

INTEGRATING VIRTUAL WORLD WITH CHOICE
EXPERIMENT METHOD: CASE OF RESIDENTIAL
STORMWATER MANAGEMENT MEASURES

BY

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DISSERTATION

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Abstract

This dissertation is a pioneering study that integrates the concept of social presence to choice experiment method by enhancing the level of social presence while presenting attributes information to participants. I employed a virtual world platform and designed two experiments that are differentiated in terms of the level of social presence while describing attributes of a choice experiment study to participants. The impact of this integration was explored using four metrics. First, the impact on marginal utility (i.e. importance) of attributes was examined. The results showed no significant difference between the two conditions. Second, the impact on error variance and goodness of fit were tested. I found a minor improvement for the high social presence condition, which was not statistically significant. Third, the impact of social presence on self-reported measures was examined. The two sub-samples were not significantly different in terms of self-reported measures. However, the whole sample reported high level of attribute clarity, involvement and motivation. Therefore, I conducted an exploratory analysis and found a significant correlation between social presence and attribute clarity. This finding implied that a relationship existed and the original finding indicating no significant difference of self-reported measures between the two treatments (low and high social presence) might be due to design issues. Therefore, new regression analysis was conducted to test the relationship between social presence and self-reported measures. Significant relationship between social presence and outcomes such as attribute clarity, motivation, involvement, and effectiveness of movie in task performance and decision-

making, was found. This is a promising result, which implies that social presence may be able to enhance the choice experiment method. The finding that social presence predicts outcomes such as higher clarity of attributes, higher level of motivation and higher level of involvement may have implications in addressing comprehension, fatigue and boredom issues of participants while participating in a choice experiment study. The possible outcome would be more accurate estimate.

Second, I designed a choice experiment to study residents' preferences for selected public and private attributes of residential level stormwater management strategies. The choice experiment study is novel in estimating the value of residential level LID attributes. My study adds to the literature and extends the field of choice experiment by identifying and examining the role of LID attributes at a small residential scale (micro level). I found that basement flooding reduction and water quality improvement and neighborhood flooding reduction have positive marginal values while maintenance and cost have negative marginal values. Basement flooding reduction has the highest value, followed by water quality improvement and neighborhood flooding reduction. Based on these results, it can be recommend that city planners and designers promote LID techniques by focusing on their ability to solve basement flooding issues. Residents would also be more likely to adopt LID techniques if rebates and incentives to compensate the costs were offered.

The fact that people valued the effectiveness of LID in providing public attributes such as water quality improvement and neighborhood-flooding reduction is a promising finding.

It shows that people value public attributes and are willing to pay for LID techniques that are effective in providing these attributes. Valuing the neighborhood flooding reduction may have implications for private provision of climate adaptation while valuing water quality improvement may have similar implications for private provision of public environmental good such as water quality improvement.

In addition, the data on LID familiarity showed that residents overall had low levels of familiarity with LID techniques, particularly with rain gardens and permeable pavement. They had higher levels of familiarity with rain barrels. Therefore, there is a need for more educational programs that cover different types of LIDs, not just rain barrels.

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I dedicate this dissertation to my grandfather who was among the first in his generation that earned a college degree. He was an inspiring visionary who always encouraged us to continue our education to the highest level possible. He led a life that will continue to sustain aspirations of higher education for generations to come. I also dedicate this dissertation to my wonderful husband, Reza, whose ongoing love, support and encouragement made my grandfather's vision and my own dream a reality!

Table of Contents

Chapter 1 - Introduction.....	1
1.1 Foreword	1
1.2 Background	2
1.3 Problem Statement and Motivation of the Study	5
1.4 Objectives and Research Questions	9
1.5 Research Contributions	14
1.6 The Dissertation Structure	19
Chapter 2 - Literature Review.....	20
2.1 Introduction	20
2.2 Choice Experiment Modeling	20
2.3 Communication and New Media	29
2.4 Urban Stormwater Management	33
2.5 Conclusion	39
Chapter 3 - Theoretical Framework and Choice Experiment Method.....	40
3.1 Introduction	40
3.2 Social Presence Theory	40
3.3 Choice Experiment Methodology	43
3.4 Conclusion	56
Chapter 4 - Research Methodology	58
4.1 Introduction	58
4.2 Problem Statement	59

4.3	Generating Attributes and Their Levels for the CE	60
4.4	Experimental Design.....	72
4.5	Designing the Survey Instrument for Choice Experiment.....	74
4.6	Survey implementation and data collection.....	87
Chapter 5 - Analysis and Results		90
5.1	Introduction.....	90
5.2	Data	90
5.3	Sample Descriptive / Basic Statistics.....	93
5.4	Social Presence Formation.....	99
5.5	The Results of Choice Experiment	105
5.6	Impact of Social Presence on CE Outputs	112
5.7	Exploring Factors Affecting the Importance of Attributes	121
5.8	Extension of the Study: Explanatory Analysis of Variables.....	125
5.9	Conclusion	128
Chapter 6 - Conclusion and Future Research		133
6.1	Summary of the Study	133
6.2	Summary of the Results	135
6.3	Interesting Findings	138
6.4	Methodological Contribution and Implications	139
6.5	Theoretical / Other Contribution and Implications	140
6.6	Limitations and Future Research	143
References.....		147
Appendix A - Scenarios		165

Appendix B - The Scripts	170
Appendix C – Low Impact Development Scenarios.....	174
Appendix D – Survey.....	176

Chapter 1 - Introduction

1.1 Foreword

Choice experiment (CE) is an attribute-based valuation method that offers promising advantages over other valuation methods. It provides more flexibility and information compared to other valuation methods. It allows the inclusion of both environmental and social attributes and hence estimates the importance of these attributes as well. However, its attribute-based nature poses some concerns about the cognitive burden on participants filling out a CE survey. The number of attributes and the way they are being presented to a respondent plays an important role in participants' decision making process and hence the accuracy of estimates. Therefore, information provision (both the amount of information and the information format) can determine the complexity of the CE survey and therefore the accuracy of CE estimates.

With regards to information provision, one field that offers great potential to address the comprehension and cognitive burden of CE surveys is virtual world and virtual reality. Virtual world offers distinctive characteristics that may be able to enhance CE design and accuracy of estimates. However, the potential role and advantages of these tools in enhancing CE design has not been explored much. This dissertation uses an interdisciplinary approach, linking three bodies of literature together, to explore the possibility and potential of virtual world in improving CE design and therefore estimates. The primary goal of this dissertation is to employ a virtual world and explore the role of

specific characteristics of this environment, namely social presence, on CE model and outputs.

This question will be explored in the context of urban stormwater management. The secondary focus of the dissertation is to explore public's preferences for residential level urban stormwater management strategies using the CE surveys. Section 1.2 provides a background of the CE and virtual world, section 1.3 describes the problem statement and the study's motivation, and section 1.4 explains the research objectives and research questions in more detail. Finally, section 1.5 points out the research contributions.

1.2 Background

Choice experiments (CE) or choice-based conjoint analysis is a stated preference method used to elicit consumer valuation of nonmarket goods (i.e. Adamowicz et al., 1998a; Boyle et al., 2001) and marketable goods with novel attributes (i.e. Darby et al, 2008; Tonsor et al., 2005). The application of stated choice method in environmental valuation offers promising advantages over other valuation methods (Hanley, et al, 2001).

The increasing popularity of CE types of surveys is partially in response to recognized problems of contingent valuation by the National Oceanic and Atmospheric Administration (NOAA) panel in 1990 (Hausman, 1993). In contrast, choice experiment methods identify tradeoffs among different products or service attributes relative to other approaches (Hanley, et al., 2001). CE is based on Lancaster's characteristics theory of value (Lancaster, 1966) that means a good can be described in terms of its attributes and

characteristics. The utility of a good is derived from the attributes and characteristics that it provides, not from the good itself. For example, the utility of a car is obtained through attributes such as speed, brand, color and gas efficiency. Therefore value of each product or policy and service would be defined as a set of attributes. While methods such as contingent valuation (CV) would just ask people how much they are willing to pay for a policy that improves water quality, CE would provide them with a list of attributes of the policy including the water quality improvement. This approach makes the context more real since it offers more information to participants.

However, this extra information comes at a price. The attribute-based nature of the choice experiment method makes it a cognitively demanding method (Hanley et al., 2001). Stated choice text passages may be quite extensive, especially when explaining scientific concepts and technical measurements to lay subjects (Keeney, 1992). Participants are asked to choose between bundles of attributes, which may induce cognitive burden to participants when filling out the survey. On the other hand, arguably one main disadvantage of the CE approach is comprehension and the cognitive difficulty associated with multiple complex choices or ranking between bundles with many attributes and levels (Hanley et al., 2001). There is ample evidence that show there are limits to how much information respondents can meaningfully handle while making a decision (Hanley et al., 2001). As a result they may adopt decision heuristics as a strategy to simplify a complex decision problem (see Loewenstein, 2001) for a review of the concept.

The way in which these attributes are described and presented to respondents plays a key role in comprehension of attributes and therefore the final outcomes (Kragt, et al., 2012). The more people understand the more accurate their expressed preferences or choices would be. Since the results of CE studies are increasingly being used to support policy development, the validity and reliability of the value estimates are very important (Kragt, et al., 2012)

To address the complexity problem of CEs, there have been lots of studies on information provision in CE design. Information provision studies cover multiple dimensions, ranging from the optimum number of attributes and alternatives (design dimension) to information format (the way information is presented to participants). Information formats determine nominal complexity—the level of complexity that respondents experience Kragt, et al., 2012). With regard to information format, there has been a growing amount of literature showing the effectiveness of using visual stimuli in promoting comprehension, reducing complexity and enhancing evaluability of information (Krupnick et al., 2006; Mathews et al., 2006 ; Bateman et al., 2009). Visualization started with incorporating simple visual stimuli such as graphs and pictures in CE surveys. Later, more sophisticated techniques were used, such as 3D videos and most recently virtual environments (including virtual world platform environments and virtual reality). The use of virtual environments has been more common in the field of marketing and design than in environmental valuation. It has only recently been used in environmental valuation (Bateman et al., 2009, Reichhart et al., 2010).

Virtual environments (virtual reality and virtual world) provide a rich extension to visualization methods by offering an immersive environment and adding dynamic rendering over time (Fiore et al., 2009). Bateman et al. (2009) showed that conducting a CE in virtual reality would decrease the willingness to accept (WTA) and willingness to pay (WTP) asymmetry and could enhance the accuracy the CE outputs (Bateman et al, 2009). This new trend is the primary motivation of my research. My proposed research aims to employ a virtual world platform and explore the role of virtual world characteristics in enhancing CE design and accuracy. Despite the possible potential of virtual world and virtual reality in enhancing CE design, their role and potential contributions have not been much explored. In fact, there have not been many studies that specifically examine the role of virtual environment characteristics and their potential contribution to CE. This dissertation attempts to fill this gap by exploring the impact of a selected characteristic of virtual world (namely social presence) on choice experiment model and outputs.

1.3 Problem Statement and Motivation of the Study

Choice experiment is a non-market valuation method that has been brought to environmental studies over the last two decades. The attribute-based nature of method provides more information and outputs for analysis, but it also induces some complexity to participants who take the choice experiment survey. There has been growing concerns over comprehension of information in these surveys. To address the comprehension issues, one recent promising approach has been to use virtual environments in choice

experiment surveys.

Virtual world offers a promising approach to enhance information presentation in CE surveys. Although virtual environments have been used in choice experiment surveys before, the extent to which these virtual characteristics may enhance the choice experiment has not been explored.

Virtual world offers distinct characteristics and possibilities such as immersion and presence (Bulu, 2012). Presence consists of two interrelated phenomena (Heeter, 1992; Biocca, 1997): spatial (physical) presence--the sense of “being there,” and social presence--the sense of “being together with another” (Bulu, 2012).

These characteristics may be able to address the challenge of information comprehension, information evaluability, and information complexity in the choice experiment methodology. For example, the role of social presence on learning has been studied in online education literature (Richardson et al., 2003). These studies suggest that when information is presented in a way that increases social presence, this information is better remembered and learned and Learning process is considered more engaging (Homer et al., 2008).

Because enhancing social presence while presenting information can contribute to better comprehension outcomes, it may help solve the problems of comprehension and complexity in choice experiment surveys. This has not been explored and is the motivation for my dissertation. My proposed research is the first attempt to explore the

potential contribution of social presence to choice experiment methodology. This dissertation explores to what extent and how the level of social presence may enhance or affect choice experiment models and outputs.

Another objective of my dissertation is to enhance the level of social presence when presenting attribute information to CE participants. By enhancing the level of social presence, the learning process may be improved, which may contribute to increased comprehension and reduction of complexity for CE participants, hence producing more accurate results.

This idea will be explored in the context of urban climate adaptation (stormwater management) and therefore this dissertation is expected to contribute to the urban stormwater management literature by exploring people's preference for residential level urban stormwater management strategies.

Low Impact Development (LID) strategies are novel approaches to urban stormwater management and cost effective strategies for climate adaptation. Cities are more prone to surface water flooding due to an increase in impervious surface. The surface flooding is expected to be exacerbated by increased precipitation as a result of climate change (Mees & Driessen, 2011). Therefore, adopting LID would not only be useful to manage urban stormwater (rain water runoff) but also an effective strategy to respond to future climate-induced precipitation and flooding issues. LID, which encompasses a range of characteristics and attributes, not only manages rainwater and flooding but also provides multiple benefits and services (Wise et al., 2010). LID is a unique strategy that responds

to pollution and flooding risks while providing other environmental benefits, such as water quality improvement, heat reduction and carbon sequestration (Grant & Gallet, 2010). Because it has multiple attributes and multiple benefits, it is an ideal candidate for a choice experiment approach to examine the role of its different attributes on participants' choices and decision-making.

Residents and households as potential investors and adopters of LID practices can play a major role in successful implementation of LID practices. Therefore, residents' responses and motivations to invest in LID are important to stormwater managers and program developers. Hence, the secondary objective of this dissertation is to elicit preferences for private and public attributes of residential level LID strategies. From these results, stormwater managers could learn about incentives and barriers of the public's LID adoption.

In summary, this dissertation uses an interdisciplinary approach and brings together theories from media and communication literature and environmental economics literature to explore the possibility of enhancing the design of choice experiment method. The research is guided by three main sets of theories: random utility theory, Lancaster's characteristics theory of value and social presence theory. The premise of the study is that the degree of social presence provided in a CE may systematically affect subjects' responses and the model's outputs.

In order to enhance the level of social presence, a virtual platform called Second-Life (SL) was adopted. The attributes of the choice experiment study were built and visualized

in this platform. A virtual human agent avatar was adopted to present these attributes through a virtual tour. The literature on social presence confirms that human-like agents (e.g., avatars) enhance the perception of social presence (Sundar, 2008; Verhagen et al., 2014). The presence of an avatar could cue “the social presence heuristic” and thereby increase involvement and comprehension (Sundar, 2008).

To test this, I estimate a preference model that can capture differences in responses between a low social presence information presentation treatment (Non-avatar attribute presentation) and a high social presence information presentation treatment (Avatar presents attributes).

The general and particular objectives and research questions I wish to address are as presented in the next section.

1.4 Objectives and Research Questions

The objectives of this research could be classified into two main categories: General Objectives and Specific Objectives. The General Objectives focus on the design of the study and scenarios. The Specific Objectives then focus on the core contributions of this study.

1.4.1 General Objectives

The General Objectives are:

1. To design attributes of a choice experiment study in a virtual environment.

This will be achieved by employing a virtual world platform (Second life: www.secondlife.com) and constructing a virtual neighborhood that depicts the attributes of the choice experiment study. The choice experiment is being used to explore resident preferences for adoption of residential level stormwater management strategies, called Low Impact Development (LID). In order to visualize the LID attributes, two different neighborhoods will be constructed in Second life. In neighborhood one, the residents have installed LID techniques, while the residents of the second neighborhood have not. The selected private and public attributes of LID techniques, will be demonstrated in 3D virtual format.

2. Low and high social presence information (attribute) presentation scenarios were designed within the neighborhoods. In order to enhance the level of social presence while presenting attributes, an avatar performs a virtual tour of the attributes of the choice experiment for respondents.

1.4.2 Specific Objectives

The specific objectives are divided into two categories: primary and secondary objectives. The primary objectives are the ones that lead to the main contribution of the dissertation, while the secondary objectives are those existing under the umbrella of the main ones.

Primary objectives:

The primary objectives of this study are to explore the impacts of social presence on

choice experiments. Specifically:

1. The first primary objective is to examine the formation of social presence between the two treatments of the study. This will be done by comparing the results of self-reported perception of social presence between the avatar and non-avatar attribute presentations. In order to address this goal, two specific Research Questions have been developed:
 - a. Are the two treatments significantly different in terms of social presence formation (perception of social presence)?
 - b. Which treatment shows a higher level of social presence?
2. The second primary objective is to examine the role of low and high social presence information (attribute) presentation on choices and preferences of respondents in a choice experiment study. This will be done in three ways: First, by comparing the differences in attribute importance for the two low and high social presence treatments (based on estimated coefficients). Second, by comparing the two models for differences on scale of error variance. It is expected that the social presence will reduce the complexity by enhancing the learning and engagement of participants. Reducing complexity can reduce the use of decision heuristics. (Loewenstein, 2001). The use of fewer heuristics is expected to lead to a smaller estimated error variance for the treatment with a higher level of social presence. Third, we explore the difference in social presence by comparing the goodness of the fit between the two models. In order to address these objectives, several specific Research Questions have been developed:

- a. How do low and high social presence information presentations affect the importance of attributes (attribute's relative weight, i.e. the coefficients) and their willingness to pay (WTP)? Which attributes are more affected by level of social presence? This research question specifically addresses the enhancement of learning and engagement of participants.
 - b. How do low and high social presence models differ in terms of error variance (scale of error variance in choice model)? This research question addresses whether a higher level of social presence has improved the decision making process for participant or not.
 - c. How do the low and high social presence models differ in terms of the goodness of the fit? This research question is very close to the above questions it focuses on the impact of the social presence on the ability of the participants to make a better connection between the attributes and their choices.
3. The third primary objective is to examine the difference in the clarity of self-reported attributes under different levels of social presence and to examine the role of social presence on attribute comprehension. This objective also includes the analysis of the role of social presence on self-reported task performance and attribute clarity. In order to address these goals, two specific Research Questions have been developed:
 - a. How is self-reported attribute clarity different for a low and high social presence information presentation format? What is the role of social

presence, and does it affect attribute comprehension?

- b. How do low and high levels of social presence affect task performance and experience of complexity for participants who complete the choice cards? Does the difference in the level of social presence affect people's understanding of choice cards and task performance?

Secondary objectives

The secondary objective is to apply CE to urban stormwater management, which is the context of the study. First, the goal is to identify the important attributes of residential level stormwater management strategy called low impact development (LID) for residents. Which attributes of LID are valued higher by residents, when considering adoption of LID? Since the price of LID is listed as one attribute, it is possible to estimate the willingness to pay (WTP) for this attribute of LID as well. The next goal is to identify the factors that affect the importance of those attributes. In other words, what factors including socio-economic characteristics, housing characteristics and attitudes would affect the importance of each attribute? The secondary objectives and their corresponding research questions are listed below:

1. I seek to examine preferences for selected public and private attributes of LID.

This research aims to find out what benefits people would consider when exploring the possibility of adopting LID techniques, and what barriers would impact people in their decision to adopt LID techniques, as shown in the research question below.

- a. Which attributes (private and public) are more important for residents?
What are the tradeoffs between different attributes? What is the Willingness to Pay (WTP) for attributes?
2. This research aims to examine the role of factors that may influence the importance of attributes. Those factors include but are not limited to: familiarity with LID techniques, the housing characteristics, the socio-economic characteristics, previous flooding experience and the role of rainwater attitudes and risk perception.
 - a. What is the impact of familiarity with LID techniques on importance of attributes?
 - b. What is the impact of housing characteristics such as type of housing, ownership, and type of basement on importance of attributes?
 - c. What is the impact of socio-demographic characteristics (such as age, gender, education and income) on importance of attributes?
 - d. What is the impact of prior flooding experience (neighborhood and basement) on importance of attributes?
 - e. What is the impact of rainwater attitudes and risk perception on importance of attributes?

1.5 Research Contributions

This dissertation makes a number of important contributions. First, it brings the concept of social presence to choice experiment for the first time. There has been growing

concern over participants' information comprehension in CE surveys. There is an emerging understanding that enhancing the level of social presence contributes to learning and comprehension. This dissertation explores to what extent and how the level of social presence may enhance the choice experiment method. The study is methodologically innovative in its integration of social presence in a choice experiment. To my knowledge, this is the first choice experiment study specifically examining the role of social presence on preferences and value estimates using a virtual world platform. The objective is to explore the possibility of an approach that may have the potential to enhance the accuracy of choice experiment value estimates by enhancing comprehension and learning of information presented in choice method surveys, therefore providing more accurate information for policy developers.

Integrating social presence into choice experiment methodology is a novel approach. It may potentially contribute to and extend environmental valuation literature. The promise of the social presence concept is that it offers a new dimension that may improve the design of CE by enhancing learning and comprehension and reducing complexity. The creation and enhancement of perception of social presence is easier and more cost effective compared to other characteristics of virtual worlds such as visualization or perception of spatial presence. Social presence can happen in a variety of media and is not limited to virtual world. It is one distinct characteristics offered by virtual worlds but not limited to virtual world. Researchers have examined social presence in a variety of mediated communication contexts (text, email, video, teleconference systems). Therefore, the findings of this research will have implications for other media contexts

and can be extended to choice experiment studies employing other media formats. If social presence is found to be effective in addressing the complexity and comprehension issues in CE surveys, we have found a cost effective way to address these issues. Conducting CE surveys inside virtual reality or virtual world could be expensive and time consuming while producing a high level social presence scenario to be used for information presentation is less expensive and time consuming.

Second, this dissertation uses an interdisciplinary approach and integrates three literatures and therefore extends those literatures as well. It brings new theories and concepts from communication and new media literature to environmental valuation literature and applies environmental valuation tools to urban stormwater management literature.

Third, the study adopts a virtual world platform to present attributes of a choice experiment, and the effectiveness and validity of this platform will be tested. The use of virtual world is new in the environmental valuation field and there have been very few studies using it or validating its use. Virtual world can enhance immersion and presence and increase a sense of realism for participants. Studying environmental preference is more difficult than studying market goods, since the context is not as familiar as market goods. The familiarity issue poses more challenges to accuracy of responses. The possibility of simulating real-world environmental scenarios in a virtual-world environment would contribute to the field by reducing bias that may happen due to unfamiliarity of the environmental context.

Fourth, the study may enhance public participation in decision making by facilitating the use of virtual world in preference studies. New technological formats, such as the use of virtual world, are increasingly used in marketing, transportation, and environmental valuation research. Employing technologies such as virtual world to study preference and conduct environmental valuation studies may induce more participation from a younger population.

Fifth, besides the methodological contributions of this research, the results of this study contribute to urban stormwater management research by providing insights into citizens' response to LID and the importance of LID attributes for citizens. LID practices are innovative decentralized stormwater management techniques that manage rainwater by storing it on site and therefore reduce surface water run-off and combined sewage overflows from increased precipitation rates (Oberndorfer et al., 2007). They are unique because they manage rain water runoff, and prevent flooding and sewage overflow while offering multiple ecosystem benefits as well. Benefits include but are not limited to enhancing biodiversity, contributing to urban pollution abatement, improving air and water quality, and mitigating the urban heat island effect. Therefore, LID techniques contribute to overall urban sustainability and increase the resilience and adaptability of the cities facing future climate induced precipitation and flooding (Mees et al., 2013). LID practices are called "no regrets" climate adaptation measures for the same reason (Mees et al., 2013). Some LID practices such as green roofs and trees also deliver private benefits to property owners (e.g., energy savings, thermal comfort, aesthetics) (Mees et al., 2013). Despite their great potential and multiple applications, knowledge about their

important attributes and public motivation to adopt these practices is low. One reason for the lack of knowledge may be the lack of methodological approaches, which allow people to investigate the relative importance of factors related to the adoption of LID practices. This study presents an approach for exploring these factors in a holistic manner using a virtual world platform.

Successful implementation of LID is of great interest to local governments since they serve multiple societal goals (Tompkins et al., 2010; Berrang-Ford et al., 2011). Residents play an important role in LID's successful implementation. The LID managers and program designers need to know what factors influence residents' decisions when it comes to adopting LID. The findings of this study can shed light on such factors. The impact of socio-economics characteristics and attitudes on preferences will be explored as well. This will provide more insights for LID managers and program developers on factors influencing adoption of LID.

The results of this research may also add some insights into private provisions of public goods, since both private and public attributes are being studied. Few scholars have discussed the private provision of climate adaptation (Tompkins et al., 2012). LID practices as a no regret climate adaptation measure are good examples of a private provision of climate adaptation service.

1.6 The Dissertation Structure

Chapter 2 presents the literature review. Chapter 3 discusses the theoretical framework as well as the methods used in this study. The first section begins with explaining the theory of social presence as well as methods of constructing and measuring the social presence index. The second section explains the theoretical foundation and the process of developing the choice experiment. Chapter 4 goes over the experimental design, the design of the virtual neighborhood, the survey design and data collection. Chapter 5 presents and discusses the findings. Chapter 6 presents a summary and conclusion, discusses the limitations of the study, and suggests directions for future research.

Chapter 2 - Literature Review

2.1 Introduction

This interdisciplinary research is built on three main bodies of literature: environmental valuation (choice experiment modeling), communication and new media (virtual world characteristics), and urban stormwater management (low-impact development techniques). The following sections discuss each of these literatures.

2.2 Choice Experiment Modeling

Choice modeling is often referred to in the literature as “choice experiment” (Alpízar et al., 2001), “stated choice” (Adamowicz et al., 1998b; Louviere et al., 2000), and “attribute based stated choice method” (Adamowicz & Boxall, 2001). Choice modeling has its origin in conjoint analysis; the terms “conjoint analysis” and “choice experiment” are used interchangeably in the literature. In this study, the term “choice experiment” (CE) is adopted.

Choice experiment is an attribute-based valuation method and is particularly suited to situations where changes are multi-dimensional and tradeoffs between them are of particular interest (Hanley et al., 2001; Louviere, Hensher, and Swait, 2000). Its inherent ability is to separately identify the value of individual attributes of a good or program. While other valuation methods are able to provide such estimates, they generally are unable to do the combination of attributes (Hanley et al., 2001). It would take several

studies and much greater cost to employ the same study using other valuation methods such as contingent valuation (Hanley et al., 2001; Louviere et al., 2000). The method was initially developed in the marketing and transportation literature by Louviere and Hensher (1982) and Louviere and Woodworth (1983). Over the last two decades, it has been applied in many areas, such as health research (Ryan, 1999; Ryan & Hughes, 1997) and environmental economics (Adamowicz et al., 1994; Hanley et al., 1998). Other areas of application include forest (Horne et al., 2003; Lehtonen et al., 2003; Rolfe et al., 2000), wetland (Carlsson et al., 2003), renewable energy (Alvarez-Farizo & Hanley, 2002) and energy-efficient techniques (Kwak et al., 2010).

2.2.1 Advantages and Limitations

Choice experiment offers a range of advantages over other valuation methods. However, like other methods, it has its limitations. These advantages and limitations related to the context of our study are discussed below.

Advantages

The application of choice experiment method in environmental valuation offers promising advantages over other valuation methods (Hanley et al., 2001). The CE method relies on social science surveys for data collection, as does the related contingent valuation (CV) method (Bateman et al., 2002; Perrings, 1995a). However, instead of asking questions such as, Are you willing to pay \$X to obtain Y amount of services? Choice experiments focus on tradeoffs among different attributes of that service

(Louviere et al., 2000). One concern with CV method is the possibility of “yea-saying,” whereby respondents indicate that they are willing to pay for an alternative when in reality, they are not (Blamey et al., 1999). The choice experiment does not have this problem since the respondent would see a bundle of attributes to select from, not a yes/no option. Other advantages of choice experiments over the CV include improved flexibility, increased information provision, and increased realism (Hanley et al., 2001; Rolfe et al., 2000). The other example is the study of Adamowicz et al. (1998a) that confirmed that CE outperforms CV in applied analysis. Therefore, CE is usually the preferred technique for the economic valuation analysis (Blamey et al., 1999).

Limitations

Despite being a promising approach and offering significant advantages over traditional valuation methods, choice experiment does have its limitations. It is well documented in research that intended response from stated-choice surveys tends to be biased (Louviere et al., 2000).

One main limitation is related to the attribute-based nature of CE. Stated choice text passages may be quite extensive, especially when explaining scientific concepts and technical measurements to lay subjects (Keeney, 1992). Therefore, one main disadvantage of the CE approach is the cognitive difficulty associated with multiple complex choices or ranking between bundles with many attributes and levels (Hanley et al., 2001). The way in which these attributes are described and presented to respondents plays a key role in final outcomes.

Both experimental economists and psychologists have found evidence that there is a limit to how much information respondents can meaningfully handle while making a decision (Bateman 2009; Hanley, et al., 2001) or decision heuristics (e.g., information filtering) potentially happens. Previous research studies that indicate the occurrence of heuristics in a stated choice experiment include Hensher, Rose, and Bertoia (2007), Hensher, Rose, and Greene (2005), and (Hensher, 2006). Heuristics and information filtering happens when participants intend to simplify information presented to them (Hoehn et al., 2010). It means that respondents tend to undervalue or give less importance to or even eliminate information that they believe to be less relevant and give significance to information that they believe to be more salient or important (Hoehn et al., 2010).

2.2.2 Choice Experiment and Information Provision

Two major bodies of literature address the complexity issues of CE surveys with regard to information provision: First, the information load or task complexity literature that studies the complexity according to design dimensions (i.e., studying the number of attributes, number of options, and number of choice cards). Second, information format literature that studies the way information is presented in CE surveys. This literature addresses complexity by offering different information formats such as visualization, decision aid tools such as 3-D multimedia, virtual worlds, and virtual reality in choice experiment surveys. The following section presents a more comprehensive review of these two areas.

2.2.2.1 The Role of Information Load/Design Dimension

Information provision is one major challenge in designing CE studies (Gao et al., 2010) that is, providing enough information to be able to accurately elicit consumer preferences and at the same time make the length of CE reasonable. In either case, *too few* or *too many* attributes can have a negative impact on the results. Too many attributes can lead to respondents considering only a few attributes instead of all attributes. Too few attributes make the product concept too unrealistic. Consequently, these results are no longer useful (Gao et al., 2010). In the CE literature, the number of attributes, alternatives, and number of choice cards are studied as choice task complexity or task-based complexity (Arentze et al., 2003). Task-based complexity is related to the absolute number of attributes or alternatives in one choice set, and the total number of choice sets faced by a respondent (Arentze et al., 2003). Examples of studies that have examined task-based complexity include Payne (1976), Swait and Adamowicz (2001a), DeShazo and Fermo (2002), Sandor and Franses (2004), Sandor and Wedel (2005), and Conlon et al. (2001a). Dellaert and Stremersch (2005) and Conlon et al. (2001a, 2001b) studied the impact of task complexity on choices of consumer goods, while DeShazo and Fermo (2002, 2004) examined similar impacts in individuals' visits to recreational sites.

The general finding of these studies is that the complexity of choice tasks has an important influence on choice decisions. Therefore, the design dimensions (number of attributes and levels, number of options, and number of choice cards) as well as the content and format of information play an important role in choice decisions.

2.2.2.2 Information Format (Information Presentation)

Information format is another factor in experiencing/creating complexity. Information formats in CE survey determine nominal complexity (the level of complexity that respondents experience) (Hoehn et al., 2010). Previous studies suggest that attribute presentation and the way it is conveyed to respondents affect their susceptibility to larger and/or more frequent errors of judgment (Bateman et al., 2009). Social science research beyond stated choice analysis identifies methods to control the decision effects of complexity and information load, particularly through the use of alternative information formats (Hoehn et al., 2010). These alternative information formats range from simple diagrams and tables to more sophisticated formats such as photos, 3-D multi-media videos, and, recently, virtual worlds and virtual reality.

Several authors have studied the effectiveness of visualization in reducing complexity and enhancing comprehension. Lipkus et al. (1999) show that visual information outperforms numeric data as a basis for accurate comprehension of risk. Workman (2008) reported that diagrammatic formats significantly reduce cognitive effort and performance errors relative to text-only displays. Other studies confirming the superiority of visual information over numeric and text include Luck and Vogel (1997), MacGregor and Slavic (1986) and Ganier (2001). Luck and Vogel (1997) concluded that subjects assimilate and remember more information when presented with both text and graphical representations as opposed to text alone. Using visualizations in stated preference studies is becoming a widespread practice. There is also a growing consensus in environmental

valuation and choice experiment studies that an effective route for promoting comprehension, reducing complexity, and enhancing information evaluability (Hess, 1996) is via the use of visual stimuli (Bateman et al., 2009; Krupnick et al., 2006; Mathews, Freeman, & Desvousges, 2006). Visualizations help to convey realistic change scenarios, reduce reliance upon response heuristics, and thereby allow underlying preferences to be more effectively measured (Bateman et al., 2009). They also reduce the fatigue of respondents and thus help prevent tiring effects (Dijkstra et al., 2003). Other examples include Arentze et al. (2003), Brouwer and Schaafsma (2013), Gudishala et al. (2010), Johnston et al. (2002), Morse-Jones et al. (2012), Nguyen et al. (2013), Olschewski et al. (2012) and Ryffel et al. (2014).

Visual information is not limited to graphs and pictures but includes 3-D, movies, and other types of multimedia. The role and contribution of these media in environmental field is not new. Stock and Bishop (2005) linked GIS to a realistic 3-D model to show, in real-time, the visual and environment effects of land use change in a rural context. Heft and Nasar (2000) used video films to compare static with dynamic representations of rural landscape. They suggested that the dynamic representation mode seems to be more robust for preference research.

Examples of CE and multimedia

Richarme and Colias (2008) used 3-D animation to present a hypothetical marketing scenario in their study. They found that the amount of work and level of frustration were higher among respondents who used the traditional approach (i.e., text-based survey) and

that participants preferred 3-D animation to the traditional approach in terms of cognitive burden and in presenting a more realistic environment. Klabbers et al. (1996) proposed a multimedia engine for stated choice and preference experiments that enables researchers to use varying presentation formats (textual, pictorial, and auditory, and combinations of these), thereby measuring the influence of the presentation format. Other examples of 3-D visualizations include, for example, Dijkstra et al. (2003), Laing et al. (2009), Hensher et al. (2007) and Rid and Profeta (2011).

2.2.3 Emergence of Virtual Reality and Virtual World CE

Recently, a lot of attention has been paid to the concept of virtuality in visualization.

Virtual reality (VR) and virtual world (VW) provide a rich extension to the visualization method by offering an immersive environment and adding dynamic rendering over time (Fiore et al., 2009). They have the potential of generating both the internal validity of lab experiments and the external validity of field experiments (Fiore et al., 2009). Researchers have begun to use VR technology to create virtual environments or landscapes as experimental platforms for the measurement of environmental response. Fiore et al. (2009) conducted a study of wildfire prevention policies using VR technology. (Bishop et al., 2001) conducted studies that allowed the respondents to visualize a recreational area using 3-D rendering and walk virtually around that area. Their findings were encouraging for the future use of virtual environments and confirmed the validity of virtual world to be used for preference studies. Chesney et al. (2009) explored the scientific potential of virtual worlds for experimental economics in terms of

the subject pools and experimental platforms they present. Their results offered tentative, qualified support for virtual world experimentation. Some authors have expressed the advantages of conducting controlled economic decision-making experiments in virtual worlds (Bainbridge, 2007; Bloomfield, 2007; Castranova, 2006). Recent advances within the field of virtual reality (VR) and virtual world (VW) visualization have opened up the possibility of directly addressing complexity and comprehension issues of CEs (Bateman et al., 2009).

Examples of CE using virtual world and virtual reality

The Bateman et al. (2009) study suggests that employing virtual reality to conduct a non-market valuation study might enable the ability to address some existing anomalies of decision making in standard economic theory. Other examples of using virtual reality in choice experiment studies include Dijkstra et al. (2003), Berneburg (2007), Bateman et al. (2009). Dijkstra et al. (2003) presented an alternative design of an office in a virtual reality environment. Berneburg (2007) tested the virtual reality in terms of its usability in a choice-based conjoint study and confirmed that the 3-D simulation does not create bias as a result of immersion. The study showed that the simulation provides much better test results in terms of estimated utilities and conjoint importance than simple two-dimensional stimuli (Berneburg, 2007).

In summary, the majority of studies have confirmed the validity of using virtual world and virtual reality in choice experiment studies. However, the tools are still in their infancy, and more explorations and needed to confirm their validity. Researchers need to

explore how and to what extent different modalities of these environments may trigger positive or negative perception in participants. It should not be assumed that different modalities would spark positive perception all the time. For example, Sundar (2000) found that college-age participants showed that text-only and text-plus-picture modalities triggered more positive evaluations from receivers than did audio and audiovisual modalities. Therefore, the studies should be extended to test the role of different modalities and characteristics of virtual worlds and virtual realities.

2.3 Communication and New Media

Despite the adoption of virtual world and virtual reality in choice experiment studies, their potential roles and possible contributions have not been explored much.

Virtual environment (VE), including virtual world and virtual reality platforms, offers unique characteristics, for example, interactivity, immersion, and presence. Immersion and presence are two distinct characteristics of VE. Immersion is characterized as a psychological state in which the individual perceives himself/herself to be enveloped by, included in, and interacting with an environment that provides a continuous stream of stimuli (Witmer & Singer, 1998). The concept of presence has been conceptualized differently across various theoretical models. Presence, in some cases, has consisted of two interrelated phenomena (Biocca, 1997; Heeter, 1992): *spatial presence* or *physical presence*: the sense of “being there”; and *social presence*: the sense of “being together with another.”

Since the objective of the study was to explore the impact of social presence on choice experiment, a comprehensive literature review was conducted to learn about social presence. The following section presents the review.

2.3.1 Social Presence

The concept of social presence has its base in telecommunication literature. Social presence is increasingly being acknowledged as an important factor for understanding the effects of new media. Hwang (2005) and Short et al. (1976) developed social presence theory as a model for analyzing the social psychological dimensions of mediated communication from a “social cues perspective.” They defined social presence as “the degree of salience of the other person in the interaction and the consequent salience of the interpersonal relationships” (Short et al., 1976). Different scholars have defined social presence in different ways across the field. Biocca et al. (2003) offers a comprehensive definition of social presence, defining it as simply the “sense of being with another” in a mediated environment, whether that other is human or artificial.

Social presence was one of the earliest concepts provided to explain media usage in organizational settings (Durlak, 1987). It describes the degree to which a communication medium approximates the personal characteristics of a face-to-face interaction (Bulu, 2012; Durlak, 1987). For a detailed discussion of the literature on social presence, see Gunawardena (1995) and Gunawardena and Zittle (1997).

2.3.1.1 The Creation/Development of Social Presence

Social presence was originally studied in traditional media such as audio and closed circuit television (as well as face-to-face communication). J. Towell and E. Towell (1997) examined the users' experience of "being with others" in a text-based virtual environment (e.g., MUDs). Tu (2002) examined the relationship between social presence and various types of Computer Mediated Communication (CMC).

Studies suggest that interactive virtual environments created by some Internet technologies foster social presence (Mikropoulos et al., 2011). Research has shown that computer users psychologically assume a social presence while interacting with a computer (Sundar & Nass, 2000), to the point of applying social rules in their interaction (Reeves & Nass, 1996), including longer-term affiliations such as loyalty (Sundar, 2004). This is demonstrated even in the absence of any visibly anthropomorphic features of the technology, although if there are cues in the interface that represent human characteristics such as voice, language, and personality (Isbister & Nass, 2000), the social presence heuristic appears to be more strongly invoked (Sundar, 2008). On the other hand, when the technology possesses cues that invite anthropomorphism, it may produce the social presence heuristic (Sundar, 2008).

They have identified that the design of a communication system influences its level of social presence and the extent that it conveys feelings of sociable and sensitive human contact. For example, adding human images (Cyr et al., 2009) and personalized greetings (Gefen & Straub, 2003) to an Information technology (IT) artifact have all been shown to

positively influence perceptions of social presence. According to Verhagen et al. (2014), humanlike virtual customer service agents (VCSA) are likely to elicit high feelings of social presence as well. By simulating human behavior and having the ability to visually represent human representatives, VCSAs cue human characteristics, which in turn may elicit social responses and can also convey feelings of warmth (Nass & Moon, 2000). Short et al. (1976) viewed social presence as a quality of the communications medium itself and hypothesized that “communications media vary in their degree of social presence.” Differences on factors contributing to social presence and the importance of each of those factors are highly individualized (Hwang, 2005).

2.3.1.2 Outcomes of Social Presence Experience

The first phase of research on social presence started in telecommunication literature (Short et al.) in 1970s. The second phase (1980 to early1990) focused on computer mediated communication (CMC). The third phase was early to mid-1990 to the present and became focused on online learning (Rourke et al., 2001). Social presence has been identified as key to the level of learner participation and success of online collaboration (Lakin, 2005). It is now a central concept in online learning (see Benbunan-Fich, Hiltz, & Harasim, 2005). According to Homer et al. (2008), a general finding of the body of research into social presence and learning is that when information is presented in a way that increases social presence, it is better remembered by learners, and the learning process is considered more engaging. Some find that social presence is a significant

predictor of the user's satisfaction with interactive television classes and text-based computer conferences (Cobb et al., 2009).

It is generally accepted that people are most receptive to media with a high degree of social presence (Chang & Ian, 2012). Media with a high degree of social presence are perceived as being warm, personal, sensitive, and sociable (Short et al., 1976).

2.4 Urban Stormwater Management

In this study, the choice experiment is being conducted in the context of urban stormwater management. Urban areas are more prone to surface water flooding due to an increasing level of impervious surfaces and a decreasing level of green space (Mees et al., 2013). In response to the surface water flooding and managing the runoff, local governments are implementing stormwater management strategies (Dietz, 2007). Residents as potential adopters of low-impact development (LID) practices can play an important role in its successful implementation. The goal of this study is to elicit preferences for selected private and public attributes of residential level LID techniques to inform stormwater managers on public values and preferences for these attributes.

In order to develop the important attributes of LID to be used for the choice experiment, a comprehensive literature review was required to learn about different types of LID practices and their effectiveness, costs, benefits, and other characteristics. The following section presents the review.

2.4.1 Low-Impact Development Practices

Urban stormwater runoff has been exacerbated by urbanization due to loss of permeable surfaces. Stormwater runoff causes different types of environmental problems. For example, frequent routing of stormwater runoff to urban streams is the primary stressor to this aquatic ecosystem (Paul & Meyer, 2001).

Conventional stormwater management has been designed primarily to collect the stormwater runoff, hence reducing issues such as flooding caused by the runoff. Recently, there has been a new generation of decentralized stormwater management as an alternative to gray infrastructure, called “green infrastructure” (GI) or low-impact development practices. Green infrastructure or low-impact development practices are innovative, decentralized stormwater management strategies that seek to manage runoff using distributed and decentralized micro-scale controls. These practices are generally referred to as systems and practices that use or mimic natural processes to capture, infiltrate, evapotranspire (the return of water to the atmosphere either through evaporation or by plants), or reuse and harvest of rainwater runoff (through rain barrels and cisterns) on the site where it is generated (Benedict et al., 2006). There is no universal definition for green infrastructure, but it can broadly be defined as *an interconnected network of natural areas and other open spaces that conserve natural ecosystem value and functions, sustain clean air and water, and provide a wide array of benefits to people and wildlife* (Benedict et al., 2006).

Low-impact development techniques (practices) encompass a range of practices from

large scale ones such as detention ponds, wetlands, reforestation, and protection and enhancement of riparian buffers and floodplains to small-scale practices that can be adopted at residential/household level (examples include green roofs, trees, tree boxes, rain gardens, vegetated swales, infiltration planters, porous and permeable pavements, vegetated median strips. By adopting these practices, the rainwater would be kept out of the sewer system so that it does not contribute to a combined sewer overflow (Foster et al., 2011). New York, Philadelphia, Seattle, and Portland, among other major American cities, have identified that LID must play a significant role to solve their combined sewer overflow problems (Olorunkiya et al., 2013). Adopting LID techniques will also reduce the amount of polluted runoff discharging to surface waters, and hence enhancing the quality of water in nearby streams and rivers (Benedict et al., 2006).

In summary, LID is a proactive, comprehensive, and holistic approach to manage storm water runoff while providing multiple environmental benefits. It is anchored on two main principles: first, LID views stormwater as an asset to be used, and not as waste. Second, LID provides the opportunity to landscape to mimic pre-developed on-site hydrology (Olorunkiya et al., 2013).

In light of emerging LID practices, scholars and organizations are studying their values, effectiveness, costs, and benefits. In the next section, a summary of these studies is presented. It should be noted that the terms “green infrastructure” and “low-impact development” are being used interchangeably in the literature because several elements

of LID—such as preserving natural drainage and landscape features—fit right into the green infrastructure approach. In this study, low-impact development has been adopted.

2.4.2 The Value of Low-Impact Development (LID): Costs and Benefits

The costs and benefits of LID have been studied through several different approaches. Two common methods of measuring the economic costs and benefits of stormwater controls include the *cost-effectiveness* and the *benefit-cost* methods (economic valuation of GI). Another approach is quantification of benefits; see Grant & Gallet (2010). The Center for Neighborhood Technology (CNT) has done a comprehensive study that calculated the runoff reduction of different LID practices and quantified the benefits accordingly (Grant & Gallet, 2010). Other studies have shown the financial benefits of adopting green infrastructure and LID over gray infrastructure (Benedict et al., 2006; Grant & Gallet, 2010). The Center for Neighborhood Technology has also developed a tool that quantifies the benefits and cost saving of adopting green infrastructure over gray infrastructure¹.

Besides financial and economic benefits, there are multiple environmental and social benefits associated with implementation of LID techniques. Some major examples of benefits are illustrated below.

Environmental Benefits: LID practices offer multiple environmental benefits (Wise et al., 2010). Examples include improving water quality and flooding reduction (by reducing

¹ <http://greenvalues.cnt.org/national/calculator.php>

the volume of runoff and the pollutant loadings discharged into receiving waters), urban heat reduction, and improving air quality (Wise et al., 2010).

Ecosystem services: Another construct to study the benefits of green infrastructure was first introduced by the Millennium Ecosystem Assessment (MEA 2005). Millennium Ecosystem Assessment describes four different types of ecosystem services:

provisioning, regulatory, supporting, and cultural. Provisioning services include all the products obtained from ecosystems, for example, genetic resources, food and fiber, and fresh water (Kumar, 2010). Regulating services control ecosystem processes, for example, ameliorating air, water, and solid waste pollution, climate extremes, flooding, erosion, disease, pests, and natural hazards. Supporting services include long-term and less visible processes such as soil formation, photosynthesis, and nutrient and water cycling. Finally, cultural services are the non-material benefits that people derive from nature. This category includes the opportunities for cultural, spiritual, inspirational, aesthetic, educational, and recreational experiences provided by diverse ecosystems (Kumar, 2010).

Climate change mitigation and adaptation: Recently, Green urban infrastructure and LID have gained a lot of attention as a cost-effective resource for climate change mitigation and adaptation strategies (e.g., Demuzere et al., 2014; Gill et al., 2007; Mees et al., 2013)

Other benefits include landscape aesthetics, enhancing property values and energy savings, habitat creation, and encouraging environmental stewardship (Kloss et al., 2006). The health benefits of green space have been studied in variety of settings and

contexts (see Henwood, 2002; Kweon et al., 1998; Thompson & Aspinall, 2011). The general summary is that green urban space has value for improving mental and physical health for urban residents.

The above literature review was conducted to learn about different types of LID practices, LID attributes, and LID valuation. The literature review was used to develop LID attributes for the choice experiment study (see Chapter 4).

2.4.3 Public preferences and values for Low-Impact Development techniques

Low-impact development techniques are new emerging practices; therefore, there have not been many studies to examine public preferences and values for these practices. (Bowman et al., 2012) studied the value of LID features used in a neighborhood. They employed four types of valuation methods. The majority of respondents indicated they would be willing to pay for pervious pavers and rain gardens in their neighborhood (Bowman et al., 2012).

Although there have been many studies on green space valuation using choice experiments (see Bullock, 2006, 2008; Ravenscroft et al., 2005) and stormwater management valuation (Jorgensen & Syme, 2000), there have been only two studies applying choice experiment directly to LID practices. First, the study by Cadavid et al., (2013), which measured the value of multiple attributes of stormwater management outcomes. They found that people value reduced basement flooding more than reductions in yard or street flooding, and willingness to pay exist if they are already experiencing

basement flooding. The study also found that citizens valued both improved water quality and improved hydrologic function and aquatic habitat from runoff reduction. The second study by Olorunkiya et al. (2013) elicited stakeholders' preferences for five types of generic LID incentives within the New Zealand context. The study findings showed that incentivizing implementation of LID infrastructure, in general, will positively mediate stakeholders' LID-adoption decisions.

2.5 Conclusion

The literature review was conducted on three major fields that this dissertation is built on.

First, the choice experiment part provided a background and reviewed the complexity issues induced by information load and information format of CE surveys. It also reviewed the trend of responding to the problem in information format (information presentation) literature. Second, the related literature in communication was reviewed and presented. A short summary of distinctive characteristics of virtual world and an elaboration of the selected characteristics for this study, social presence, its development and outputs, was conducted. Third, the urban stormwater management and low-impact development techniques literature was reviewed. Stormwater runoff issues and problems, as well as the role and potentials of LID techniques to address those problems, were reviewed. Different types of LID, and their benefits, public preferences, and LID valuation studies were reviewed as well. The review revealed that despite multiple benefits and services provided by these practices, there have not been many studies on assessing their values and the preferences of the public to adopt such practices.

Chapter 3 - Theoretical Framework and Choice Experiment

Method

3.1 Introduction

This study takes a novel approach and links theories from environmental economics and communication literature to study the impact of social presence on the choice experiment model and outputs. This chapter will go over the theories that were used in this study as well as the methods including conceptualization of social presence and design of the choice experiment method that is the major part of this study. The theories will be explained in the following sections: Section 3.2 goes over social presence theory, conceptualization, and measurement of social present. The fundamental theories of choice experiments and the process of conducting them are explained in section 3.3

3.2 Social Presence Theory

SP theory has been explained in literature review. The following sections review how it is being conceptualized and measured in the literature.

3.2.1 Conceptualizing Social Presence

There are multiple ways to conceptualize the concept of social presence. Conceptualizing social presence means theorizing the experience of the feeling of social presence to examine what it is that cues the perception of social presence in a virtual environment.

Social presence is described as a construct that comprises a number of dimensions relating to the degree of interpersonal contact (Short et al., 1976). Biocca et al. (2003) systematically reviewed the conceptualization and measures of social presence, suggesting that social presence was in the past conceptualized using three categories: co-presence, psychological involvement, and behavioral engagement. However, they separated the categories of co-presence and psychological involvement into four dimensions to measure social presence: co-presence, social richness, involvement, and social attraction (Chand & Ian, 2012).

When conceptualizing a social presence in a study, based on the context of study, related dimensions will be selected and adjusted for the purpose of the study. Depending on the context and purpose of study, social presence can be conceptualized as a multi-dimension construct or uni-dimensional construct.

The purpose of this summary is to shed light on how social presence is being theorized and conceptualized in the field of communication. The field of communication and new media as the main discipline that studies social presence is interested in different dimensions; therefore, multiple dimensions are being studied and evaluated. However, for the context of this study and the research objectives, the specific dimension explained above would not be necessary. The goal is to examine the impact of social presence on the choice experiment method; therefore, a general conceptualization of social presence will be sufficient. Hence, this study has adopted a uni-dimensional approach, and social presence has been conceptualized as a uni-dimensional concept. Future studies can

examine different dimensions of social presence such as co-presence, attention allocation, and socialness, and extend the application of social presence to the choice experiment method.

3.2.2 Measuring Social Presence

The next step after theorizing the concept of social presence is to develop ways to identify, measure, and test social presence theories. Measures are based on the conceptualizations of social presence (Biocca et al., 2003).

Biocca et al. (2003) suggest three broad approaches to measure social presence. These categories include subjective self-reported measures, behavior indicators, and psychophysiological measures. It seems that subjective self-reported measures have been adopted as the most reliable tool among the three tools. Our study has adopted the same tool to measure the formation of social presence. This measure is explained in the next section.

Behavioral indicators or behavioral measures are common in studies of face-to-face interactions, where they are used as measures of interrelated variables such as involvement and immediacy. Some of the verbal or nonverbal indicators (such as voice or facial expression) may be indicative of social presence (Biocca et al., 2003).

Psychophysiological measures can include things like MRI, measuring physiological attributes to test the formation of social presence. The psychophysiological measures have not been performed, but they can offer new insights if applied (Biocca et al., 2003).

3.2.3 Subjective Self-Reported Measures

Subjective self-reported measures use a bi-polar scale that involves participants to rank those scales on 5-to-7-point Likert scale² from negative to positive. One of the early examples is Gunawardena (1995) who used a bi-polar scale and had students to rank 17 bi-polar scales on a 5-point Likert-type scale (from negative to positive). It seems that subjective self-reported measures have been adopted as the most reliable tool among the three tools discussed above. Our study has adopted the same tool to measure the formation of social presence. (See Biocca et al., (2003) for a review)

3.3 Choice Experiment Methodology

As discussed in Chapter 2, choice experiment (CE) methodology involves generating and analyzing choice data by constructing a hypothetical market using a survey. Each respondent is presented with several choice sets, each containing a set of mutually exclusive hypothetical alternatives. The participants are then asked to choose their preferred alternative. Alternatives are defined by a set of attributes, each attribute taking one or more levels. Basically, the respondent's choices imply implicit tradeoffs between the levels of the attributes among the different alternatives included in a choice set.

Because a good can be described in terms of its attribute levels, changing those levels will essentially result in a different good being produced (Bateman et al., 2002). Choice

² The Likert Scale is a rating scale commonly used in questionnaires. Respondents choose a their level of agreement or disagreement on a symmetric scale. For example, a 7-point Likert Scale is completely disagree, disagree, somewhat disagree, neither agree nor disagree, somewhat agree, agree, completely agree.

modeling focuses on the value of such changes in the attributes, and is especially useful in a policy context by identifying the following (Bateman et al., 2002):

1. Which attributes are significant determinants of the values people place on nonmarket goods
2. The implied ranking of these attributes
3. The value of changing more than one of the attributes at once
4. The total economic value of a resource or good

In the following section, we elaborate on theoretical foundation and the design stages of the choice experiment method.

3.3.1 Theoretical Framework

3.3.1.1 Fundamental Theories, Building Blocks of CE

Choice modeling techniques, particularly the choice experiment (CE) method, are based on two fundamental theories: (1) Lancaster's characteristics theory of value (Lancaster, 1966), and (2) random utility theory (Adamowicz et al., 1998a; McFadden, 1973).

3.3.1.1.a Lancaster's Consumer Theory

Lancaster's consumer theory (Lancaster, 1966) states that the utility an individual derives from a good comes from the characteristics of that good, not from the consumption of the good itself. Thus the value of the good is represented by the sum of the value of the good's characteristics. The underlying idea of a choice experiment is that any good can

be described in terms of its attributes, or characteristics, and the levels that these attributes take (Bateman et al., 2002).

3.3.1.1.b Random Utility Theory

The random utility theory (RUT) is the theoretical basis for integrating behavior with economic valuation in the CE method. The random utility theory recognizes that there is both an observable and unobservable component to the utility that individuals derive from the consumption of goods.

According to RUT, the utility of a choice is comprised of a deterministic component (V) and an error component (e), which is independent of the deterministic part and follows a predetermined distribution. This error component implies that predictions cannot be made with certainty. While the deterministic component is observed through survey response data, researchers must make assumptions about the distribution of the unobserved components of utility in modeling the probability function to predict which alternatives are most preferred over the sample population (Hensher et al., 2005). Within the framework of random utility, an individual's indirect utility can take the following functional form (Louviere, 2001):

The RUM model:

$$U_j = V(X_j, C_j; \beta) + \epsilon_j \quad (1)$$

where U_j is the true but unobservable indirect utility associated with profile j , X_j is a vector of attributes associated with profile j , C_j is the cost of profile j , β is a vector of

preference parameters, and ϵ_j is a random error term with zero mean (Hensher et al., 2005).

Choice behavior is assumed to be deterministic (without error) from the perspective of the individual but stochastic from the perspective of the researcher because the researcher does not observe everything about the individual. Thus the error term in the random utility expression reflects researcher uncertainty about the choice. It is usually assumed that utility is linear-in-parameters:

$$U_j = \sum_{k=1}^n \beta_k X_{jk} + \beta_C C_j + \epsilon_j \quad (2)$$

where β_k is the preference parameter associated with attribute k , X_{jk} is attribute k in profile j , and β_C is the parameter on profile cost.

The random utility model provides the theoretical foundation for the class of empirical models based on consumer choices between competing alternatives. These alternatives are presented to the respondents in the choice experiment, who then need to choose the most preferred alternative from a choice set. Economic theory suggests that respondents choose the program that entails the highest utility. Based on the stated choices, it is possible to calculate the implied marginal rate of substitution between the attributes of two choices such as a climate response and the costs associated with it.

3.3.2 Design Stages in a Choice Experiment

The process of conducting a choice experiment has been defined as consisting of five components (Louviere et al., 2000):

1. Defining the problem
2. Defining the attributes and their levels
3. Experimental design (creating scenarios)
4. Questionnaire design and data collection (defining choice sets and obtaining preference data)
5. Model specification (estimating the model parameters)

3.3.2.1 Problem Definition

The first step is to clearly identify the economic and environmental problem that the choice experiment is intended to address.

3.3.2.2 Defining Attributes and Levels

Attribute selection is the main key task in designing a choice experiment (Louviere et al., 2000). Generating attributes for a choice experiment happens through a literature review, focus group meetings (e.g., Hanley et al., 2001), or a combination of both (e.g., Christie et al., 2006). Attributes and levels are the individual features that comprise the research object, among which the survey will elicit tradeoffs (Louviere et al., 2000). Depending on research objective and the context of the study, attributes can take different forms such as numeric, categorical, or a combination of both.

3.3.2.3 Experimental Design

Experimental design is the systematic arrangement in matrices of the values that analysts use to describe the attributes representing the alternatives or policy options of the hypothetical choice cards (Scarpa & Rose, 2008). Experimental design is a crucial component of any choice experiment study. It is an important aspect with multiple tools and multiple approaches and a number of nuances. Since discrete-choice experiments have intuitive appeal, it is easy to underestimate the complexity of experimental design. Different types of design strategies have been developed (see Louviere et al., 2000) for various purposes. However, there has been no agreement on the best design approach (Gao et al., 2010). Each design approach has its own advantages in capturing certain types of effects, and there is no superior design for all purposes (Louviere et al., 2000).

3.3.2.4 Full and Fractional Factorial Designs

There are different classes of experimental designs, however, full and fractional factorial designs are two of the most commonly used types of designs (Louviere et al., 2000; Hensher et al., 2005).

3.3.2.4.a Full Factorial Design

Full factorial design is a design in which all possible attribute levels are considered (Louviere et al., 2000; Hensher et al., 2005). For example, if attribute A has two levels (A1,A2) and attribute B has three levels (B1,B2,B3), then the following design is called full factorial design:

A1B1, A1B2, A1B3, A2B1, A2B2, A2B3.

This design includes all possible combinations of the attribute levels. However, in real cases when the number of attributes and levels are larger, then having a full factorial design might be impossible. For example, a case that includes five 4 level attributes and two 3 level attributes will eventually produce 9216 ($4^5 \cdot 3^2$) alternatives. Therefore, usually a fraction of possible combination is selected for the design. This type of design is called fractional design (Hensher et al., 2005).

3.3.2.4.b Fractional Factorial Design

Selection of the combinations could be random; however, random selection might produce inefficient or sub-optimal design. In order to have an optimal fractional design, two main characteristics should be considered: orthogonality and efficiency. These two concepts will be discussed in Sections 3.3.2.5.b and 3.3.2.5.c.

3.3.2.5 Comparison between Full and Fractional Factorial Designs

The full factorial design includes all possible combinations of attribute levels. It allows the analyst to estimate both main effects and interactions effects (explained below). Considering all possible alternatives would achieve a dataset that will produce better coefficients in terms of statistical efficiency and overall model goodness of fit (Louviere, 2006). However, full factorial creates so many options. Too many questions for a single respondent put a high cognitive burden on respondents and might result in less reliable information (Hensher, 2006). The choice cards may also contain “useless” choice

situations. Given the complexity of full factorial design, fractional factorial designs are usually preferred (Blamey et al., 2001).

3.3.2.5.a Types of Effects

Different types of experimental designs produce different kinds of effects; main effects and two-factor interaction effects are the most common ones being used in the literature.

Main effects, generic, plain

“Main effect” refers to a scenario where the utility for a change in a particular attribute level remains the same, while changes are introduced in other attributes (Louviere et al., 2000).

Interaction effects

Interactions occur when the combined effect of two attributes is different from the sum of their two main effect utilities. On the other hand, the effect of a particular attribute is dependent on other attribute levels in the design (Bateman et al., 2002).

3.3.2.5.b Design Characteristics: Orthogonal Designs

An experimental design is called orthogonal when correlations of all attributes in the design are zero (Bliemer & Rose, 2006). Orthogonality has been used to create hypothetical choice situations in which the attribute levels vary independent of each other. Orthogonal designs have some limitations: First, this type of design is not able to measure the interaction effect. Therefore, when interaction among the attributes really

exists in the data, an orthogonal design will not capture it. Second, even when an orthogonal design has been generated, the collected data may not be orthogonal due to several issues such as non-response to a choice question, unequal frequency of a block in a block design, or unequal ranges in attribute levels (Bliemer & Rose, 2006).

3.3.2.5.c Design Characteristics: Efficient Design

It has been suggested that from a statistical perspective, experimental design for a choice experiment should convey the maximum amount of information about the parameters of the attributes (Sandor & Wedel, 2001). This feature cannot be guaranteed with just orthogonality. This has resulted in the introduction of a class of design known as optimal or statistically efficient designs. The generation of statistically efficient designs has been addressed by several authors (Sandor & Wedel, 2001), each of whom offer different construction strategies to generate such designs. One common measure of efficiency is called *D-error*, which is defined as the determinant of the Asymptotic Variance Covariance (AVC) matrix. Two types of efficiency are defined by *D-error*: The first is *D-optimal* in which *D-error* is the lowest. The lowest *D-error*, however, is very difficult to find; therefore, a second type of efficiency is defined as *D-efficient* in which the *D-error* is sufficiently low (Bliemer & Rose, 2006).

To summarize the difference between the two, orthogonal fractional factorial designs are generated so that the attributes of the design are statistically independent. Thus while optimal design optimizes the amount of information obtained from the design, the construction process for orthogonal fraction factorial designs minimizes to zero the

correlations evidence within a design (Louviere et al., 2000). Optimal design will be statistically efficient but will likely have correlations; orthogonal fractional factorial designs will have no correlations but may not be the most statistically efficient design available (Louviere et al., 2000). Hence the type of design generated reflects the belief of the analyst as to what is the most important property of the constructed design.

3.3.3 Questionnaire Design and Data Collection

Questionnaire design of a choice experiment involves several stages as follows:

- *Whether the alternatives in choice cards need to be labeled*

One of the issues in questionnaire design for CE is whether to depict the alternatives in a generic or a labeled format (Blamey et al., 2000). Generic formats are associated with the assignment of a generic label to each alternative in the choice cards (i.e., alternative/option A, alternative/option B, etc.). This kind of labeling is usually used when the research question is centered around policy or program development. The labeled format on the other hand, refers to a situation where analysts assign information, either directly or indirectly, that could reflect the alternatives (Bateman et al., 2002).

- *Whether the status quo option needs to be included in the alternatives*

A baseline alternative corresponding to the status quo is generally included in each choice set to ensure welfare-consistent estimates (Bateman et al., 2002). The status quo option, called an “opt-out” option, adds to the realism of scenarios and helps generate welfare-consistent estimates by mimicking actual market situations

whereby individuals are able to choose neither of the two alternatives offered (Holmes & Adamowicz, 2003).

- *The optimum number of the alternatives for each choice card*
- *Pairing alternatives*

Pairing alternatives is the next and final stage of the experimental design. This stage can be done in two ways, using software such as Ngene, Sawtooth, or manually.

- *The optimum number of choice cards to be added to the survey*
- *The sections of the questionnaire:* The final stage is to organize and construct the survey. The questions need to be structured into various sections (i.e., introduction, choice cards questions, attitude or informational questions, and socio-demographic characteristics).

3.3.4 Model Specification

After collecting the data, the utilities for the different attribute levels of a product or service can be estimated. There is more than one model available for this, thus there is no unique way of analyzing the data. The data is then subject to discrete choice modeling using tools such as multinomial logit (MNL), conditional logit (CL), or other types that fits the context.

These two main models are explained in the following section.

3.3.4.1 Multinomial Logit (MNL)

For modeling purposes, it is usually assumed that the utility function, in its general form, is a linear function of the attributes and their interactions:

$$U_j = \sum_{k=1}^n \beta_k X_{jk} + \beta_c C_j + \sum_{m=1}^n \sum_{k=1, k \neq m}^n \beta_{km} X_{jk} X_{jm} + \epsilon_j \quad (3)$$

Where n is the number of attributes, β_k is the preference parameter associated with attribute k , β_c is the preference associated with the cost of the profile, β_{km} is the preference associated with the interaction of attribute k and m in profile j , and X_{jk} and X_{jm} are attributes k and m of profile j .

β_k are the parameters that will be estimated using the survey results. In the absence of interactions, β_k is the marginal utility of attribute k ($\beta_k = \frac{\partial U}{\partial X_k}$). However, in the presence of interactions, the marginal utility of attribute k depends on the level of other attributes:

$$\frac{\partial U}{\partial X_k} = \beta_k + \sum_{m=1, m \neq k}^n \beta_{km} X_m$$

β_c is the marginal utility of cost or, in other words, marginal utility of decrease in disposable income for other goods. Thus $-\beta_c$ could be viewed as the marginal utility of money. Willingness To Pay (WTP) for attribute k , therefore can be calculated by dividing marginal utility of attribute k by the marginal utility of money.

$$WTP_k = -\frac{\frac{\partial U}{\partial X_k}}{\beta_c} \quad (4)$$

The standard model for the multinomial Logit makes a strong assumption that the respondents have homogeneous preferences. To relax this assumption, it is suggested (Hensher & Greene, 2001; Carlsson et al., 2003) to use a mixed multinomial Logit model to incorporate the heterogeneity of the preferences. In this model, the respondents' individual characteristics will be entered in the utility function:

$$U_{ij} = V(X_j, C_j, Z_i) + \epsilon_{ij} \quad (5)$$

Thus the linear model to be estimated with interaction terms could be written as:

$$U_{ij} = \sum_{k=1}^n \beta_k X_{ijk} + \sum_{l=1}^L \gamma_l Z_{il} + \beta_C C_j + \sum_{m=1}^n \sum_{k=1, k \neq m}^n \beta_{km} X_{jk} X_{jm} + \sum_{m=1}^n \gamma_{im} Z_i X_{jm} + \epsilon_{ij} \quad (6)$$

where L is the number of individual characteristics for each respondent.

Multinomial Logit also makes another assumption that choices conform to the Independence from Irrelevant Alternatives (IIA) with a type I extreme value distribution (Holmes and Adamowicz, 2003). In other words, the introduction of a third alternative does not affect the people's preferences about the first two alternatives.

In the literature, sometimes MNL is used to refer to the model in which only the individual's characteristics are used. In other words, the respondent's choice is only a function of his/her individual characteristics. With this definition, the researcher assumes that the satisfaction gained from a level of an attribute is the same for each respondent.

This will result in a single set of utilities for this whole population. By using a multinomial Logit model, heterogeneity cannot be investigated. That is not very realistic because no two respondents have the same preferences.

3.3.4.2 Conditional Logit

Conditional logit is the most common model for analyzing choice data because it has a simple and closed form for probabilities (Cadavid et al., 2013). Conditional Logit assumes that the respondent's utility and therefore his/her choice is a function of the attributes of the choice alternatives. This study adopts conditional logit model, since the objective is to elicit the marginal utility of selected attributes of LID techniques.

3.4 Conclusion

This chapter presented an overview of the theories and method that are being used in this study. The first section reviewed the concept of social presence, how it is being conceptualized and measured. This study has conceptualized social presence as a uni-dimensional concept, which is in-line with objective of the research, and has adopted a self-reported technique to measure its formation. The second section introduced the theories that a choice experiment is built on and the process of conducting it. Designing a choice experiment involves multiple stages and details that need careful attention. Therefore, a comprehensive review of the process was presented. Experimental design is the main rigorous part, which requires making several decisions on the part of the analyst. First, the analyst needs to decide which type of design to choose from. The two major

design types are full factorial and fractional factorial, which were presented in section 3.3.2.4. Second, the analyst needs to decide what types of effects need to be studied. Depending on the context of the study and research question, it could be main effects only, or main effects and interactions. These effects have been explained in detail in section 3.3.2.5.a. The third decision is about characteristics of the design, whether orthogonal or efficient, which is also explained in sections (3.3.2.5.b and 3.3.2.5c). In light of the research questions and objective of the research, our study has adopted the fractional factorial main effect design.

Building the survey is the next step, and again several decisions need to be made. Examples include labeling alternatives, the number of alternatives (options) within a choice card, whether to include the status quo option or not, parring the alternatives, and the number of choice cards in a survey (blocking). All these processes were conducted and examined in detail in our study. The process has been explained in chapter 4, the experimental design section. When the choice experiment part of the survey is completed, the survey will be constructed, adding the other sections such as socio-economic characteristics, informational questions, and so on.

Chapter 4 - Research Methodology

4.1 Introduction

The primary objective of this study was to examine the role of a high and low social presence attribute presentation on participant preferences and choices in a choice experiment. This objective was achieved by employing a virtual world environment to enhance the level of social presence. We manipulated the level of social presence by using an avatar in a virtual world environment when presenting the choice experiment study. The study elicited residents' preferences for private and public attributes of residential level Low Impact Development (LID) techniques, using Choice Experiment (CE) technique.

The general process of designing a choice experiment is discussed in the previous chapter. This chapter will explain the process I used to design the choice experiment and the virtual part, design the survey, implement it and collect the data. It will cover the following processes:

- a. Problem statement
- b. Generating Attributes and their levels for the Choice Experiment
- c. Experimental design
- d. Designing the survey instrument
 1. Designing the paper version
 2. Designing the green virtual neighborhood and attribute presentation

scenarios

3. The final survey instrument

e. Survey implementation and data collection

The detailed process of these stages is discussed in several sections, beginning with the problem statement and the process of generating attributes and their levels for the CE questions in Section 4.3.1. The attributes and their levels are then tested which is explained in 4.3.2. The selected attributes and their levels are employed in experimental design, which resulted in creation of alternatives and presented in choice card, explained in section 4.4.

Section 4.5.1 discusses the design of paper version of the questionnaire used as a base for the online version and its pilot testing. The details of developing attributes presentation scenarios and the construction of virtual neighborhood are explained in section 4.5.2 and its sub sections. Subsection 4.5.2.5 describes the testing of different virtual components including scenarios, the script, movies and voiceover. The final version and its testing are discussed in section 4.5.3. The implementation of the final survey is explained in section 4.6.

4.2 Problem Statement

Low impact development (LID) practices are innovative decentralized stormwater management strategies to manage urban stormwater run-off. LID practices provide multiple ancillary benefits while managing the stormwater run-off. Therefore, widespread

investment in LID practices would not only manage the stormwater run-off but also would yield multiple benefits for societies. Residents and households as potential investor and adopters of LID practices can play a major role in successful implementation of LID practices. Therefore residents' response and motivations to invest in LID is of important value to stormwater managers and program developers. By learning about residents' preferences for benefits and barriers to adopt LID, stormwater managers would know what issues to address when designing stormwater management Programs. The goal of this study is to elicit residents' preferences for benefits and barriers of adoption LID practices. The study will examine the role of selected private and public LID attributes and characteristics on resident's decision making.

4.3 Generating Attributes and Their Levels for the CE

4.3.1 Attributes of Low Impact Development Techniques

Attribute selection is a key task in designing a choice experiment (Hensher et al., 2005). Researchers generate attributes for a choice experiment through literature review, expert opinion and focus groups (Hensher et al., 2005).

In this study, the goal was to discover what attributes of Low Impact Development techniques—benefits and barriers— residents would consider when exploring Low Impact Development techniques. If a resident were considering planting a rain garden, for instance, what attributes of rain garden would be important for her?

To come up with these attributes, I asked two general questions:

- What benefits would people consider when exploring the possibility of adopting Low Impact Development (LID) techniques?
- What barriers would impact people in their decision to adopt LID techniques?

In order to identify the important attributes of LID techniques for residents, two main steps were taken. First, an in depth literature review was conducted. Second, residents and experts were consulted in order to learn about important LID attributes according to their perspectives (explained in the next section)

The detailed literature review of Low Impact Development techniques has been presented in Chapter 2. From this review, we came up with the following attributes:

- Water quality improvement
- Carbon sequestration
- Heat reduction
- Flood reduction

4.3.1.1 Public Group Meetings and Expert Opinion

In order to consult residents and experts, I started attending related public meetings. I attended two sessions of Chicago's climate action meetings in January and February 2011 that discussed climate change mitigation and adaptation services. My goal was to learn about people's perceptions and attitudes toward individual level actions and their willingness to respond to climate change. In those meetings, I approached and consulted with some people from audience as well as city officials. As a result two other follow-up phone meetings were scheduled with city of Chicago officials. The first phone meeting

resulted in some general discussions to learn about residential level programs offered by the city, the shortcomings of the programs and barriers of adopting those programs by residents. The second phone meeting dealt with LID practices and how their adoption can solve specific problems caused by run off in the city, for example; combined sewer overflow (CSO), city and basement flooding.

Barriers or concerns discussed:

- Lack of small-scale customization of climate response programs
- Suspicion or lack of trust by public
- Language barriers
- Engaging minorities and elders
- Cost
- Comfort of program
- Undesirable aesthetic
- Unfamiliarity/ lack of knowledge

Benefits:

- Solve runoff issues such as sewer overflow
- Solve city and basement flooding
- Saving money on water bills

Next, I was introduced to several other resources including a well-known NGO, called The Center for Neighborhood Technology (CNT). CNT is a nonprofit organization in the

city of Chicago, working on different neighborhood level initiatives. I requested an in person meeting with them to learn about their neighborhood level climate adaptation and stormwater management projects, one of which was adoption of LID by residents. CNT's main question and concern was about residents' motivations to invest in LID techniques, specifically in rain gardens. Through CNT, I was invited to a community event on LID techniques at Alderman Joe Moore's (49 ward) house in Rogers Park in Chicago (May 2011). The purpose of the event was to introduce some LID techniques to people using real demonstrations. The event was a great opportunity to speak with different people and learn about their concerns and what mattered the most for them in terms of adopting LID techniques.

A summary of findings:

- People were not familiar with LID techniques and their benefits at all.
- The first widely expressed concern was basement-flooding issues that people wanted to solve through these techniques.
- People were interested in saving money (on water bills).
- The cost and maintenance were important issues for people.

The next step was identifying and contacting LID experts who were directly working on promoting these techniques in different communities. The goal was to learn about their opinion on important issues that needed to be studied in this domain. First, I contacted Prairie River network, an NGO in city of Urbana, Illinois. I was referred to their staff

scientists, who help residents with adoption of LID techniques. Second, I contacted department of environment in Washington DC and spoke with their environmental protection specialist who was in charge of LID implementation. I shared similar questions with both individuals and received their inputs via email³.

Summary of findings (both communions):

- Desirable feature (attributes) of rain gardens included the look, green space and the useful function of the gardens
- Undesirable features include the labor work of construction.
- Main motivation to adopt a rain garden was solving some type of stormwater issue such as basement flooding that a homeowner would like to solve. Some wanted to lessen their stormwater footprint.
- Barriers to adopt LID techniques were, cost and lack of technical familiarity with LID practices.
- The important attributes of LID for residents included price, aesthetics and ease of maintenance.
- Some homeowners preferred to be directed to contractors that are qualified, as they do not have their own capacity to build rain garden or green roofs. For rain gardens, creating the depression involves a lot of earth moving, and some don't

³ Example of questions:

1. What are some obstacles and barriers for people to adopt LID programs?
2. If you were going to learn about residents' preferences for LID attributes, what would be most important things you would like to know about them?
3. What attributes of an LID program matters the most for residents? What is their motivation to adopt LID practices (E.g. rain garden)?

want to do that physical labor, or cannot do it.

- The experts were interested in learning about scale and types of projects residents are interested in. How much is the homeowner willing to invest, to what extent is the homeowner prepared or willing to learn how to maintain the practices. What is their main motivation to adopt LID (save money on water bills, purely to do the environmentally conscious thing), how do residents see their role Vis a vis the long term goals we need to reach? Are they willing to pay for it? Do they expect a break on their water bills if the make LID/green infrastructure investments in their property? (Personal communications, summer 2012 & spring 2013)

Table 1. List of Stakeholders Interviewed for this study

Department	Purpose
City of Chicago (Two phone interviews)- Feb & Aug 2011	Attribute development
CNT (In person meeting)- May, 2012	Attribute development
Prairie river (Email corresponding)- July, 2012	Attribute development and testing
Department of environment (Washington DC) (Email corresponding)- March, 2013	Attribute development and testing

The three processes of literature review, speaking with public, and consulting with experts resulted in developing the list of important attributes. The list was narrowed down based on several criteria:

- First, testing and revisions through different stages of study, including the initial development when consulting experts and later stages involving the testing of the survey.

- Second, the potential of attributes to be visualized was taken under consideration (since the objective of the study was to visualize them in a virtual world platform).
- Third, in consultation with the doctoral dissertation committee, it was decided to choose the six most important attributes to keep the list small and comprehensible for people. For example the cost and rebate attributes (originally as two different attributes) were then put together to reduce the number of attributes. Table 2 presents the list of attributes.

Table 2. List of selected attributes
(Based on literature review, expert and public opinion as well as the objectives of the study)

Attributes	Type- description
Water quality improvement	Public Improving the water quality in near by streams and lakes by reducing pollution
Neighborhood flood reduction	Public Neighborhood flood reduction through LID installation in the neighborhood.
Basement flood reduction	Private Reducing or eliminating the basement flooding by installing LID.
Private benefits	Private Includes green space & water storage (reuse) provided by some LID techniques.
Maintenance	Private The maintenance effort that is required for different types of LID techniques.
Cost after rebate	Private The cost of installing LID after reducing the rebate.

Therefore, another phase of research, literature review, and expert consultation was conducted to develop the levels of attributes. The search resulted in finding two valuable resources: A comprehensive study that was done by number of scientists and researchers led by Center for Neighborhood Technology (Grant and Gallet, (2010) as well as a tool that was developed by CNT called: green values tool box. The green values toolbox is comprised of several green value calculators (<http://greenvalues.cnt.org>)

- 1) Green Values: national storm-water management calculator
- 2) Green Values: storm-water management calculator:
- 3) Green Values: Storm-water ordinance compliance calculator

The stormwater management calculator and the CNT study were adopted as the main sources to develop the levels. The storm-water management calculator (2) is designed to help homeowners to calculate the benefits of green infrastructure compare to conventional gray methods. The following section elaborates more on CNT study and its contribution to defining attribute levels.

4.3.1.2 Water Quality Improvement Levels

The CNT study (Grant, J., & Gallet, D. (2010) has been done at site level for Chicago. The benefits of selected LID techniques are all listed and quantified. The study has developed formulas to calculate run off reduction of different techniques and to estimate the impact of LID measures at landscape level (Grant, J., & Gallet, D. (2010). For example LID techniques such as Tree planting, bio-retention and infiltration practices (rain gardens), and permeable pavements are listed and their benefits such as run off

reduction, and heat reduction have been quantified. The formula to calculate each benefit has been developed at site level.

In consultation with LID expert and her approval (S. James, personal communication, Nov, 2013) it was decided to use the volume of rainwater run off captured on site (run off reduction) as a proxy for effectiveness of each technique in terms of water quality improvement.

Hypothetical scenarios of adopting all techniques verses just one or a number of techniques were developed for an average single family house of 1600 Square Feet (for example a small rain garden of 80 Square feet (SF) or medium of 150 SF, one medium tree or two small trees, a rain barrel or two rain barrels and etc). Next, the level of run off reduction for all those scenarios was calculated, using the run off reduction formula as shown below:

For example, the following equation provides a simplified estimate of the potential volume of runoff captured using bio-retention and infiltration practices: (Grant, J., & Gallet, D. (2010).

[Annual precipitation (inches)(featured area (SF)+drainage area (SF))* % of rainfall captured]* 144sq inches / SF * 0.00433 gal cubic inch= total run off reduction (gal)*

A site in Chicago, Illinois, that retains 80% of stormwater runoff, with an infiltration area of 2,000 square feet and a drainage area of 4,000 square feet, reduces the volume of runoff as follows:

$$\frac{[38.01 \text{ inches annual precipitation} * (2,000 \text{ SF} + 4,000 \text{ SF}) * 0.80 \text{ retention rate}] * 144 \text{ sq inches/SF} * 0.00433 \text{ gallons/cubic inch}}{= 113,760 \text{ gallons of runoff reduced annually}}$$

The same procedure was followed and run off reduction was calculated for different scenarios. Appendix C shows the detailed calculation for each LID measure.

Next, the results of different scenarios were categorized to three groups of low, moderate and high. At first, it was quantitative percentages instead of qualitative; low, med, high. However, the latter testing revealed that people don't feel comfortable with mix of numeric and qualitative levels and it was decided to use qualitative ones only. The categories are listed in Table 3 (For details refer to Appendix C).

Table 3. The range of water saved for different levels of LID effectiveness

Water saved on site (Gal)	Category
1100-5500	Low effectiveness
6000-10500	Moderate effectiveness
11000-14000	High effectiveness

4.3.1.3 Neighborhood Flood Reduction Levels

The next attribute was neighborhood flood reduction. Although LID can play an effective role in neighborhood flood reduction, implementation of LID plays the main role in terms of neighborhood flood reduction (L. Lemoine, Personal communication, Feb 2014). Therefore, the same levels: low, moderate and high effectiveness were selected, which would be related to implementation.

4.3.1.4 Basement Flood Reduction Levels

Basement flooding happens due to different factors, for example combined sewer overflow as well as downspout disconnect. LID techniques such as rain garden and downspout disconnect can fix some types of basement flooding completely (S. James, Personal communication, June 2013). So if the basement flooding is happening due to downspout disconnect it can be completely fixed by adopting LID techniques such as rain garden or downspout disconnect. Therefore, two levels were assigned to basement flooding: high effectiveness, meaning that the LID can fix the basement flooding completely) or if the basement flooding is related to other issues LID would not be able fix it (i.e. no effectiveness).

4.3.1.5 Side Benefits Levels

Side benefits include the extra green space that is provided when adopting rain gardens/trees and other green LIDs. Water storage and reuse is another side benefit provided by rain barrels. Therefore three levels were assigned to side benefit attribute: green space, water storage and reuse, both.

4.3.1.6 Maintenance Levels

Different LID techniques need different levels of maintenance, for example rain gardens need gardening. If native plants (always recommended) were used, the maintenance time will be less. Rain barrels need to be clear from debris to prevent clogging, so clearing

debris from the catchment area periodically and using the collected rainwater as soon as possible after each rain event is recommended (City and County of San Francisco, 2008).

Preamble pavements need occasional sweeping and cleaning. Therefore some techniques are high maintenance some are low maintenance. Therefore, three levels of zero maintenance; medium and high was assigned to maintenance. However, when testing it in the survey, it was decided to use hours per month instead of qualitative ones. Using similar method that was applied to define water quality levels, we defined three levels of zero hours (none), 3-4 hours, and 7-8 hours.

4.3.1.7 Cost

Different LID techniques require different levels of installation cost. The cost of typical LID techniques such as rain barrel, rain garden and permeable pavements was estimated and a similar procedure to estimate water quality levels was adopted to establish the different levels of cost. In order to reduce the number of attributes and cognitive burden for respondents, it was decided to put rebate and cost of installation together. Therefore, the levels represent total costs after the rebate was received. Five levels were defined, \$100, \$250, \$375, \$500, \$700.

4.3.2 Testing the Attributes and Their Levels

Testing the attributes and their levels was done in two stages; first during the initial development process, and second during questionnaire testing. The first process was mainly expert consultation. The attributes and their levels were shared with Dr. Stacy

James from Prairie river network (in person meeting and email corresponding) and Ms. Leah Lemoine from department of environment in DC, as well as two people in city of Urbana (Summer, 2013). I also requested a meeting and shared the attributes (and levels) with Dr. Srinivasan⁴ for his feedback.

The feedbacks resulted included but not limited to the following changes: originally, the levels were defined numerically; it was not as clear for respondents and the qualitative ones seemed to work better. Therefore, numeric values were changed to qualitative ones. The wording of attributes was also tested and changes were applied. The final list of attributes and their levels is listed in Table 4.

Table 4. The final list of attribute and levels

Attributes	Levels
Water quality improvement	Low effectiveness, Moderate effectiveness, High effectiveness
Neighborhood flood reduction	Low effectiveness, Moderate effectiveness, High effectiveness
Basement flood reduction	High effectiveness, No effectiveness
Private benefits	Green space, water storage (reuse), both
Maintenance hours per month	None, 3-4 hrs. , 7-8hrs
Cost after rebate	\$100, \$250, \$350, \$500, \$700

4.4 Experimental Design

The major types of design have been explained in Chapter 3. The experimental design in this study was developed following the standard practice in the choice modeling literature

⁴ Dr. Srinivasan is one of the conjoint analysis pioneers. He is the Adams Distinguished Professor of Management, Emeritus at the Stanford Graduate School of Business, Stanford University. The second process of testing the attributes happened during the survey testing. The survey was shared with people similar to the target sample as well as some students to find out if the attributes and levels are comprehensible for them or not.

(Adamowicz et al. 1998; Louviere et al. 2000). This study's design is a generic design (i.e. unlabeled alternatives). There were three alternatives of which two represented different levels of LID attributes and services and the other represented the fixed status quo (doing nothing). The study had six attributes, four with three-levels, one with two-levels and one attribute with five levels. Therefore, there were $3 \times 3 \times 3 \times 3 \times 2 \times 5 = 810$ possible combination of attributes and levels to form choice sets. However, conducting a survey with this many profiles would be impractical. Thus an orthogonal fraction of this full factorial design, which allowed the estimation of all main effects, was constructed. It was therefore assumed that the interactions between the selected attributes do not significantly affect overall utility and choice probabilities beyond the effects of each individual attribute level, and that individuals arrive at some overall preference by adding their utilities for the attribute levels.

The orthogonal main effect design method is most commonly used method and is effective in terms of isolating the effects of individual attributes on choice (Hanley et al., 1998). Using SPSS 12.0 package, we draw 24 alternatives, which made 12 choice sets (choice cards).

The last stage involved pairing the alternatives. This stage can be done in two ways, using software such as Ngene or Sawtooth or manually. In this study, we employed the manual option. The status quo option (not adopting LID techniques) was also included in the alternatives, where the option represents the current situation of not adopting LID techniques. By combining the status quo along with the two options, the total number of

alternatives used in each choice card in the study is three. The combination of three alternatives together is known as a choice card. (See Table 5)

Table 5. Example of a choice set (choice card: sample list of attributes and their levels)

Attribute name	Option-1	Option-2	Default (doing nothing)
Water quality improvement (due to pollutant reduction)	Moderate effectiveness	Moderate effectiveness	
Neighborhood flooding reduction	Low effectiveness	Low effectiveness	
Basement flooding reduction	No effectiveness	High effectiveness	
Private benefits	Water storage (reuse)	Green space	
Maintenance effort per month	None	3-4 hours	
Cost after rebate	\$250	\$375	\$0

4.5 Designing the Survey Instrument for Choice Experiment

4.5.1 Designing the Paper (Hardcopy) Instrument

Designing the hardcopy instrument consisted of two steps: Designing, and testing the survey instrument.

4.5.1.1 The Hardcopy Survey Instrument

The survey for this research will present respondents with opportunities to express preferences over pairs of hypothetical LID options that differ in terms of their private and public costs and benefits. The first version of the survey instrument was designed as a hardcopy. It consisted of three sections: The first section included knowledge and perception questions to identify variables that may significantly affect choices (e.g. knowledge about impact of rainwater runoff, previous flood experience, knowledge and familiarity with LID). The second section consisted of an explanation of the different LID

techniques, their benefits and costs, and then choice card questions, asking for people's preference for different LID options (in this stage we used text and pictures to explain LID techniques). The last section was demographic questions.

4.5.1.2 Testing the Survey Instrument

First, the survey instrument was taken to the University of Illinois' survey consulting services. Some revisions and changes were suggested and applied to the instrument. Next, the testing process of the hardcopy got started. The copies of survey instrument were printed and shared with different groups and experts. First, we surveyed a small group of students (6-7) who were asked to fill out the survey and provide feedback. Next, the survey was shared with few older people (40-70 years old), since our final survey would be going out to homeowners. The necessary changes were applied and then the survey instrument was shared with experts. Section 4.4 provides more detailed discussion on this process. This process was done in summer 2013. The next stage was building the virtual neighborhood, designing virtual scenarios (attributes' visualization), filming and building the online survey.

4.5.2 Designing the Green Virtual Neighborhood and Attribute Presentation Scenarios

Designing the green virtual neighborhood consisted of five steps: building the neighborhood in virtual environment, developing scenarios for presenting attributes, writing the script, making the movies, and testing all of them.

4.5.2.1 Building the Virtual Neighborhood

The next process was designing the virtual scenarios according to final attributes. The selected virtual platform of interest was Second-life: <http://secondlife.com>.

The goal was to build a virtual neighborhood and present attributes in that neighborhood so that the level of immersion and realism will be increased. In order to build the neighborhood, we consulted with and hired an experienced Second Life developer. The neighborhood was designed as a typical suburban neighborhood. I requested a neutral appearance for the neighborhood to alleviate any impact on respondents' decision-making. The same strategy was applied for designing the houses in that neighborhood. The houses were typical and neutral houses that would not affect decision-making by attracting attention. All houses on each sides of streets were analogues and consistent for both neighborhoods. The only difference was that, the residents of one neighborhood had installed LID techniques, while the residents of the other neighborhood had not (Figure 1).

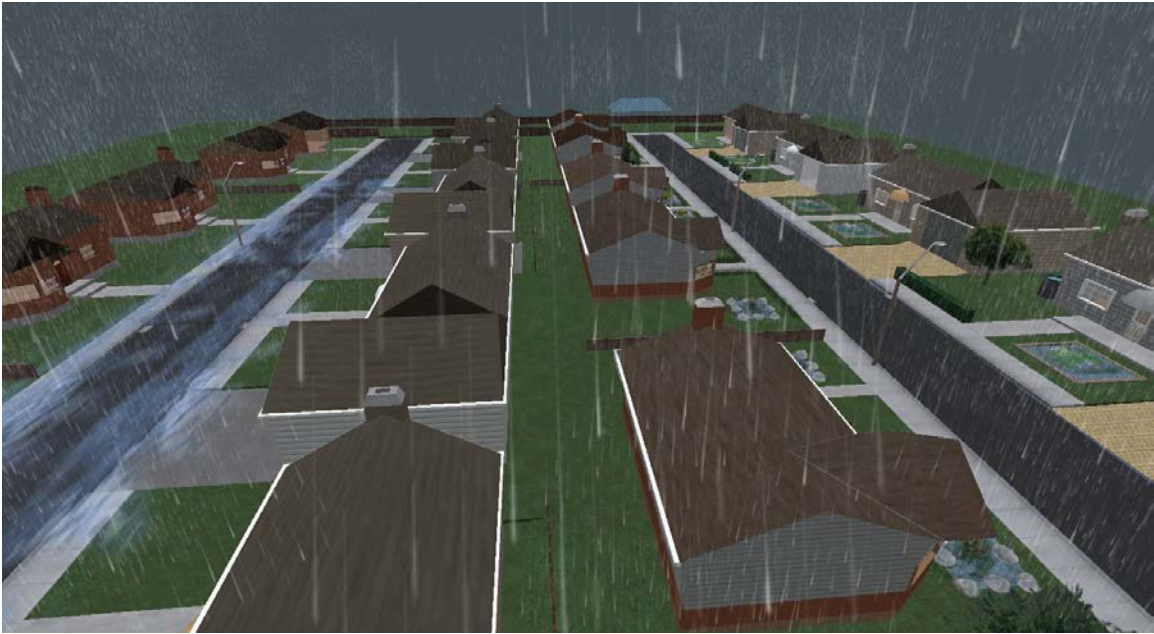


Figure 1

4.5.2.2 Developing Scenarios to Present Attributes

Next, we developed detailed scenarios to present each attribute. For example, the water quality improvement attribute was visualized by showing a clean river near by the neighborhood that has adopted LID practices versus a polluted river close by to the other neighborhood. The neighborhood with LID practices was not flooded, while the non-LID neighborhood was flooded, to show the impact of LID on neighborhood flooding reduction. A similar scenario was designed to visualize the basement flood reduction. Side benefits were visualized by adding green space and showing the water stored in a rain barrel. Some avatars (as neighbors) working on their rain garden and permeable pavements were used to visualize maintenance. The cost was visualized, using some price signs on a hypothetical rain garden, rain barrel and permeable pavement. The screen shot

of each visualization scenario can be found in Appendix A.

4.5.2.3 Developing the Script

When the construction of virtual neighborhood and attribute scenarios came to an end, we wrote a script for those scenarios. An avatar as tour guide walked people through the neighborhood and explained the attributes for them. The final version of narration can be found in Appendix B.

4.5.2.4 Making Movies

The movies were filmed inside Second Life, using Quick time player. The movies were then sent to I-movie (a feature in Macbook laptop) to be edited and put together. The script was added as a voiceover and mixed with movies. It went under lots of edits and revisions. The links of the movies are as follow:

- Version 1: With Avatar
 - o Part-I: <https://www.youtube.com/watch?v=diqHRyJapi4>
 - o Part-II: <https://www.youtube.com/watch?v=ew7rME5HryQ>
- Version 2: Without Avatar
 - o Part-I: <https://www.youtube.com/watch?v=3ljvDVjdCZ0>
 - o Part-II: https://www.youtube.com/watch?v=a2ms8PhFVDI&feature=em-upload_owner

The primary objective of this study was to examine the role of a high and low social presence attribute presentation on participant's preferences and choices. Therefore, the

study offers two treatments; one has been designed to accommodate a high social presence by adding a virtual avatar (version-1) that gives a tour of attributes. The other one offers the same tour without using avatar (version-2). According to theories, (discussed literature review), the mere presence of the avatar can enhance the level of social presence. The role of spatial presence will be explored as well but our treatments are differentiated in terms of social presence.

4.5.2.5 Testing the Virtual Scenarios, Script, Movies and Voice Over

Another round of testing, revisions and editing had to be done. This time, testing took several months since different pieces of the work had to go under testing and revisions. These included, but not limited to, virtual scenarios⁵, the tour scenarios' script⁶, voiceover and movies⁷. The whole process took place between fall 2013 to spring 2014.

4.5.3 The Final Survey

The product of the green virtual neighborhood design was a set of movies that were put together with the hardcopy surveys to build the final online survey instrument. The process of combining these two instruments consisted of two steps: designing the final survey, and testing it.

⁵ Each attribute's presentation scenario was shared with LID experts for their opinion to check the realism and content (whether the scenario is conveying the message correctly). There were several suggestions that were adopted and incorporated.

⁶ The script was shared with some people for their feedback. The academic content needed to be revised to fit (communicate) the lay language. This was done through several revisions, proof reading and consulting.

⁷ Several versions of movies were made and edited according to feedback and comments that I received from different people.

4.5.3.1 Designing the Final Survey

The final survey was a redesign of the paper version. The university survey consulting services had suggested using Surveygizmo: <http://www.surveygizmo.com> as the platform to be used for the online version. Therefore, that platform was adopted to design and build the final version. The questionnaire consisted of the following parts: knowledge and perception questions, two short movies, measurements, choice cards and demographics. A copy of the survey can be found in the Appendix D.

4.5.3.1.a Knowledge and Perception Questions

The knowledge and perception part consisted of questions regarding rainwater run off impacts, previous flooding experience and etc. Our previous tests revealed that putting similar questions as one question with multiple parts would make it easier and faster for people to respond, than having multiple questions. Therefore, the first part (knowledge and perception questions) was redesigned. The knowledge and perception questions were put together as one question with multiple parts. Respondents were asked to report their levels of agreement with eight statements on a 7-point Likert scale (started with 1=strongly disagree, to 7=strongly agree).

4.5.3.1.b Movies

Two movies were embedded in the survey. The first one introduced participants to LID techniques and three major types including rain barrel, rain garden and permeable

pavements. The second movie, presented all attribute via a tour of the neighborhoods.
(See section 4.5.2.4)

4.5.3.1.c Measurements

The measurements consisted of two parts. First, social and spatial presence indices, second, self-reported measures (attribute clarity and task performance)

4.5.3.1.d Constructing Social Presence and Spatial Presence Index

a) Social presence index

To assess the feeling of social presence, the study used four items for social presence, adopted from (Yoo and Alavi, 2001) and other studies (Harms and Biocca (2004), Hwang & Lombard (2006). The items were modified for this context. Respondents were asked to report their levels of agreement with four statements on a 7-point Likert scale (1=strongly disagree, 7=strongly agree).

Items:

- I felt a sense of actually being together with the tour guide.
- The tour guide's presence was obvious to me.
- I felt a sense of sociability with the virtual tour guide.
- I felt a sense of human warmth with the virtual tour guide.

b) Spatial presence (self-location) index

This measure is an exploratory one. The theory suggests the creation of social presence due to presence of the avatar but it does not say anything about the creation of spatial presence. Therefore, we do not have a hypothesis for that, we are just interested to examine whether spatial presence happens or not.

There was also four items for spatial presence adopted from Balakrishnan & Sundar (2011). Respondents were asked to report their levels of agreement with four statements on a 7-point Likert scale (1=strongly disagree, 7=strongly agree).

Items:

- I felt like I was actually there in the neighborhood.
- It seemed as though I actually took part in the neighborhood's tour.
- I remained focused throughout the tour
- The experience seemed real to me.

4.5.3.1.e Self-Reported Measures: Attribute Clarity and Task Performance

Self-reported measures have been used in some choice experiment studies to compare participants attitudes and self-reported assessment of two different treatments, for example virtual treatment versus traditional (text based) treatment (Richarme & Colias (2009). I followed the same path and developed two series of self-reported measures as follows:

a) Attribute clarity (comprehension)

One question consisted of seven parts (the name of each attribute, the side benefit was broke down to its levels) was generated to measure self-reported attribute clarity. The respondents were asked to report the level of the clearness of each attribute using 7-point Likert scale (1-completely unclear to 7-completely clear).

b) Task performance and effectiveness of movie

One question consisted of five parts, was generated to measure participants' assessment of task performance and effectiveness of movies. The respondents were asked to report the level of their agreement with the following statements, using 7-point Likert scale (1-completely disagree to 7-completely agree)

Items:

The choice table questions were easy.

I understood the choice table questions very well.

The movie was helpful for answering choice tables.

The movie made it easy to understand the choice tables questions.

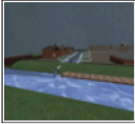
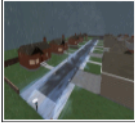
The movie made it easier for me to decide about the option that I preferred the most.

4.5.3.1.f Choice Cards

As explained in experimental design section, we ended up having 12 choice cards blocked to three surveys each presenting four choice cards. At first, choice cards were

built inside the virtual neighborhood. The goal was to test if having choice cards in that format would keep the presence level high and whether it would reduce the nominal complexity or not. Therefore, physical tables of choice cards were added at the end of the tour. The idea was asking people to look at those tables and fill out their most preferred choice in their questionnaire. It seemed a nice setting and we expected that people would enjoy it. However, the initial testing revealed that it's hard for people and they did not like it. Therefore, those tables were removed and the tables were built inside Surveygizmo. This was also a challenging task, since Surveygizmo did not accommodate the format similar to a typical choice card table. Therefore, someone with html expertise designed the choice card tables inside Surveygizmo. The choice cards were created using snapshots of related attributes from the virtual tour. The choice cards for avatar treatment included pictures with the avatar tour guide, while the treatment without avatar included the same pictures without the avatar.

11. Choice Table-4: Please review the following options:

Benefits and Characteristics of run off reduction techniques		Option 1	Option 2	Default
	Water quality improvement	Low effectiveness	Low effectiveness	Do Nothing
	Neighborhood flooding reduction	Moderate effectiveness	Moderate effectiveness	
	Basement flooding reduction	No effective	High Effective	
	Private benefits	Both	Water storage (reuse)	
	Maintenance effort per month	None	7-8 hours	
	Cost after rebate	\$375	\$500	

Which option do you prefer the most?

☐ Option 1
 ☐ Option 2
 ☐ Default (Do Nothing!)

Figure 2. An Example of the final choice cards (with Avatar)

4.5.3.1.g Demographics

The demographic section was designed to obtain simple demographic and socio-economic characteristics of the respondents as well as some questions about the type of their housing (see the final survey in Appendix D).

4.5.3.2 Final Tests

The final testing and revisions happened between January 2014 and June 2014. The first round of testing was conducted using the choice cards inside the virtual tour. It revealed that the format was not favorable and people did not like it. The second round started after new changes were adopted and added to the survey. The link of new questionnaire was sent to several people of different demographics and backgrounds as well as experts and the members of my doctoral dissertation committee.

The time taken to complete the entire questionnaire was approximately 10-12 minutes. The majority of respondents said that the questionnaire was easy to understand and the length of the survey was just fine. Some people said they needed more elaboration on choice cards, therefore we added to and revised the description of choice cards accordingly.

In terms of the quality of the movie, people's feedback was positive; they thought it looked fine and easy to understand. Almost everyone liked it and found it interesting.

I obtained feedback from Dr. Flora a senior research scientist at Stanford, on making some changes in the movie to increase the level of presence (for example taking shots from front side of the avatar and her face or adding personalized greeting to the script, like introducing herself).

The electronic pilot study was useful in terms of confirming the appropriateness and clarity of the survey questions and the movie. Therefore, it was expected that the study would be likely to generate meaningful data.

4.6 Survey Implementation and Data Collection

Implementing the survey required defining the sample frame and the sample size needed to get reliable results. After deciding about the sample size, data collection is the last step before statistical analysis.

4.6.1 Sampling Frame

The sampling frame defines the universe of respondents from which a finite sample is drawn to administer the data collection instrument (Rose & Bliemer, 2013). The objectives of the study dictates sampling frame (Rose & Bliemer, 2013). In this study the goal was to learn about the values and preferences of residents. Originally, we limited our sample to residents of Chicago and Urbana-Champaign. However, the final attributes turned out to be general and applicable to any place interested in small-scale climate adaptation and rainwater management strategies. Therefore, we collected our sample from residents and households living anywhere in the United States.

4.6.2 Sample Size

The traditional sampling theories do not address the issue of minimum sample size requirements in terms of the reliability of the parameter estimates produced, which is of interest to the CE analyst (Rose & Bliemer, 2013).

A number of researchers report rules of thumb for estimating sample size requirements for choice experiments. (Orme, 1998) suggested the following equation, which has been the most commonly cited rules of thumb. The formula provides an estimate of sample size for estimation of main effects only (Omre, 1998). We adopted the same formula since the study will be estimating the main effects only.

$$N \geq 500 \cdot \frac{L^{max}}{J \cdot S}$$

Where L^{max} is the largest number of levels for any of the attributes, J is the number of alternatives, and S is the number of choice tasks each respondent faces. Therefore, according to the formula ($500 \cdot 5 / 3 \cdot 4 = 208$), our sample size needs to be equal or larger than 208.

4.6.3 Implementation and Data Collection

Different methods of survey implementation were studied, including: sending letters with the link of questionnaire, sending an email with the link, using convenient sampling method. In midst of investigating implementation methods, I learned about a novel tool that has emerged in the last five years for conducting online behavioral research. The tool

is called crowd-sourcing platforms (Mason et al, 2012). Crowd-sourcing is a term that was first brought up in an article by Howe (2006), who defined it as a job outsourced to an undefined group of people in the form of an open call (Mason et al, 2012). These platforms provide access to a persistently available, large set of people who are willing to do tasks, including participate in research studies, for a relatively low pay (Mason et al, 2012). Amazon Mechanical Turk (AMT) is one of the most used crowd-sourcing platforms that have been employed by researchers. After testing the tool, we found it cost effective approach and decided to adopt it. The data for this study was gathered via AMT between Sep and Dec 2014. A sample of 300 was collected. Participants were limited to United States and were not allowed to retake the survey.

Chapter 5 - Analysis and Results

5.1 Introduction

This chapter presents and discusses the results of the study. It is organized in terms of the primary and secondary research questions that defined the study. The data collection has been explained in Chapter Four. Section 5.2 reports the data cleaning and data coding processes. Section 5.3 reports socio-demographic and basic statistics, which includes the housing information as well as attitude and perception results. The results of social presence formation and related procedure are explained in section 5.4. The choice experiment model specification and the results of the regression is described in Section 5.5 describes the results of choice experiment regression and it is. Section 5.6 examines the impact of social presence on choice experiment. Section 5.7 examines the role of socio-demographics, perception, attitudes and housing information on attributes and choice of LID, and Section 0 concludes the analysis.

5.2 Data

This study involved several steps of data cleaning and data coding which are described below.

5.2.1 Data Cleaning

Surveys were administrated using the Amazon Mechanical Turk (AMT). Section 4.6.3 talks about the validity of AMT and surveys done through this medium. For each survey

type, equal number surveys were released to the AMT users (called workers). A total sample of 304 surveys was collected. In AMT, the researcher can specify the criteria for the workers who can take the surveys and can reject the surveys that do not match with the criteria. Therefore, the collected data were verified for their validity and the surveys that did not follow the rules, were removed.

- One rule was that no one should take the survey more than once. This was checked using two methods: their life cycle approval rate in AMT which demonstrates how reliable they are from other researchers' point of view, and checking the internet IP addresses from which the surveys had been submitted. It was realized that few participants had retaken the survey. For the similar IP addresses, the one with the shortest survey time was dropped.
- Another rule was set that only the AMT workers from the US can participate in the surveys, however there were few Non-US participants who had taken the survey. Those participants were identified and dropped from the sample.
- It was realized that for some participants, the survey time was too short. Therefore the whole survey was checked based on response time. There frequency distribution of response time showed that 5% of the sample took less than seven minutes (while the original testing had revealed an average of 10-12 minutes). Therefore it was decided to drop the surveys with less than 7 min response time. We ended up with a sample of 198 after conducting the data cleaning.

Table 6. Distribution of the collected data during the data cleaning process

	Total	Survey 1	Survey 2
Total Data Collected	304	146	158
After Removing duplicate IPs	260	124	136
After Removing Partial answers and Non-US	217	109	108
Subtotal	217	109	108
Time >=7	198	100	98

5.2.2 Data Coding

5.2.2.1 Social Presence Coding

- Respondents had seven choices in answering the social presence item questions. The answer choices were: completely disagree, disagree, somewhat disagree, neither agree nor disagree, somewhat agree, agree, and completely agree. Scores were assigned from 1 (complete disagree) to 7 (completely agree).
- The implicit assumption in this coding is that the marginal utility is constant among the levels, meaning that the utility gained/lost from going from completely disagree to disagree is equal to the utility gained/lost from going from disagree to somewhat disagree. Therefore, there is only one coefficient estimated for each question.
- Another way of coding is to create a dummy variable for each answer. Each dummy variable takes a value of 1 if the respondent has chosen that answer, and 0 otherwise. In this case, one answer choice is considered as the base case. Therefore, $n-1$ dummy variables should be created for each question, where n is the number of choices. For the question that has seven possible choices, six

dummy variables should be created. The advantage of this coding is that it lets the marginal utilities of going from one choice to the next differ from going from another level to its next. This advantage, however, comes at a cost, that is, $n-1$ parameters need to be estimated. Estimating more parameters require a larger sample size. Therefore, this coding puts a high burden of data collection and computational power on the researcher. In this case, due to the limitations on data collection, the first method was selected.

- Attitude⁸, Perception⁹, Clarity¹⁰, and Choice Card Complexity¹¹ questions all have similar answer choices and were coded similarly.

5.3 Sample Descriptive / Basic Statistics

This section reports the socio-demographic characteristics of respondents, housing information as well as attitude and perception information.

5.3.1 Socio-demographic Data

Table 7 summarizes the personal socioeconomic characteristics of the participants. The age of respondents ranged from 18 to 65+ years of age with a median age of (25-34) years. However, the majority of participants (60%) were between 26 to 45 years old. The sample consisted of 117 (60%) female and 78 (40%) male. The large majority of the sample, 97.46 percent, graduated from high school or had attended or graduated from

⁸ Survey Question 1

⁹ Survey Question 2

¹⁰ Survey Question 7

¹¹ Survey Question 12

college; 54.82 percent were college graduates while 5.58 percent were holding graduate degrees. The types of employment reported were as follows: 77% (others), 39% (belonged to business), 30% (service) and 28% (sales). A small percentage (8%) was in academics and government and 6% were students. The personal income level for almost half of participant (48%) is below \$10,000, while 33.5% of participants' income level is between 10,000-35,000K and rest above 35, 000 (10.15% are between 35,000-70,000 and 7.61% above 70,000)

Table 7. Frequency distribution of the Socio-economic information in the collected data

Description		Frequency	Percent
Gender	Female	117	60.0
	Male	78	40.0
Age	18-25	20	10.3
	26-35	80	41.0
	36-45	47	24.1
	46-55	35	18.0
	56-65	11	5.6
	65+	2	1.0
Education	1 no school	1	0.5
	2 some school	4	2.0
	3 high school graduate	73	37.1
	4 college graduate	108	54.8
	5 grad school	11	5.6
Occupation	Academic	8	4.1
	Business	39	19.9
	Government	8	4.1
	Other	77	39.3
	Sales / Retail	28	14.3
	Service	30	15.3
	Student / Other	6	3.1
Income	1 below \$10,000	96	48.7
	2 \$10,001 - \$35,000	66	33.5
	3 \$35,001 - \$70,000	20	10.2
	4 \$70,001 - \$150,000	15	7.6

5.3.2 Housing Data

Housing data was collected through questions that explored type and age of housing, ownership status and the existence of basement. Residential level LID techniques are those LID techniques to be installed at resident's house. Therefore housing related questions, were added to the survey as informational questions. The results of these questions are reported in Table 8 below. The result showed that about half of participants (51.53%) were homeowners and the rest (48.47%) did not own their houses. The majority of participants (66.67%) lived in detached houses, while the rest lived in an apartment (22.56%) and semi-detached houses (10.77%). More than half (58.88%) of participants did not own a basement, while 21.32% owned a finished basement and 19.8 owned an unfinished one.

Table 8. Frequency distribution of housing information in the collected data

Description	Frequency	Percent
Ownership	Own	101
	Rent	95
House Type	Apartment	44
	Detached house	130
	Semi-detached house	21
Basement	I do not have a basement.	116
	I have a finished basement.	42
	I have an unfinished basement.	39
House Age	I do not know	18
	Less than 10 years old	22
	Less than 30 years old	73
	Less than 75 years old	58
	More than 75 years old	26

5.3.3 Knowledge and Perception Questions

In this section the results of knowledge and perception questions will be presented. The literature shows that LID knowledge and perception affects choice (Bowman et al.,

2012), previous flooding experience and risk perception (e.g. Grothmann & Reusswig, 2006) are predictors of taking action. Therefore questions about were added to the survey. Questions reflecting familiarity with LID, and if there is any plan to adopt it, were also added. These questions were asked in the beginning of the survey before the participants watch the movie and learned about LID techniques

5.3.3.1 Familiarity with LID

Familiarity questions contained three questions asking participants to rank their level of familiarity with the three selected LID techniques, namely: rain garden, rain barrel and permeable pavement. Figure 3 presents the results. More than half of participant indicated that they were not familiar with two of the three LID techniques: rain garden (68.02%) and permeable pavement (63.27%). However, the majority of participants were familiar with rain barrels (66.84%) and it was only one third of participant who were not familiar with rain barrels (33.16%). The average familiarity score was 1.56, 2.54, 1.69 out of 5 for rain garden, rain barrel and permeable pavement respectively.

5.3.3.2 Adoption of LID This Year

It was useful to know whether participants had any plan to adopt LID in this year. Figure 4 shows the results. Majority of participants indicated that they do not plan to add any of the three LID techniques to their home this year; rain garden (75.25%), rain barrel (71.72%) and permeable pavement (85.05%).

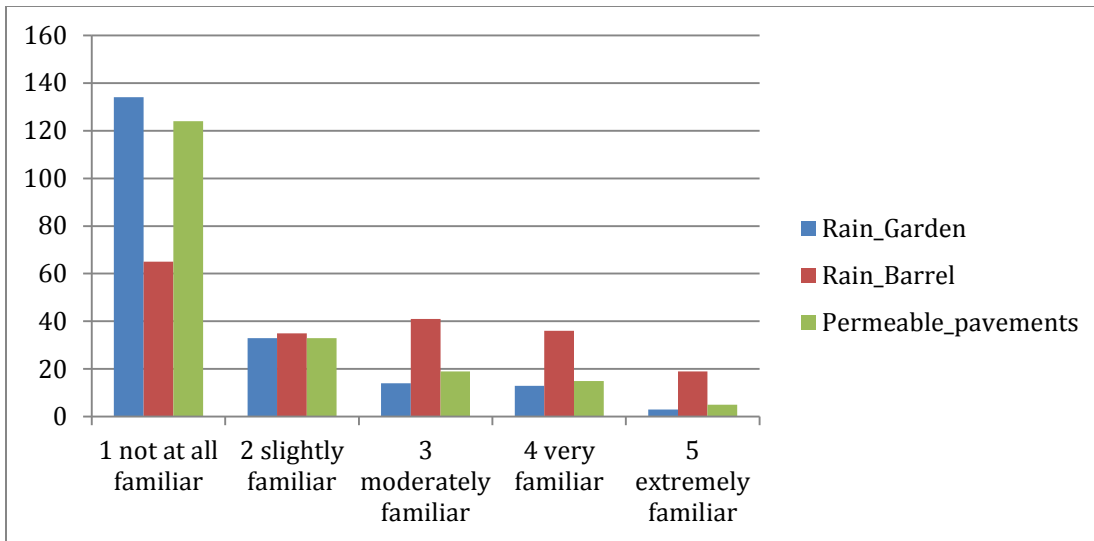


Figure 3. Frequency distribution of familiarity with LID techniques

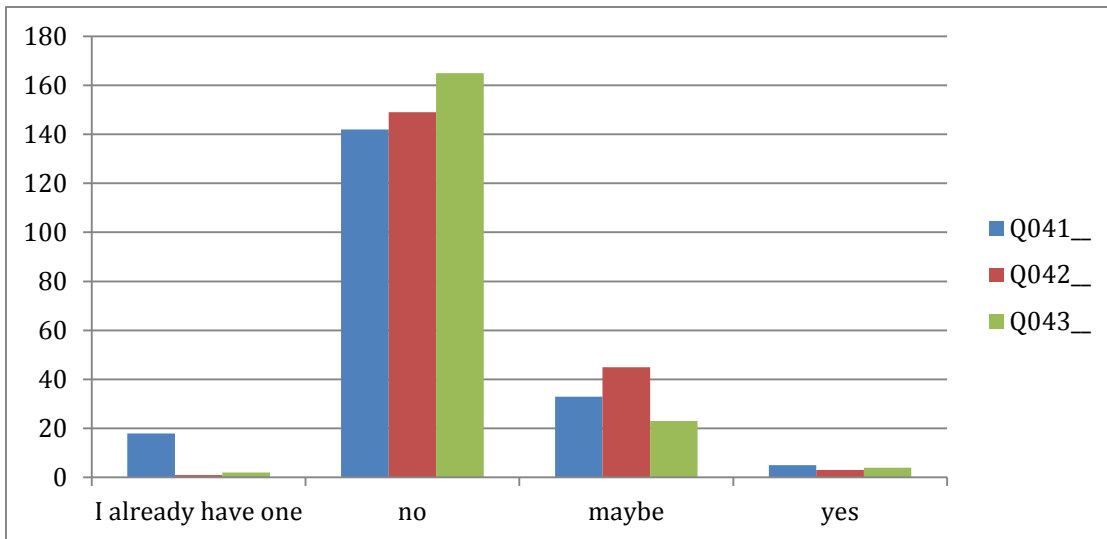


Figure 4. Frequency distribution of possibility of adoption of selected LID in the coming year

The graph shows the distribution of the answers to the following questions:

Q041: Do you plan to add rain barrel to your home this year?

Q042: Do you plan to add rain garden to your home this year?

Q043: Do you plan to add permeable pavement to your home this year?

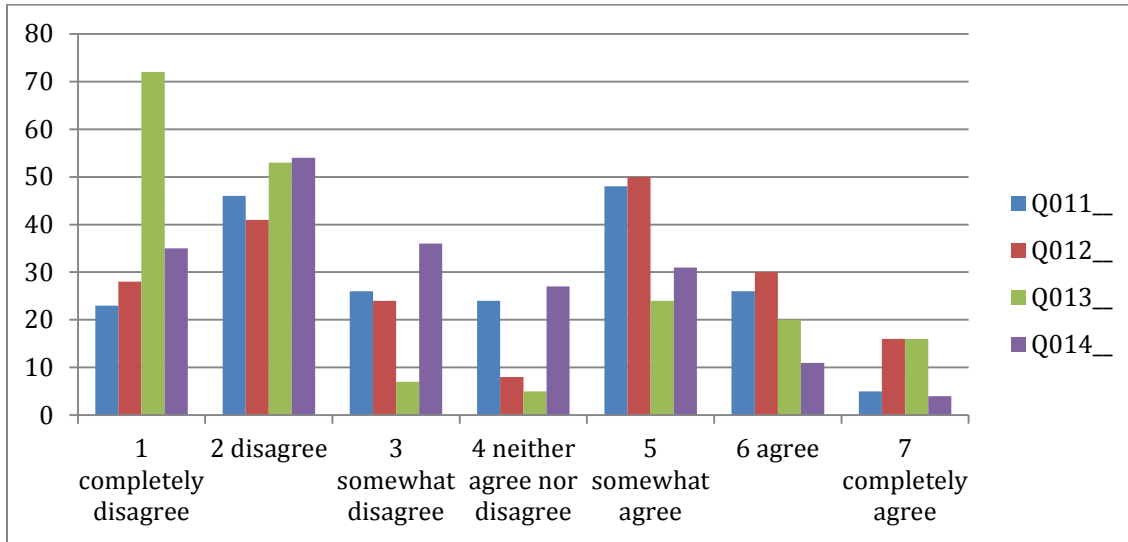


Figure 5. Frequency distribution of prior flooding experience and risk perception
The graph shows the distribution of the answers to the following questions:
Q011: my neighborhood gets lots of rainwater run off
Q012: I have experienced sever rain and flood events
Q013: I have experienced basemen-flooding events
Q014: I am concerned about the current pattern of rain in my city

5.3.3.3 Previous Flooding Experience and Risk Perception

According to the results (Figure 5), the majority of participants had not previously experienced basement flooding (67%).

5.3.3.4 Rainwater Knowledge and Perception

In order to explore perception and knowledge about rainwater, we asked participants to rank their level of agreement with three statements on impacts of rainwater run off. It was important to know whether participants link the current raining events to climate change or not. Therefore the last question, asked them to rank their level of agreement with that statement. The statements have been listed below Figure 6. The majority of participants

(over 70%) agreed that rainwater run off causes basements and neighborhoods to flood, while the rate of agreement that rainwater causes neighborhoods to flood was a little higher (78.46%) than the belief of rainwater causes basements to flood (73.60%). However, 60% of participants agreed that rainwater run off pollutes nearby streams and rivers. Approximately 60% of participants believed current rain events are being influenced by climate change.

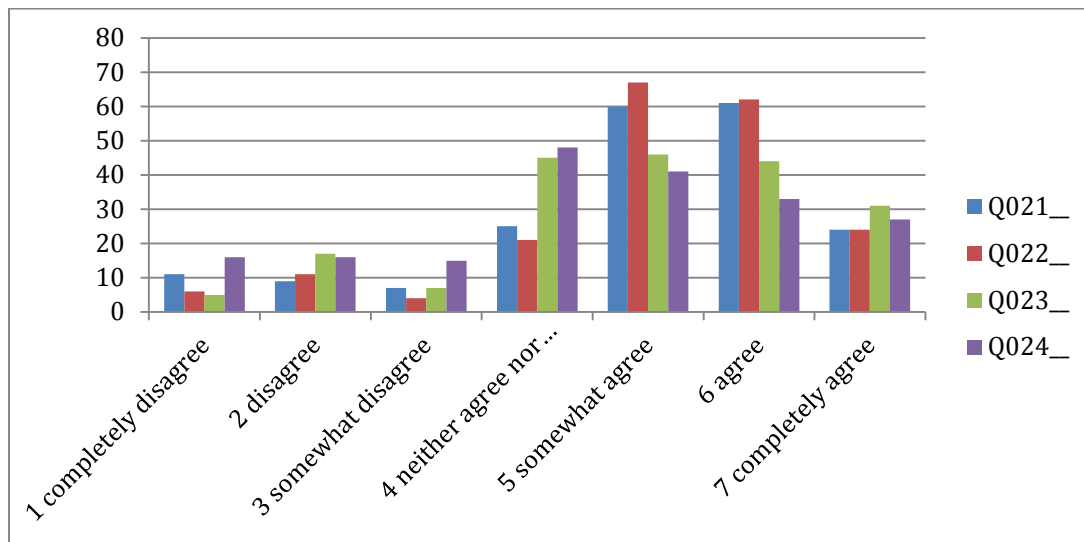


Figure 6. Frequency distribution of rainwater knowledge and perception
The graph shows the distribution of the answers to the following questions:
Q021: rainwater run off cause the basements to flood
Q022: rainwater run off cause neighborhoods to flood
Q023: rainwater run off pollutes near by streams and rivers
Q024: The current rain events are caused by climate change

5.4 Social Presence Formation

5.4.1 Social Presence

The primary goal of this research was to examine the impact of social presence on choice

experiment model and outputs. However, before examining the impact, it was required to measure the formation of social presence between the two treatments. This was achieved in two steps: first defining and conceptualizing SP and second measuring social presence. The following section presents the result and statistics related to social presence formation.

5.4.1.1 Social Presence Scale (Defining and Conceptualizing Social Presence)

The general process of how social presence is being conceptualized in the literature explained previously in chapter 3. Social presence can be conceptualized as a uni-dimensional or a multi-dimensional concept. Since this study is, to our knowledge, the first to link social presence with choice experiment, it was decided to define social presence as a unidimensional concept. A minimum of three items is required if social presence is conceptualized as a unidimensional concept.

Review of published literature revealed that co-presence, perceived message understanding and, ‘socialness’ dimensions might be suitable dimensions to be used for the context of this study. Hence, four items were selected from these dimensions and were adjusted accordingly. The four items included:

- 1) The tour guide's presence was obvious to me.
- 2) It was easy to understand the tour guide.
- 3) I felt a sense of actually being together with the tour guide.
- 4) The movie felt sociable.

The four items were tested in a pilot study using 40 participants. A sample of 40 (20 of each treatment) was collected through Amazon Mechanical Turk. An independent sample t-test was performed comparing the mean score of each item in survey one with its corresponding item in survey two. It was found that the two samples were not significantly different. Although the results were inconclusive, (since the sample size was small), analysis identified some items to be possibly poor indicators. It was therefore, decided to make some changes and revise the selected items. First, the item from perceived message understating dimension (e.g. it was easy to understand the tour guide) was removed, since both treatments seemed to be very similar in terms of this item. Second, the item from socialness dimension (the movie felt sociable) was rephrased to; *I felt a sense of sociability with the virtual tour guide*. Third, another item from socialness dimension (*I felt a sense of human warmth with the virtual agent*) was added. The list of new items is as follows:

- 1) I felt a sense of actually being together with the tour guide
- 2) The tour guide's presence was obvious to me.
- 3) I felt a sense of sociability with the virtual tour guide.
- 4) I felt a sense of human warmth with the virtual agent

5.4.1.2 Measuring Social Presence

The social presence was measured through subjective self-reported measure as described in Chapter 3. Participants had to choose from a 7-point Likert scale asking their level of

agreement with each of the above items. The scale ranged from completely disagrees to completely agree.

Table 9 shows the Social Presence Scale used in this study along with the descriptive statistics. The mean and standard deviation was evaluated for each of the 4 items in the Social Presence Scale. Maximum score possible for each item is seven.

It should be noted that the spatial presence formation was also checked. However, it was not anticipated that spatial presence would happen since the treatments were designed and differentiated to accommodate social presence. We did not find any difference between the two treatments in terms of spatial presence formation.

Table 9. Descriptive statistics of the social presence questions

Social presence items	Mean	Standard Deviation
1- I felt a sense of actually being together with the tour guide.	4.70	1.50
2- The tour guide's presence was obvious to me	5.56	1.27
3- I felt a sense of sociability with the virtual tour guide.	4.60	1.51
4- I felt a sense of human warmth with the virtual tour guide.	4.67	1.63

(The answers range from 1 (completely disagree) to 7 (completely agree), and the midpoint (4) is “neither agree nor disagree”. The mean of all answers are out of 7 and all are above the midpoint.)

Factor analysis: In order to create the SP variable, the factorability of items needs to be checked. The factor analysis tells us how many factors we really have, for example if three factors are so correlated, they are not representing three but two. The Eigenvalue was 2.734 and the result showed that the all four items load on one factor. Therefore, all

items can be used and averaged to construct the social presence variable. The result of factor analysis has been reported in Table 10.

Table 10. Factor analysis for social presence questions

Eigenvalues of the Correlation Matrix: Total			
Eigenvalue	Difference	Proportion	Cumulative
2.734	2.038	0.684	0.684
0.696	0.357	0.174	0.858
0.339	0.109	0.085	0.942
0.230		0.058	1.000

(The first factor, represented with the highest eigenvalue, explains 68.4% of the information of the four special presence questions. The first three factors, explain 94.2% of the inforamtion in those questins.)

The items were then averaged and constructed the social presence variable. An independent t-test was performed and it was found that the social presence variable between the two groups were significantly different in 10% ($\text{pr}(T < t) = 0.09150$).

The spatial presence items and therefore the spatial presence variable were not found to be significant, as expected ($\text{Pr}(|T| > |t|) = 0.5621$).

Results show that the difference between the two treatments is statistically significant. However, the direction of change was unexpected and contrary to our initial hypothesis. Published literature indicates that the presence of an avatar, which is a form of human agent, can cue the heuristic of social presence. Therefore, we had hypothesized that the sample with avatar would experience higher level of social presence. However the results revealed that the sample without avatar has been showing higher level of social presence. One theory that may explain this, is the theory called uncanny valley (Mori et

al., 2012). According to this hypothesis, that a type of human look that is almost but not exactly like natural human being, causes a response of revulsion among some human observers. This area of repulsive response aroused by a robot with appearance and motion between a "barely human" and "fully human" entity is called the uncanny valley. It implies that an almost human looking robot will seem overly strange to some human beings and will produce the feeling of uncanniness (Mori et al., 2012).

In this experiment, the appearance of the avatar, may have sparked similar feelings because it is not exactly a human being but is very similar to one, therefore it may have created such an effect. The other possibility is that our sample participants may not necessarily be familiar with Second Life (SL), therefore have not experienced avatars before. So, the result could have been different if a sample of participants who are familiar with SL (or had previous experience with SL) had been selected for this study. Another issue might be the design-related issues. In our initial design, when the avatar was introducing the attributes, she was mostly walking around while her back was toward the camera. In the testing process, it was suggested to add some scenes from her face to increase the presence. Therefore, we deliberately added few scenes that she speaks to people while her face is toward the camera. These scenes were added in the beginning, middle and the end. This may have created the feeling of uncanniness too because the look of her face is an avatar face and artificial while her voice is a human voice and may create that expectation of human face.

5.5 The Results of Choice Experiment

In this section the results of choice experiment for the whole sample is presented. In the next section, we present the impact of social presence on the results of choice experiment for the two sub-samples that received the low and high social presence treatments.

5.5.1 Model Specification

The major types of econometrics model specifications are discussed in Chapter 3. The Multinomial model (MNL) is the most popular among the researchers as demonstrated by the published literature. However, the model uses a strong assumption that choices conform to the independence from irrelevant alternatives (IIA) as discussed in chapter 3. In a real choice experiments research, however, this assumption is not realistic. Therefore, the conditional Logit model, also described in Chapter 3, was adopted. Our model follows the random utility framework and characteristics theory discussed in the same chapter.

In a discrete choice experiment, choices can be modeled as a function of the attributes of the alternative profiles relevant to a given choice problem (Louviere et al., 2000). It is assumed that the relative importance is reflected by the part-worth utilities associated with each of the attributes, and the choice selected by participants will normally have the highest overall utility. Given that it is not possible to measure all characteristics of a choice objectively, the overall utility (U_i) of choice i is considered to have both a deterministic component (V_i) and a stochastic component (ϵ_i).

$$U_i = V_i + \epsilon_i$$

The deterministic component (V_i) represents a vector of attributes of the choice that can be measured. In this study, V_i expresses the relative importance of choice attributes as shown in the model below. Water quality represents effectiveness of LID in improving water quality in nearby streams and rivers (measured by amount of rainwater run off collection on site). Neighborhood and basement represent effectiveness of LID in neighborhood and basement flooding reduction. Side benefits represent benefits such as extra green space, water reuse obtained by installing LID. Maintenance represents the amount of effort (hours per month) required for the maintenance of LID, and cost represent the cost of installation after rebate reduction (the residents need to pay that out of their own pocket).

$$U_i = \beta_1.Water\ Quality_i + \beta_2.Neighborhood_i + \beta_3.Basement_i + \beta_4.Side\ Benefit_i \\ + \beta_5.Maintenance_i + \beta_6.Cost_i + \epsilon_i$$

where β_j are coefficients of the j -th attribute and ϵ_i is the error function of the utilities. These coefficients represent respondents' partial utilities for each attribute, which are assumed to represent the overall utility for a choice alternative. For example, β_1 represents the marginal utility of an extra unit improvement in water quality.

Significant coefficients indicated which attributes and values are influential to respondents' choice between the offered LID options. The magnitudes of the coefficients represent the relative degree of preference for each attribute: the larger the coefficient, the

greater the preference for that attribute. In another word, the higher the overall utility for an alternative, the more likely that alternative is to be selected.

The discrete choice model to fit the data was Conditional Logit that was discussed in Chapter 3.

As discussed in coding, the approach taken to code the attribute levels determines the number of parameters to be estimated and their interpretation and assumption. A simple coding, that was adopted here, assigns ascending numbers with equal distance (e.g. 1,2,3) to the ascending levels of each attributes. This implies that for every attribute there is only one parameter that needs to be estimated. Therefore, in this approach the number of parameters that need to be estimated is equal to the number of attributes. This reduces the need for computational power and the number of observations needed to fit the model compared to other coding methods explained in the same section. These benefits, however, come at a cost and that is the assumption that the marginal utility of each attributes is constant among its levels. In another word, the utility gained from one level increase from 1 to 2 is the same as the utility gained from one level increase from 2 to 3, etc.

5.5.2 Results

Table 11 reports the results of the conditional Logit model:

Table 11. The results of conditional logit

(The estimates are the estimated coefficients and represent the marginal utility of each attribute. The standard error shows the estimate error and p-value shows the statistical significance of the coefficients. Generally, a p-value less of than 5% is considered statistically significant, implying that the estimated coefficient is statistically different than zero at 5% margin of error.)

Analysis of Conditional Maximum Likelihood Estimates			
Parameter	Estimate	Standard Error	P-Value
Water	0.2961	0.098	0.0025
Neighborhood	0.2223	0.087	0.0107
Basement	0.7955	0.1347	<.0001
Private	0.061	0.0574	0.2882
Maintenance	-0.0858	0.0237	0.0003
Cost	-0.00179	0.000766	0.0197

5.5.2.1 Participants Preferred LID Attributes: Main Effects

All main effects utility parameters for the LID attributes were statistically significant, except the side benefits (i.e. *private*). This means that the estimated parameters are statistically different than zero (i.e. statistically significant) at 5% margin of error, as shown by their *p-values* that are less than 5%. The obtained signs of the attribute are as expected: *water quality*, *neighborhood*, and *basement* have positive coefficients (marginal utility) and *maintenance* and *cost* have negative coefficients.

5.5.2.1.a Preferences for Water Quality Improvement (Effectiveness)

The first attribute examined the respondents' preference for effectiveness of LID in improving the water quality at nearby streams and lakes, positing that this people preferred more effective LID techniques in water quality improvement. This hypothesis was supported by the findings. It was expected that any LID technique that offers higher water quality improvement would increase the utility of individuals. Therefore, it was

expected that water quality improvement would have a positive sign. The coefficient is also statistically different than zero at 5% level of error ($p\text{-value}<5\%$), meaning that it is a factor that impacts people's preferences.

5.5.2.1.b Neighborhood Flood Reduction

The second attribute/hypothesis examined the participants' preference for effectiveness of LID in reducing neighborhood flooding. The hypothesis is that the effectiveness of LID in reducing the neighborhood flooding will predict the residents' choice. Therefore, it was expected that water quality improvement will have a positive sign, which it has. It is also statistically significant at 5% level ($p\text{-value}<5\%$) that means this factor has a relation with people's choices.

5.5.2.1.c Basement Flood Reduction

The third attribute examined the participants' preference for reduction of basement flood, hypothesizing that the higher the effectiveness of LID in reducing basement flooding, the higher the probability of choosing the LID. As expected by this hypothesis, the coefficient is positive showing there is positive relation between this factor and choices. The coefficient is also statistically significance at 5% level ($p\text{-value}<5\%$).

5.5.2.1.d Private / Side Benefits

The fourth attribute was side benefits. Side benefits are positive private benefits that the resident would obtain by installing LID. Examples include water reuse (for rain barrel), extra green space or both. This attribute was not found to be statistically significant at 5%

significance level, showing that there is no statistical relation between this factor and the choices in this sample. Therefore, the alternative hypothesis that this factor plays a role in respondents' adoption of LID is not supported.

5.5.2.1.e Maintenance

The fifth attribute was maintenance, which examined the role of effort (hours per month) required for a specific LID. It was hypothesized that the higher the level of maintenance required, the lower the utility of the individual and therefore the lower the probability of adopting LID practice. Hence, it was expected that the parameter sign will be negative. The estimated parameter confirmed the hypothesis: maintenance was found to be negative. The parameter is also statistically significant at 5% level of error ($p\text{-value} < 5\%$) meaning that this factor has an influence on the respondents' choices.

5.5.2.1.f Cost After Rebate

The last attribute is cost after rebate. Initially the cost and rebate had been listed as two different attributes. That way, it could have provided more detailed information on the impact of cost and rebates on people's choices. However, in the pilot testing process, it was decided to combine them to shorten the list of the attributes.

The hypothesis is that cost should have a negative impact on utility, therefore the higher the cost, the lower the probability of adopting LID practice. The estimated parameter confirms the hypothesis: The cost was found to be negative. It is also statistically significant at 5% level of error.

5.5.2.2 The Tradeoff Among Different Attributes

The tradeoff between different attributes, i.e. the rate at which the participants are willing to give up one unit of an attribute for a one unit increase in another attribute, is also known as marginal rate of substitution. This can be calculated by dividing the coefficients. (Louviere et al., 2000)

For example, from the respondents' responses it is inferred that the effectiveness of LID in terms of improving water quality in nearby streams and rivers from one level to another was considered $0.2961/0.2223=1.33$ times more important than the LID's effectiveness in neighborhood flood reduction. In another word, the utility gained from one level increase in water quality is 1.33 times more than the utility gained from one level increase in neighborhood flood reduction. This could be also explained as marginal rate of substitution: it is inferred that the respondents may be willing to give up 1.33 level of neighborhood water reduction to gain one more level of water quality in the nearby rivers.

5.5.2.3 Willingness to Pay (WTP) for Attributes of LID

The WTP for each attribute can be calculated for those that are significant. Since money is involved as one of the attributes, the tradeoff ratio between the attribute involving money (i.e. cost) and the other attribute gives its willingness to pay value.

Mathematically, the willingness-to-pay value for moving from one level of the attribute to the other can be calculated by $\beta_{attribute}/\beta_{Cost}$. Table 12 shows the estimated amount of money that the participants are willing to pay for one additional level of each attribute.

Table 12. Willingness to Pay (WTP) for the attributes

Paramter	Willingness To Pay
Water	165.4
Neighborhood	124.2
Basement	444.4

5.6 Impact of Social Presence on CE Outputs

5.6.1 Introduction

The previous section presented the results of choice experiment (the outputs). In this section the impact of social presence on choice experiment outputs and model is presented. In order to measure the impact of social presence on choice model, it is necessary to develop and define metrics of comparison.

The literature review (presented in Chapter 2) presented three common metrics (among others metrics) that have been used in comparative studies and are considered suitable in the context of this study. Regarding information provision in CE, there are two main types of comparative CE studies. One type is the study of design dimensions (number of attributes, number of alternatives, and number of choice sets) and the other is the study of information presentation (the impact of visual stimuli, virtual attribute presentation). Both type of studies have used the impact size of parameter estimates (coefficients) as a proxy to measure the impact of the study treatment, whether variation in design dimensions or

information presentation. (Mazzotta and Opaluch (1995), Bateman et al., 2009)

The second common metric that is used in such comparative studies is goodness of fit (Arentze, T. H et al., 2003). Goodness of fit is a statistical model that describes how well it fits a set of observations.

The third metric is the error variance of the utility model. Random utility model defines utility as two parts: a deterministic part that can be captured by the researcher, and a random part that is unknown to the researcher. According to the literature, lower variance of this parameter means less variations in preferences and hence more accurate estimate of preferences (Hoehn et al., 2010), Bateman et al., 2009).

This study adopts the same three approaches that seemed to be commonly used in the literature. Besides the above approaches, other studies have asked subjective self-reported questions on task performance and complexity (see Berneburg (2007). A similar approach was adopted in this study and few questions on attribute clarity and task performance were added to examine the difference between the two treatments from participant subjective views as well.

The following section reports the analysis of the results. The first section reviews the comparison of the two models in more detail and describes the results of the final comparison in terms of the size of coefficients (attributes' weights) to examine whether the level of social presence has affected the importance of attributes for participants or not. Second, the outputs of the two models were compared for the fitness of the good.

Third, the error variance was estimated for the two models. Fourth, the self reported attribute clarity and task performance was compared for the two treatments.

5.6.2 The Importance of Attributes (The Model's Coefficients)

There are several ways to measure the impact of social presence on choice experiment model, such as: fitting one model with dummy variable for one of the two samples, fitting separate models on each sample and comparing them, and introducing the interaction of the dummy variable for one sample with the coefficients. To compare the models, the following statistics were used: goodness of fit measures, and error variance.

5.6.2.1 Dummy Variable

One simple and commonly used method in econometrics is to assume that both samples have similar relation with the attributes (i.e. similar coefficients) and they only differ in level (i.e. intercept). This method employs a simple dummy variable that takes the value of 1 for one sample and 0 for the other sample. The estimated coefficients show the difference of two samples. This method, however, does not work for the study because this dummy variable is constant within both groups and plays no role in determining the conditional probabilities of positive outcomes within groups. Therefore, the conditional Logit fitting procedure either simply drops the dummy variable or produce an insignificant coefficient.

5.6.2.2 Interaction with Coefficients

Another method is to relax the assumption mentioned in the first approach and assume that two samples have different relations with the attributes, i.e. they have different coefficients. In other words, the impact of social presence reflects whether or not the coefficients are different and if they are, in what direction. To verify this, the interaction of the attributes was used with a dummy variable that takes the value of 1 for survey two and 0 for survey one. In other words, I estimated the following model:

$$\begin{aligned} U_i = & \beta_1.Water\ Quality_i + \beta_2.Neighborhood_i + \beta_3.Basement_i + \beta_4.Side\ Benefit_i \\ & + \beta_5.Maintenance_i + \beta_6.Cost_i + D.(\gamma_1.Water\ Quality_i \\ & + \gamma_2.Neighborhood_i + \gamma_3.Basement_i + \gamma_4.Side\ Benefit_i \\ & + \gamma_5.Maintenance_i + \gamma_6.Cost_i) + \epsilon_i \end{aligned}$$

where D is the dummy variable and γ_1 to γ_6 are the *difference* of survey one and two in relation to each attribute. For example, β_1 is showing the marginal utility of Water Quality for survey one and $\beta_1 + \gamma_1$ is the marginal utility of that attribute for survey two. Table 13 shows the estimated parameters for this model. Parameters γ_1 to γ_6 are shown by adding “_S2” suffix to the attribute names. The standard errors and p-values of these parameter estimates show that none of γ_1 to γ_6 is statistically significant at 5% significance level. Therefore, this method cannot reject the hypothesis that the coefficients have no difference and is inconclusive.

Table 13. The results of conditional logit for the interaction of the attributes with-avatar and no-avatar (The coefficients with _S2 ending represent the incremental marginal utilities of each attribute for no-avatar sample compared to with-avatar.)

Analysis of Conditional Maximum Likelihood Estimates			
Parameter	Estimate	Standard Error	Pr > ChiSq
Water1	0.4458	0.1398	0.0014
Neighbor1	0.1848	0.1202	0.1243
Basement1	0.7772	0.1866	<.0001
Private1	0.0783	0.0811	0.3342
Maintenance1	-0.1174	0.0337	0.0005
Cost	-0.00223	0.00106	0.0354
water_S2	-0.3072	0.1966	0.1182
Neighbor_S2	0.0877	0.1755	0.6173
Basement_S2	0.0513	0.2709	0.8497
Private_S2	-0.0365	0.1153	0.7515
Maintenance_S2	0.0643	0.0478	0.1779
cost_s2	0.000846	0.00154	0.5835

5.6.2.3 Two Models

Another way of comparing two samples is to model them separately. In this approach, the data for surveys one and two are separated, and they are regressed against the same attributes using the conditional Logit. Each survey then has its own parameter estimates that may or may not be the same as the others. Table 14 shows the output of this experiment. As the table shows, the signs of the estimates match with the expectations for each model. The models, however, are different in terms of the statistical significance of their parameters. In survey one, Neighborhood becomes statistically insignificant (in addition to Private that was insignificant in the original model) while in the model for survey two, more parameters become insignificant: Water Quality, Maintenance and Cost

are insignificant and Neighborhood and Basement are significant, all at 5% significance level.

Table 14. The results of conditional logit for with-avatar and no-avatar sampels separately

Parameter	Survey 1		Survey 2	
	Estimate	P-Value	Estimate	P-Value
Water	0.4458	0.0014	0.1386	0.3162
Neighborhood	0.1848	0.1243	0.2725	0.0331
Basement	0.7772	<.0001	0.8285	<.0001
Private	0.0783	0.3342	0.0418	0.6097
Maintenance	-0.1174	0.0005	-0.053	0.1173
Cost	-0.002232	0.0354	-0.001386	0.2159

(Survey 1 represents the with-avatar sample and survey 2 represents the no-avatar sample.)

5.6.2.4 Goodness of Fit

Another way of comparing survey one and two in terms of the impact of the social presence on sensitivity to attributes is to compare their model fit. The idea behind the method is that if social presence has helped the respondents to get a better sense of the questions, their responses should be more precise and exhibit less variations, and the model error should be smaller. This could be tested by comparing the goodness of fit measures of the models.

Table 15 shows the goodness of fit statistics for the separate models for each survey discussed in the previous section. All of the statistics show a better fit for survey two. It should be noted that these goodness of fit statistics penalize the models for additional variables in the model, therefore the better fit of survey two is in spite of having more insignificant variables. Therefore, these statistics show an improvement for the treatment with higher level of social presence (survey two).

Table 15. Comparison of goodness of fit measures for the models for with-avatar sample and no-avatar sample

Goodness-of-Fit Measures			
Measure	Survey 1	Survey 2	Formula
Likelihood Ratio (R)	141.19	143.29	$2 * (\text{LogL} - \text{LogL0})$
Upper Bound of R (U)	878.89	850.33	$-2 * \text{LogL0}$
Aldrich-Nelson	0.2609	0.2702	$R / (R+N)$
Cragg-Uhler 1	0.2974	0.3094	$1 - \exp\{-R/N\}$
Cragg-Uhler 2	0.3346	0.3481	$(1 - \exp\{-R/N\}) / (1 - \exp\{-U/N\})$
Estrella	0.3194	0.3333	$1 - (1 - R/U)^{(U/N)}$
Adjusted Estrella	0.2948	0.3082	$1 - ((\text{LogL} - K) / \text{LogL0})^{(-2/N * \text{LogL0})}$
McFadden's LRI	0.1606	0.1685	R / U
Veall-Zimmermann	0.3796	0.3932	$(R * (U+N)) / (U * (R+N))$

(Survey 1 represents the with-avatar sample and survey 2 represents the no-avatar sample.)

5.6.2.5 The Error Variance

The variance of error term indicates how much of the variability of the dependent variable is not explained by the independent variables in the model. Obviously, to have a good model, a lower error variance is desired. The error and its variance, however, are not observable. Thus, an estimator is needed. The usual approach is to use an estimator that is based on the sum of squared residuals. If the model is specified correctly, then the mean squared error, defined as sum of squared residuals divided by degree of freedom, is an unbiased estimator of error variance. The degree of freedom is the number of observation minus the number of parameters in the model that need to be estimated (number of variables plus one for intercept if there is any). Based on this approach, the residuals were calculated, then sum of squared residuals was divided by the number of variables in the model. It was found that the error variance reduced for the model with higher level of social presence.

Table 16. Error variance analysis for the models for with-avatar sample and no-avatar sample

Survey_Number	Error Variance
1	1.013756
2	1.004994

(Survey 1 represents the with-avatar sample and survey 2 represents the no-avatar sample.)

5.6.2.6 Self-reported Measures

Self reported measures were developed as two categories; First, the clarity of attributes. Second, task performance difficulty and the effectiveness of the movie in facilitating task performance. The clarity of attributes question (explained in ch4) included seven part, asking participants to rank the level of clarity of each attribute that was presented by the tour guide. (The list of questions can be found in chapter four). The same 7-point Likert scale was adopted except that the range was defined as completely unclear to completely clear (1=completely unclear, 7=completely clear). The task performance questions included questions related to choice card difficulty and the effectiveness of the movie (footnote: ch4). Respondents were asked to report their levels of agreement with those statements on a 7-point Likert scale (1=strongly disagree, 7=strongly agree). The results are reported in the following sections:

5.6.2.7 Self reported Clarity of Attributes

First the distribution of attribute clarity for the whole sample was estimated. One positive result is that participants report high level of clarity of different attributes (see Figure 7). This adds to validity of the study, it shows that the attributes have been clear for people and they have not had problem understanding them. However, the two samples

do not show a significant difference in terms of attribute clarity. In order to explore the possibility of any relationship, the correlation between social presence and attribute clarity was checked. It was found that a correlation between social presence and attribute clarity do exist for the whole sample. Since there is significant correlation, the social presence has been important in attribute clarity for the whole survey but it seems that the two samples do not show a significant difference.

5.6.2.8 Self-reported Task Performance and Effectiveness of Movie

In this section participants were asked to rank their level of agreement with five statements regarding the task performance and effectiveness of the movie. It was also found that the two samples were not significantly different on self-reported task performance.

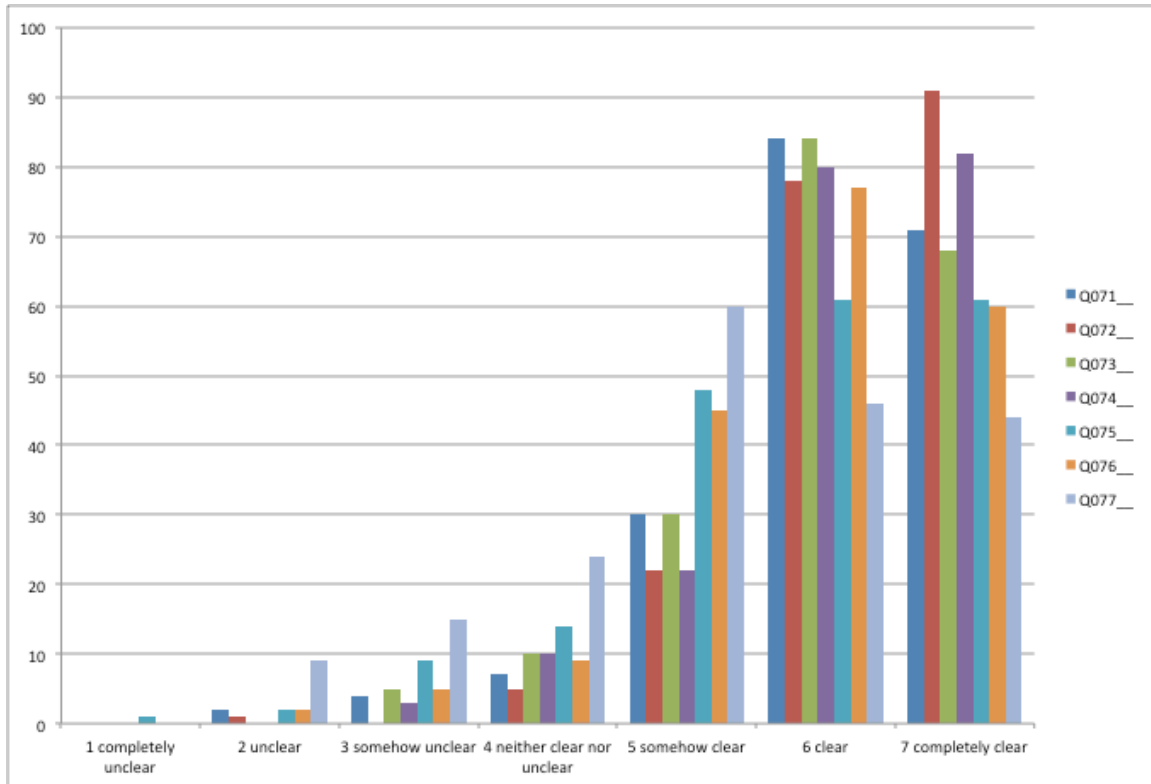


Figure 7. Distribution of self reported attribute clarity
The graph shows the distribution of the answers to the following questions:
Q071: Water quality improvement in nearby steams,
Q072: Neighborhood flooding reduction,
Q073: Basement flooding reduction, Q074: Water storage (reuse),
Q075: Green Space, Q076: Maintenance effort, Q077: Cost

5.7 Exploring Factors Affecting the Importance of Attributes

The results in section 5.4 revealed the important attributes that would affect participants' decision making when considering adoption of LID. In this section, we extend the analysis by exploring factors that may have affected (contributed to) the importance of those attributes. As discussed in section 5.3, one important factor is the role of socio-economic characteristics. Housing characteristics is also hypothesized to play a role since

LID techniques would be installed on houses. In this section the role of such factors on importance of attributes has been explored.

a) Impact of socio-economics characteristics on attributes: For analyzing the role of socio-economic factors on importance of attributes, several models were tested and eventually, the model with significant variables was selected.

Income: the impact of income on importance of cost was explored by examining the interaction of income and cost. Different interactions of income and cost was examined and it was found that the interaction of cost and income for less than \$70,000 is statistically significant while its interaction with income greater than \$70,000 is not. Therefore, the group was split into two samples (low income – income less than \$70,000 / high income – income greater than \$70,000). The cost is only statistically significant for the low-income group. Although coefficients were different but we wanted to make sure that they are statistically significant too. Therefore a t-test was also conducted to see if the coefficients are statistically different, the test shows that the coefficient of cost for those who earn below 70,000 is significantly different than the one for those who earn above 70,000. Next, the interaction between income and maintenance was analyzed. A negative and significant interaction was found. On the other hand, as income increase the negative impact of maintenance on participants' utility increase in higher rate. However, the later t-test revealed that the difference is not statistically significant.

Gender: Gender did not make a difference in importance (marginal utility) of water quality improvement, neighborhood-flooding reduction, basement flooding reduction and

cost attributes but it was significantly different for maintenance attribute. The sign was negative which means that the level of maintenance had negative impact on their utility (decreased males' utility more than females).

b) Impact of housing type on attributes: The impact of housing information was examined on basement flood reduction attribute. The type of ownership was not significant; having basement did not affect the utility of basement flood reduction, while the prior experience of flooding did.

c) Impact of rainwater knowledge and familiarity with LID: The first section of the survey asks participants to rank their level of agreement with statements about rainwater opinion and knowledge; examples include:

The role of these factors on importance of attributes was tested as well. It was found that the belief that rainwater runoff pollute nearby stream and rivers was significant for selecting water quality improvement attribute. A t-test was conducted to check if they are significantly different too. The test also showed that the coefficient of water quality for those who believed that rainwater causes pollution is significantly higher than those who do not believe in that. I did not find any significant relationship between the beliefs that rainwater run off causes neighborhoods and basements to flood with the importance of neighborhood and basement flood reduction attributes. The belief that the current rain events are influenced by climate change did not have any significant impact on attributes.

LID knowledge: The survey asked about the level of familiarity with three LIDs (rain barrel, rain garden and permeable pavement). The role of familiarity was then examined on attributes (water quality, neighborhood flood reduction, basement flood reduction and maintenance). It was found that familiarity with rain garden affects the importance of water quality attribute. The higher level of familiarity with rain garden, resulted in higher marginal utility for water quality improvement. We did not find any relationship between the level of familiarity with rain barrel and permeable pavement and importance of attributes. The interest in gardening did not have any impact on importance of attributes as well. The impact of some socio-economic variables on rainwater knowledge was examined. We did not find any difference between rainwater knowledge and perception by gender. The role of age was also examined, the age groups were put together and two main categories were built, below 45 and over 45.

The above analysis was conducted by adding interactions of variable of interest to the original model. The details of results can be found in Table 17.

Table 17. The result of conditional logit analysis for the interaction of selected socio-economic factors with the attributes

Analysis of Conditional Maximum Likelihood Estimates			
Parameter	Estimate	Standard Error	P-Value
water_NoPol	0.1415	0.1152	0.2193
water_Pol	0.4426	0.1143	0.0001
Neighborhood	0.2281	0.0884	0.0099
base_NoExp	0.6742	0.1436	<.0001
base_Exp_Yes	0.8799	0.1754	<.0001
base_Exp_No	1.9557	0.358	<.0001
Private1	0.0686	0.0581	0.2376
Maintenance_IncLT70	-0.0809	0.0244	0.0009
Maintenance_IncGT70	-0.18	0.0839	0.0319
cost_IncLT70	-0.00201	0.000781	0.0101
cost_IncGT70	0.000921	0.00143	0.5192

(water_NoPol and water_Pol: Water Quality attribute for those who “do not agree” and “agree” with “Rainwater runoff pollutes nearby streams and rivers”; base_NoExp: basement flooding attribute for those who did not have prior basement flooding experience; base_Exp_Yes: basement flooding attribute for those who had prior basement flooding experience and currently have basement; base_Exp_No: basement flooding attribute for those who had prior basement flooding experience and currently do not have basement; Maintenance_IncLT70: maintenance attribute for those with income less than \$70,000; Maintenance_IncGT70: maintenance attribute for those with income greater than \$70,000; Cost_IncLT70: cost attribute for those with income less than \$70,000; Cost_IncGT70: cost attribute for those with income greater than \$70,000;)

5.8 Extension of the Study: Explanatory Analysis of Variables

The primary analysis that compared the impact of the social presence for the two conditions (avatar vs non-avatar) did not find a significant difference between the two conditions. However, correlation analysis revealed that there was a significant correlation between social presence and attribute clarity (see section 5.6.2.7). Therefore it was speculated that the social presence might have had some impacts that was not captured by the conditions and so the comparison between the two conditions did not reveal any significant difference.

To explore the role of the social presence further, I did some tests across the two conditions. The social presence was defined as the independent variable to predict the dependent variables with the condition entered as a dummy variable with 1 for avatar and 0 for no avatar.

The following equation was estimated for several dependent variables:

$$Y_i = \beta_0 + \beta_1 \text{SocialPresence} + \beta_2 \text{Condition} + \epsilon_i$$

in which, β_0 is the intercept, β_1 captures the relation between the social presence and the dependent variable, and β_2 shows the impact of the condition (avatar vs. no-avatar). The model was run for different dependent variables including the involvement factor, the attribute clarities, and task performance variables.

First the relationship between involvement and social presence was tested. The social presence was found to be positive and significant (p-value <0.0001). The condition coefficient was statistically insignificant. The R^2 for the model was 0.44, showing that there is a relatively strong relationship between the social presence and involvement.

Second, the model was used to estimate the relationship between the average of attribute clarity (Q07Av) as well as each of the attribute clarity variables (Q071 to Q077) with social presence. In all of the models, the coefficient of social presence was positive and statistically significant and the condition was insignificant, implying a relationship between social presence and attribute clarities but no condition effect, although the R^2 is not as strong as it was for involvement factor.

Third, each item of task performance section (Q12-1 to Q12-5) was tested as dependent variable. Again, the social presence coefficient was positive and statistically insignificant. However, the R^2 were not high. The condition coefficients were all statistically insignificant.

Fourth, using motivation as dependent variable, we tested the relationship between motivation and social presence. In this model, the condition showed a positive and statistically significant coefficient, implying that the group with avatar got higher motivation compared with the group with no-avatar. The coefficient for social presence was also positive and statistically significant as in previous questions.

Overall, the results showed that social presence was a significant predictor for all these outcomes (attribute clarity, task performance, involvement and motivation), but the condition (avatar vs. no-avatar) had no impact except on motivation (See Table 18 for details).

This study had previously examined the role of spatial presence and it was found that the two treatments were not significantly different in terms of spatial presence. In our explanatory section, we decided to test the role of spatial presence as an explanatory variable. The same tests were conducted for spatial analysis as an explanatory variable, and the following equation was estimated:

$$Y_i = \beta_0 + \beta_1 \text{SpatialPres} + \beta_2 \text{Condition} + \epsilon_i$$

The results showed that spatial presence also predicts outcomes such as attribute clarity, task performance, involvement and motivation (see Table 19 for details).

5.9 Conclusion

This chapter presented the results and findings. Next chapter will present the conclusion and discussions. A summary of the study and the results will be presented along with the discussion on importance (contribution) of findings and their implications. The limitations of the study and future research will be discussed as well.

Table 18. Analysis of relation between social presence and attribute clarity

Dependent Variable	Variable	Parameter Estimate	Standard Error	t Value	Pr > t	R_Square
Q068_ The_movie_was_involving	Intercept	1.30251	0.3606	3.61	0.0004	0.4449
	SocialPresence	0.79857	0.06843	11.67	<.0001	
	avatar	0.1573	0.16264	0.97	0.3348	
Q07Av- Average of Q071 to Q077	Intercept	4.26767	0.22498	18.97	<.0001	0.2738
	SocialPresence	0.34022	0.04269	7.97	<.0001	
	avatar	-0.02469	0.10147	-0.24	0.8081	
Q071_ Water_quality_improvement_in_nearby_steam	Intercept	4.3855	0.29733	14.75	<.0001	0.1685
	SocialPresence	0.33026	0.05642	5.85	<.0001	
	avatar	0.10924	0.1341	0.81	0.4164	
Q072_ Neighborhood_flooding_reduction	Intercept	4.79164	0.24906	19.24	<.0001	0.2035
	SocialPresence	0.30947	0.04726	6.55	<.0001	
	avatar	-0.03545	0.11233	-0.32	0.7527	
Q073_ Basement_flooding_reduction	Intercept	4.09894	0.29138	14.07	<.0001	0.2474
	SocialPresence	0.40394	0.05529	7.31	<.0001	
	avatar	-0.14442	0.13142	-1.1	0.2733	
Q074_ Water_storage_(reuse)	Intercept	4.71335	0.29223	16.13	<.0001	0.1376
	SocialPresence	0.2879	0.05545	5.19	<.0001	
	avatar	0.10122	0.1318	0.77	0.4436	
Q075_ Green_Space	Intercept	4.21553	0.36564	11.53	<.0001	0.1234
	SocialPresence	0.3317	0.06938	4.78	<.0001	
	avatar	-0.11854	0.16491	-0.72	0.4732	

(Questions 071 to 077 and 07Av), and between social presence and involvement (Questions 068 and 121 to 125), and between social persence and motivation (Question 130)

Table18 (cont'd). Analysis of relation between social presence and attribute clarity.

Dependent Variable	Variable	Parameter Estimate	Standard Error	t Value	Pr > t 	R_Square
Q076_ Maintenance_effort_	Intercept	4.42068	0.33528	13.19	<.0001	0.1082
	SocialPresence	0.28829	0.06362	4.53	<.0001	
	avatar	0.09312	0.15122	0.62	0.5388	
Q077_ Cost	Intercept	3.24805	0.4326	7.51	<.0001	0.1458
	SocialPresence	0.42996	0.08209	5.24	<.0001	
	avatar	-0.178	0.19511	-0.91	0.3629	
Q121_ The_choice_table_questions_were_easy	Intercept	4.53066	0.42712	10.61	<.0001	0.0237
	SocialPresence	0.16383	0.08105	2.02	0.0448	
	avatar	-0.01261	0.19264	-0.07	0.9479	
Q122_ I_understood_the_choice_table_questions_very	Intercept	5.08731	0.33033	15.4	<.0001	0.0379
	SocialPresence	0.15947	0.06268	2.54	0.0118	
	avatar	0.09549	0.14898	0.64	0.5224	
Q123_ The_movie_was_helpful_for_answering_choice	Intercept	3.68876	0.30021	12.29	<.0001	0.268
	SocialPresence	0.44882	0.05697	7.88	<.0001	
	avatar	0.01423	0.1354	0.11	0.9164	
Q124_ The_movie_made_it_easy_to_understand_the_c	Intercept	3.90225	0.34019	11.47	<.0001	0.2026
	SocialPresence	0.41305	0.06456	6.4	<.0001	
	avatar	-0.16423	0.15343	-1.07	0.286	
Q125_ The_movie_made_it_easier_for_me_to_decide_a	Intercept	3.21485	0.37124	8.66	<.0001	0.2253
	SocialPresence	0.49481	0.07045	7.02	<.0001	
	avatar	0.02431	0.16743	0.15	0.8847	
Q130_ How_motivated_were_you_to_follow_the_quest	Intercept	2.52605	0.2728	9.26	<.0001	0.1894
	SocialPresence	0.30677	0.05177	5.93	<.0001	
	avatar	0.31216	0.12304	2.54	0.0121	

Table 19. Analysis of relation between spatial presence and attribute clarity

Dependent Variable	Variable	Parameter Estimate	Standard Error	t Value	Pr > t	R_Sq
Q068_ The_movie_was_involving	Intercept	0.86222	0.2451	3.52	0.0006	0.6756
	SpatialPresence	0.89748	0.04734	18.96	<.0001	
	avatar	-0.05239	0.12263	-0.43	0.6697	
Q07Av- Average of Q071 to Q077	Intercept	4.52892	0.20397	22.2	<.0001	0.2355
	SpatialPresence	0.2872	0.0394	7.29	<.0001	
	avatar	-0.09305	0.10205	-0.91	0.3631	
Q071_ Water_quality_improvement_in_nearby_steam	Intercept	4.34157	0.26512	16.38	<.0001	0.2056
	SpatialPresence	0.33975	0.05121	6.63	<.0001	
	avatar	0.04948	0.13264	0.37	0.7096	
Q072_ Neighborhood_flooding_reduction	Intercept	5.10712	0.22205	23	<.0001	0.1644
	SpatialPresence	0.24905	0.04289	5.81	<.0001	
	avatar	-0.10953	0.11109	-0.99	0.3255	
Q073_ Basement_flooding_reduction	Intercept	4.67723	0.2734	17.11	<.0001	0.157
	SpatialPresence	0.29137	0.05281	5.52	<.0001	
	avatar	-0.23776	0.13679	-1.74	0.084	
Q074_ Water_storage_(reuse)	Intercept	4.88002	0.26479	18.43	<.0001	0.1229
	SpatialPresence	0.24491	0.05114	4.79	<.0001	
	avatar	0.10397	0.13248	0.78	0.4336	
Q075_ Green_Space	Intercept	4.72477	0.3297	14.33	<.0001	0.07
	SpatialPresence	0.22595	0.06368	3.55	0.0005	
	avatar	-0.15094	0.16495	-0.92	0.3614	

(Questions 071 to 077 and 07Av), and between spatial presence and involvement (Questions 068 and 121 to 125), and between spatial presence and motivation (Question 130)

Table 19 (cont'd). Analysis of relation between spatial presence and attribute clarity

Dependent Variable	Variable	Parameter Estimate	Standard Error	t Value	Pr > t	R_Sq
Q076_ Maintenance_effort_	Intercept	4.42835	0.29974	14.77	<.0001	0.1264
	SpatialPresence	0.2894	0.0579	5	<.0001	
	avatar	-0.02493	0.14997	-0.17	0.8682	
Q077_ Cost	Intercept	3.54336	0.39212	9.04	<.0001	0.1264
	SpatialPresence	0.36997	0.07574	4.88	<.0001	
	avatar	-0.28164	0.19618	-1.44	0.1529	
Q121_ The_choice_table_questions_were_easy	Intercept	4.77016	0.3827	12.46	<.0001	0.0155
	SpatialPresence	0.12157	0.07392	1.64	0.1019	
	avatar	-0.04955	0.19147	-0.26	0.7961	
Q122_ I_understood_the_choice_table_questions_very	Intercept	5.00667	0.29434	17.01	<.0001	0.0568
	SpatialPresence	0.17939	0.05685	3.16	0.0019	
	avatar	0.06618	0.14726	0.45	0.6537	
Q123_ The_movie_was_helpful_for_answering_choice	Intercept	3.75856	0.2604	14.43	<.0001	0.3036
	SpatialPresence	0.43682	0.0503	8.68	<.0001	
	avatar	-0.07518	0.13028	-0.58	0.5647	
Q124_ The_movie_made_it_easy_to_understand_the_c	Intercept	4.00434	0.2951	13.57	<.0001	0.2226
	SpatialPresence	0.3954	0.057	6.94	<.0001	
	avatar	-0.2501	0.14764	-1.69	0.0921	
Q125_ The_movie_made_it_easier_for_me_to_decide_a	Intercept	3.49453	0.3323	10.52	<.0001	0.2156
	SpatialPresence	0.44261	0.06418	6.9	<.0001	
	avatar	-0.09321	0.16625	-0.56	0.5758	
Q130_ How_motivated_were_you_to_follow_the_quest	Intercept	2.0935	0.2335	8.97	<.0001	0.3242
	SpatialPresence	0.39786	0.0451	8.82	<.0001	
	avatar	0.18853	0.11682	1.61	0.1084	

Chapter 6 - Conclusion and Future Research

This chapter presents an overview of the study and the results. It will also discuss the contributions of the dissertation as well as the limitations of the study and future areas of research.

6.1 Summary of the Study

This study brought the concept of social presence to a choice experiment model. It is innovative and pioneering in that to my knowledge, it is the first study to integrate social presence to choice experiment modeling. The integration enabled the examination of the impacts of social presence on choice experiment model and outputs. This was one of the primary goals of the study, which was achieved through enhancing the level of social presence while presenting (describing) attributes of a choice experiment to survey participants.

This integration was done in the virtual world platform, Second life. The attributes of the choice experiment were visualized and built within this virtual environment. The context of the study was residents' adoption of low impact development (LID) techniques. The choice experiment study is also innovative in its study of preference for small scale (residential level) LID techniques. Previous choice experiment studies have looked at the value of large-scale LID techniques

The study design consisted of two major parts that were interconnected and involved lots of back and forth between the two. The two stages included the design of the choice experiment and the design of the virtual part.

The choice experiment was designed to examine the importance of selected public and private attributes of residential level LID techniques on residents' decision making. The attributes and their levels were defined through several stages of literature review, attending public meetings and consulting with LID experts. An orthogonal fractional factorial experimental design was developed, and the options were put together to build the choice cards.

For the virtual part, two neighborhoods were designed inside a virtual world platform called Second life. The residents of one neighborhood had adopted LID practices while the residents of the other neighborhood had not. Different scenarios were designed to visualize each attribute. The scenarios were then delivered to my developer who constructed those scenarios inside the neighborhood.

To enhance the level of social presence, a human agent avatar was adopted. The avatar gave a tour of LID attributes, and the same tour was conducted without an avatar as control treatment. Both treatments were filmed and added to the survey that was built using an online survey platform called Surveygizmo. The data was collected in fall 2014 using Amazon Mechanical Turk (see chapter 4).

6.2 Summary of the Results

This dissertation was explored the extent to which the level of social presence would affect the choice experiment model and outputs. In order to measure the impact, four metrics were developed using the previous comparative studies from the literature. First, the impact on marginal utility (importance of attributes) was examined. I did not find any significant impact on coefficients of the model (marginal utilities), indicating that social presence has not affected the utility of attributes. Second, the impact on goodness of fit and error variance was examined. A slight improvement in both metrics was observed; however, further analysis revealed that the changes were not significant. Third, the impact of social presence on self-reported measures was examined. I analyzed whether the self-reported measures (attribute clarity and task performance questions) were significantly different for the high and low social presence treatments. Although the whole sample reported high levels of clarity and task performance, the sub-samples did not show a significant difference. Since the level of attribute clarity was high, I checked the correlation between social presence and attribute clarity and found that there is a significant correlation between attribute clarity and social presence. Therefore, another process of explanatory analysis was conducted (see section 5.8). The analysis revealed that the social presence was significant in predicting attribute clarity, motivation, involvement and facilitating the task performance.

Next I analyzed the choice experiment to see which LID characteristics people preferred and why. All proposed attributes (except the side benefits) were significantly different

than zero and the sign of each attribute was the same as expected. The marginal utility of basement flooding reduction, water quality improvement and neighborhood flooding reduction were all positive, while the marginal utility of maintenance and cost were negative. The results indicate that the participants valued the effectiveness of LID in fixing basement flooding higher than other attributes, which is confirmed by previous studies.

The second most important factor for participants was the effectiveness of LID in improving the water quality in nearby streams and river. The third was neighborhood flooding reduction. However, the coefficients of these two attributes were so close to each other and the tradeoff would not be high.

The next two important factors were maintenance and cost after rebate, which both had negative marginal utility. This finding is confirmed by previous studies. It implies that the higher the required maintenance time, the lower the probability of choosing LID techniques would be. The higher cost would also decrease the utility of LID and the probability of choosing LID techniques. However, it was found that the cost was not significant when income level increased to 70,000. It is important to note that the cost attribute accounts for the rebate and is not the real cost before rebate. Had the cost attribute excluded the rebate, the result would have been different. The results of the choice experiment are promising, and previous studies confirm the validity of the findings (see chapter 5 for details).

The willingness to pay for each attribute was obtained as well. Willingness to pay is the amount of money one is willing to pay to move from one level of attribute to the next level. In this study, it is assumed that the utility of moving from level one to level two is the same as the utility of moving from level two to level three.

The willingness to pay for basement flooding reduction is \$444.4. This implies that people are willing to pay \$444 if the technique is effective in fixing their basement flooding completely. The willingness to pay for water quality improvement is \$165.4; this willingness to pay indicates water quality improvement from a low to a moderate effectiveness level or from a moderate to a high effectiveness level. The willingness to pay for neighborhood flood reduction is \$124.2, implying a move from low to moderate or from moderate to high-level flood reduction.

Next, I analyzed the impact of socio-economic status, housing characteristics, prior experience of basement and neighborhood flooding, and rainwater and LID knowledge on importance of attributes. I found some of these factors do affect the importance of the attributes. I found that the interaction between income and cost is negative and significant, which is expected. Cost would affect the utility of people who have lower income more than those who have higher income. In fact, the analysis showed that as income goes above 70,000, the interaction would not be significant. Therefore, the cost would not be significant for those whose income is higher than 70,000.

Gender did not make a difference in importance (marginal utility) of water quality improvement, neighborhood-flooding reduction, basement flooding reduction and cost

attributes, but it was significantly different for maintenance attribute. The level of maintenance had a negative impact on their utility (decreased males' utility more than females).

The type of ownership and having a basement did not affect the utility of basement flood reduction, while the prior experience of flooding did.

The belief that rainwater run off pollutes nearby streams and rivers had a significant impact on the importance of the water quality improvement attribute while the belief that rainwater run off causes basements and neighborhoods to flood did not have a significant impact on the importance of basement flooding and neighborhood flooding attributes. The belief that the current rain events are influenced by climate change did not have a significant impact on the attributes.

The impact of familiarity with LID was also examined. It was found that familiarity with rain garden affects the importance (marginal utility) of the water quality attribute. I did not find any relationship between the level of familiarity with rain barrel and permeable pavement and importance of attributes. The interest in gardening did not have any impact on importance of attributes as well.

6.3 Interesting Findings

Social presence was found to be significantly different between the two models at 10% significance level; however, an interesting finding is the direction of the difference. It was hypothesized that the treatment with avatar would show a higher level of social

presence, but the results show a different direction. The non-avatar sample formed a higher level of social presence. One explanation could be that the look of the avatar may have induced a feeling of alienation to participants. We do not know if our participants were familiar with virtual world platforms such as Second life and the look of avatars on these platforms. Another possible reason that the avatar sample had lower levels of social presence is because the avatar had her back toward the camera while explaining attributes. Although a few scenes of the front side were added to enhance the level of presence, it seems that it did not affect the level of social presence.

6.4 Methodological Contribution and Implications

This study brought the concept of social presence to choice experiment modeling. This study is the first attempt to explore the role of social presence on choice experiment. Choice experiment offers a promising approach for environmental valuation, it offers higher flexibility and multiple possibilities. Its inherent advantages over other valuation methods make it a favorable method to be adopted while conducting a non-market valuation study. However, concerns have been expressed on comprehension and evaluability of information conveyed to participants, which may affect the accuracy of estimates. In response to this concern, this study proposes using virtual environments in choice experiment studies. Virtual environment (VE), including virtual reality and virtual world, offers characteristics that may have the potential to address some shortcomings of the choice experiment. This dissertation examined the extent of which the level of selected characteristics, namely social presence, may enhance choice experiment. The

original results were not conclusive: the two treatments of avatar / non-avatar did not show any significant differences in terms of attribute clarity and other self-reported measures. However, the significant correlation between social presence and self-reported measures implied the existence of some relationships. Analysis revealed that social presence was significant in predicting the outcomes of attribute clarity (task performance and effectiveness of the movie), motivations and involvement. So it seems that social presence has played a role, and the original inconclusive results could be due to the design of the study.

These findings are promising and have implications for the design of choice experiment studies. Enhancing the level of social presence while presenting information may enhance attribute clarity and comprehension. The level of social presence was also found to be significant for predicting involvement and therefore higher level of comprehension.

The promise of social presence is that it can be produced in different media platforms which makes it very cost-effective. Many studies using virtual reality or virtual world need people to physically be present in the lab. However, the formation of social presence can happen in multiple settings without needing a physical presence.

6.5 Theoretical / Other Contribution and Implications

The second objective of this study was to analyze the structure of public willingness to pay for selected attributes of residential level low impact development techniques using a choice experiment survey. The choice experiment study was novel in estimating the

value of residential level LID attributes. The study extends the field of choice experiment by applying it to residential level urban stormwater strategies and low impact development (LID) techniques. Previous CE studies related to LID were conducted at a large scale. In contrast, this study adds to the literature by identifying and examining the role of LID attributes at a small residential scale (micro level). These findings have broad implications for storm water management, climate change adaptation and environmental valuation.

First, I find that basement flood reduction, water quality improvement and neighborhood flooding reduction have positive marginal values while maintenance and cost have negative marginal values. Based on these results, I recommend that city planners and designers promote LID techniques by focusing on their ability to solve basement flooding issues. Residents would also be more likely to adopt LID techniques if rebates and incentives to compensate the costs were offered.

The fact that people valued the effectiveness of LID in providing public attributes such water quality improvement and neighborhood-flooding reduction is a promising finding. It shows that people value public attributes and are willing to pay for LID techniques that are effective in providing those attributes. This finding may have implications for the private provision of climate adaptation as a public good. Adopting LID techniques would not only manage the current rainwater run off but would also be a good adaptation strategy for future rain events that may be exacerbated by climate change. This finding

implies that people are willing to pay higher for LID techniques that provide a higher level of public adaptation services such as neighborhood flooding reduction.

In addition, the data on LID familiarity showed that residents overall had low levels of familiarity with LID techniques, particularly with rain gardens and permeable pavement. They had higher levels of familiarity with rain barrels. Therefore, there is a need for more educational programs that cover different types of LIDs, not just rain barrels.

Second, the use of virtual world in CE is another contribution to the field of CE. Although the benefits of virtual environments have been expressed in the literature, few studies have applied virtual environments to choice experiments. These few studies are mostly in a design, architecture, or marketing context to visualize a design or a good in 3D format. To my knowledge there are very few studies using CE and virtual environment in context of an environmental issue such as land use (see Bateman et al, 2009). This study is another example of a successful application of virtual environment to the field of CE and in the context of environmental valuation. The participants reported a high level of clarity of attributes and a high level of realism of the experience. They also reported a high level of motivation to answer the questions after watching the movie. The effectiveness of the movie for task performance was also high (see chapter 5). These findings confirm that the use virtual world in CE surveys is appropriate and add to the validity of this technique.

6.6 Limitations and Future Research

Since this research was the first study integrating social presence to a choice experiment, we needed to keep the scope small and manageable. Therefore, the basic and most common practices in both fields were adopted. The social presence was defined as one-dimensional, and the choice experiment was designed to study the main effects only. Future studies in both fields can examine the role of one or more dimensions of social presence (for example co-presence, attention allocation, perceived message understanding, etc.) on CE model and outputs in a more specific way. This study was the first attempt; hence, more studies are needed to validate the findings. Both fields can explore this new and fertile area of study.

It seems that the two treatments (avatar vs non-avatar) were not distinct enough to capture the impact of social presence. Future studies should come up with experiment designs where the treatments are more distinct to capture the role of social presence.

To enhance the level of social presence, an avatar was selected. I did not test whether the sample was familiar with Second life and avatars or not. A study with a sample familiar with second life may change the direction of social presence and produce different results. The appearance and attributes of an avatar may change the direction of social presence as well as the results.

This study shows what the field of communication and new media can offer CE surveys. More research should be done to examine the effects and contributions of new media

such as online surveys, 3D multimedia and virtual world technology in choice experiment surveys and preference studies.

We know from social cognition research that cues are the primary solution for dealing with information overload of any kind (Sundar, 2008). “Even when there is no desperate overload situation, people are known to be “cognitive misers” and will not expend more cognitive energy than necessary to arrive at a particular inference, and so will rely on cognitive heuristics (Fisk & Taylor, 1984)”, (Sundar, 2008, p:77). Virtual worlds can create cues to enhance the perception of social or spatial presence that may convey information or stimulate heuristics to enhance participants’ comprehension. The role of such cues and their potential contributions to CE should be explored in future studies.

Other issues expressed in CE literature that virtual world may be able to address include fatigue and boredom of participants while participating in the study. Future research can examine the role of virtual world characteristics in addressing such issues.

This study explored the concept of social presence and its potential contribution to CE. Other characteristics of a virtual environment can be explored in the future, such as the role of interactivity, immersion and spatial presence. My primary exploratory analysis revealed that spatial presence was significant in predicting some outcomes. Future research should study the impact of spatial presence in more detail.

The role of virtual world characteristics on addressing other limitations of CE such as hypothetical bias can also be explored. Bateman (2009) found that willingness to accept

(WTA) and willingness to pay (WTP) asymmetry anomaly would be reduced using virtual reality, and studies can be extended to test other anomalies such as decoy effects (Bateman et al., 2008).

In this study the social presence did not affect the importance of preferences. If such impact had been observed, further testing would have been required to avoid affecting people preferences in a way that might lead to overexpress their values.

While our discussions have been centered around contributions of virtual world effects and characteristics, one should not overlook the possibilities of negative impacts of such characteristics in future studies. For example, the type of avatar in my study may have affected the perception of social presence and therefore the results. Depending on how a particular affordance manifests itself to users, it can lead to positive or negative outcomes (Sundar, 2008). Therefore, one should take those factors into consideration when using virtual worlds.

The secondary goal of this research was to provide insight to LID program developers by identifying important attributes for residents who are considering adopting LID. Those attributes were identified and included in the study. LID techniques include multiple attributes. If the goal is mere valuation of LID techniques, different types of attributes might be necessary. Since the attributes needed to be visualized, attributes such as heat reduction or carbon sequestration could not be added.

The scale of the study (residential level) made it more challenging since there have not

been many studies on small-scale LID techniques. As the field develops, more attributes of LID techniques can be used in studies exploring people's preferences. In the testing stage, it was decided to combine cost and rebate attributes to reduce the number of attributes and to provide a general estimation of importance of cost. Future research can examine these attributes separately.

Another limitation was that participants were recruited throughout the United States instead of in a particular region. Because location was not the primary interest, this study adopted Amazon Mechanical Turk (AMT), a recruiting tool that does not limit participants according to geographic area. Future studies can conduct this study in a specific geographic area and compare the results. Geographic-based studies are important because features of a location (such as soil type, rain pattern, and climate) play a role in which LID practices will be most effective. These geographic-based studies can provide more location-based information for adoption of LID. Geographic-based studies can provide more precise information by taking such factors under consideration.

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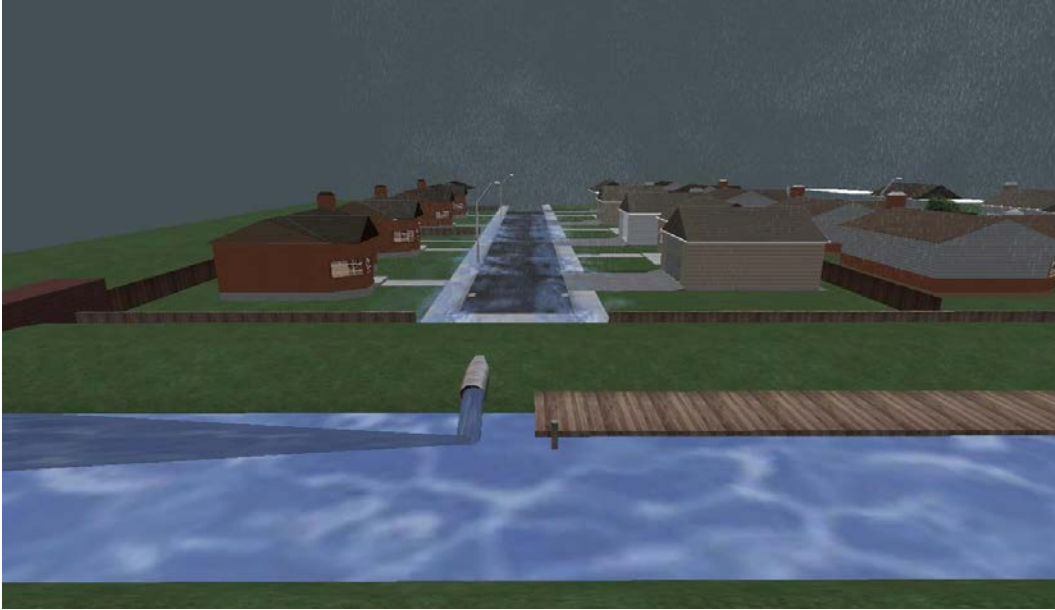
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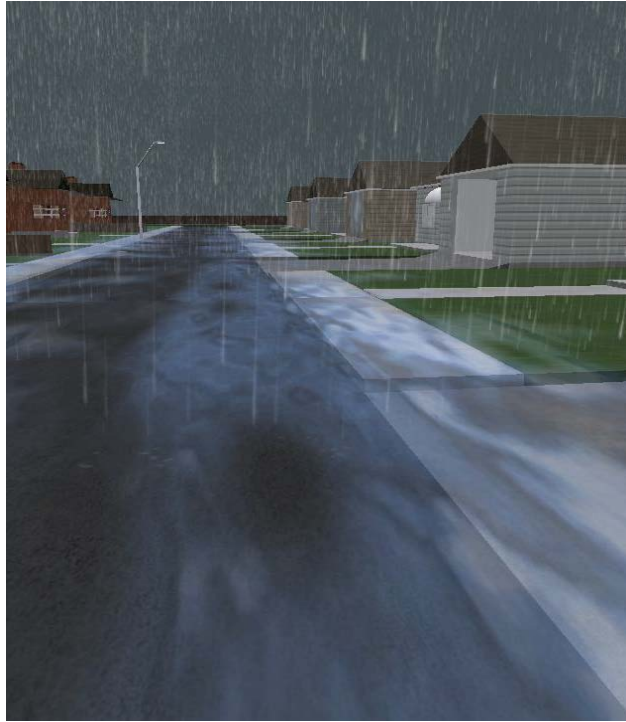
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Appendix A - Scenarios

Water quality improvement



Neighborhood flooding reduction:



Basement flooding reduction



Cost and rebate



Maintenance



Side benefits



Appendix B - The Scripts

Script- Part I:

Did you know that rainwater can be used as a valuable resource in your home? Did you know that by adopting techniques to prevent run off, rainwater is not only saved from being wasted but also issues such as neighborhood flooding and water pollution can be solved?

My name is Sara and I'll be your tour guide as we explore a few rainwater run-off reduction techniques. These techniques are strategies used to soak up rainwater on site and prevent run off, therefore helping with neighborhood flooding and water quality improvement.

There are many types of run-off reduction techniques, but today I will introduce you to three: rain gardens, rain barrels and permeable pavements.

A rain garden is a planted depression or hole that reduces rainwater run off by allowing it to be absorbed and soaked into the garden. Most rain gardens are then decorated with plants and flowers, making them a beautiful addition to a family home.

Rain barrels collect rainwater draining from the roof and store it to be used later, as the homeowner desires.

Permeable pavements are pavements made of materials that soak up rainwater and allow it to filter through them, reducing run off and effectively trapping pollutants from the water.

While all types of run off reduction techniques help with reducing run off, each provides its own unique benefits and characteristics that may appeal differently to each homeowner.

I will cover more of the unique characteristics of these methods in the next video.

Script- Part II:

Hi there! It's me, Sara, your tour guide! In this video I'll tell you a bit more about the characteristics and benefits of rainwater run-off reduction techniques, and towards the end I'll have a small survey asking you to answer some questions for me.

Why don't we start off our discussion with a tour of two neighborhoods?

You can see that the neighborhood on the right is using run off reduction techniques and the one on the left is not. Let's walk through both neighborhoods to see the differences:

A difference that you might not normally think of is water quality in nearby streams and lakes. Think about this: Every time it rains, rainwater runs off the roof and onto parking lots and streets, picking up pollutants along the way. Those pollutants flow into nearby streams and lakes, and eventually end up in our local water purification systems. By using runoff reduction techniques we can filter and soak up the rainwater on site and

prevent the pollution running off into the systems, contributing to overall water quality improvement. Recreational activities such as boating, fishing, and swimming are just few activities benefited by water quality enhancement in local water bodies.

As we walk through the neighborhood, you can see that the neighborhood without runoff reduction techniques is getting a great deal of run off, and several homes in the neighborhood are struggling with basement flooding. Both neighborhood flooding AND some types of basement flooding can be fixed or reduced by installing run off reduction techniques. For example, the owner of this house installed a rain garden a little distance from the basement, and has a perforated pipe that drains water from the downspout to the rain garden. Runoff problem solved!

Other benefits of installing run off reduction techniques for residents, include water storage and reuse and additional green space. For example, by installing a rain barrel, you can store water and reuse it to water your garden. Rain gardens can enhance your property value by providing additional green space.

When looking at the benefits of run off reduction techniques, I'm sure you're thinking, "this is great, so what's the catch? The catch is that you need to balance these benefits with installation cost and maintenance efforts. These techniques need different levels of maintenance, For example, a rain garden needs weeding and gardening. Permeable pavements need occasional sweeping, and rain barrels need occasional cleaning. The installation cost varies according to design, size and type of materials used. However, the

good news is that your city may provide incentive and rebates for residents who install run off reduction systems.

So if we put together all of the benefits of rainwater runoff reduction techniques that we've learned, the list would be: water quality improvement, overall neighborhood and basement flood reduction, water storage and reuse, and extra (additional) green space. Of course, we must balance those benefits with the maintenance and cost required for each option.

Now I would like you to go to your survey and answer some questions about what you learned in your tour. And thank you very much for your participation!

Appendix C – Low Impact Development Scenarios

Table 20. Scenarios considered for permeable pavement

$$\text{Water Saved (gal)} = \text{Area (ft}^2\text{)} * \text{Retention Rate} * \text{Average Rain (inch)} * 144 \text{ inch}^2/\text{ft}^2 * 0.00433 \text{ Gal/inch}^3$$

The annual average rain was assumed to be 41.46 inch (<http://www.weather.com/weather/wxclimatology/monthly/61820>).

The areas are estimates for a hypothetical 1600 ft² house.

Measure	Scenarios	Area (SqFt)	Retention Rate	Water Saved (gal)
Permeable Pavement	Driveway	200	0.8	160
Permeable Pavement	Walkway	80	0.8	64
Permeable Pavement	Both	280	1.8	504

Table 21. Scenarios considered for planting trees

$$\text{Water Saved(gal)} = \text{Number} * \text{Avg Interception per Tree (gal/tree)}$$

Measure	Type	Number	Avg Interception per Tree (gal/tree)	Water Saved (gal)
Planting tree	1 Small	4	292	1,168
Planting tree	1 Medium	3	1129	3,387
Planting tree	1 Large	2	2258	4,516

Table 22. Scenarios considered for rain barrel

$$\text{Water Saved (gal)} = (\text{Efficiency Rate} * \text{Drainage Area (ft}^2\text{)} * \% \text{ of rainfall captured} * \text{Average Rain (inch)} * 144 \text{ inch}^2/\text{ft}^2 * 0.00433 \text{ Gal/inch}^3$$

The annual average rain was assumed to be 41.46 inch (<http://www.weather.com/weather/wxclimatology/monthly/61820>).

The areas are estimates for a hypothetical 1600 ft² house

Measure	Efficiency Rate	Drainage Area (SqFt)	% of Rainfall Captured	Water Saved (gal)
Rain Barrel	0.85	1000	25%	5,493
Rain Barrel	0.85	1000	50%	10,987
Rain Barrel	0.85	1000	75%	16,480

Table 23. Scenarios considered for bioretention and infiltration

Water Saved (gal) = (Area (ft²) + Drainage Area (ft²) * % of rainfall captured) * Average Rain (inch) * 144 inch²/ft² * 0.00433Gal/inch³

The annual average rain was assumed to be 41.46 inch (<http://www.weather.com/weather/wxclimatology/monthly/61820>).

The areas are estimates for a hypothetical 1600 ft² house.

Measure	Scenarios	Area (SqFt)	Drainage Area	% of Rainfall Captured	Water Saved (gal)
Bioretention and infiltration	Small raingarden Native	80	1000	0.25	8,531
	Small raingarden Non-native	80	1000	0.25	8,531
	Medium raingarden Native	150	1000	0.25	10,340
	Medium raingarden Non-native	150	1000	0.25	10,340
	Large raingarden Native	200	1000	0.25	11,633
	Large raingarden Non-native	200	1000	0.25	11,633
	Small raingarden Native Bio Swale	110	1000	0.25	9,306
	Small raingarden Non-native Bio Swale	110	1000	0.25	9,306
	Medium raingarden Native Bio Swale	180	1000	0.25	11,116
	Medium raingarden Non-native Bio Swale	180	1000	0.25	11,116
	Large raingarden Native Bio Swale	230	1000	0.25	12,409
	Large raingarden Non-native Bio Swale	230	1000	0.25	12,409
	BioSwale	30	1000	0.1	3,361

Appendix D – Survey

Informed Consent Form

Greetings,

My name is Zara. I am a PhD student in Department of Natural Resources and Environmental Sciences at University of Illinois at Urbana-Champaign. My advisor, Dr. Guillermo Mendoza and I are conducting this study to understand the preferences of residents for residential stormwater management strategies.

You have been invited to participate by taking part in an online survey using the link provided. The approximate time required will be about 10 to 12 minutes and you must be 18 or older to participate. Your participation is entirely voluntary and you can stop participating or withdraw your answers at any time. Your refusal to participate or withdrawal will not harm you in anyway and will not jeopardize current or future relationships with the researchers or the University of Illinois at Urbana-Champaign or any other group associated with this project. However, in order to receive your compensation you need to watch two videos and submit a complete survey. Each participant will be compensated \$1.00 for his or her participation. If you have already participated in this study, please do not continue because we will not be compensating duplicate participant.

The results of this research study will be included in my PhD dissertation and may be presented at academic conferences or published in academic journals. Your name and any identifying information will be kept entirely confidential. There will be no attempt to connect your AMT worker ID to your identity that may be found on the internet. Your confidentiality will be protected completely. The results will be kept in a secure location accessible only to me and my advisor. If you have any questions about the research please do not hesitate to contact me at: research.projects19@gmail.com or Dr. Guillermo Mendoza at gamendoz@illinois.edu. If you have any questions about your rights as a participant in this study or any concerns or complaints, please contact the University of Illinois Institutional Review Board at (217).333.2670 (collect calls will be accepted if you identify yourself as a research participant) or via email

at irb@illinois.edu. The Institutional Review Board is the office at the University of Illinois responsible for protecting the rights of human subjects involved in studies conducted by the University of Illinois.

I have read and understood the above online consent form and by clicking the submit button and completing the survey I am indicating that I voluntarily agree to participate in this study.

This survey is being conducted to study opinions on residential rainwater runoff reduction techniques. The survey should take about 10-12 minutes. There are no right or wrong answers; we would just like to know your opinion. First we will start with some general questions and then we will guide you through the rest of the survey.

1) Please tell us how much you agree with the following statements:

	Completely disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Completely agree
My neighborhood gets lot of rainwater runoff.	()	()	()	()	()	()	()
I have experienced severe rain and flood events.	()	()	()	()	()	()	()
I have experienced basement-flooding events.	()	()	()	()	()	()	()
I am concerned about the current patterns of rain in my city.	()	()	()	()	()	()	()

2) Please tell us how much you agree with the following statements:

	Completely disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Completely agree
Rainwater runoff causes basements to flood.	()	()	()	()	()	()	()
Rainwater runoff causes neighborhoods to flood.	()	()	()	()	()	()	()
Rainwater runoff pollutes nearby streams and rivers	()	()	()	()	()	()	()
The current rain events are influenced by climate change.	()	()	()	()	()	()	()

3) How familiar are you with the followings:

	Not At all familiar	Slightly familiar	Moderately familiar	Very familiar	Extremely familiar
Rain Garden	()	()	()	()	()
Rain Barrel	()	()	()	()	()
Permeable pavements (pavements that soak up rainwater, reducing runoff)	()	()	()	()	()

4) Do you plan to add any of the followings to your home this year?

	Yes	No	Maybe	I already have one
Rain Garden	()	()	()	()
Rain Barrel	()	()	()	()
Permeable pavements	()	()	()	()

5) I like to Garden.

- () Not at all
- () A little
- () Somewhat
- () A lot
- () Very much

In this section we will show you two short videos about some techniques that you can adopt to reduce the rainwater runoff that leaves your property. Please watch the videos and answer the related questions at the end, make sure your speaker is on!

In the first video you'll be learning about runoff reduction techniques.

- Part-I: <https://www.youtube.com/watch?v=diqHRyJapi4>

In the second video we will explain for you the benefits of adopting techniques that you watched in the previous video. We would like to learn about your preferences for these benefits.

- Part-II: <https://www.youtube.com/watch?v=ew7rME5HryQ>

6) Please tell us how much you agree with the following statements:

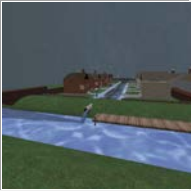
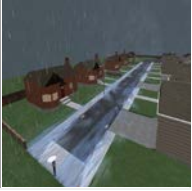
	Completely disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Completely agree
I felt a sense of actually being together with the tour guide.	()	()	()	()	()	()	()
The tour guide's presence was obvious to me.	()	()	()	()	()	()	()
I felt a sense of sociability with the virtual tour guide.	()	()	()	()	()	()	()
I felt a sense of human warmth with the virtual tour guide.	()	()	()	()	()	()	()
I felt like I was actually there in the neighborhood.	()	()	()	()	()	()	()
It seemed as though I actually took part in the neighborhood's tour.	()	()	()	()	()	()	()
I remained focused throughout the tour.	()	()	()	()	()	()	()
The movie was involving.	()	()	()	()	()	()	()
The experience seemed real to me.	()	()	()	()	()	()	()

7) The tour guide gave you a tour of the benefits and characteristics of runoff reduction techniques, how clear was her explanations for each of the following benefits and characteristics:

	Completely unclear	Unclear	Somehow unclear	Neither clear nor unclear	Somehow clear	Clear	Completely clear
Water quality improvement in nearby streams	()	()	()	()	()	()	()
Neighborhood flooding reduction	()	()	()	()	()	()	()
Basement flooding reduction	()	()	()	()	()	()	()
Water storage (reuse)	()	()	()	()	()	()	()
Green Space	()	()	()	()	()	()	()
Maintenance effort	()	()	()	()	()	()	()
Cost	()	()	()	()	()	()	()

Choice Tables: In this section, you will see four tables that give you two options and a default option (doing nothing). Option one and option two are different types of benefits and characteristics of selected run off reduction techniques. Please go to each table and choose the option you prefer the most.

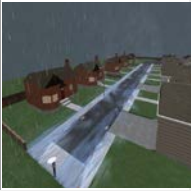
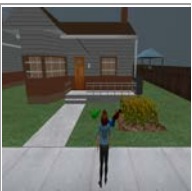
8) Choice Table-1: Please review the following options:

Benefits and Characteristics of run off reduction techniques		Option1	Option2	Default
	Water quality improvement (due to pollutant reduction)	Moderate effectiveness	Moderate effectiveness	Do Nothing
	Neighborhood flooding reduction	Low effectiveness	Low effectiveness	
	Basement flooding reduction	No effectiveness	High effectiveness	
	Private benefits	Water storage (reuse)	Green space	
	Maintenance effort per month	None	3-4 hours	
	Cost after rebate	\$250	\$375	

Which option do you prefer the most?

- ☐ Option 1
- ☐ Option 2
- ☐ Default (Do Nothing)

9) Choice Table-2: Please review the following options:

Benefits and Characteristics of run off reduction techniques		Option 1	Option 2	Default
	Water quality improvement (due to pollutant reduction)	High effectiveness	High effectiveness	Do Nothing
	Neighborhood flooding reduction	Moderate effectiveness	Low effectiveness	
	Basement flooding reduction	High effectiveness	No effectiveness	
	Private benefits	Green space	Green space + Water storage (reuse)	
	Maintenance effort per month	None	7-8 hours	
	Cost after rebate	\$500	\$250	

Which option do you prefer the most?

- ☐ Option 1
- ☐ Option 2
- ☐ Default (Do Nothing)

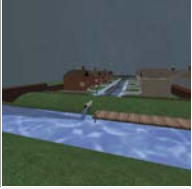
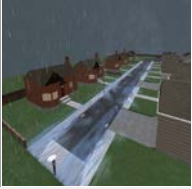
10) Choice Table-3: Please review the following options:

Benefits and Characteristics of run off		Option 1	Option 2	Default
	Water quality improvement (due to pollutant reduction)	High effectiveness	Low effectiveness	Do Nothing
	Neighborhood flooding reduction	Moderate effectiveness	Moderate effectiveness	
	Basement flooding reduction	High effectiveness	No effectiveness	
	Private benefits	Green space	Green space	
	Maintenance effort per month	None	None	
	Cost after rebate	\$500	\$375	

Which option do you prefer the most?

- ☐ Option 1
- ☐ Option 2
- ☐ Default (Do Nothing)

11) Choice Table-4: Please review the following options:

Benefits and Characteristics of run off reduction techniques		Option 1	Option 2	Default
	Water quality improvement (due to pollutant reduction)	Moderate effectiveness	Moderate effectiveness	Do Nothing
	Neighborhood flooding reduction	Low effectiveness	Moderate effectiveness	
	Basement flooding reduction	High effectiveness	High effectiveness	
	Private benefits	Green space	Green space + Water storage (reuse)	
	Maintenance effort per month	3-4 hours	None	
	Cost after rebate	\$375	\$700	

Which option do you prefer the most?

- ☐ Option 1
- ☐ Option 2
- ☐ Default (Do Nothing)

12) Please tell us how much you agree with the following statements.

	Completely disagree	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Completely agree
The choice table questions were easy.	☐	☐	☐	☐	☐	☐	☐
I understood the choice table questions very well.	☐	☐	☐	☐	☐	☐	☐
The movie was helpful for answering choice tables.	☐	☐	☐	☐	☐	☐	☐
The movie made it easy to understand the choice tables questions.	☐	☐	☐	☐	☐	☐	☐
The movie made it easier for me to decide about the option that I preferred the most.	☐	☐	☐	☐	☐	☐	☐

13) How motivated were you to follow the questions after you watched the movie?

- ☐ Not at all
- ☐ A little
- ☐ Somewhat
- ☐ A lot
- ☐ Very much

Demographic Questions

14) I live in: (Please add the name of both your city and your state in the following boxes)

My City's name:: _____

My State's name:: _____

15) My gender is:

- ☐ Male
- ☐ Female

16) My age is:

- ☐ 18-25
- ☐ 26-35
- ☐ 36-45
- ☐ 46-55
- ☐ 56-65
- ☐ 65+

17) My highest level of education is:

- ☐ No School
- ☐ Some School
- ☐ High school graduate
- ☐ College graduate
- ☐ Grad School

18) I am currently employed in:

- ☐ Service
- ☐ Government
- ☐ Academic
- ☐ Sales / Retail
- ☐ Business
- ☐ Student
- ☐ Other

19) My annual income is roughly:

- ☐ Below \$30,000
- ☐ \$30,001 - \$60,000
- ☐ \$60,001 - \$90,000
- ☐ \$90,001 - \$120,000
- ☐ More than \$120,000

20) Do you own or rent your home?

- ☐ Rent
- ☐ Own

21) Which best describes your home?

- ☐ Apartment
- ☐ Semi-detached house
- ☐ Detached house

22) Which best describes your basement?

- ☐ I do not have a basement.
- ☐ I have an unfinished basement.
- ☐ I have a finished basement.

23) Approximately how old is your home?

- ☐ Less than 10 years old
- ☐ Less than 30 years old
- ☐ Less than 75 years old
- ☐ More than 75 years old
- ☐ I do not know