A Social Interface to Control Public Lighting.

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Where innovation starts

Preface

This thesis is the final part for completion of the master Human Technology Interaction at the University of Technology Eindhoven. During my bachelor's degree in IT & Media Design, I developed a great interest in creating unique and intuitive user interactions, which later developed in designing engaging user experiences. Because of this, I decided to pursue this interest and gain a deeper understanding of the interplay between people and technology. Following the master Human Technology Interaction helped me in achieving this knowledge and helped me obtain a higher degree of reasoning in general.

Observing current advancements in technology, I am confident that technology will increasingly be intertwined with our environment, evolving into a connected internet of everything. With this research, I dove into this topic by researching the development of smart cities. This research serves as an exploration of possible ways people may interact with such cities. I hope it may contribute to future research on this topic and may eventually be of value for creating human-city interactions. My mentor and supervisor Antal Haans helped me develop interest in this topic. I would like to thank Antal for all the valuable insights he has provided, the fun discussions we had and for guiding me in the right direction at difficult times. Additionally, I would like to thank my second supervisor Elke den Ouden for the interesting introduction to the topic of smart cities and smart public lighting. I want to thank the participants of the interviews and experiment for their time and inspiration. Lastly, I would like to thank my family and friends for providing reassurance and encouragement.

Joep Snijders
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Abstract

The concept of smart cities has increasingly been mentioned as a possible solution for issues concerning urbanization and increasing the quality of life in a city. Interestingly, applying smart technology to objects in the city allows for new ways for citizens to interact with the city. This thesis serves as an exploration of the possible methods for designing such human-city interactions. The exploration was done in two parts. The first part focused on the investigation of the role of the user in a smart city and identifying possible applications for research in terms of user-city interaction by performing qualitative interviews and desk research. In the second part an experiment was performed in which participants could collaboratively control smart public lighting with a mobile interface. The aim of this experiment was to investigate the effectiveness of using the Social Translucence Framework (Erickson & Kellogg, 2000) to avoid social conflicts and to investigate whether using the up/down-voting model could serve as an appropriate input model for such an interface. Unfortunately, due to recruitment issues results should be interpreted with care. Results may suggest that providing social feedback might negatively affect user satisfaction with the voting process and the resulting output. In addition, providing the possibility to down-vote may negatively affect users' involvement with the voting process. No clear distinctions were found in the voting behaviour of participants. We propose that further investigating the effects of providing social translucence and using the up/down-voting model may provide valuable insights for the development of human-city interaction interfaces.

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Introduction

1.1 Urbanisation and Smart Technology

About 54% of the world's population are currently residing in urban areas (United Nations, 2014). It is projected that this urbanisation will continue to develop for decades to come, from 3.9 billion in 2014 to an estimated 6.4 billion in 2050 (United Nations, 2014). Consequently, cities are required to deal with an increase of pressure and newly developing problems in areas like waste management, scarcity of resources, air pollution, human health concerns, traffic congestion, and deteriorating infrastructures (Chourabi, Nam, Walker, Gil-Garcia, Mellouli, Nahon & Scholl, 2012). To be able to keep providing pleasurable living conditions, municipalities worldwide will be required to gain knowledge about possible solutions to these problems. One of the possible solutions may lie in the utilization of smart technology. Smart technology employs sensing, actuating, and communicative qualities to perform actions based on available data (as can be observed in e.g. smartphones and self-driving cars). In recent years, applications of smart technology have changed the way we interact with each other and the world. Today, "computing spills out from our desktop and smartphones, into the sidewalks, streets and public spaces of the city" (Shepard, 2011, p. 18). The sensing quality of smart technology may allow cities to reflexively monitor its public spaces and the behaviour of its inhabitants, equipping them with tools to advance the level of management and efficiency. Importantly, the installation of smart technology throughout the city may not only aid just as a monitoring and data collection service for the municipality, but could provide additional benefits. Making objects in the city smart may enable the development of new ways for citizens to interact with the city, proposedly increasing its liveability (Chourabi et al., 2012). Examples of this could be, smart automated parking systems, blue-tooth beacons that send location or action related information to the inhabitant's smartphone (e.g. about improving environmental awareness), or the collaborative control of public lighting (Shepard, 2011).

This study serves as an exploration of the possible methods for designing such human-city interactions. This exploration was done in two parts. The first part of this research focused on the investigation of the role of the user in a smart city and identifying possible applications for research in terms of user-city-interaction. This was done by carrying out qualitative interviews with people that play an important part in the development of Dutch smart city: Eindhoven (preferably named 'Smart Society Eindhoven'). Additional literature research was performed to gain a better understanding of the term smart city and to gain a general overview of the user-types that typically inhabit a city.

The second part of this research details an experiment that was performed based on the insights gathered from part one. An experimental mobile interface was developed in which participants could collectively control the colour of public lighting using a voting method. The main goal of this experiment was to test whether providing social feedback cues of other participants' votes, and whether allowing the possibility to down-vote affects the general voting behaviour and satisfaction with the voting process.

By performing this experiment we aimed to gain a better understanding of the requirements for creating an interface that allows the citizens of a city to interact with smart enabled objects in the city.

An exploration of Smart City Eindhoven

Historically, Eindhoven has had a long lasting collaboration of research and industry (Van Der Zee, 2013). In 1891, Philips was founded in Eindhoven, a company that would later develop into one of the largest global companies in electronic devices. The presence of Philips was perhaps the largest single contributing factor to the major growth of Eindhoven as a technological centre, now called the Brainport region (Van Der Zee, 2013). Brainport has grown into one of Europe's prominent high-tech regions. Collaboration within this region stimulates open innovation and brings high-tech, design, manufacturing, and entrepreneurship together (Goulden, 2015).

Currently Eindhoven has several on-going projects in relation to smart city development. The following are a few examples. Stratumseind 2.0 is a living lab situated in a vibrant nightlife area, in which smart technology is utilized to gain insights into topics as safety and privacy (Den Ouden, Valkenburg & Blok, 2016). Smart Strijp-S is a creative urban living lab focused on creating value to enhance the quality of life and sustainability. Strijp-S consists of multiple modules, such as light, work- and living space (Goulden, 2015). AiREAS is a project with a bottom-up organizational approach that measures the quality of air on multiple locations throughout Eindhoven (AiREAS, 2016). This data can be openly viewed and is used in health research. Eindhoven's vision is that technology may act as an enabler to create a better-connected society: applying technology to improve the quality of life in a city. They believe that in order to do so, it is important to start development based on the needs of their citizens.

Because of these projects, Eindhoven has gathered valuable insights regarding human-city interaction and the general development of smart cities. To learn from these insights, qualitative interviews were planned with people involved.

2.1 Interviews

The interviews were planned to cover a broad scope of the development of Smart City Eindhoven. The goal of these interviews was to gain a better understanding of the current status of development, possible challenges regarding this development, and visions for the future. More specifically, we wanted to learn how projects in Eindhoven utilize citizen participation to develop these visions and how they view the role of the users in a future smart city scenario. Interviews were held at and with:

Living Lab Stratumseind:

- Neeltje Somers (Strategic Advisor Municipality of Eindhoven regarding Smart Cities)
- Tinus Kanters (Manager Stratumseind Living Lab)
- drs. ing. Peter van de Crommert (DITSS: Project leader of field labs)

The University of Technology Eindhoven:

- dr. ir. Elke den Ouden (Intelligent Lighting Institute)

Urban Area STRIJP-S Eindhoven:

- Alwin Beernink (Project Manager PARK-STRIJP BEHEER)

During the interviews it became evident that Eindhoven currently has quite some technology installed and in operation or in testing phase, such as car recognition systems, visitor-counting methods, and sound-level monitoring equipment (T. Kanters, personal communication, February 22, 2016). The Living Labs of Eindhoven currently use this technology to gain a better understanding of how to use the data generated by this technology to create a smart city that is not just in a technological smart way, but rather in a way that involves the inhabitants of Eindhoven and to “utilize the data to create a better connected society” (N. Somers, personal communication, February 22, 2016). The data that is generated in public spaces is considered to be “open data”. However, there are certain levels of openness, concerning privacy and ethics. Data has to be anonymised. These principles are currently a result from Eindhoven’s local agreement, and are not (yet) governed nationally. There still remain interesting aspects that require further debate. For example, anonymous data may be anonymised, but this cannot warrant full anonymity when data from multiple sources are combined and expertly analysed (T. Kanters, personal communication, February 22, 2016). In today’s situation, Kanters poses that there is a duty of providing awareness to the inhabitants of Eindhoven. We should disclose what the current possibilities are, and ask inhabitants if they want to join the conversation. At the moment, publicly organized hackathons or bottom-up directed projects are fulfilling a minor role in this communication (e.g. AiREAS). Additionally, Kanters states that there may be a risk of creating a gap of knowledge between parties, with on one side people that are knowledgeable of the technology (who are able to utilise the data), and on the other side people that lack this knowledge (who are unable to use the data). The knowledgeable group would therefore be able to gain advantages (e.g. use public data to increase company sales), while the non-knowledgeable group would not.

Elke den Ouden (Eindhoven University of Technology) illustrates the current situation of global smart cities as "based on technology push: tech suppliers offer their smart applications to municipalities, but the municipalities are in doubt of how to specifically use the applications in order to create a better living environment for the inhabitants of smart cities" (E. den Ouden, personal communication, February 21, 2016). Den Ouden states that "municipalities often start pilot projects in order to investigate options, however these are often cancelled due the lack of a complete business model and value proposition". Modern business models often rely on a service or subscription model. These models require continuous innovation and maintenance to be sustainable.

Peter van de Crommert (Project Leader of Field Labs at DITSS) continues this view by stating that "the current situation consists of a technology push by technology companies but there is less of a 'human-pull' from the inhabitants of the city" (P. van de Crommert, personal communication, February 24, 2016). According to van de Crommert, the development of smart cities can be divided into two segments: the technology and the people. However, van de Crommert states that the people "are often forgotten" and that it sometimes remains unclear what the user actually wants. Therefore, it is a challenge to establish successful business models and value propositions.

In a final interview with Alwin Beernink (Strijp-S Beheer), Beernink discussed that he does not wholly support the view that the users of smart cities are completely forgotten, but does support the claim that in its current situation, the development of smart cities is approached heavily from a technological perspective. Beernink describes that because of the fast development of new technology, business models, users, and eventually politics are continuously chasing the fast pace of newly invented technology. However, Beernink does state that "what we are structurally forgetting is the actual human-resources, the social side and the emotional side of users which actually translate into the quality of life" (A. Beernink, personal communication, April 6, 2016). Beernink illustrates that due to the big differences in pace of technology and political decision-making, it could be interesting to explore the possibilities of creating systems that contain "some form of democratic justification to gain insights into the vision of the crowd, locally in your neighbourhood or street: this is what we are looking for at Strijp-S" (A. Beernink, personal communication, April 6, 2016). In other words, Beernink notes that it could be valuable to use the fast-paced advantage of technology to create a new platform. This platform would use democratic user input to control smart enabled technology in a neighbourhood, thereby generating data on citizens' preferred settings. Combining the individual users' data could create a real-time "vision of the crowd": displaying how citizens use the smart technology to benefit their daily lives. Analysing this vision may be helpful in gaining a better understanding of how to correctly utilize smart city modules to enhance the quality of life of citizens in a city.

In summary, the performed interviews outline that Eindhoven is currently utilizing living labs to gain knowledge about how to use smart technology to improve the connectedness of society. While the technology is available, it remains difficult to establish sustainable business models and value propositions to provide a wider adoption of smart city modules. It is important to note that the focus of these business models is not just making profit on top of the smart infrastructure, but rather to provide long-term social benefits for the inhabitants and visitors of Eindhoven. The goal of formulating value propositions is to provide all stakeholders with new and meaningful ways to interact with the city. In order to gain a better understanding of the user requirements to develop these business models and value propositions it may be helpful to establish greater user participation. The key here is to learn how smart city modules can improve the quality of life in a city. To do so, it could be meaningful to explore systems that use some form of democratic user input to control smart enabled objects. Using such a system could perhaps lower the participation threshold of traditional participation methods. In addition, this system could directly generate data about citizens' preferred settings, which could be valuable to learn how smart technology may enhance the quality of life.

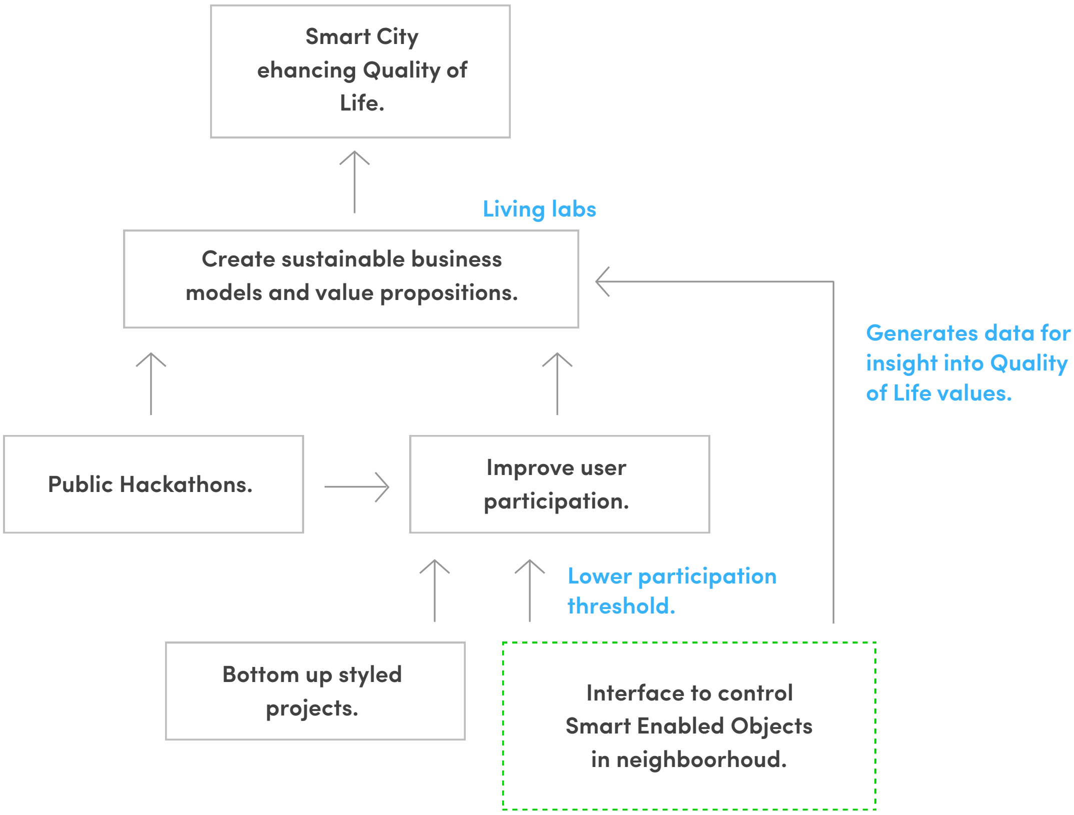


Figure 1. A global overview of the insights gained by performing qualitative interviews on how Smart City Eindhoven develops a wider adoption of smart technology. The dashed block is added as possible way to improve user participation and provide valuable insights of using smart technology to improve the quality of life.

2.2 Literature Research

The definition of smart cities

The term "smart city" is often found confusing and is criticized as a term that is too broad to accurately describe the true nature of what makes a city smart, as well as a term that is too eagerly used by cities for its "self-congratulatory" characteristics (Hollands, 2008). Historically, cities have constantly been undergoing development in order to be able to resolve capacity related issues as well as creating better living environments. So why start calling this development smart only now? There is a wide agreement that smart cities are to be identified by pervasive use of ICT applications: implementing sensory and actuating technology in the urban landscape. Yet, this would imply that the more technology a city uses, the smarter a city becomes. However, an increase in the use of technology does not directly mean that the quality of life in the city improves (Neirotti, De Marco, Cagliano, Mangano & Scorrano, 2014). Nam and Pardo (2011) argue that the term "smart" in smart city can be interpreted in different ways, dependent on the point of view. In marketing, for instance, "smart" can be labelled as user-friendly, instead of intelligent, while in urban planning, the term "smart" would be more likely to be interpreted as a strategic direction for growth. Nam and Pardo (2011) continue with the notion that in order for a smart city to become successful, they should start with the "human capital" side, rather than blindly believing that IT itself will improve cities. An interesting view by Kitchen (2014) describes a smart city as a city that uses big data generated by technology applications throughout the city to enable real-time analysis of city life, create new opportunities for urban governance and provide information to act more efficient, sustainable, competitive, productive, and transparent. Importantly, Kitchen (2014) further provides critical thought on the implications of this big data.

To clarify, current study employs the term "smart" in smart city with a focus on improving the real-time connectedness of society in order to enhance the quality of life in a city while planning for urbanization related issues such as congestion and air pollution.

City user-types

The first part of this study aimed to identify possible applications for research in user-city-interaction. To do so, it was of importance to gain a better understanding of the different types of users that may inhabit a city, how these types function within the city, and learn more about the core values they feel are valuable for this functioning. We expected to find related literature from fields of research such as architecture or urban planning. However, research concerning the analysis of such user-types in cities remains rare. Nevertheless, valuable information regarding these types was found in the research area of user participatory governance. Where citizen participation previously regarded citizens as a homogenous group, Agger (2008; 2011) describes an array of different citizen and participant types. In these studies a major distinction is made between active and disengaged citizens.

Active citizens are described as being able to use participation opportunities to promote their interests. Active citizens are further divided into the user-types: expert citizens, everyday makers and social entrepreneurs. The expert citizen is defined in that they see themselves as a part of the political system instead of opposing or being outside it. Their political goal is to have some form of influence rather than achieve social solidarity (Agger, 2011). Typically, they participate on a full-time basis and usually are representatives of several organisations. The everyday maker is in many ways like the expert citizen, although they can be described as being more individualistic and more project-oriented; acting part-time and on a more personal level to improve their personal capacities. The last type of active citizen is the social entrepreneur. The social entrepreneur is depicted as a citizen that utilizes participation with a goal of recognizing needs and opportunities in their community, that motivate others, and construct social networks. Social entrepreneurs are more often motivated by a personal interest rather than an ideology (Agger, 2011).

Disengaged citizens have the same resources as active citizens but choose to not participate. Disengaged citizens are divided into: monitorial and young citizens. The monitorial citizen can be depicted as an interested and critical citizen, but would rather avoid institutionalized forms of political participation. Though they are interested in politics, they consider the time and energy active participation takes and therefore choose to keep their participation to a minimum (Agger, 2011). The last disengaged user-type described in the studies by Agger is young people. Young people have an age typically ranging from 14 to 24 and are not disinterested in politics by definition, but are disengaged because they are not used to formal participation procedures or are not interested to join such formal procedures.

2.3 A Social Interface to control Smart Public Lighting

The conducted qualitative interviews allowed for a detailed insight into current issues concerning human-city interaction in smart city Eindhoven. As previously discussed, the information gathered from the interviews indicated that in order to provide a wider adoption of smart city modules, it would be valuable to establish greater user involvement. Specifically, details about the social and emotional aspect of user-city interaction are of great importance, as they may offer new insights that can be used to enhance the quality of life in a smart city. An interesting way that may aid in obtaining this knowledge could be by offering inhabitants a democratic system to control the smart technology in their neighbourhood. In this system, inhabitants could easily indicate their preferred setting on the smart enabled applications in their neighbourhood. The data generated by this system may reveal valuable insights into how to use smart technology to enhance the quality of life in a city. Interestingly, using technology to ask inhabitants could perhaps reduce the lag of the traditional political participation method, create actionable real-time data and perhaps even instigate disengaged citizen user-types to more actively participate in this public debate. For instance, investigating the implementation of low-level interaction methods for such a system could potentially save energy, which is critical for participation of the monitorial user-type, and offer a participation method that is less formal, which is critical for participation of the young citizen user-type (Agger, 2011).

The second part of this study is aimed at exploring the possible features of such low-level interaction method in a smart city scenario by performing empirical research. However, smart cities typically consist of many different applications, such as smart energy, smart mobility and smart lighting. In order to perform suitable empirical research, it was opted to focus on smart lighting. Despite this focus, findings from this research may also be applicable to other smart city applications. Public lighting and its infrastructure can play an important role for cities to become smart cities (Den Ouden, Valkenburg, Schreurs & Aarts, 2015). Implementations of smart lighting projects have an advantage in that the light that is emitted adds an actuator to the city: it does not only just generate invisible data but actually executes behaviour that is visible to the people on the streets, making it directly capable of influencing the quality of life (Den Ouden et al., 2015). In addition, it has been recognized that there is a need for citizen participation in the development of public lighting (De Kok & Oerlemans, 2012). Currently, in the Netherlands, citizen participation in this area is done using traditional methods. Participants are either asked for consultation, asked for advice or asked to co-produce during the design process (De Kok & Oerlemans, 2012). When public lighting becomes smarter, these smart capabilities may offer new ways to improve citizen participation. These arguments make smart public lighting an interesting starting point for cities to begin their smart city development. The city of Eindhoven is currently investing in the development of smart public lighting (Eindhoven, 2015), and the urban area of Strijp-S already has smart public lighting installed and in use (Goulden, 2015). This illustrates a promising view for the adoption of smart public lighting in the future and consequently offers interesting opportunities for researching interaction with citizens and smart city technology.

One interesting solution to engage inhabitants with smart public lighting and to, at the same time, gain insight into their preferences is to provide citizens with a mobile app for collaborative control of the public lighting. Eindhoven's urban space Strijp-S is equipped with smart public lighting capable of such direct citizen control (Goulden, 2008). However, at this moment, no publicly available controllable interface has been designed yet. Interestingly, a recent survey by Croes (2016) indicated that inhabitants of the Strijp-S area could potentially be interested in an increased control over the public lighting. Respondents indicated a desire to be directly involved in the decision process about the light. In addition, a slightly above neutral response was shown to the question "I think it is of added value when the residents can alter the street lighting (for example using an app on their telephone)".

Designing such an app interface for the control of smart public lighting reveals interesting complications, especially on a social level (Magielse, Hengeveld & Frens, 2013). For instance, conflicts may arise when the preferences of individuals collide with each other. One possible way to avoid these conflicts may be through the human ability of taking each other into consideration, thereby altering their own voting behaviour (Niemantsverdriet, Broekhuijsen, van Essen & Eggen, 2016). The Social Translucence Framework by Erickson and Kellogg (2000) offers valuable insights for the development of interfaces that allow for a "greater shared understanding" of users by allowing for visibility, awareness, and accountability of other users actions. Implementing these three constructs into an interface for the control of smart public lighting may reveal valuable insights into how users deal with such conflicts. Another interesting complication is creating a way to handle the multi-user input to create an optimal output. As the interface receives multi-user input, it will require the ability to make a decision on which setting is most optimal and thus to be activated. Subsequently, this selected setting must then satisfy the users that provided the input. Therefore a fitting input model is necessary. Interestingly, popular social internet applications as Reddit and YouTube successfully utilize a model consisting of the possibility to up-vote or down-vote forum entries to make ranking decisions (Van Mieghem, 2011; Poon, Wu & Zhang, 2011). The up- and down-vote input model has also been used in research for the recommender systems: systems that are constructed to optimally recommend items based on previous input (Masthoff, 2011; Yu, Zhou, Hao, & Gu, 2006).

In order to start gaining a better understanding of how to develop a mobile interface that provides users a way to interact with smart public lighting, it may be interesting to investigate the effects of the above-mentioned concepts of social translucence and the up/down-vote model. The concepts are hypothesized to influence the effectiveness of using such interface and the effectiveness of the resulting output. This results in the following research question:

"How do social translucence and the up/down-vote model affect the effectiveness of an interface for collaborative control over public lighting?"

However, effectiveness can be interpreted in multiple ways, dependent on the context and the goals in mind (e.g. most democratic or most preferred by users). In this study we expressed effectiveness as users' satisfaction with the voting process and satisfaction with the resulting light. A more precise definition of effectiveness can be found in the research aims section of this thesis.

Theoretical Framework

3.1 Public Lighting and Social Translucence

Research shows that light can affect human behaviour in various ways. For instance, light may influence affective response, thereby influencing behaviour and cognition (Baron, Rea & Daniels, 1992). With advances in solid-state lighting technology (LEDs and OLEDs) an increasing number of light sources can be controlled by programmable microprocessors (Magielse, Hengeveld & Frens, 2013). Products as Philips HUE have recently been developed to offer people a greater control over the lighting in their house, making it easy to change features as colour and intensity. This increase of control may affect one's satisfaction with the light. A study by Newsham, Veitch, Arsenault, and Duval (2004) found that when office workers had individual control over their lighting conditions they indicated a higher satisfaction with those lighting conditions. Additionally, studies have shown that lighting preferences are highly individual (Butler & Biner, 1987) and may change for different genders and ages (Knez & Kers, 2000).

With the adoption of smart public street lighting, public domain lighting will too become programmable. This development could allow inhabitants of neighbourhoods with such smart public lighting to exert greater control over the lighting outside their doors. However, contrary to in-door lighting, public domain lighting affects a greater number of people. Consequently, allowing inhabitants to take control over public lighting may trigger conflicts of interests. The following is an example of a possible scenario in which such a conflict may arise: when a majority of inhabitants control the light to be of low intensity, this may not be suitable for older inhabitants, which may require brighter light in the evening (Figueiro, 2002). Another example could be: 51% of inhabitants voting for a blue light and 49% vote for a red light. As there is little common ground, chances are high a conflict arises about the colour of public lighting. For these reasons, it could be crucial that if multiple inhabitants control the lighting in their environment, we need to incorporate mechanisms to support the social structure and allow for ways to avoid conflict (Magielse, Hengeveld & Frens, 2013).

One such mechanism could be providing social feedback in the interface with which the light is controlled. The Social Translucence Framework by Erickson and Kellogg (2000) describes a process that enables the design of digital systems or interfaces that are socially coherent by making other users' behaviour visible in the interface. With coherent the authors mean that by providing social feedback within the interface, users can keep each other's actions into consideration, thereby avoiding conflicts and facilitate multi-user interaction. The framework suggests three constructs to enhance the social interaction within the interface. These three constructs are: *visibility*, *awareness* and *accountability*. To clearly illustrate the purpose of implementing these constructs, the following example can be used. A door is situated in a hallway so that when it opens, it opens in the direction of the hallway, and is likely to hit someone walking in that hallway when opened abruptly. Making the door "socially translucent" by putting a glass window in the door however, allows people that approach the door to see whether there is someone approaching from the other side. If so they can alter their behaviour accordingly. Firstly, applying the construct of *visibility* allows people to see whether someone is approaching. Secondly, the glass window supports *awareness*: people do not open the door because it will hit the person on the other side. Lastly, people may open the door more slowly or wait to open the door because they will be held *accountable* when it hits the other person (or in other words: *"I know that you know that I know someone is there"* (Erickson & Kellogg, 2000, p. 62)).

In other words, *visibility* explains how people use information from their environment to decide what the appropriate behaviour is. This information enables people to build up *awareness* of each other's actions, the intentions behind them, and the effect that actions can have on others. When this information is available, other people can hold you *accountable* for your actions if they go against the appropriate behaviour. But when the information is not available (due to a lack of visibility and awareness), you cannot be held accountable. The Social Translucence Framework argues that knowing you can be held accountable changes a users' behaviour to more closely follow the appraised appropriate behaviour. In order to coordinate actions amongst multiple users, the system should provide sufficient visibility, awareness and accountability (Niemantsverdriet et al., 2015). In turn, this allows users to avoid conflicts and facilitate multi-user interaction. A clear distinction is made in naming the framework "social translucent" instead of “social transparent”, as transparent would mean no privacy could exist after the constructs have been applied. The goal of applying translucence is to create a “greater shared understanding” while keeping privacy warranted. This means that the displayed social information should be carefully considered due to the “tension between visibility and privacy” (Erickson & Kellogg, 2000, p. 62). In the scenario of controlling public light, providing social feedback in the interface could potentially make other users aware of the needs of others, thereby influencing control behaviour. For example, if older users indicate that they would like to have brighter light between 8 and 10 pm, perhaps younger users could take their preferences into account when it is visible in the interface.

The research regarding the Social Translucence Framework has mostly taken place in the domain of Computer Supported Collaborative Work. However, since the framework was presented, advancements in technology have blurred the lines between this digital domain and the physical world (Niemantsverdriet et al., 2015). A recent example in which the use of social feedback in an application influenced the physical world can be found in the addition of the blue checkmarks in the messaging application WhatsApp (WhatsApp, 2016). By introducing the checkmarks, WhatsApp enabled users to see when recipients had read their message.

A study by Niemantsverdriet et al. (2016) explores the implementation of the Social Translucence Framework in the domestic setting by designing interfaces for several multi-user applications. This study poses that humans have developed social skills to interpret social cues, opinions, behaviour, and intentions of other people. During daily life, people prevent conflicts by communication, making agreements, negotiating, and intervening. However in a digital interface this may be more difficult to do. By implementing the Social Translucence Framework; users of the interface can see each other’s actions as they are performed. This allows for users to keep each other’s actions into consideration, thereby making the system more socially coherent: conflicts can be avoided and interaction may be facilitated. Lastly, applying the framework in an interface for the collaborative control of smart public lighting may provide valuable information about its efficiency outside of the domestic setting and into the somewhat less tight-knit social structure of the neighbourhood.

3.2 Input aggregation and interaction methods

As described in the previous section, it is acknowledged that human-city interaction in a smart city scenario may rely heavily on the input of multiple users, but may often consist of only a single output. The main problem that arises is "how to adapt to this group based on information about individual users' likes and dislikes" (Masthoff, 2011, p. 682). Naturally, there are many different ways to aggregate this input data. However, there are only so many that are effective in terms of allowing a system to make democratic decisions while remaining a low-level interaction (making it easy for the users to enter their preferences). The research area of Recommender Systems has dealt with a similar problem, and investigated these different types of user input aggregation methods called user models (Masthoff, 2011). Traditionally, research on recommender systems focused on making optimal recommendations to individual users (e.g. suggesting a music album to a person based on a his or her preferences). However, situations can occur in which it would be useful for a recommender system to make recommending decisions for a group of users (e.g. recommending television programmes for a group of users with different preferences). Masthoff (2011) summarizes research done in this area of recommender systems and specifies different effective strategies of aggregating individual user input. These aggregation strategies are inspired by the Social Choice Theory (Elster & Hylland, 1989). Examples of these aggregation strategies are: a) Plurality Voting, in which users can vote once and the option with most votes wins, b) Averaging, asking users to rate options (e.g. from 1 to 10) and the highest average wins, c) Least Misery, in which users rate options and each minimum rate leads the ranking, highest rank wins, d) Borda Count, in which individuals increasingly rate options (bottom option receiving zero points, next option one point, and so on), highest rank count wins. For a full review see Masthoff (2011). Importantly, these aggregation strategies only use input that either consist of voting for an option (in other words, rating 1 or 0) or rating an option by entering a number, for instance between 0 and 10.

Current study focuses on exploring design possibilities for creating a mobile interface to control smart public lighting. An important principle for creating a successful mobile interface is that the interaction should allow for speed and recovery, as time is often critical in the use of a mobile application (Gong &

Tarasewich, 2004). When comparing the vote-based and rate-based user models, implementing a vote-based user model into the mobile interface allows for swift entry of input on a touchscreen interface (the user only has to vote on preferences by pressing touchable buttons) while implementing a rate-based user model would require significantly more interaction from the user. This increase in interaction creates a steeper learning curve and takes more time, as suggested by the Hick-Hyman Law (Hick, 1952). As noted before, reducing time and energy is perhaps a crucial factor for an increased participation of the disengaged monitorial user-type. For this reason, it was chosen to continue the investigation on the vote-based user model.

As mentioned above, the main problem that arises is how to adapt to the collective group's preferences based on information about individual users' likes and dislikes. Interestingly, Masthoff (2011) mentions a study that does just this. A study by Yu, Zhou, Hao, and Gu (2006) investigated displaying group recommendation of TV-programs based on individuals' ratings of TV-program features. Users could either +1 a feature (like a feature), leave a feature blank (0: neutral), or -1 a feature (dislike a feature). By averaging the voting scores for multiple features of TV-programs for each user, a group-based television program recommendation was calculated.

In recent years large-scale social media have adopted a similar technique in which individual users can indicate their preferences by liking or disliking, commonly known as up- and down-voting (Van Mieghem, 2011; Poon, Wu & Zhang, 2011). Sites as Reddit and YouTube utilize the up- and down-vote paradigm to gain knowledge about the popularity of content and to form a profile of the user, which is used to recommend other content. Interestingly, there is a clear distinction between uses of this paradigm. Some websites or applications utilize an up- and down-voting model, where others use only an up-vote model (commonly known as "like" model; e.g. Facebook). Interestingly, there is support for both paradigms (Van Mieghem, 2011). However, there has been some debate about which one is most effective in what type of context, and whether down voting affects the social experience of the interface. A study by Cheng, Danescu-Niculescu-Mizil, and Leskovec (2014) found that that negative feedback leads to significant behavioural changes that are detrimental to a social community. The study investigated how ratings on content affected its author's future behaviour, and found that authors who received negative feedback will post more content in the future, but of lower quality. Consequently, these authors later evaluate their fellow users more negatively (Cheng et al., 2014). On the other hand, it can be argued that providing the possibility to both up- and down-vote allows users to express their opinion in more depth, as they can both express whether they like or dislike the option opposed to just indicating a like. This could allow for users to express more control, have more influence over the resulting output and consequently more involvement and satisfaction with the voting process (Prince, 2004).

As previously mentioned, there are multiple strategies to aggregate input, such as plurality voting, least misery, counting, and the averaging strategy. However, when social media utilize a voting mechanism, they use a different variant of aggregation strategy. This aggregation strategy can be described as repeated plurality voting: one vote can be cast per post, which is either an up- or a down-vote (Van Mieghem, 2011). The popularity of this post is then calculated by counting the votes, and down-votes count as negative votes. For example, counting 8 up-votes and 3 down-votes would result in a "popularity score" of 5. This study adopted this repeated plurality voting variant over other strategies as it is common in social media and therefore perhaps most commonly known. In addition, counting votes could perhaps be the easiest available method for users to understand and form a mental model (Norman, 1983).

Lastly, by allowing users to both up- and down-vote more detailed analysis can be made, not only of users' likes, but also of their dislikes. This could aid in attaining a more detailed view on how to improve the quality of life in a city. It is thus valuable to test the effectiveness of using such user input model. Applying the up/down-vote user model in an interface to control smart public lighting may reveal insights into whether the possibility to down-vote affects the process of setting the light and satisfaction with resulting output.

Research Aims

4.1 Human-City Interaction

As more and more cities adopt smart technology in their public spaces, smart cities are expected to remain a largely debated topic in the future. However, as we are currently in the early stages of worldwide smart city development, there is limited literature available about the interaction of citizens and smart technology enabled objects. The general aim of this research is to gain a better understanding of the requirements for creating an interface that allows the citizens of a city to interact with smart enabled objects in the city. This research can be viewed as an exploration of possibilities of human-city interaction. In order to explore these possibilities, we have developed a mobile interface with which users can collaboratively control smart public lighting. By performing an empirical experiment on the use of this interface, we aim to gain a deeper understanding of the effects of social translucence and the up/down-vote user model on the process of controlling public lighting, and whether these mechanisms can be valuable in creating efficient human-city interaction applications.

However, the term efficient can be interpreted in multiple ways. These interpretations may be context and/or goal dependent. One could argue that, in this context, efficient could mean for instance: most democratic, most preferred by its users, most satisfactory to use, or most satisfactory in terms of output. Unfortunately, as comparable research remains scarce, no inspiration could be drawn from other studies. However, in traditional human computer interaction (HCI) studies, user satisfaction is a critical measure of a system's success (Chin, Diehl & Norman, 1988). For this reason we express effectiveness mainly as satisfaction with the voting process, and satisfaction with the resulting light. In addition, we measure perceived engagement with the system, which could be an indicator of motivation for prolonged use of the system (O'Brien & Toms, 2010).

Firstly, we manipulate the level of social translucence available in the interface. By doing this, we are able to gain insight into whether social feedback influences the process of setting the public domain lighting. Importantly, this may reveal details about whether participants are considering the choices of other participants before they make their own. Gaining insight into this level of consideration is a valuable analysis as keeping each other into consideration may be a promising method of avoiding social conflicts (Niemantsverdriet et al., 2016). However, Niemantsverdriet et al. (2016) focuses on applications in the domestic domain. As social structures in the domestic domain may differ from public domain social structures, the notion of taking each other into consideration may apply in a different way. It is therefore valuable to analyse whether social feedback alters participants' behaviour in an interface to collaboratively control public lighting.

Secondly, current experiment investigates the difference between using an up-vote user model and an up/down-vote user model. As previously discussed, employing a voting model allows for straightforward and fast interaction, which are crucial aspects of mobile interface development (Gong & Tarasewich, 2004). Both the up-vote and up/down-vote model are widely used in popular internet websites and applications (such as Facebook, YouTube and Reddit). However, residential environments have a different social structure than online environments, and knowing votes come from people in physical proximity, or knowing them personally, may alter your voting behaviour (Erickson & Kellogg, 2000). An interesting aspect of the down-vote feature is that it allows for additional control over provided settings: users can not only indicate their own preference by up-voting, but also indicate their dislike of a setting by down-voting. This additional functionality potentially adds a new layer of depth to the social interplay and consequently the process of collaboratively selecting a light setting. This higher level of control could therefore allow greater user influence, involvement and consequently user satisfaction (Prince, 2004). On the other hand, providing the possibility to down-vote may negatively affect the social coherence (Cheng et al., 2014). By manipulating this level of control participants have over the interface, new insights can be gained about whether adding the down-vote functionality aids the process of collaboratively controlling public lighting.

4.2 Hypotheses

To measure the effects of social translucence and up/down-vote user model in the experimental interface, we combined behavioural data (generated by the interface which saved all actions performed by participants) with psychological data obtained with questionnaires. The psychological measures consisted of process satisfaction, end-result satisfaction, perceived control, perceived involvement, perceived endurability, perceived consideration, and perceived conflict. The scales for these measures are described in more detail in the method section. With these measurements, the following hypothesis were formulated:

Hypothesis 1: Participants with social feedback will vote in an increasingly conformant manner over time compared to participants without social feedback.

By employing the Social Translucence Framework to provide participants social feedback of other participants' voting behaviour, we expect to see participants use the human notion of taking each other into consideration and consequently vote in an increasingly conformant manner as votes are being cast (Niemantsverdriet et al., 2016). With conformant, we denote the tendency to up-vote more and down-vote less on popular light settings.

Hypothesis 2a: The social feedback condition scores higher on perceived process satisfaction than the no social feedback condition.
Hypothesis 2b: The up/down-vote condition scores higher on perceived process satisfaction than the up-vote condition.
Hypothesis 2c: The social feedback condition scores higher on perceived end-result satisfaction than the no social feedback condition.
Hypothesis 2d: The up/down-vote condition scores higher on perceived end-result satisfaction than the up-vote condition.

We expect that social feedback serves as a method that prevents conflicts in the voting process (Niemantsverdriet et al., 2016). This would in turn allow for a higher perceived process and end-result satisfaction. Additionally, allowing participants more control by offering the possibility to down-vote could positively influence engagement with the experiment and therefore also positively influence perceived process and end-result satisfaction (Prince, 2004).

Hypothesis 3: The up/down-vote condition scores better on perceived control than the up-vote condition.

As offering this possibility adds another way for the participants to show their opinion, we hypothesize that it positively affects the level of perceived control (Prince, 2004).

Hypothesis 4a: The up/down-vote condition scores higher on endurability than the up-vote condition.
Hypothesis 4b: The social feedback condition scores higher on endurability than the no social feedback condition.
Hypothesis 4c: The up/down-vote condition scores higher on felt involvement than the up-vote condition.
Hypothesis 4d: The social feedback condition scores higher on felt involvement than the no social feedback condition.

We expect that the engagement measures of endurability and felt involvement are both positively influenced by social feedback and by allowing both up- and down-vote. Providing the possibility to both up- and down-vote allows participants an additional way to indicate their preference, thereby perhaps increasing control and in turn perceived engagement (O'Brien & Toms, 2008). Additionally, providing social feedback in the interface could make the interface more interesting as participants can see the preference of other users evolve over time, thereby positively influencing perceived engagement (Erickson & Kellogg, 2000).

Hypothesis 5: The social feedback condition scores lower on perceived level of conflict than the no social feedback condition.

We expect that providing social feedback in the interface allows participants to take the choices of other participants into consideration, thereby avoiding conflicts during the voting process (Niemantsverdriet et al., 2016).

Hypothesis 6: The social feedback conditions scores higher on perceived level of consideration than the no social feedback condition.

Lastly, by measuring the perceived level of consideration we can gain insight into whether a lower level of conflict was indeed caused by the notion of taking each other into consideration and whether this process was consciously perceived or perhaps took place on a more subliminal level. On the other hand, if perceived consideration is higher when receiving social feedback but perceived conflict is not lower, perhaps a different process is taking place. In any case, it may be valuable to gain a better understanding of which process is leading and whether there is an interaction of perceived consideration and avoiding conflict.

Method

5.1 Experimental Design

This study followed a 2 (level of social feedback: social feedback from other participants vs. no social feedback) by 2 (level of control: up- and down-vote vs. up-vote) between-subjects design to answer the research question. Participants were randomly assigned to one of the conditions. Voting behaviour was measured by storing the participant's voting data in a private database. Perceived satisfaction, control, engagement, consideration and conflict were measured using a paper questionnaire.

Table 1. The 2 (social feedback vs. no social feedback) by 2 (high control vs. low control) experimental design.

Interface A	Interface B	Interface C	Interface D
High control	Low Control	High Control	Low Control
High Social Feedback	High Social Feedback	No Social Feedback	No Social Feedback

High Social Feedback: utilizes the Social Translucence Framework to indicate other users voting behaviour.
No Social Feedback: other participants' voting behaviour not visible.
High control: participant can up-vote (+1), down-vote (-1) or not cast votes.
Low control: participant can only up-vote (+1) or not cast votes.

During the experiment, participants could vote for the colour of the lighting (red, green, yellow, and blue). It was chosen to focus on voting for the colour of the lighting because people typically differ in colour preferences (Guilford & Smith, 1959). Keeping it basic by letting participants to vote on 4 different colours allowed us to present an interface with low complexity. The colours were chosen as they offer clear distinctions and are clearly visible. For each of the four colours, participant could either cast a vote (an up-vote in the low control condition, and an up or down-vote in the high control condition) or not cast a vote (i.e., neither giving an up or a down vote). Each participant could thus cast a maximum of 4 votes (one per colour). Participants could cancel a vote by re-pressing their casted vote. The colour with the highest vote score was activated. The vote score was calculated by subtracting the number of down-votes from the number of up-votes (otherwise known as the count aggregation method; Masthoff, 2011).

5.2 Participants

Sixty-six people (53 men, 13 woman, *Mage* = 25.42, *SDage* = 9.20, age range: 18-75 years), registered in the Eindhoven University of Technology experiment database, participated in the experiment. The experiment was conducted in English. Anyone with a smartphone and access to the internet was allowed to participate. The experiment lasted about 15 minutes in which an average of 10 participants participated. Participants were compensated €3,- for participating.

Unfortunately, some troubles occurred when recruiting participants. To clearly show the colour of the light, experiment sessions were held when it was dark outside, at 21:30 and 22:30 in the evening between 23th and 31th of May. The late session times may have had a negative effect on the recruiting numbers. Additionally, it could have had a negative effect on the last-minute drop-off rates, which where extraordinary high (about 30%). These factors not only severely limited sample size, but also made it difficult to keep the sessions equal in number of participants. This unbalance may have caused issues for the interpretation of the results. Table 2 displays the number of participants and the number of sessions held per experimental condition.

Table 2. Spread of participants between conditions.

Condition	Session1	Session 2	Session 3	Total
A	14 Participants	7 Participants	n/a	21 Participants
B	12 Participants	n/a	n/a	12 Participants
C	18 Participants	n/a	n/a	18 Participants
D	7 Participants	3 Participants	5 Participants	15 Participants

5.3 Procedure

Upon arrival, participants were asked to carefully read and sign the informed consent form. Afterwards, participants were asked to take out their smartphones and start the web application interface by opening a specified URL in the web browser. The order of the colour settings displayed in the interface was randomized. At the top of the interface, a participant identification code was displayed (e.g. 215A). Participants were asked to memorise or write down this ID as it was required to link interface data with questionnaire data. Once everyone was ready, the experiment leader verbally explained the interface and its purpose, after which the to be voted for light colours (blue, red, yellow and green) were demonstrated by showing the four optional colours to the participants in randomized order.

Thereafter, the first round of voting commenced. Participants used the interface on their smartphones to cast votes indicating their preference. Once all the participants had cast their votes, the experiment leader turned the highest scoring colour on. In the next step, the experiment leader verbally explained that participants could also remove votes by tapping another time on the vote buttons. Participants were then offered a moment to re-cast their votes. Once a final consensus was reached, the now most popular light was turned on and participants were asked to fill in a questionnaire on paper. Upon completion, participants were paid and thanked for their participation of the experiment.

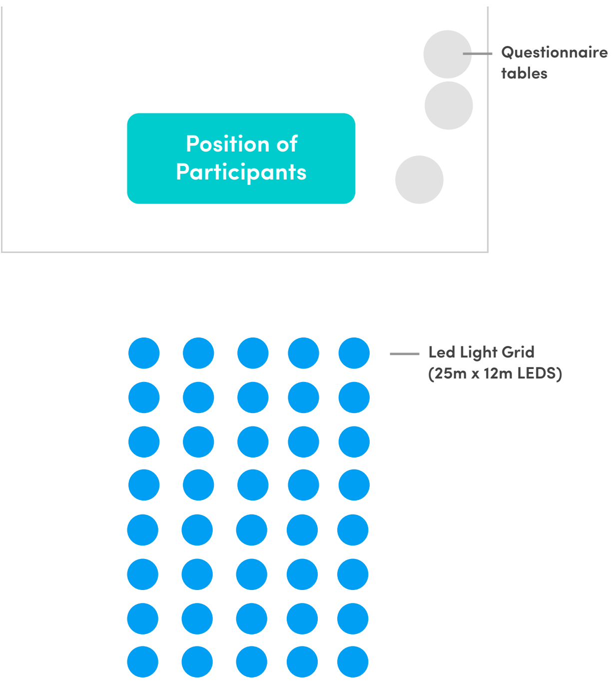


Figure 2. An illustration of the experiment layout. Blue circles represent the LED lighting grid (12,5m x 25m). Grey circles indicates the tables on which participants could fill in the questionnaires, and the green square indicates the position of the participants during the voting process.

5.4 Materials and manipulation

5.4.1 Experimental Interface

The experimental interface was developed using the Ionic JavaScript framework and a model-view-controller (MVC) design pattern (http://ionicframework.com/). This interface was designed to communicate with a back-end Node.js webserver using both REST API calls and web-socket technology to be able to display social feedback updates real-time (https://nodejs.org/en/). The front-end web technology Angular 2 was used to create the MVC layers (https://angular.io/). The back-end server used Nodejs's Express to receive data through the API endpoints and store data into a private NoSQL database (https://www.mongodb.com/). Participants used their own smartphones to open the web application interface by visiting a specified link. By using a web application, as opposed to creating a native mobile application, we could swiftly create an application that worked on both iOS and Android devices, thereby allowing for more participants to participate in the study.

Figure 3. Screenshots of the experimental interface. From left to right: A. High Social Feedback and High Control - B. High Social Feedback and Low Control - C. No Social Feedback and High Control - D. No Social Feedback and Low Control

5.4.1 Experiment location and technicalities

The Markthal is an indoor square located at the Eindhoven University of Technology. This square is actively used for lighting experiments. The lab area spans 25 by 12.5 meters, with 4 trusses hanging from the ceiling at 6 m height. The lighting consists of 32 Philips CK Powercore RGB LED and 32 Philips CK Powercore iWhite LED arranged spots in an 8 by 4 matrix (Markthal Living Light Lab, 2016). During the experiment, the following colour values were used: blue = RGB(0,0,255), red = RGB(255,0,0), green = RGB(0,255,0) and yellow = RGB(255,255,0).

Figures 4 and 5. Photos of the experiment location: Markthal. On the left side a photo of the Markthal with the various coloured lighting enabled. On the right side a detailed image of the lighting construction.

5.5 Measurements

5.5.1 Voting behaviour

Each time a participant casted a vote, data was saved to a private database connected to the experiment application. This stored data consisted of:

- The participant and condition ID.
- The *type of action*: up-vote, down-vote, removed up-vote or removed down-vote.
- The *individual calculated score* of voted light setting and *total calculated score* of all settings (up-votes minus down-votes).
- The current up- and down-votes of voted light setting, and current total up- and down-votes of all settings.
- A timestamp.
- Current *rank* of voted light setting, ranging 1 to 4.

Plotting and analysing this information made it possible to gain insights into the voting behaviour of participants during the voting process.

5.5.2 Voting conformance and popularity scores

The Social Translucence Framework by Erickson and Kellogg (2000) describes a process in which it becomes possible to design systems that are socially coherent by making participant behaviour visible, employing the constructs: visibility, awareness and accountability. To be able to test whether the application of these constructs in the interface have an effect, it is required to gain insight into voting conformance. Voting conformance is depicted as the increased tendency to up-vote on popular light settings opposed to less popular settings, and down-voting less on popular light settings. By analysing the voting data, it was investigated whether there would be an effect of the level of social feedback on voting behaviour (Van Mieghem, 2011).

The popularity score is calculated for each casted vote by dividing the selected light setting's current number of up-votes by the current total up-votes across all light settings. In the high control conditions, the selected setting's current number of down-votes divided by the current total down-votes across all light settings is then subtracted from the up-vote calculation:

Popularity Score = (selected setting upvotes) / (total upvotes) - (selected setting downvotes) / (total downvotes)

By plotting this popularity score with time on the x-axis, we can gain insight into the voting behaviour of participants during the voting process, and whether there are clear distinctions between conditions. If popularity is high, there is high conformance amongst participants. If popularity is low, there is low conformance amongst participants.

Elapsed time

If an experiment session took longer than average, it could imply that it took longer for a group to reach consensus on what light setting is to be turned on, thereby suggesting conflict may have taken place. Additionally, as different experiment sessions may differ in elapsed time, for example because of differences in group size, it could be argued that spending more time with the interface allows a participant to learn more about it, thereby affecting the engagement with the system. Time will be measured during the voting processes of the experiment sessions, from the starting signal to the stop signal.

The timestamps on individual votes can also be analysed to gain insights on the voting process. If a participant took more time to vote, this may have had effects on the questionnaire results.

5.5.3 Questionnaire response

Perceived satisfaction

User satisfaction is a critical measure of a system's success (Chin, Diehl & Norman, 1988). For current study, perceived satisfaction measurement is a key indicator for determining the effectiveness of the experimental factors: level of control and level of social feedback.

A lot of questionnaires have been developed in terms of measuring user satisfaction for interacting with a system (Doll & Torkzadeh, 1988). However, less has been developed to measure satisfaction in relation to a user-interface (Chin et al., 1988; Bailey & Pearson, 1983; Calisir & Calisir, 2004). More so, remaining questionnaires have been designed to test full-fledged systems, meaning they cover factors as screen information, error handling and responsiveness (Chin et al., 1988). The goal of current study however was not to test a full-fledged system but rather to focus on the effects of manipulated factors in the experimental interface. Therefore, this study adopted a more basic form of user satisfaction measurement.

In order to test perceived user satisfaction with the interface, we created a custom perceived satisfaction scale using a 5-point Likert scale. This custom scale consists of two factors: satisfaction over the voting process and end-satisfaction over the end-resulting light setting. Both these factors consist of three items each. The Perceived Process Satisfaction scale had a low but acceptable Cronbach's alpha of 0.67, and the Perceived End-Result Satisfaction scale had a good Cronbach's alpha of 0.84.

Process Satisfaction:

- I liked the process of setting the light.
- I enjoyed the process of setting the light.
- I think that the process of setting the light was fun.

End-Result Satisfaction:

- I am satisfied with the resulting light.
- I am content with the resulting light setting decision.
- I am pleased with the light setting outcome.

Perceived control

In current experiment, the level of control participants receive was directly manipulated. Participants could either be offered the possibility to up-vote or not vote, while other participants could be offered the possibility to up-vote, down-vote or not vote. It was therefore interesting to investigate whether there was a difference in participants' perception of control over the light settings.

There currently exist some scales that are constructed to measure the level of perceived control a user experiences in a user interface (Bailey & Pearson, 1983; Venkatesh, 2000). However, upon inspection of these scales, it was noted that the questions focussed on testing full-fledged interfaces, and were therefore not fitting for our experimental interface. It was therefore opted to develop an independent, stand-alone perceived control measure. Current thesis study used a custom-made perceived control scale, using a 5-point Likert scale. The Perceived Control scale had an adequate Cronbach's alpha of .74.

- I felt in control over the resulting light setting.
- I felt in charge of setting the light.
- I felt that I could regulate the resulting light setting to my preference.

Perceived engagement

The main goal of measuring engagement is to gain insights into whether users would continue to use the interface for a longer period of time or on a more frequent basis. If users signal that they find an interface to be engaging, it could be a positive motivator to continue researching such an interface. A common scale to measure user engagement in computer interaction is the User Engagement Scale (UES; O'Brien & Toms, 2010). The UES measures six factors that qualify as an engagement indicator: aesthetics, focussed attention, felt involvement, perceived usability, novelty and endurability. However, the aim of current study was not to test a full-fledged system, making the factors aesthetics, focussed attention, perceived usability and novelty unnecessary. Therefore this study used an altered version of the UES, leaving only the factors felt involvement and endurability in for assessment, each consisting of three items. Participants could respond using a 5-point Likert scale. Both the Perceived Engagement Involvement and Endurability scales had a good Cronbach's alpha of .76 and .77 respectively.

Felt involvement:

- I felt this experience was engaging.
- I felt involved when doing this task.
- I was really drawn into the task.

Endurability:

- I would like to be able to do this in my own street.
- It would be nice to be able to do this in my own street.
- I could see this system work in my own street.

Perceived level of consideration

If the level of social feedback was found to affect voting conformance, then it would be interesting to investigate the extent to which this effect was consciously perceived during the experiment. By analysing the degree to which voting conformance and perceived level of consideration correlate, we may be able to investigate whether the process of taking others into consideration while casting votes was experienced as a conscious process or more subliminal (Kahneman, 2011). However, when perceived consideration is high, but perceived conflict is also high, perhaps a different process takes places that could be valuable to investigate.

Participants were asked to fill in the custom-made perceived level of consideration scale to investigate the extent to which participants took other participants' voting behaviour into consideration when voting. This scale consists of a 5-point Likert scale. The Perceived Level of Consideration scale had a low but still acceptable Cronbach's alpha of .68.

- The choices of other participants influenced my choices.
- I took the votes of other participants into consideration when voting.
- The votes of others affected my voting behaviour.

Perceived level of conflict

When the input of multiple users' preference is to result in one output, situations could arise in which a user's input conflicts with the conclusive output. Therefore, during the experiment conflicts could arise between participants that wish to set a different lighting setting than the resulting light setting. To be able to investigate whether conflicting situations have occurred and whether these conflicts are detrimental to user satisfaction, participants were asked to answer the following custom-made perceived level of conflict scale. This scale consists of a 5-point Likert scale and the second item is reverse coded. The Perceived Conflict scale had a good Cronbach's alpha of .86.

- I felt that the opinion of other participants was different than mine.
- I feel that other participants voted the same as me (reverse coded).
- I think that other participants voted different than me.

5.6 Data Analysis

Before interpreting following results, it is important to note that due to recruiting issues performed tests are low on power. As an additional consequence, distributions of measurement did not indicate normality. With exception of the perceived conflict measurements, none of the measures appeared to be normally distributed. Therefore, statistical tests were performed using the non-parametric Mann-Whitney U Test.

Results

6.1 Behavioural Measures

6.1.1. Colour preferences

Figure 6 illustrates the amount of up-votes and down-votes a certain colour received during the complete experiment. From this figure, we see that the colours yellow and green scored slightly above average (25%) in up-votes, and that the colours blue and red received above average down-votes. Figure 6 indicates that yellow is the most positively voted for colour. However, inspection upon Figure 6 indicates that the voting data is reasonably spread: there are some differences between the colours but there is no colour clearly more popular than the others. If one colour was noticeably most popular, perhaps results were biased due to a distinct preference for one colour. However, these differences between colours are not large enough to cause problematic interpretation for upcoming analyses.

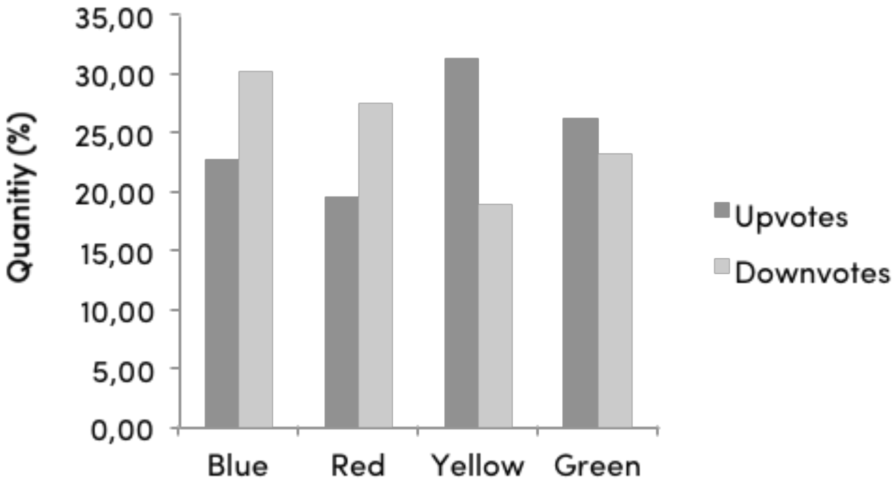
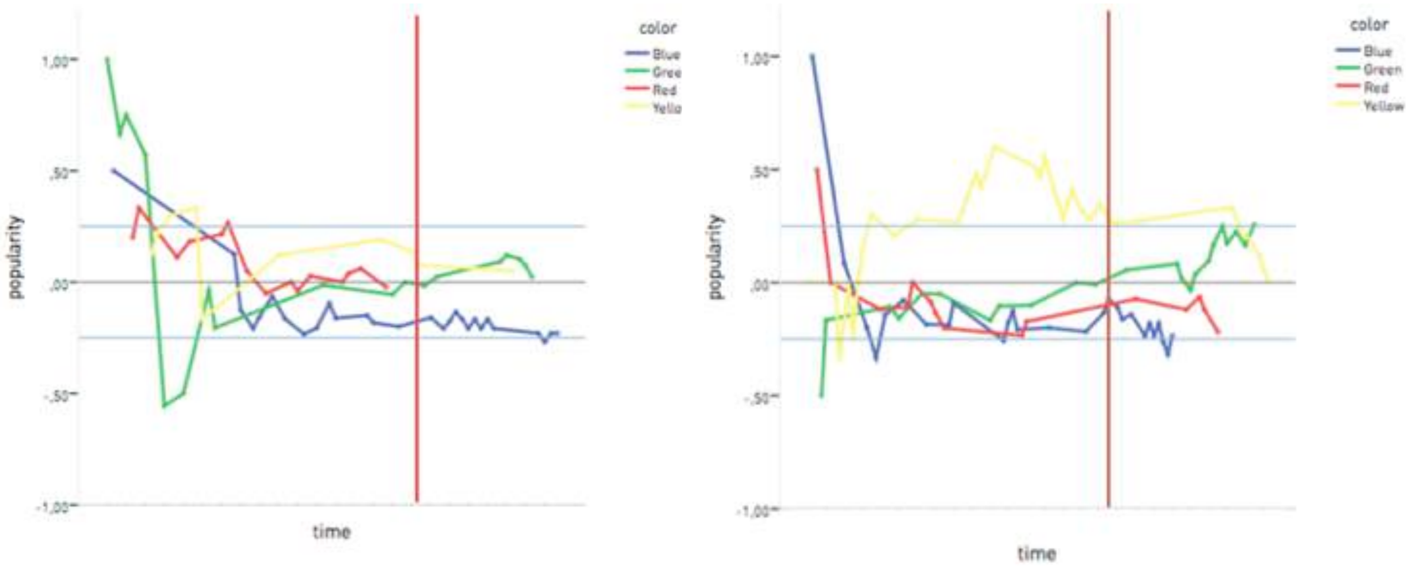


Figure 6. The amount of up- and down-votes per colour. Quantity is expressed in percentage of total votes cast.

6.1.2 Popularity

Participants' voting behaviour is presented in the following figures. By plotting this popularity score with time on the x-axis, we can gain insight into the voting behaviour of participants during the voting process, and whether there are clear distinctions between conditions.



Figures 7 and 8. Two sessions of the "high social feedback" and "high control" condition. The vertical red line indicates the start of the second voting round. Numbers of plotted votes are 72 and 102 respectively.

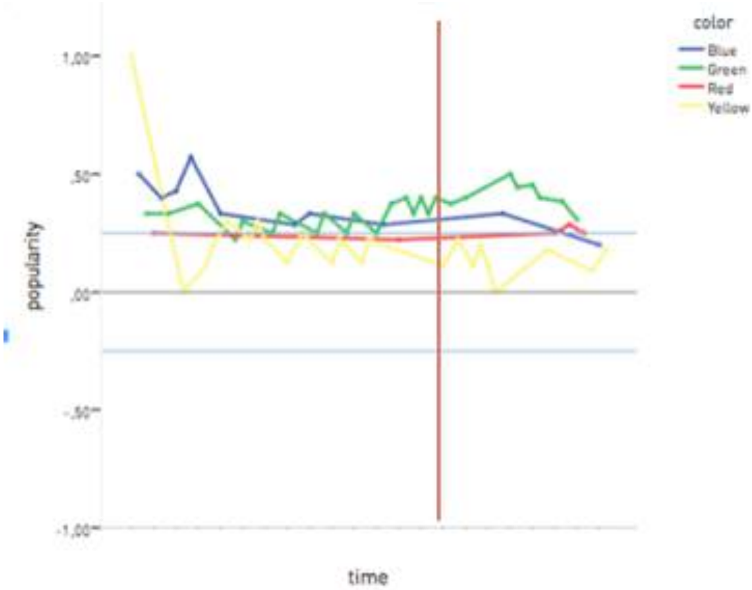


Figure 9. One session of the "high social feedback" and "low control" condition. The vertical red line indicates the start of the second voting round. Number of plotted votes is 65.

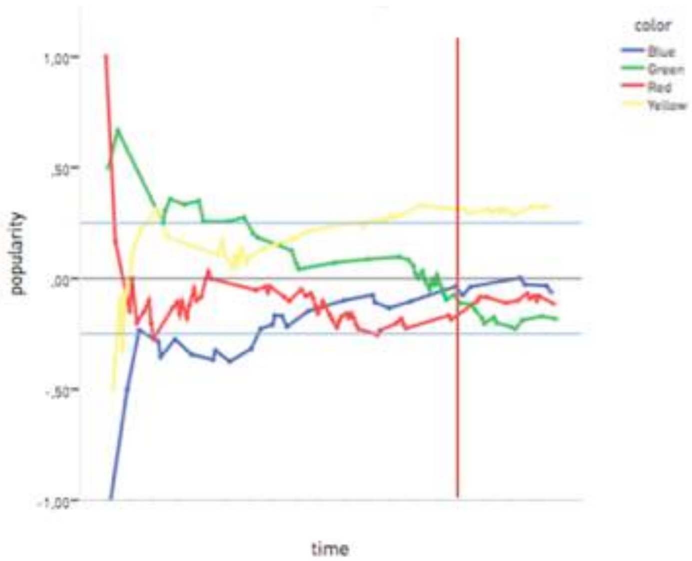
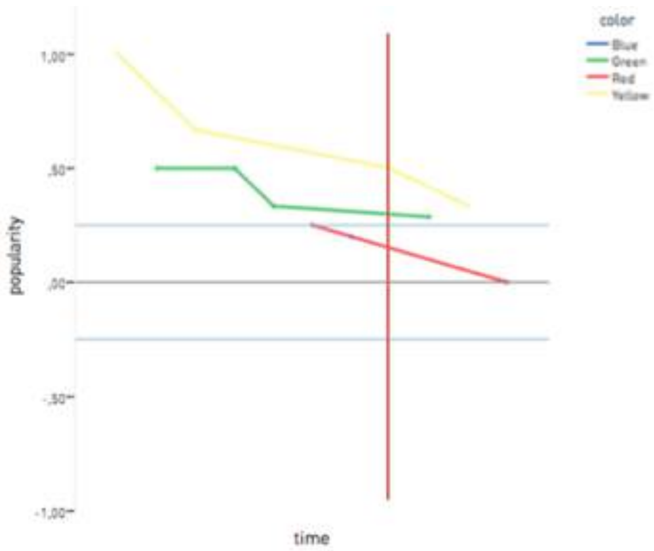
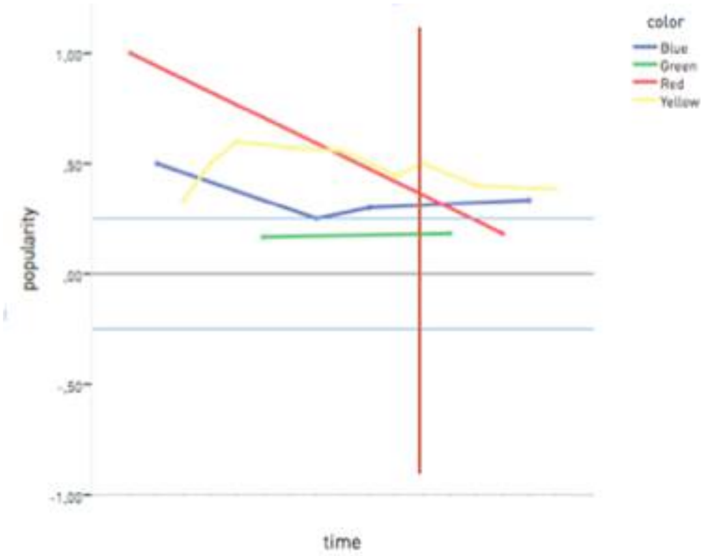
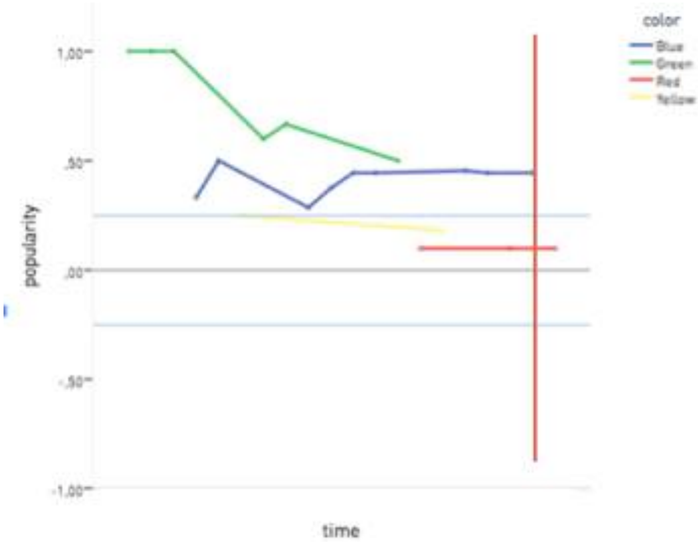


Figure 10. One session of the "no social feedback" and "high control" condition. The vertical red line indicates the start of the second voting round. Numbers of plotted votes is 190.







Figures 11, 12, and 13. Three sessions of the "no social feedback" and "low control" condition. The vertical red line indicates the start of the second voting round. Numbers of plotted votes are 17, 11 and 32 respectively.

By manipulating the level of social feedback between conditions, we expected to see a tendency in which the social feedback conditions would vote in an increasingly conformant manner. This would graphically convey in one colour gaining higher popularity over time opposed to the other colours, and a more stable voting process in general (indicated by a line that is less shaky or hesitant). It is important to note that due to a lack of knowledge on performing statistical tests regarding the analyses of such trends, no tests could be performed to provide evidence for the following claims. However, based on inspection of the figures, no clear indications of increased conformity can be found. The social feedback figures do not illustrate more stable trends. Figure 7 (first session of social feedback and high control) does not show a single colour gaining popularity over time, but Figure 8 (the second session of social feedback and high control) does somewhat illustrate this trend before starting the revote session. Interestingly, Figure 10, which depicts the no social feedback and high control condition, more clearly indicates the yellow colour becoming more popular over time and other colours becoming less popular, even after starting the revote. This could be a sign that, contrary to the initial hypothesis, no social feedback may actually allow for a more conformant voting process to take place. However, this should be interpreted with care, as Figure 8 (social feedback and control) also shows signs of the same trend. Due to large sample size difference between the high social feedback + low control (Figure 10) and no social feedback + low control (Figure 11, 12 and 13), no analysis can be made to provide evidence.

A Mann-Whitney test indicated no significant difference in popularity scores for up-votes between social feedback (*Mdn* = 0.22) and no social feedback (*Mdn* = 0.22) conditions, *U* = 6185.0, *p* = .909, *r* = .01. Two additional Mann-Whitney tests were performed to investigate whether social feedback had effect on the amount of casted up- and down-votes. No significant effects were found for either of the tests. Amount of up-votes between social feedback (*Mdn* = 3) and no social feedback (*Mdn* = 3) conditions, *U* = 558.0, *p* = .542, *r* = .07. Amount of down-votes between social feedback (*Mdn* = 2) and no social feedback (*Mdn* = 2.5) conditions, *U* = 157.5, *p* = .515, *r* = .11.

6.2 Psychological Measures

The scale statistics for all scale measurements are reported in Table 3.

Table 3. Scale statistics for all psychological measures by experimental manipulation.

Manipulation		**High Social Feedback**		**Low Social Feedback**		**High Control**		**Low Control**	
Measures	**Cron. Alpha**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Satisfaction - Process	0.67	3.78	0.58	4.01	0.56	3.90	0.63	3.88	0.51
Satisfaction - End	0.84	3.41	0.85	3.84	0.88	3.56	0.88	3.73	0.89
Control	0.74	3.31	0.74	3.59	0.78	3.37	0.70	3.57	0.85
Engagement - Involvement	0.76	3.49	0.67	3.55	0.78	3.39	0.77	3.70	0.60
Engagement - Endurability	0.77	3.41	0.83	3.77	0.86	3.51	0.82	3.70	0.90
Consideration	0.68	2.27	0.95	2.05	0.93	2.25	0.96	2.04	0.91
Conflict	0.86	2.89	0.93	2.96	1.08	2.99	0.98	2.83	1.05

Statistics of performed tests are displayed in Table 4. A marginally significant main effect of social feedback was found on the satisfaction with the voting process (*Mdn Social Feedback* = 3.67, *Mdn No Social Feedback* = 4, *U* = 399.5, *p* = 0.058, *r* = .23). This may be an indication that *not* having social feedback improves satisfaction of the process of voting. In contrary, no statistically significant main effect of control was found with respect to satisfaction with the voting process (*Mdn Control* = 4, *Mdn No Control* = 4, *U* = 520.5, *p* = 0.937, *r* = .01). There was a statistically significant main effect of social feedback with respect to the satisfaction with the resulting (*Mdn Social Feedback* = 3.67, *Mdn No Social Feedback* = 4, *U* = 382.0, *p* = 0.034, *r* = .26). This may indicate that *not* having social feedback also positively influences the satisfaction of chosen light settings at the end of the voting process, which again counters the initial hypothesis conform the Social Translucence Framework. No statistically significant main effect of control on the satisfaction with the resulting light was found (*Mdn Control* = 3.67, *Mdn No Control* = 4, U = 466.0, *p* = 0.423, *r* = .10).

Lastly, we found a marginal significant main effect of control on the felt involvement participants experienced during the voting process (*Mdn Control* = 3.67, *Mdn No Control* = 3.67, *p* = 0.067, *r* = .23). This may be an indication that having *less* control (or *not* having the down-vote possibility) creates higher perceived involvement with the voting process.

Table 4. Results of the Mann-Whitney U tests on the psychological measures, and their effect sizes. Mdn 0, indicates the no social feedback and low control conditions. Mdn 1, indicates the social feedback and high control conditions.

Main Effects	**Social Feedback**				**Control**			
Measures	**Mdn 0**	**Mdn 1**	**p**	**r**	**Mdn 0**	**Mdn 1**	**p**	**r**
Satisfaction - Process	4.00	3.67	.058	.23	4.00	4.00	.937	.01
Satisfaction - End	4.00	3.67	.034*	.26	4.00	3.67	.423	.10
Control	3.67	3.67	.258	.14	3.67	3.33	.216	.15
Engagement - Involvement	3.67	3.67	.520	.08	3.67	3.67	.067	.23
Engagment - Endurability	4.00	3.67	.097	.20	3.67	3.67	.399	.10
Consideration	2.00	2.00	.307	.13	2.00	2.33	.396	.10
Conflict	3.00	3.00	.718	.05	3.00	3.00	.758	.04

Note. **p is significant at the .01 level. *p is significant at the .05 level.

As can be observed in Table 4, no other significant or marginally significant main effects were found in the psychological data. The reported effect sizes range from .26 (small to medium) to .01 (very small). Inspection upon plots of the interaction between social feedback and control on the psychological measures indicated no sign of meaningful interaction effects (see Appendix B). Therefore, no tests were performed.

Discussion

The aim of this research was to gain a better understanding of the requirements for creating an interface in which citizens can interact with smart cities. Importantly, this research serves as an exploration of such human-city interaction. In order to start exploring useful methods, an experiment was conducted to investigate the efficiency of providing social feedback and utilizing the up/down-vote user model in an interface to control smart public lighting. Efficiency was expressed as user satisfaction with the voting process and resulting light, and as users' engagement with the system.

Unfortunately, due to recruitment issues, results from this study lack statistical power. It is therefore advised that reported results are interpreted with care. With this in mind, the main aim of the following discussion is to elaborate on the reported results by carefully considering design recommendations, discuss possible limitations and, importantly, propose points of attention for future work on human-city interaction.

7.1 Design recommendations

We initially hypothesized that providing participants with social feedback in a mobile interface to collaboratively control the colour of public lighting would increase voting conformance, and would lead to an increased tendency of up-voting on popular settings and a decreased tendency of down-voting on popular settings. However, the composed graphs showed no indication of increased conformance and performed tests showed no signs of social feedback affecting voting behaviour. The results from the psychological measures show an interesting finding that may indicate that providing social feedback may negatively affect participants' satisfaction with the process of setting the light, and with the resulting light (i.e., the outcome determined by the application based on the votes). Interestingly, this finding is opposite to our hypothesis. Against expectations, social feedback also did not affect the perceived control, engagement, consideration, and conflict. Manipulating the user model by providing the possibility to down-vote in addition to an up-vote may have affected felt involvement of participants, but again the effect appeared opposite to our expectations: providing a down-vote possibility may negatively affect felt involvement. This effect is only marginally significant. The other psychological measures of perceived satisfaction, control, endurability, consideration and conflict were not affected by the provision of a down-vote possibility.

Due to the lack of statistical power and the indication that found effects are opposite to the initial hypotheses, it is difficult to provide solid design recommendations for interfaces to collaboratively control smart public lighting, or interfaces for human-city interaction in general. Nevertheless, reported findings may be of valuable information for understanding the conditions and contexts in which providing social feedback and the possibility to down-vote may or may not be effective.

Results may suggest that there are situations in which providing social feedback has a negative effect in terms of improving user satisfaction. Participants of the experiment mostly consisted of university students who did not know each other. The study by Niemantsverdriet et al. (2016) utilizes the Social Translucence Framework in a domestic setting. It could be argued that the experiment setting and the domestic setting have different social structures. By not knowing each other, the effect of providing social feedback to keep each other in consideration could have actually backfired and transformed into an additional obstacle in finishing the process. Another explanation could be that participants in the study did not like the idea of being held accountable for their actions. In other words, providing social feedback could have imparted participants with a negative feeling, as they would rather have voted in complete anonymity. As mentioned before, the Social Translucence Framework is more commonly applied in digital or internet based applications. By gathering participants that did not know each other in a physical place together, social feedback may have had negative effects on their anonymity. Lastly, it could be that participants were negatively affected by social feedback because they could see that other participants had different preferences, thereby experiencing the hypothesized social conflicts. However, if this were the case, it would be expected to show in the perceived conflict measurements.

The analysis for the high control condition showed that there might be an indication that offering participants the down-vote possibility may have had a negative effect on felt involvement. This is interesting, as our initial hypothesis expected that the possibility of down voting would instead enhance felt involvement. One reason for this negative effect could be that participants felt they could not comfortably express their preference because other participants down-voted the same colour they up-voted. Another explanation could be that offering participants the possibility to down-vote is experienced as a concept that is detrimental to the social effect of collaboratively setting the light, thereby influencing social involvement. In other words, providing the down-vote possibility could worsen the social experience of controlling the light. However, no evidence for these arguments was found in the other psychological measures, such as perceived satisfaction and conflict.

Most of the reported measures did not reach significance. As this study is of an explorative nature, not much is known about the effect sizes of performing these manipulations in an experimental setup. The reported effect sizes ranged from a small to medium effect to a very small effect, which may be an indication that in current experimental setting the manipulations did not cause large enough effects to be examined with current sample size.

Despite that we cannot accurately recommend design implementations to control smart public lighting based on results, we can recommend experiment method implementations based on experience of performing this experiment. During the experiment we found that the use of a mobile web application to control the public lighting was generally feasible. An important thing that we noted was that participants used a wide variety of smartphone models. This sometimes led to problems opening the web-based interface. Fortunately, most of the participants were students and sufficiently tech-savvy to resolve the problems, for instance by installing a different mobile web browser or restarting the web browser. We recommend creating an experimental interface by using web technology over building native applications. This saves time by not having to create different versions and generally makes it available for a large range of smartphones. In addition, we recommend taking time to extensively test the web interface on different smartphone models and brands. This is particularly recommended when it is expected that participants are less tech-savvy.

7.2 Future work

We believe that human-city interaction will play a big role in the future of our society. In order to gain a better understanding of the methods we may use for such interaction, it is important to continue researching this topic. Based on findings from this report we suggest several aspects for future research.

First, we recommend that future work focuses on investigating new ways to form insights into how smart technology may enhance the quality of life in a city. During the qualitative interviews from the first part of this study, it was noted that using technology could be a valuable tool to gain insights about the emotional and social aspects of the users. We argued that an interesting way of gaining these insights could be offering inhabitants a democratic system with which they can control the smart technology in their neighbourhood. This system could collect valuable data to perhaps learn more about how people use the technology to enhance their quality of life. We believe future research could help shape ideas on what such a system may entail, how users interact with it and how it may help enhance the development of smart cities. By investigating this we can gain insight into how it may affect user participation, and whether it can aid in turning the disengaged city user-types into more actively engaged citizens.

Secondly, we recommend that future research on human-city interaction is performed in an environment that resembles its final use, with participants that represent its end-users (e.g. a neighbourhood and its inhabitants). We believe that researching at such a location may be critical for the interpretability and practicality of the results, especially for factors in which social context is critical, such as response on providing social feedback. Perhaps studying the effects of social feedback in a neighbourhood could reveal valuable information about the interplay of controlling smart technology and the social structure of a neighbourhood (e.g. considering the needs of elderly). In our study we found that participants scored high on perceived endurability (M all participants = 3.59), suggesting that participants would perhaps like to be able to control the public lighting of their own street. Also, the survey by Croes (2016) indicated that, at least the inhabitants of Strijp-S, would be interested in controlling the public lighting for example through a mobile application. This could be an indication that it could be valuable to continue human-city interaction research on the specific topic of smart public lighting. In addition to changing the location, it may also be interesting to extend the time and frequency users interact with the interface. During the experiment, users only interacted with the interface for a couple of minutes when casting votes. For future research it could be interesting to evaluate the interaction based on multiple sessions (for instance once every day for a week) as this more naturally reflects the intent of the final use of such an interface. Additionally, this could provide the opportunity for participants to experience the controlled light for a longer period of time, which may be needed for people to truly experience the light and how it impacts their daily function (e.g. walking the dog). Moreover, testing for a longer period of time could reveal insights about the engagement of the system: how long and how often participants are willing to control the public lighting. Perhaps it could even be studied how seasonal changes may affect for instance voting behaviour to control the public lighting.

Thirdly, we recommend continuing investigating the effects of social feedback in a human-city interaction interface. It could be valuable to gain a deeper understanding of the conditions in which providing social feedback positively or negatively affects satisfaction of using such an interface. Providing social feedback may be of key value in avoiding conflicts in the process of selecting an output for smart enabled objects in the city. Though, findings from current experiment may suggest that social context may affect whether providing such feedback is perceived positively or negatively. Additional research may be required to create a deeper understanding of these possible conditions.

Fourthly, in our experiment we utilized a specific input aggregation variant, namely repeated plurality voting. It was chosen to focus on this input aggregation method as it is commonly used in social media, and therefore perhaps known to participants. However, it is important to note that there are several other input aggregation methods that could be interesting to investigate. Examples of other methods could be the Least Misery strategy, or the Most Pleasure strategy, which take the minimum or maximum of ratings to select an output. For a full review of input aggregation strategies see Masthoff (2011). In addition to investigating other aggregation strategies, it could also be valuable to investigate additional means to measure the efficiency of the system. In current study, we mainly described efficiency as satisfaction with the voting process and resulting light, but perhaps there are other measures that offer a more complete evaluation.

Lastly, we encourage research that continues the investigation of the effectiveness of using a voting-model to create a system that allows users to control smart technology. In current study we utilized the up/down-vote user model to collect input for selecting the colour of public lighting. Although we found no significant effects of using the up/down-vote model versus the up-vote model, we would recommend for future research to further investigate the use of the up/down-vote model, and more specifically gain a better understanding of the consequences of providing a down-vote possibility to control smart enabled objects in the city. Perhaps employing this model in a different context (such as a neighbourhood), or using the model for a longer period of time (a few days instead of a couple of minutes) influences the behaviour of participants. Additionally, it could be interesting to investigate how participants react to receiving down-votes and whether they believe this system allows for increased justification over the up-vote model (Cheng et al., 2014). Finally, it could be interesting to investigate the effects a model in which multiple votes can be cast versus a model in which only one vote can be cast.

7.3 Limitations

This study has several limitations that may have influenced the results or their interpretability. In the following section, important limitations are discussed.

Firstly, as discussed before, this study had issues recruiting participants. This eventually led to a lack in statistical power, but importantly also to problems in balancing sample sizes between experimental conditions and sessions. For example, one session consisted of eighteen participants, while another session consisted of only three participants. It can be argued that as the group size becomes larger, one vote influences the group trend less and less. In a small group, a vote would therefore be more powerful than a vote in a large group. This may have had a critical influence on the results. To review the balance between conditions and sessions, see Table 2.

Secondly, the environment and the social structure of participants of this study may not completely represent an environment in which an interface to control smart public lighting may be used. Participants in this study may have not had the same interest in controlling the lighting as they may have had in their own street, where they live and spend more time. Participants may therefore differ from potential end-users, affecting the ecological validity of the study. Participants were mostly unfamiliar with each other, which is likely to be different from a somewhat more tightly knit social environment as a neighbourhood. In addition, the final use of an interface to control the public lighting would most likely not require users to gather at a certain location and stand next to each other, as was the case during this experiment. It would rather allow for users to control the lighting from inside their own houses, which may affect participants perceived anonymity.

Thirdly, it can be argued that participants had somewhat limited time to get to know the interface and get used the lighting scenario and how the light may have affected them. During the experiment, participants only had a couple of minutes to get used to the idea of controlling the public lighting with their smartphone and learn how the interface works. Participants may differ in the time needed to learn how the interface works. It therefore may be a good idea to distribute the interface to participants prior to the experiment.

Fourthly, performing an experiment was an effective method of gaining empirical data. However, it may have been valuable to gain some insight into more qualitative data by asking participants open questions at the end of the experiment. By gaining insight into this qualitative data, it may be easier to identify critical issues and offer a more detailed insight into participants' evaluation of using the interface (e.g. learn more about how people experience the possibility to down-vote).

Fifthly, as current study allowed participants to vote on a colour, perhaps participants colour preference biased the resulting colour of the lighting. It should therefore be noted that the outcomes of popular colours might not be generalizable for public lighting in general. Also, it could be that a strong individuals' preference for a certain colour overruled the conformance implied by the social feedback they received from other participants. Perhaps it is interesting to research whether this collaborative interface could allow for the control of for instance intensity and brightness of the public lighting, and investigate whether conformance implied by social feedback has a stronger effect on these settings.

Lastly, due to a lack of knowledge on how to perform statistical tests on the voting behaviour conformance over time, no clear evidence could be obtained to support our claims. We believe that it may be important for future studies to look into how this data could be tested in order to provide more clarity about possible differences in voting behaviour conformance.

7.4 Contribution

Cities are becoming smarter (Chourabi et al., 2012). Yet, currently not much has been written about how to interact with smart enabled objects in these smart cities. This study contributes to the existing academic literature as it explores the possible methods we can use for such interaction. More specifically, we focussed on the interaction with smart public lighting by providing an interface to collaboratively take control of this lighting. By performing an experiment we contribute insights based on empirical data concerning the use of voting models as user input and whether providing social feedback affects this voting behaviour. These insights may be valuable for the design of interfaces for human-city interaction in the future.

This research adds to the research done on the Social Translucence Framework. Where social translucence has mostly been investigated in the digital domain of Computer Supported Collaborative Work, this study may aid in understanding its mechanisms in a different context or social structure. Although results should be interpreted with care, findings may imply that there may be certain conditions in order for the provision of social feedback to be evaluated positively. It may be of interest for future studies to further investigate these possible conditions.

In addition, this study contributes to research done in using voting-models as user input. The up/down-vote model had mostly been utilized on popular social internet applications, but the effectiveness of using this model in applications that are more tightly coupled to the physical world were yet unknown. Due to the interesting social implications of providing the possibility to down-vote (Cheng et al., 2014), it is interesting to research the use of this up/down-vote model in different social structures. This study contributes to the research of using such a model in interfaces to collaboratively control smart public lighting or perhaps other smart enabled objects in smart cities.

7.5 Conclusion

The work presented in this thesis aimed as an exploration to gain insights into the possible methods we can use to create interfaces with which users can interact with smart enabled objects in the city, such as smart public lighting. In the first part of the study, we performed qualitative interviews with people that play an important role in the development of smart city Eindhoven. We noted that this development is currently well on its way, and applications are being tested and evaluated in the living labs. An interesting notion was proposed, suggesting that valuable insights concerning improving the quality of life with smart cities may be found by creating a real-time system that actually allows people to control the smart technology in their neighbourhood. We may learn over time, on the basis of votes, what people like and dislike in public lighting. This is valuable data for researchers and professionals in the public lighting domain. Offering people an informal, fast and easy way to engage with smart technology may allow for an increased participation of the disengaged monitorial and young user-types. In addition, creating such a system may be valuable to collect the data that we so critically need to advance our understanding of how lighting affects human behaviour, performance and experience. Formerly, when installing public lighting, research was mostly done prior to the instalment. However, with the new flexible capabilities of smart public lighting, research can also be done afterwards, allowing us to learn more about how to create optimal light settings for certain users.

The second phase of this study performed an experiment in which participants could collaboratively control smart public lighting with a mobile interface. This experiment provided an exploration for the design of interfaces for human-city interaction by investigating the effectiveness of providing social feedback and using a voting-model as input. Due to recruitment issues, results should be interpreted with care. Results from the experiment may suggest that providing social feedback may negatively affect user satisfaction with the voting process and selecting a specific output. In addition, providing the possibility to down-vote may negatively affect users' involvement with the voting. No clear distinctions were found in the voting behaviour of participants.

As urbanization presses and technology advances, we expect that the development of smart cities will continue to be an important topic for research in the future. As one of the main arguments for its development is improving the quality of life, we argue that it is important to continue to investigate the possibilities for citizens to interact with the smart city. By applying smart technology to objects in the city, new opportunities for such interaction will be made available, perhaps changing the way we currently experience living in one.

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Appendixes

Appendix A: Questionnaire Form

A Social Interface to Control Public Lighting
Questionnaire

1. What **number and letter** was on top of the screen in the smartphone application (e.g. 274F)?

____

2. What is your age?

____

3. What is your gender?

- Male - Female - Other

See next page.

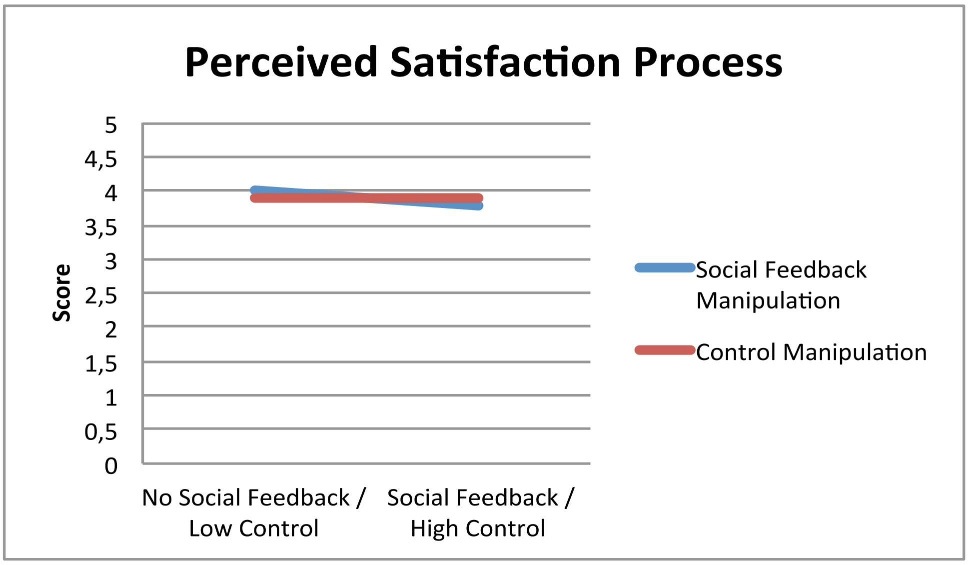
	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I think that other participants voted completely different than me.	1	2	3	4	5
I felt this experience was engaging.	1	2	3	4	5
I could see this system work in my own street.	1	2	3	4	5
I liked the process of setting the light.	1	2	3	4	5
I feel that the resulting light was a group decision.	1	2	3	4	5
The choices of other participants influenced my choices.	1	2	3	4	5
I am satisfied with the resulting light.	1	2	3	4	5
I enjoyed the process of setting the light.	1	2	3	4	5
I felt in control over the resulting light setting.	1	2	3	4	5
I felt involved when doing this task.	1	2	3	4	5
It would be nice to be able to do this in my own street.	1	2	3	4	5
I felt that the opinion of other participants was different than mine.	1	2	3	4	5
I am pleased with the light setting outcome.	1	2	3	4	5
I took the votes of other participants into consideration when voting.	1	2	3	4	5

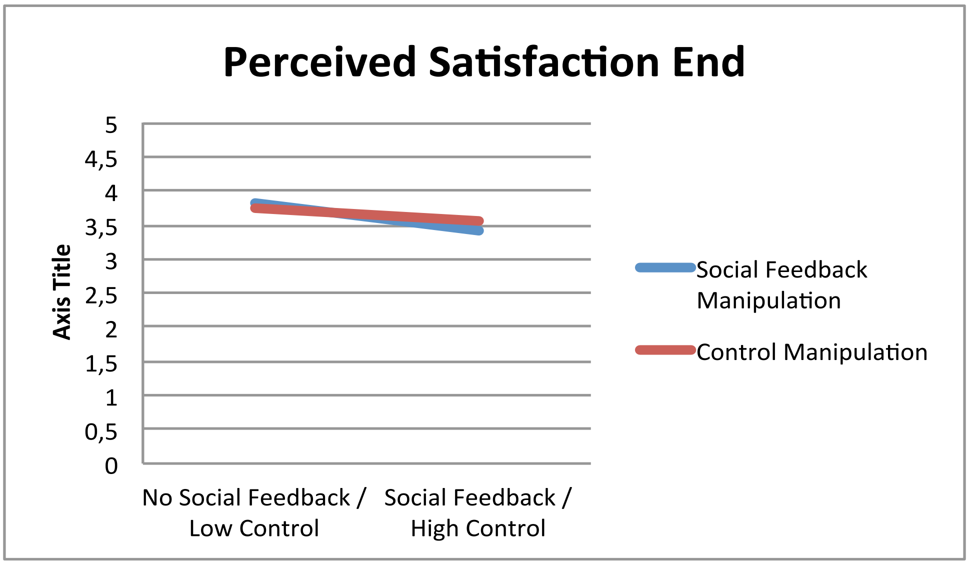
See next page.

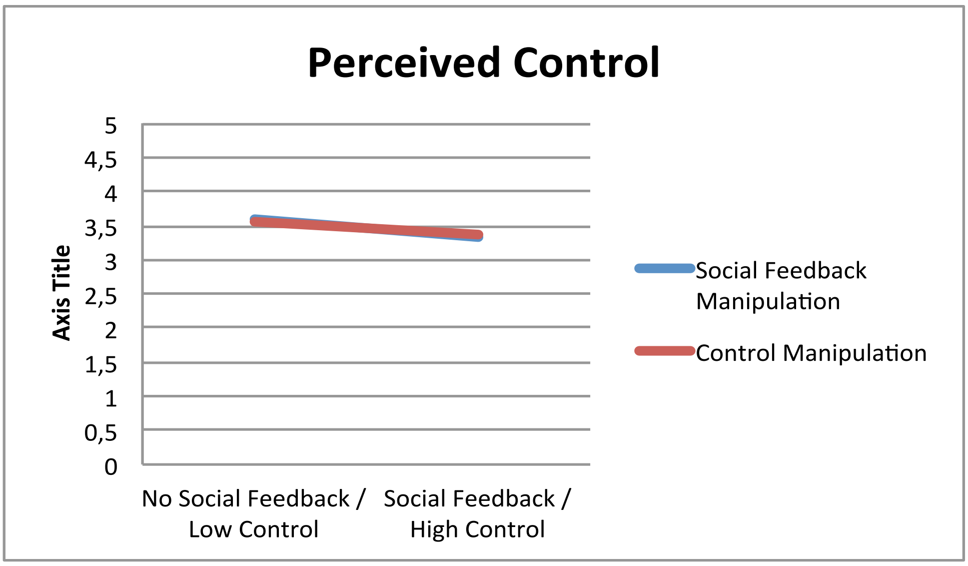
	Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
I think that other participants voted completely different than me.	1	2	3	4	5
I feel that the group voted together to reach a light setting decision.	1	2	3	4	5
I think that the process of setting the light was fun.	1	2	3	4	5
I felt that I could regulate the resulting light setting to my preference.	1	2	3	4	5
I was really drawn into the task.	1	2	3	4	5
I would like to be able to do this in my own street	1	2	3	4	5
The votes of others affected my voting behaviour.	1	2	3	4	5
I feel that other participants voted the same as me.	1	2	3	4	5
I am content with the resulting light setting decision.	1	2	3	4	5
I felt in charge of setting the light.	1	2	3	4	5

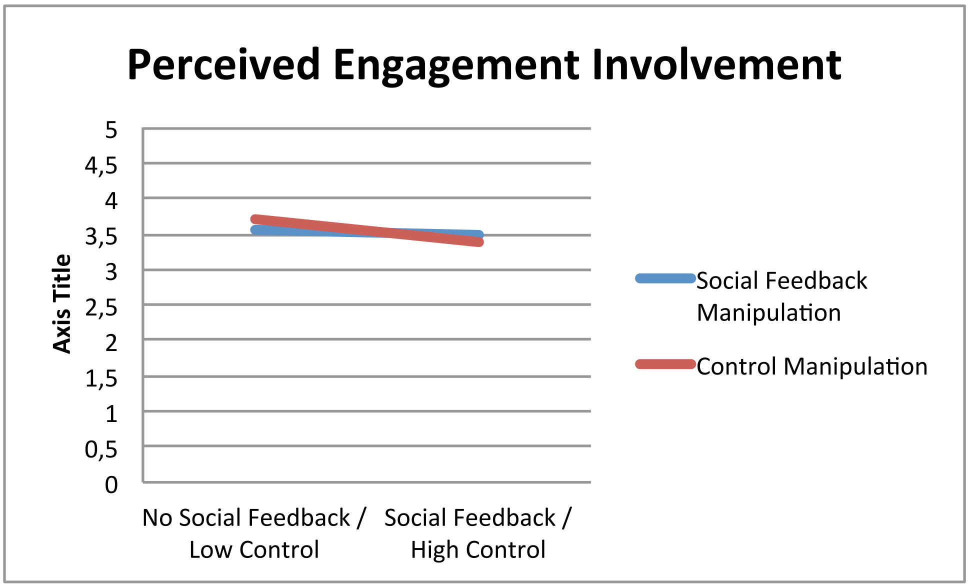
Thank you for your participation. Please hand in this form to the experiment leader to collect your compensation.

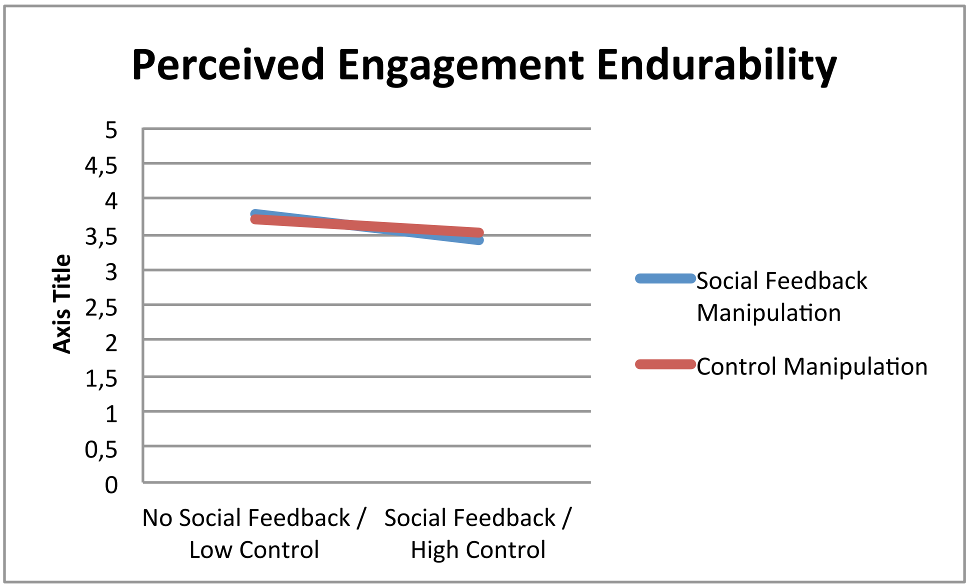
Appendix B: Interaction Effect Plots

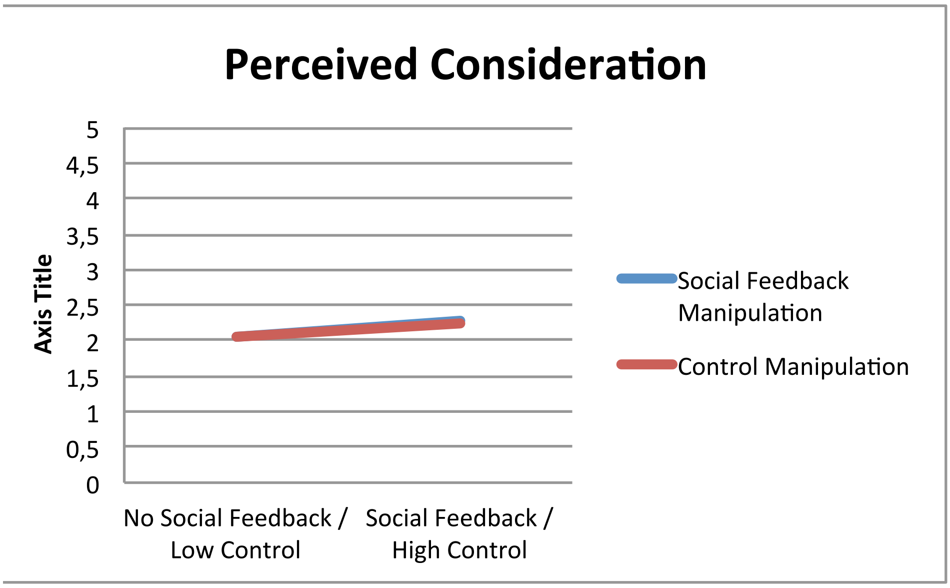


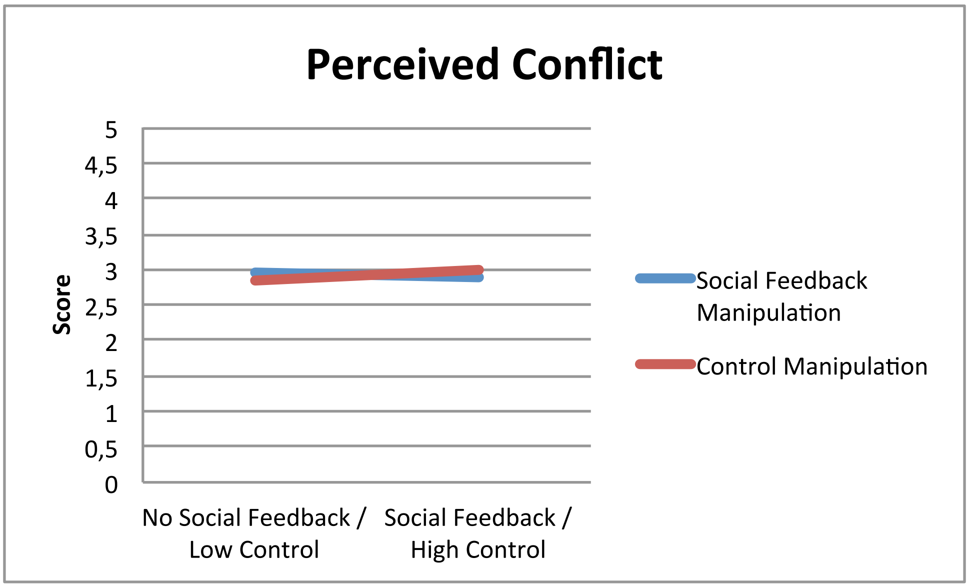





Perceived Engagement Involvement
Axis Title
5
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
No Social Feedback / Low Control
Social Feedback / High Control
Social Feedback Manipulation
Control Manipulation


Perceived Engagement Endurability
Axis Title
5
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
No Social Feedback / Low Control
Social Feedback / High Control
Social Feedback Manipulation
Control Manipulation


Perceived Consideration
Axis Title
5
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
No Social Feedback / Low Control
Social Feedback / High Control
Social Feedback Manipulation
Control Manipulation


Perceived Conflict
Score
5
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
No Social Feedback / Low Control
Social Feedback / High Control
Social Feedback Manipulation
Control Manipulation

Appendix C: Interface Frond-End Code (Javascript ES6)

```
import { Page, NavController, NavParams } from ‘ionic-angular’;
import { NgZone } from “angular2/core”;
import { AddModal } from ‘./../AddModal/AddModal’;
import { API_URL, SOCKET_URL } from ‘./../../constants’;
import { Page2 } from ‘./../page2/page2’;
import request from ‘axios’;

@Page({
    templateUrl: ‘build/pages/page1/page1.html’
})
export class Page1 {
    static get parameters() {
        return [[NavController]];
    }
    constructor(nav) {
        var vm = this;
        vm.data = [];
        vm.upvote = upvote;
        vm.downvote = downvote;
        vm.goToQuestionnaire = goToQuestionnaire;
        vm.refresh = refresh;
        this.tabs = document.querySelector(‘ion-tabbar-section’);
        this.nav = nav;
        // Helps view update in check.
        this.zone = new NgZone({enableLongStackTrace: false});
        this.socketHost = SOCKET_URL;
        this.socket = io(this.socketHost);
        // Socket Upvote
        this.socket.on(“upvote”, (data) => {
            console.log(‘Upvoted:’ + data.id);
            var selected = $.grep(vm.data, function(e) {
                return e._id == data.id;
            });
            // Fix for Safari
            this.zone.run(() => {
                selected[0].calculated = selected[0].calculated + 1;
                selected[0].upvotes = selected[0].upvotes + 1;
                sort(vm.data);
            });
```

```
});
// Socket Upvote Removed
this.socket.on("upvote-removed", (data) => {
    console.log('Upvote removed: ' + data.id);
    var selected = $.grep(vm.data, function(e) {
        return e._id == data.id;
    });
    this.zone.run(() => {
        selected[0].calculated = selected[0].calculated - 1;
        selected[0].upvotes = selected[0].upvotes - 1;
        sort(vm.data);
    });
});
// Socket Downvote
this.socket.on("downvote", (data) => {
    console.log('Downvoted: ' + data.id);
    var selected = $.grep(vm.data, function(e) {
        return e._id == data.id;
    });
    this.zone.run(() => {
        selected[0].calculated = selected[0].calculated - 1;
        selected[0].downvotes = selected[0].downvotes - 1;
        sort(vm.data);
    });
});
// Socket Downvote Removed
this.socket.on("downvote-removed", (data) => {
    console.log('Downvote removed: ' + data.id);
    var selected = $.grep(vm.data, function(e) {
        return e._id == data.id;
    });
    this.zone.run(() => {
        selected[0].calculated = selected[0].calculated + 1;
        selected[0].downvotes = selected[0].downvotes + 1;
        sort(vm.data);
    });
});

// Socket Get PP ID and Condition
this.socket.once("participant", (data) => {
    console.log('Participant: ' + data.id);
```

```
            vm.participant = data.id;
            console.log('Condition: ' + data.condition);
            vm.condition = data.condition;
        });
        activate();
        function activate() {
            getAll();
        }
        function getAll() {
            request.get(API_URL + 'lightsettings/').then(function(response)
{
                vm.data = response.data;
            });
        }
        function upvote(id, event, index) {
            event.preventDefault();
            event.stopPropagation();
            if ($(event.target.parentElement).hasClass('disabled')) {
                // Already Upvoted
                var target = event.target.parentElement;
                var targetParent = event.target.parentElement.parentEle-
ment;
                $(target).removeClass("disabled");
                $(targetParent).removeClass("disabled");
                var color = event.target.parentElement.parentElement.paren-
tElement.getAttribute('data-color');
                console.log(color);
                request.post(API_URL + 'lightsettings/' + id + '/upvote?re-
move=1', {
                    upvote: 1,
                    participant: vm.participant,
                    condition: vm.condition,
                    color: color,
                    rank: index
                }).then(function() {
                });
            } else {
                // Already Downvoted
                if ($(event.target.parentElement.parentElement).has-
Class("disabled")) {
                    event.preventDefault();
```

```
                    event.stopPropagation();
                } else {
                    // Upvote!
                    var target = event.target.parentElement;
                    var targetParent = event.target.parentElement.paren-
tElement;
                    $(target).addClass("disabled");
                    $(targetParent).addClass("disabled");
                    var color = event.target.parentElement.parentElement.
parentElement.getAttribute('data-color');
                    console.log(color);
                    request.post(API_URL + 'lightsettings/' + id + '/up-
vote', {
                        upvote: 1,
                        participant: vm.participant,
                        condition: vm.condition,
                        color: color,
                        rank: index
                    }).then(function() {
                    });
                }
            }
        }
        function downvote(id, event, index) {
            event.preventDefault();
            event.stopPropagation();
            if ($(event.target.parentElement).hasClass('disabled')) {
                var target = event.target.parentElement;
                var targetParent = event.target.parentElement.parentEle-
ment;
                $(target).removeClass("disabled");
                $(targetParent).removeClass("disabled");
                var color = event.target.parentElement.parentElement.paren-
tElement.getAttribute('data-color');
                console.log(color);
                request.post(API_URL + 'lightsettings/' + id + '/downvot-
e?remove=1', {
                    downvote: 1,
                    participant: vm.participant,
                    condition: vm.condition,
                    color: color,
```

```
                    rank: index
                }).then(function() {
                });
            } else {
                // Already Upvoted
                if ($(event.target.parentElement.parentElement).has-
Class("disabled")) {
                    event.preventDefault();
                    event.stopPropagation();
                } else {
                    // Downvote
                    var target = event.target.parentElement;
                    var targetParent = event.target.parentElement.paren-
tElement;
                    $(target).addClass("disabled downvote");
                    $(targetParent).addClass("disabled downvote");

                    var color = event.target.parentElement.parentElement.
parentElement.getAttribute('data-color');
                    console.log(color);
                    request.post(API_URL + 'lightsettings/' + id + '/down-
vote', {
                        downvote: 1,
                        participant: vm.participant,
                        condition: vm.condition,
                        color: color,
                        rank: index
                    }).then(function() {
                        //sort(vm.data);
                        //vm.data[index].calculated = vm.data[index].calcu-
lated - 1;

                        //vm.data[index].downvotes = vm.data[index].down-
votes - 1;
                    });
                }
            }
        }
        function refresh(refresher) {
            getAll();
            refresher.complete();
        }
```

```
        function sort(arr) {
            // arr.sort(function(a, b) {
            //     return b.calculated - a.calculated;
            // });
        }
        function goToQuestionnaire(){
            this.nav.push(Page2, {
                condition: vm.condition,
                participant: vm.participant
            });
        }
    }
    onPageDidEnter() {
        // Hide tabs!
        this.tabs.style.display = 'none';
    }
}
```

Appendix D: Interface Back-End Code (Express JS)

```
// BASE SETUP
// =========================================================================
=====
import { MONGODB_URL } from './app/constants';
import _ from 'lodash';

// call the packages we need
var http = require('http');
var express = require('express'); // call express
var app = express(); // define our app using express
var server = http.createServer(app);
var bodyParser = require('body-parser');
var morgan = require('morgan');
var io = require('socket.io').listen(server);

var mongoose = require('mongoose');
var Lightsetting = require('./app/models/lightsetting');
var Vote = require('./app/models/vote');
var Participant = require('./app/models/participant');
mongoose.connect(MONGODB_URL); // connect to our database

// configure app to use bodyParser()
// this will let us get the data from a POST
app.use(bodyParser.urlencoded({
    extended: true
}));
app.use(bodyParser.json());
app.use(morgan('dev')); // use morgan to log requests to the console

var port = process.env.PORT || 8070; // set our port


// ROUTES FOR OUR API
// =========================================================================
=====
var router = express.Router(); // get an instance of the express Router

// CORS
app.use(function(req, res, next) {
```

```
    var allowedOrigins = ['http://jsnijders.com', 'http://www.jsnijders.
com', 'http://localhost:8100'];
    var origin = req.headers.origin;
    if (allowedOrigins.indexOf(origin) > -1) {
        res.setHeader('Access-Control-Allow-Origin', origin);
    }
    res.header('Access-Control-Allow-Credentials', true);
    res.header('Access-Control-Allow-Methods', 'GET,PUT,POST,DELETE');
    res.header("Access-Control-Allow-Headers", "Origin, x-access-token,
X-Requested-With, Content-Type, Accept");
    next();
});

// middleware to use for all requests
router.use(function(req, res, next) {
    console.log('Something is happening @ the API.');
    next(); // make sure we go to the next routes and don't stop here
});

// get all the requests (accessed at GET http://localhost:8080/api/re-
quests)
router.route('/lightsettings?')
    .get(function(req, res) {
        Lightsetting.find().sort({
            calculated: -1
        }).exec(function(err, requests) {
            if (err)
                res.send(err);
            res.json(requests);
            console.log('Performed GET ALL');
        });
    })
    .post(function(req, res) {
        var lighsetting = new Lightsetting();
        lighsetting.color = req.query.color;
        lighsetting.save(function(err) {
            if (err)
                res.send(err);
            res.json({
                message: 'Setting created!'
            });
```

```
        });
    });
router.route('/lightsettings/:id/upvote?')
    .post(function(req, res) {
        if (req.query.remove == 1) {
            // Remove the upvote
            Lightsetting.findById(req.params.id, function(err, setting) {
                if (err)
                    res.send(err);
                setting.upvotes = setting.upvotes - 1; // update the re-
quests info
                setting.calculated = setting.calculated - 1; // update the
requests info
                // Save the Setting
                setting.save(function(err) {
                    if (err)
                        res.send(err);
                    res.json({
                        message: 'Setting upvote removed!'
                    });
                    io.sockets.emit('upvote-removed', {
                        id: req.params.id
                    });
                });
                // Get total calculated
                var currentCalculated = 0;
                var currentUpvotes = 0;
                var currentDownvotes = 0;
                // Search Light Settings
                Lightsetting.find({}, function(err, lightsettings) {
                  _.map(lightsettings, function(key, num){
                    currentCalculated = currentCalculated + key.calculated;
                    currentUpvotes = currentUpvotes + key.upvotes;
                    currentDownvotes = currentDownvotes + key.downvotes;
                  });
                  var vote = new Vote();
                  vote.lightSetting = setting._id;
                  vote.type = "Upvote Removed";
                  vote.currentUpvotes = setting.upvotes;
                  vote.currentDownvotes = setting.downvotes;
                  vote.currentCalculated = setting.calculated;
```

```
                vote.currentTotalCalculated = currentCalculated;
                console.log('Type: ' + vote.type);
                console.log('Calculated: ' + vote.currentTotalCalculat-
ed);
                vote.currentTotalUpvotes = currentUpvotes;
                console.log('Upvotes: ' + vote.currentTotalUpvotes);
                vote.currentTotalDownvotes = currentDownvotes;
                console.log('Downvotes: ' + vote.currentTotalDownvotes);
                vote.participant = req.body.participant;
                vote.condition = req.body.condition;
                vote.color = req.body.color;
                vote.rank = req.body.rank;
                vote.save();
              });
          });

        } else {
            Lightsetting.findById(req.params.id, function(err, setting) {
                if (err)
                    res.send(err);
                setting.upvotes = setting.upvotes + 1; // update the re-
quests info
                setting.calculated = setting.calculated + 1; // update the
requests info
                // save the request
                setting.save(function(err) {
                    if (err)
                        res.send(err);
                    res.json({
                        message: 'Setting upvoted!'
                    });
                    io.sockets.emit('upvote', {
                        id: req.params.id
                    });
                });
                // Get total calculated
                var currentCalculated = 0;
                var currentUpvotes = 0;
                var currentDownvotes = 0;
                // Search Light Settings
                Lightsetting.find({}, function(err, lightsettings) {
```

```
                _.map(lightsettings, function(key, num){
                  currentCalculated = currentCalculated + key.calculated;
                  currentUpvotes = currentUpvotes + key.upvotes;
                  currentDownvotes = currentDownvotes + key.downvotes;
                });
                var vote = new Vote();
                vote.lightSetting = setting._id;
                vote.type = "Upvote";
                vote.currentUpvotes = setting.upvotes;
                vote.currentDownvotes = setting.downvotes;
                vote.currentCalculated = setting.calculated;
                vote.currentTotalCalculated = currentCalculated;
                console.log('Type: ' + vote.type);
                console.log('Calculated: ' + vote.currentTotalCalculat-
ed);
                vote.currentTotalUpvotes = currentUpvotes;
                console.log('Upvotes: ' + vote.currentTotalUpvotes);
                vote.currentTotalDownvotes = currentDownvotes;
                console.log('Downvotes: ' + vote.currentTotalDownvotes);
                vote.participant = req.body.participant;
                vote.condition = req.body.condition;
                vote.color = req.body.color;
                vote.rank = req.body.rank;
                vote.save();
              });
          });
      }
  });
router.route('/lightsettings/:id/downvote?')
    .post(function(req, res) {
        if (req.query.remove == 1) {
            // Removed downvote
            console.log('Removing downvote');
            Lightsetting.findById(req.params.id, function(err, setting) {
                if (err)
                    res.send(err);
                setting.downvotes = setting.downvotes + 1; // update the
requests info
                setting.calculated = setting.calculated + 1; // update the
requests info
                // save the request
```

```
setting.save(function(err) {
    if (err)
        res.send(err);
    res.json({
        message: 'Setting downvote removed!'
    });
    io.sockets.emit('downvote-removed', {
        id: req.params.id
    });
});
// Get total calculated
var currentCalculated = 0;
var currentUpvotes = 0;
var currentDownvotes = 0;
// Search Light Settings
Lightsetting.find({}, function(err, lightsettings) {
  _.map(lightsettings, function(key, num){
    currentCalculated = currentCalculated + key.calculated;
    currentUpvotes = currentUpvotes + key.upvotes;
    currentDownvotes = currentDownvotes + key.downvotes;
  });
  var vote = new Vote();
  vote.lightSetting = setting._id;
  vote.type = "Downvote Removed";
  vote.currentUpvotes = setting.upvotes;
  vote.currentDownvotes = setting.downvotes;
  vote.currentCalculated = setting.calculated;
  vote.currentTotalCalculated = currentCalculated;
  console.log('Type: ' + vote.type);
  console.log('Calculated: ' + vote.currentTotalCalculat-
ed);

  vote.currentTotalUpvotes = currentUpvotes;
  console.log('Upvotes: ' + vote.currentTotalUpvotes);
  vote.currentTotalDownvotes = currentDownvotes;
  console.log('Downvotes: ' + vote.currentTotalDownvotes);
  vote.participant = req.body.participant;
  vote.condition = req.body.condition;
  vote.color = req.body.color;
  vote.rank = req.body.rank;
  vote.save();
});
```

```
            });
        } else {
            // Downvoted
            Lightsetting.findById(req.params.id, function(err, setting) {
                if (err)
                    res.send(err);
                setting.downvotes = setting.downvotes - 1; // update the
requests info
                setting.calculated = setting.calculated - 1; // update the
requests info
                // save the request
                setting.save(function(err) {
                    if (err)
                        res.send(err);
                    res.json({
                        message: 'Setting downvoted!'
                    });
                    io.sockets.emit('downvote', {
                        id: req.params.id
                    });
                });
                // Get total calculated
                var currentCalculated = 0;
                var currentUpvotes = 0;
                var currentDownvotes = 0;
                // Search Light Settings
                Lightsetting.find({}, function(err, lightsettings) {
                  _.map(lightsettings, function(key, num){
                    currentCalculated = currentCalculated + key.calculated;
                    currentUpvotes = currentUpvotes + key.upvotes;
                    currentDownvotes = currentDownvotes + key.downvotes;
                  });
                  var vote = new Vote();
                  vote.lightSetting = setting._id;
                  vote.type = "Downvote";
                  vote.currentUpvotes = setting.upvotes;
                  vote.currentDownvotes = setting.downvotes;
                  vote.currentCalculated = setting.calculated;
                  vote.currentTotalCalculated = currentCalculated;
                  console.log('Type: ' + vote.type);
                  console.log('Calculated: ' + vote.currentTotalCalculat-
```

```
ed);
                    vote.currentTotalUpvotes = currentUpvotes;
                    console.log('Upvotes: ' + vote.currentTotalUpvotes);
                    vote.currentTotalDownvotes = currentDownvotes;
                    console.log('Downvotes: ' + vote.currentTotalDownvotes);
                    vote.participant = req.body.participant;
                    vote.condition = req.body.condition;
                    vote.color = req.body.color;
                    vote.rank = req.body.rank;
                    vote.save();
                  });
              });
          }
    });

// REGISTER OUR ROUTES -------------------------------
// all of our routes will be prefixed with /api
app.use('/api', router);

// SOCKET
var socketCounter = 0;
io.on('connection', function(socket) {
    console.log('Socket Connected');
    socketCounter++;
    console.log('Connected users: ' + socketCounter);
    // Generate PP ID
    Participant.findOne({}, {}, { sort: { 'connectedOn' : -1 } }, func-
tion(err, post) {
        var participant = new Participant();
        participant.participant = post.participant + 1;
        participant.save();
        io.sockets.emit('participant', {
            id: participant.participant,
            condition: participant.condition
        });
    });

    socket.on('disconnect', function() {
        socketCounter--;
        console.log('Socket Disconnected');
        console.log('Connected users: ' + socketCounter);
```

```
    });
});

// START THE SERVER
// ========================================================================
=====
server.listen(port);
console.log('Magic happens on port ' + port);
```