aim to find out if adding an interactive water feature encourages more people to use a space, and if people would visit a space for the purpose of visiting an interactive fountain.

To conduct this research, we have built an interactive water feature, which participants will be given the opportunity to interact with either individually or as part of a small group. This interaction will form the basis of a think aloud study, with participants narrating their interactions. This will allow us to examine how they would interact with an interactive water feature, as well as how this interaction changes when alone versus when in a group.

We will also conduct two surveys and an interview with each participant, to gain an insight into their thoughts on interactive water fountains in general, as well as gathering some feedback on the interaction experience of our fountain. In cases where participants interacted as a group, there will be some additional questions about how being part of a group affected their experience.

2. Describe the design of your experiment (e.g. conditions, number of participants, procedure, equipment) (BPS §2&8):

Conditions: There will be two conditions for the experiment. In one condition participants will interact with the fountain alone, while in the other condition they will interact with the fountain alongside 1 or 2 other participants.

Number of Participants: For the individual interaction condition, we aim to have 10-15 participants. For the group interaction condition, we aim to have 8-12 participants (allowing for 4 groups of 2-3 participants).

Procedure: The study will be held in a room in the Sir Alwyn Williams Building, which will be laid out to mimic the layout of a small park or public square. The fountain will be in the centre of the room, with some chairs at the sides to mimic benches or public seating.

Before a participant enters the room, they will be given an information sheet to read, which details the aims and procedures of the study. They will then be able to fill in a consent form, which covers a number of points including agreeing for data to be collected, and acknowledging their right to withdraw at any time.

We will then ask they complete a short survey to provide demographic data including age, gender and their technical background. It will also ask about their current opinion of interactive water features.

Once the paperwork has been filled in, but before they enter the room, they will be asked to imagine they are about to enter a public square, and told that if it helps to set the scene in their mind they may make up a story in their head about why they are in this square.

In the individual condition, the participant and the researcher will then enter the room that holds the fountain. The participant will spend 10 minutes in this room, acting as if they were in a public square. The fountain will be in the centre of the room, but they will not be explicitly prompted to interact with it, or told anything about it. Their interactions will be audio recorded, and the researcher will take notes of anything of interest. The participant should narrate their thoughts out loud as they interact in the space, so that we can analyse how they think about the fountain.

After the 10 minutes are up, recording will stop and the researcher and participant will exit the room. We will ask them to complete another short survey, asking again about their opinion of interactive water features, to see if this has changed. We will also ask a series of questions about their experience interacting with the fountain to find out things like how easy it was to control, and if they would use it again.

The participant will then be interviewed. Some general questions about their experience interacting with the fountain will be asked, to ensure we can make some comparisons across participants. The researcher will then have an opportunity to ask some questions that may have arisen due to interesting or unusual occurrences during the think aloud section of the study. This interview will be audio recorded.

In the group condition, the group of participants and the researcher will enter the room that holds the fountain. The participants will spend 10 minutes in this room, acting as if they were in a public square. The fountain will be in the centre of the room, but they will not be explicitly prompted to interact with it, or told anything about it. Their interactions will be audio recorded, and the researcher will take notes of anything of interest. The participants should narrate their thoughts out loud as they interact in the space, so that we can analyse how they think about the fountain.

After the 10 minutes are up, recording will stop and the researcher and participants will exit the room. We will ask them to complete another short survey, asking again about their opinion of interactive water features, to see if this has changed. We will also ask a series of questions about their experience interacting with the fountain to find out things like how easy it was to control, and if they would use it again.

Each participant will then be individually interviewed. Some general questions about their experience interacting with the fountain will be asked, to ensure we can make some comparisons across participants. The researcher will then have an opportunity to ask some questions that may have arisen due to interesting or unusual occurrences during the think aloud section of the study. As they took part in the group interaction, they will also be asked about how the presence of other people changed how they interacted, such as if they felt uncomfortable using the fountain in front of others. This interview will be audio recorded.

In both conditions, at the end of their interview the participant will be fully debriefed, including restating the aims of the study and making clear to them who they can contact with any questions or to find out the outcome of the study.

Equipment: The fountain itself has been built using the Pumpspark Fountain Development Kit and an Arduino. It is contained in a plastic enclosure. Ultrasonic sensors around the fountain allow for users to control the fountain by moving closer to them or further away. A picture of an early prototype can be found on the information sheet.

Data Collected: During the think aloud stage, users will be audio recorded interacting with the fountain. Users will be made aware of this recording and will explicitly consent to this. Written notes will also be taken of interesting occurrences during the think aloud.

During the interview, the participants responses to the questions will be audio recorded. They will have explicitly consented to this recording.

The survey responses will be recorded, with the survey conducted as a Google Form.

Age, gender and technical background data will be collected to help us examine how representative our data is, but this is the only personal data that will be collected. No personally identifiable data will be collected.

3. Describe how the procedures affect the participants

We aim to have minimal effect on the participants.

During the think aloud study, they will be free to interact as much or as little as they like, as they are told to interact as they would in a real public square. This ensures the participants remain comfortable as they will not be made to feel like they have to do anything they might not be comfortable with.

Participants will be made aware of the audio recording ongoing, and if they are not comfortable being recorded they they can withdraw from the study.

Some participants in the group condition may feel uncomfortable interacting with others, but as they are free to interact however they naturally would, they can choose the level at which they wish to interact. They do not have to talk to or interact with the other participants if they do not want to, and can withdraw from the study at any time.

During the interview, they can choose not to answer a question without having to give a reason, and they have the ability to withdraw completely if they wish. This should ensure the participants feel comfortable being interviewed.

By allowing the participant to control how much they interact with the fountain and with others, and which questions they feel comfortable answering, we hope to make them feel as comfortable as possible and minimise the effect we have on them.

4. State what in your opinion are the ethical issues involved in the proposal (BPS all sections)

The main issue of ethical concern is the non standard hardware used in the fountain. The fountain has been built using the Pumpspark Fountain Development Kit[1], which is not available to consumers. Therefore it is highly unlikely that participants will have encountered this equipment before.

The fountain kit has been used successfully in previous student projects, which demonstrates that the equipment can be safely used in studies involving the public. For example, it was used in a masters project in 2018.

The fountain has also been approved for use in an in-the-wild study by the college ethics committee.

The equipment will be secured within the fountain enclosure, and there will be no need at any point in the study for any of the participants to touch any of the hardware.

Should any participants have any questions or concerns about the equipment being used, the researcher will happily discuss these with the and tell them more about the equipment that is in use.

Use of this equipment will not put participants at any greater risk than they would experience in their day to day life.

Another ethical concern is the audio recording of participants. Participants will be made aware of the audio recording that is taking place, and will be told why this is being done. Any participants who do not wish to be audio recorded will be free to withdraw from the study. The audio recording will be performed anonymously and with the explicit consent of the participant. The audio recordings will be stored securely and anonymously at all times on a computer with a single, password protected account.

5. Specify whether the research will involve children, or those with a physical or mental disability (BPS §3):

Participants will be required to confirm they are aged 18 or over, and that they fully understand all information that has been presented and are able to give informed consent. This confirmation will be taken as part of the consent form.

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[1] https://dl.acm.org/citation.cfm?id=2598599

If so, explain the steps taken to obtain permission from LEAs, head teachers, parents etc: N/A

6. State if payment will be made to subjects:

No payments or reimbursements will be made to any participants.

7. Describe procedures for obtaining consent from participants (BPS §3):

Participants will be required to read an information sheet before taking part, which will explain in detail the aims of the study, the procedures that will be used, their right to withdraw at any time, among other required details.

After reading this, the participant will be required to fill in a consent form to confirm the following

- They are aged 18 or older
- They have read and fully understood the information sheet provided
- The consent to being audio recorded
- They consent to their responses being recorded
- They understand they can withdraw at any time
- They have had the opportunity to ask questions
- They understand what data will be collected

The consent form has been included with this application. A completed consent form will be required before they are permitted to participate.

8. State whether the proposal is in accord with the BPS code of conduct:

This study has been designed in accordance with the BPS code of conduct and the ESRC Framework of Research Ethics.

9. Describe how the participants' anonymity and confidentiality will be maintained (BPS §7):

All data collected will be collected, held and used anonymously, with no way of uniquely identifying participants from their data. No personally identifying data such as name, email, address will be collected at any time. While age, technical background and gender may be collected, participants would not be identifiable from this data. The data will be presented in an anonymous form and held securely by the experimenter.

All data recorded, including audio, will be stored securely and anonymously.

The data will be submitted alongside the code and dissertation for the project, meaning it will be accessible to the experimenter, their supervisor and university staff who mark the level 4 individual projects. The anonymised data may also be used for publication of the research results. In both cases, the data will be in an anonymous form so that readers cannot identify participants from the data.

10. Date on which the project will begin:

The project begin on Monday 18th February 2019 and will run throughout the academic year 2018/2019.

11. Location at which the project will be carried out:

The study will be carried out in the Sir Alwyn Williams Building.

12. Describe how participants will be debriefed at the end of the experiment. This must include the opportunity to contact the experimenter (or supervisor) for feedback on the general outcome of the experiment. (BPS §5&10)

After the interview has concluded, the participant will be presented with a debriefing sheet which will restate the aims of the study and clearly state what data has been collected. The sheet will include the contact details of the researcher and their supervisor, and will encourage the participant to get in contact if they have questions or wish to hear about the outcome of the study. Before the participant is dismissed, they will be asked if they have any more questions.

Student's Name Kerry Johnstone

Student's Signature Kerry Johnstone

Date 13th February 2019

Supervisor's Name Julie Williamson

Supervisor's Signature

Date 20th Feb 2019

SOCS Ethics Committee Signature Matthew Chalmers

Date 14th Feb 2019

Interactive Water Feature for Public Squares

In this study we aim to understand how interactive water features might change the way people use public spaces.

During this research you will be asked to take part in two short surveys, a think aloud study and an interview. The surveys will take around 5 minutes each. The think aloud study and interview will each last approximately 10 minutes.

Before deciding to take part you will view a briefing script with more detail on the study, and if you choose to take part you will be asked to fill in a consent form to confirm you understand this information. You will also be given a debriefing when the interview is complete.

The first survey will gather demographic data such as age, gender, and technical background, as well as ask for your opinion of interactive water features.

During the think aloud study you will be asked to interact in a mockup of a public space while narrating your thoughts out loud. Your interactions during this period will be audio recorded. In this section we are aiming to understand how people would potentially behave and interact in a public square with an interactive water fountain.

The second survey will ask some questions to understand your experience during the think aloud, and to see if your opinion on interactive water features have changed.

In the interview you will be asked a few questions to determine your thoughts and experiences of interactive water features, and to help us understand some things about your interactions in the think aloud study. The interview will be audio recorded.

All data will be stored anonymously and you will not be identified personally in any report or publication relating to this work. The questions asked have no right or wrong answers, we simply want to gather public opinion on the issue.

Contact Information
Project Author
Kerry Johnstone 2189152j@student.gla.ac.uk
Project Supervisor
Julie Williamson Julie.Williamson@glasgow.ac.uk

Interactive Water Feature for Public Squares- Briefing Script

As part of our research into how technology changes the way we use public spaces, we are inviting members of the public to take part in a study comprised of two surveys, a think aloud session, and an interview. Before deciding to take part, we ask that you read the information below.

What is the aim of the study?

We want to better understand how adding technology to a public space changes the way people use that space. This study particularly focuses on how an interactive water feature changes the way spaces are used. This study will help understand how people interact with such water features, and will give insight into public opinion of this kind of technology.

Why am I being asked to participate?

We need members of the public to interact within a mock public space, either individually or as part of a group, to help us understand how people will respond when such technology is deployed in a public space. We are asking members of the public to participate in this so that the results are as representative of real life as possible, and so that we can make meaningful interpretations of the results.

Who is conducting this research?

This research is being conducted by Kerry Johnstone, a 4th year student of Computing Science at the University of Glasgow. This research is being supervised by Dr Julie Williamson, a lecturer and researcher in Human Computer Interaction at the University of Glasgow. Contact details for both the researcher and supervisor can be found at the bottom of this sheet.

What will happen during the study?

Before taking part, you will be asked to fill in a consent form confirming you are aged 18 or over and that you understand everything you have read on this sheet.

We will then ask you to fill in a short survey, asking for demographic data including age, gender, and how much technical background you have. This is to ensure our sample of the population is representative. You will then be asked some questions about your opinion on interactive water features.

You will then be asked to imagine you are about to enter a public square. You are in fact about to enter the room in which the study is taking place, which we have set up to mimic a public square. We ask that you behave as close to how you would if you were really in a public space. If it helps, you can create a story in your head as to why you are in a public square.

Depending which condition you have been selected for, you will enter the room either alone or with 1-2 other participants. **If you are in a group with other participants, do not feel obliged to interact with them.** Simply act as you would if you were in public.

In the room, which we are imagining is a public square, you are free to behave and interact however you feel most appropriate. We ask that you narrate your thoughts out loud during this part of the study. We call this a ‘think aloud’ study, because we are asking you to narrate your thoughts as you take part. As you interact in this space, you will be audio recorded, so that we may perform analysis of how you interact. Written notes will also be taken by the experimenter. After 10 minutes, you will be asked to leave the room.

We then ask you complete another short survey. This will ask again about your opinion of interactive water features, to see if this has changed. It will also ask some questions about your experience in the think aloud.

You will then be interviewed by the researcher. This interview will be audio recorded, to assist with later analysis. **You can choose not to answer a question without having to give a reason.** We will then ask some questions about your experience of our water feature, and about any interesting points that arose as a result of the think aloud study. If you took part in a group session, you will also be asked a few questions about how being in a group affected your experience.

When your interview is complete, you will be debriefed before being dismissed.

It is important to know it is the fountain that we are evaluating, not our participants. There is no right or wrong way to behave in the think aloud study, and no right or wrong answers in the interview or surveys. Simply behave how you normally would, and answer openly and honestly.

What data will you collect?

We will record your answers to the questions in the surveys, and we will store these anonymously for later analysis. You will be asked your age, gender, and technical background, but you can opt out of answering these if you wish.

We will also take an anonymous audio recording of the interview, which will be used in analysis after the study has concluded.

You will be audio recorded during the think aloud study. The audio recording will be anonymous and used to assist in later analysis.

Who can access the data you collect?

The data will be accessible to the project author and supervisor, as well as university staff involved in the grading of the project which this study is part of. The data will be held and presented anonymously at all times, so nobody accessing the data will be able to identify participants from the data. The data in its anonymous form may be published for use in further research. At no point will you be identifiable from this data.

All participants may withdraw from this study at any point.

We encourage participants to ask questions before proceeding with the study. **You may ask questions at any point before, during or after the study.**

Contact Details:
Kerry Johnstone
Project Author
2189152j@student.gla.ac.uk

Julie Williamson
Project Supervisor
julie.williamson@glasgow.ac.uk

Interactive Water Feature for Public Squares- Debriefing Script

University of Glasgow, School of Computing Science
Level 4 Individual Project 18/19
Kerry Johnstone

Our aim during this research was to gain understanding of public opinion towards interactive water features in public spaces and to understand your experience interacting with our water feature either individually or as part of a group.

The first survey allowed us to gather demographic data to ensure our study is representative of the wider population, as well as gathering data on public opinion of interactive water features. Your responses were recorded.

The think aloud study will allow us to assess how people interact in public spaces with interactive water features. This portion of the study was anonymously audio recorded for future analysis, and written notes were taken during this by the experimenter.

The second survey allowed us to see if your opinion on interactive water features had changed, and to find out information about your experience interacting with the water feature. Your responses were recorded.

The interview will help us understand public opinion of interactive water features and your experience interacting with water features. We audio recorded the interview to help our analysis. This recording was performed anonymously.

If you have any questions or comments then you can contact either myself or my supervisor using the contact details below.

Thank you for your participation.

Contact Details:
Kerry Johnstone
Project Author
2189152j@student.gla.ac.uk

Julie Williamson
Project Supervisor
julie.williamson@glasgow.ac.uk

7 Bibliography

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