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Masterthesis

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Jannis Ramaekers

Scriptie ingediend tot het behalen van de graad van master in de toegepaste economische wetenschappen: handelsingenieur, afstudeerrichting technologie in business

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COPROMOTOR :
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Preface

I would like to thank my promotor, prof. dr. Robert Malina and copromotor, dr. Nele Witters for the supervision, advice and feedback. Many thanks go out to Ilias Mokas for all the cooperation and help I received while writing my thesis. Especially in collecting the data, cleaning the data and providing me with feedback. I would also like to thank the University of Hasselt for providing their infrastructure. I am also thankful for my family and girlfriend for supporting me and dealing with my attitude during stressful days. Last but not least I would like to thank my colleague-students, more appropriately called friends, for the support and advice throughout this process.

Abstract

In stated preference studies, respondent uncertainty can arise when answering hypothetical questions about willingness to pay for a non-market good. Due to the often abstracted environments in which traditional choice experiments like text- or video-based surveys are conducted, respondents might find it difficult to imagine how their choices would affect them in real life. The main objective of this study is to examine whether the use of virtual reality as a survey-mode reduces respondent uncertainty in comparison to traditional survey modes like video- and text-based surveys. The research was conducted at the University of Hasselt and contained 180 respondents. Upon arrival, respondents were randomly assigned to one of the three survey modes in which they answered twelve choice sets, each containing two scenario's and a status-quo option, about urban greenery. After each choice made, respondents were required to state the certainty about their choice on a scale of 0 to 10. Applying a random effects model with self-reported certainty serving as the dependent variable, results show that respondents using the virtual reality setup are more certain about their choices compared to respondents using a traditional survey-mode. However, further research shows that respondents using the virtual reality setup are only significantly more certain compared to respondents in the text-based survey and not to respondents in the video-based survey. Furthermore, the utility difference, which is defined as the difference between the utility of the chosen alternative and the highest alternative utility to that, is found to have a positive effect on choice certainty, implying that a higher utility difference makes respondents more likely to be confident about their choice.

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1 Introduction

1.1 Background

Over the past few years, a lot of attention has been drawn towards the phenomenon of 'urbanization', which refers to the gradual increase in the proportion of people living in urban areas. About half of the world's population lives in cities and the biggest part of the prognosed increase in global population is expected occur in these urban areas in the developing world. If these cities are well managed they can offer important opportunities for social and economic development (B. Cohen, 2006). If, on the other hand, cities fail to manage rapid urbanization and its impacts, human health and environmental quality are at risk to be threatened (Leitmann, Bartone, & Bernstein, 1992). These threats can range from poor air quality and water pollution to excessive noise and traffic pollution which can lead to sleep disturbance, an increase in stress levels and increased blood pressure (De Ridder et al., 2004).

A major issue is the lack of urban greenery in densified urban areas and the removing of this green space when city areas are being densified (Haaland & van den Bosch, 2015). This 'urban green space' is often defined as "any vegetation found in the urban environment" (Haaland & van den Bosch, 2015). They can include parks, open spaces, residential gardens, street trees (Kabisch & Haase, 2013) as well as sporting fields, green walls and green alleyways (J. R. Wolch, Byrne, & Newell, 2014). These types of urban green space provide ecosystem services that could help combat many urban ills and improve life of city dwellers (J. R. Wolch et al., 2014). An ecosystem and its services are thus vital for people in urban regions (Niemelä et al., 2010).

More specifically, ecosystem services support the ecological integrity of urban areas and protect the public health of urban populations (J. R. Wolch et al., 2014). These services include the filtering of air, removing pollution, attenuating noise, cooling temperatures and replenishing groundwater (Escobedo, Kroeger, & Wagner, 2011). Nowak, Crane, and Stevens (2006) give the example of a tree in an urban area, which may reduce air pollution by absorbing certain airborne pollutants from the atmosphere. So as these urban green spaces provide essential benefits to urban citizens, their planning and management is a crucial issue (Haaland & van den Bosch, 2015).

To determine the value of urban greenery or other kinds of environmental aspects, a stated preference (SP) analysis is commonly used. A relatively new method within this category of methods can be referred to as choice experiments (CE). This approach is in essence a structured method of data generation which requires a careful design of choice tasks that help reveal the factors influencing choice (Hanley, Wright, & Adamowicz, 1998). More specifically, the CE-approach is an application of Lancaster's consumer theory (Bateman et al., 2002) and the random utility theory (Manski, 1977). Different bundles of environmental non- market goods with their own specific attributes, characteristics and levels are described and the respondents are asked to choose between them to estimate the WTP of a certain (environmental) good (Hanley et al., 1998).

It is thus very important that the information provided to survey respondents is strongly accurate within non-market valuation (Bateman, Day, Jones, & Jude, 2009). However, an increasing concern has been the comprehension (Matthews, Scarpa, & Marsh, 2017) or 'evaluability' of the information provided (Hsee, 1996). In other words, people need to understand what they are valuing. If respondents are not able to fully comprehend the provided information and are not able to frame how their choices would affect them in real life, the results will not acquire external validity. (Matthews et al., 2017). The imperfect comprehension of, or uncertainty about, a non-market good will increase the valuation variability and potentially introduce or enhance certain biases. (Bateman et al., 2009).

In choice experiments specifically, choice uncertainty can arise due to the often abstracted environments in which the respondents' choices have to be made. Respondents might find it difficult to imagine how their choices would affect them in real life, inducing valuation variability (Bateman et al., 2009). To obtain a measure of the degree of uncertainty while answering valuation questions, the self-reported certainty of respondents through follow-up questions has been one of the many approaches (Olsen, Lundhede, Jacobsen, & Thorsen, 2011). This method involves respondents to make a choice, followed-up by expressing their certainty about that particular choice (Olsen et al., 2011). The self-reported certainty statements can be utilised in the analysis in numerous ways like recoding the data or including them directly into the random utility model. In this thesis, self-reported certainty is explained based on the utility differences derived from an estimated indirect utility function. This involves including the utility differences as an explanatory variable in a model with self-reported certainty as the response variable (Dekker, Hess, Brouwer, & Hofkes, 2016). This approach allows researchers to study the relationship between utility difference and choice uncertainty, as well as evaluating the effect of survey design factors and respondent characteristics on perceived certainty in choice (Olsen et al., 2011).

There is a growing agreement that the most effective way to enhance comprehension and certainty in choice experiments is via the use of visual stimuli and thus presenting the information in visual form and making it more realistic (Krupnick, 2006). The use of these visualisations to convey information to respondents in choice tasks has already been identified by multiple authors as a possible method to enhance realism, evaluability and therefore the validity of the data (Patterson, Darbani, Rezaei, Zacharias, & Yazdizadeh, 2017). Moreover, the biggest part of past research on the use of visual stimuli has been focused on static visualisations. An alternative method is to use dynamic computer-generated 3D-environments, often referred to as virtual reality (VR) (Matthews et al., 2017). Because of the recent growth and advances within VR, the critiques on evaluability within choice experiments can now be addressed directly by visualising the attribute levels, creating a new valuation methodology: virtual reality choice experiment (VRCE) (Bateman et al., 2009). A major goal of the use of VRCE's is to create virtual environments that bring about a sense of presence in participants (Bystrom, Barfield, & Hendrix, 1999). 'Presence' can simply be defined as the 'sense of being there'. An enhanced feeling of presence can make the experience more meaningful and realistic, therefore reducing choice uncertainty (Witmer & Singer, 1998). Within virtual environments, the feeling of presence can be increased even more by increasing the modalities of sensory inputs (Dinh, Walker, Hodges, Song, & Kobayashi, 1999).

1.2 Research purpose

The purpose of this study is to investigate whether a novel technique like virtual reality reduces the uncertainty of respondents in choice experiments compared to traditional techniques, being text- and video-based surveys. To the best of our knowledge, no research has explained stated certainty based on the difference between these survey modes up to this point. The results of this study might be particularly useful towards researchers who seek to reduce respondents' uncertainty in choice experiments, or companies and policy makers who seek to understand customers' and/or societal preferences towards a certain good or service with more certainty.

1.3 Research objectives

Following the research purpose, the first research objective or hypothesis is straightforward:

> *H1: Respondents report less uncertainty about their decisions in a virtual reality experiment compared to experiments based on traditional survey methods.*

This hypothesis can be subdivided into two sub-hypotheses:

> *H1a: Respondents report less uncertainty about their decisions in a virtual reality experiment compared to a text-based experiment.*

> *H1b: Respondents report less uncertainty about their decisions in a virtual reality experiment compared to a video-based experiment.*

The second hypothesis is based on the toughness of the choice and hypothesizes that tough choices (i.e. small utility differences) cause uncertainty:

> *H2: Respondents' stated certainty in choice increases with the utility difference between the alternative chosen and the best alternative to that.*

1.4 Method

The experiments took place at the University of Hasselt in Diepenbeek. Upon arrival, respondents were randomly assigned to one of the different survey modes: virtual reality, video-based or text-based. All respondents answered a choice experiment questionnaire about urban green in cities, consisting of twelve choice sets. A choice set consisted of two alternative urban green designs, each representing a combination of different attributes including a monthly cost, and a status quo option. Following their choice, respondents stated their certainty about the particular choice.

1.5 Structure

This thesis is divided into eight chapters. Chapter 2 contains a theoretical background of the content of the survey, urban green, as well as the economic valuation of environmental goods and finally respondent uncertainty. Chapter 3 contains the theoretical framework of the methodology. In chapter 4, the research design as well as the actual models used are discussed. In chapter 5, the results are presented, followed by a discussion of these results in chapter 6 and a conclusion in chapter 7.

2 Literature review

2.1 Urbanization

2.1.1 Concept

Over the past few years, the proportion of people living in urban areas has been gradually increasing. For the first time in history, more than half of the world's population lives in cities, representing a significant shift in the spatial distribution of population growth which was more evenly divided between rural and urban areas in the past decennia (B. Cohen, 2006). By 2030, the world is projected to have 43 megacities with more than 10 million inhabitants (UN, 2018). Continuing at high speed, present projections prognosticate that two in every three persons will live in urban areas by 2050 (Buhaug & Urdal, 2013). All of the population growth in this period (around 3 billion people) will be absorbed by cities (Buhaug & Urdal, 2013). In short terms, there's clear evidence that the concept of urbanization is an important current topic and won't be stopping any time soon.

2.1.2 Reasons

Numerous reasons for urbanization have been addressed and studied in previous literature. In general terms, urbanization is determined by three phenomenon: natural growth of the population, the reclassification of areas from urban to rural and rural-urban migration (Buhaug & Urdal, 2013). Natural growth of the population refers to an increase in population due to a high birth-to-death ratio (J. E. Cohen, 2003). A second reason is the transformation of rural settlements into cities. In favourable circumstances, tiny settlements can transform into small towns in the first place and then into cities as the population continues to grow, causing new political and economic structures to arise. When successful, these cities will then trigger migration as a further mechanism of urban growth (Bloom, Canning, & Fink, 2008). The third and major reason is the concept of rural-urban migration, which is the movement of people (and companies) to the cities.

2.1.2.1 Population

For rural citizens, one reason of migration is the high and still increasing population pressure in the countryside that has led to rural scarcity of renewable resources (T. F. Homer-Dixon, 2010). Typically in rural contexts, where the dependence on renewable resources is great, a rapid population growth can cause a reduced per-capita access to certain resources when resource productions cannot keep up with the rise in demand (T. Homer-Dixon & Blitt, 1998). Moreover, cities have become a major attractor for pool rural populations because of the better quality of life (Bloom et al., 2008). Cities offer a higher level of education in schools and universities than the rural areas. Better healthcare is provided by big hospitals in the form of new techniques and a variety of medical facilities, a wider range of 'entertainment' is present and better infrastructure like public transport is provided (Harvey, 2017). Next to these advantages, a major reason for urbanization is the availability of labour in cities. A lot of companies and industries, like for example restaurants, bars, banks, stores and hairdressers are located in urban areas providing many job opportunities (Harvey, 2017).

2.1.2.2 Companies

An explanation for the localization of these companies and the rural-urban migration of companies is the recent technological change (J. V. Henderson & Wang, 2007). These technological changes and economic developments involve the transformation from an agricultural-based economy to an industrial service-based economy, or in other terms 'industrialisation'. This industrialisation happens disproportionately in urban areas because of the opportunities to exploit scale economies of local agglomeration (J. V. Henderson, 2000). Cities capture some sort of agglomeration economies and the production in urban areas benefits from local external economies of scale which are not present in rural environments (McCoskey & Kao, 1998).

The theory of these agglomeration economies suggests that firms benefit from positive externalities because of the spatial proximity of other economic activities (Melo, Graham, & Noland, 2009). These benefits arise from intra- and inter-industry clustering of economic activities, also known as localization and urbanization economies in the relevant literature (Fujita, Krugman, & Venables, 2001). More specifically, localization economies of scale arise from spatial concentration from activities within a certain industry while urbanization economies of scale arise from the concentration of all economic activities (Rosenthal & Strange, 2004). In particular, the benefits can take on various forms, from information spillovers and reduced transport costs to the specialization in certain activities and access to specialized suppliers (V. Henderson, 2002).

Information spillovers especially have been widely discussed in previous literature (Asriyan, Fuchs, & Green, 2017; J. V. Henderson, 2007; Kultti & Takalo, 1998) because of the critical role of knowledge as a competitive advantage. Next to formal arrangements like acquisitions and alliances firms also seek knowledge through indirect or informal means like having common buyers and suppliers or the acquisition of employees of another firm (Alcacer & Chung, 2007). Proximity will enhance the frequency of these informal contacts so that firms can enjoy greater benefits in the form of information spillovers about technology, suppliers, purchasers and market conditions (Fujita & Ogawa, 1982). Another benefit is one of the reasons why cities were formed historically, namely the reduction of transport costs (Quigley, 2009). The proximity of buyers and thus delivering outputs and finished products to local markets as well as the proximity of sellers and thus receiving inputs and raw materials, reduces transport costs of trade (Krugman, 1991). Specialization on the other hand means that firms organize themselves around a certain product or service, which yields efficiencies and enhanced skills and creates a skilled labour pool (Turok & McGranahan, 2013). The enhanced access to specialized suppliers, access to public facilities and general public infrastructure are other examples of benefits of agglomeration economies (Quigley, 2009).

2.1.3 Downsides

The phenomenon of urbanization can offer important opportunities for social and economic development (B. Cohen, 2006). However urbanization can, if not well managed, bring along negative impacts and threaten human health and environmental quality (Leitmann et al., 1992). According to Cui and Shi (2012), urbanization has created numerous environmental problems including air, water and noise pollution.

2.1.3.1 Primary consequences

2.1.3.1.1 Air pollution

In many different regions air pollution has become a serious problem due to rapid urbanization (Barbera, Curro, & Valenti, 2010). Consequently, the improvement of air quality has been an imperative of environmental policies throughout the past decades (Tyrväinen, Pauleit, Seeland, & de Vries, 2005). Air pollution in cities as a form of pollutants includes chemicals, particulate matter and biological materials, which occur in the form of solid particles, liquid droplets or gases (Haq, 2011). Motor vehicles in urban areas for example produce air pollutants like carbon dioxide and carbon monoxide factories emit sulphur dioxide and nitrogen oxides (Haq, 2011). These detrimental contaminants can cause serious health problems, especially when children, elderly and people with respiratory problems are affected (Sorensen, Smit, & Barzetti, 1997). Apart from this outdoor air pollution, there's a significant increase in indoor air pollution. Indoor air pollution is often associated with the use of biomass fuels (coal, wood, animal dung and kerosene) although indoor tobacco smoke is also an increasing contributor (Moore, Gould, & Keary, 2003).

2.1.3.1.2 Water pollution

Water pollution is another increasing problem due to the growing urbanization (Maiti & Agrawal, 2005). It is a relatively new problem and has been increasing since the 1990s (Jian-jiang, 2002). Water pollution problems have become increasingly evident and have led to serious ecological and environmental problems because of industrial production without adequate regard for environmental impacts like soil degradation (Ma, Ding, Wei, Zhao, & Huang, 2009). Despite the increased water-related issues, there is limited social awareness for environmental protection and lack of legal and organised structures for optimal management of water (Feng, Endo, & Cheng, 2001). This has led to the disposition of industrial wastes without adequate treatment and an increase in discharge of domestic sewage and industrial wastewater (Ma et al., 2009).

2.1.3.1.3 Noise pollution

Due to the increasing number of both living people and vehicles in cities, noise pollution has recently been introduced as an environmental consequence of urbanization (Zannin, Diniz, & Barbosa, 2002). Because the urban environment is becoming more crowded, busy and noisy, noise pollution in large cities is growing in extent, frequency and severity. Noise pollution from traffic, through honking and engine noises (Moore et al., 2003) and other sources can be stressful, enhancing health problems like sleep disturbance, annoyance, hearing impairment and hypertension (Passchier-Vermeer & Passchier, 2000) for people in urban areas (Haq, 2011).

2.1.3.2 Impact on wellbeing

Urban living can be associated with a more demanding and stressful social environment (Lederbogen et al., 2011). Consequently, meta-analyses show that city dwellers have a substantially increased risk for anxiety disorders and mood disorders (Peen, Schoevers, Beekman, & Dekker, 2010). For major brain disorders like schizophrenia, incidence is doubled for people born and brought up in cities (Krabbendam & Van Os, 2005). Hartig and Kahn (2016) state that stressful urban conditions increase the risk of mental disorders like anxiety and depression to conclude that urban living conditions undermine mental health. Next to these more general consequences of urbanization, various studies have focused on the consequences of air, water and noise pollution as well. Air pollution for example is a major cause of morbidity and mortality. Air pollution can lead to asthma, chronic obstructive pulmonary disease, beryllium poisoning and other kinds of acute respiratory infections, cancers, chronic obstructed lung diseases among others (Moore et al., 2003). The polluting of water can have different kinds of impacts on urban citizens. For example, the risk for gastrointestinal pathogens is strongly associated with the lack of a direct source of water in home. Studies of louse-borne diseases and scabies in households show a strong correlation between the presence of these diseases and a limited access to water (Landwehr, Keita, Pönnighaus, & Tounkara, 1998). Noise exposure can be associated with hearing impairment, hypertension and sleep disturbance (Vlahov & Galea, 2002). Furthermore, according to a study by Evans and Maxwell (1997), chronic noise exposure can be related to elevated neuroendocrine and cardiovascular measures resulting in deficits in long term memory, speech perception and reading test scores.

2.2 Urban green

2.2.1 Concept

Ecosystem services provided by urban green can assist in combating the aforementioned urban ills and improve the life of city dwellers (J. R. Wolch et al., 2014). This 'urban green space' is often defined as "any vegetation found in the urban environment" (Haaland & van den Bosch, 2015). Urban densification and agglomeration have in the past led to environmental degradation in the form of destruction and/or fragmentation of natural or semi-natural vegetation (Johnson, 2001). The densification of cities often causes the removal and thereby lack of urban greenery in densified cities. However, because of the essential benefits provided by urban green, their planning and management is a crucial issue (Haaland & van den Bosch, 2015).

When taking a look at the different types of urban green, relevant literature makes a distinction between two types of urban green being public urban green and private urban green (J. R. Wolch et al., 2014). Roy, Byrne, and Pickering (2012) list up the majority of examples of both types of urban green. Public urban green includes parks and reserves, open spaces, sporting fields, community gardens, street trees and other types of vegetation, nature conservation areas as well as less conventional spaces such as green walls, and green alleyways. Examples of private urban green are limited to private backyards, communal grounds of apartment buildings and corporate campuses.

2.2.2 Benefits

As mentioned before, an ecosystem and its services are vital for people in urban regions (Niemelä et al., 2010). These ecosystem services support the ecological integrity of urban areas and protect the public health of urban populations (J. R. Wolch et al., 2014). The benefits derived from these ecosystem services can be classified in three major categories: environmental benefits, recreational and health benefits, economic benefits (Tyrväinen et al., 2005).

2.2.2.1 Environmental benefits

One type of benefits provided by urban green space, are environmental benefits. These environmental benefits include pollution control and the improvement of biodiversity.

2.2.2.1.1 Pollution control

2.2.2.1.1.1 Improving air quality

Urban forests and trees can make a significant contribution to urban air quality by removing air pollutants (absorption by the leaves of trees) such as the pollutants mentioned before and signify and important ecosystem service (Jim & Chen, 2006). This function is particularly useful in cities where air quality is deteriorating at a fast rate due to urbanization. Recent studies have shown that air quality in tree-covered areas improved in comparison to treeless open areas (Setälä, Viippola, Rantalainen, Pennanen, & Yli-Pelkonen, 2013). These urban trees (or forests) and their effect depend on tree-related variables (percentage canopy closure, number of trees) as well as structure and composition (Setälä et al., 2013). For example, air pollution removal and subsequent air quality improvement by urban trees/forests increases as the leaf area or proximity to the pollution source increases (Escobedo et al., 2011).

2.2.2.1.1.2 Reducing water pollution

Regarding urban water pollution, two major ecosystem services can be identified: the recharging of groundwater and flood abatement/wastewater management. The recharging of groundwater is enabled by trees in open areas by allowing the infiltration of rainwater in an otherwise sealed urban area (Tyrväinen et al., 2005). The abatement of floods and other sources of wastewater like meltwater or industrial wastewater can be provided by urban green in numerous ways. For example, by intercepting precipitation which is stored and/or evaporated from the tree (Xiao, McPherson, Ustin, Grismer, & Simpson, 2000). Previous studies have shown a clear inverse relation between green-space provision and rainwater runoff (Tyrväinen et al., 2005).

2.2.2.1.1.3 Reducing noise pollution

Noise abatement is considered as an important service of urban greenery (Nijland, Van Kempen, Van Wee, & Jabben, 2003). According to studies by Van Renthergem and colleagues (Van Renterghem & Botteldooren, 2011) & (Van Renterghem, Hornikx, Forssen, & Botteldooren, 2013) especially green roofs and green walls have a high potential to reduce noise and enhance quietness. Conventional roofs are generally hard surfaces, while vegetation in combination with a growing substrate absorbs sound waves to a greater degree than a hard surface (Van Renterghem & Botteldooren, 2008). Van Renterghem and Botteldooren (2008) found a linear relationship between the percentage of roof space that is covered with vegetation and the reduction in sound pressure. Because of the typical coarseness of green roof growing substrates, sound waves can enter the pore space and are attenuated by the interactions with substrate particles.

2.2.2.1.2 Biodiversity enhancement

Habitat loss and fragmentation are a serious threat towards biodiversity and have been identified as a primary cause of the extinction crisis (Adriaensen et al., 2003). Green spaces and green space networks can provide a solution to the problems of intensified land use and fragmentation, enabling species and threatened habitats to survive (Jongman, 2008). The development of green space networks and preserving habitat have become crucial factors in urban biodiversity conservation (Parker, Head, Chisholm, & Feneley, 2008). This development includes the protection of existing urban green, creation of new spaces and restoration of connectivity among diverse green spaces. In the last decade, many studies have suggested the positive role of biodiversity in the promoting of human health in modern urbanized society (Brown & Grant, 2005). According to Fuller, Irvine, Devine-Wright, Warren, and Gaston (2007) the psychological benefits associated with the "green" experience are found to be increased by biodiversity.

2.2.2.2 Recreational and health benefits

One of the generally acknowledged functions of urban woodland and parks is the provision of recreational opportunities (Tyrväinen et al., 2005). Recreational ecosystem services provide possibilities for all kinds of activities like outdoor recreation, nature observation and photography as well as walking, cycling and jogging (Niemelä et al., 2010). Possible areas for recreation in urban areas are often located in human-influenced environments and can range from parks, forests, meadows and marshlands to grasslands, rocks, water fronts and water areas. According to Tzoulas et al. (2007), recreational ecosystem services are an important part of a high-quality living environment. This means sufficient recreation areas with a good accessibility, connectivity and ecological diversity.

Next to these direct benefits, public health can be improved by urban greenery indirectly. The proximity of urban green may seduce people with a rather sedentary lifestyle to become more active during their leisure time, for example by walking or cycling (Tyrväinen et al., 2005). Grahn and Stigsdotter (2003) have shown that more green space within the living environment leads to people visiting it more often. Concerning health effects, particularly the obesity epidemic has been the main focus of multiple studies, which can be detrimental to children's health and increase the probability of adult obesity (Freedman, Mei, Srinivasan, Berenson, & Dietz, 2007). A recent study by J. Wolch et al. (2011) showed a significant negative relation between park access and the development of obesity.

Furthermore, psychological well-being has been linked empirically to green space (Ernstson, 2013). Its stress-reducing effect specifically is an important effect of natural scenery on health. A study by Grahn and Stigsdotter (2003) has shown that the more time people spend outdoors in urban green spaces, the less they are affected by stress. Even just visually experiencing a natural scenery reduces stress within some minutes of exposure (Tyrväinen et al., 2005). Another major study by Van den Berg, Maas, Verheij, and Groenewegen (2010) showed that respondents with more green space near the place they lived were less affected by stress when confronted with a stressful life event. As a place of social interaction, urban parks can increase perceptions of safety and belonging (Kuo, Sullivan, Coley, & Brunson, 1998).

2.2.2.3 Economic benefits

2.2.2.3.1 Energy savings

In addition to previously discussed implications of urbanization, climate change can double the rate of urban warming in cities (McPherson & Simpson, 2003). Using greenery to reduce the energy costs of cooling buildings has gained increasing recognition as a cost-effective reason to increase urban green an tree planting (Heidt & Neef, 2008). Urban green modifies climate and conserves building energy through shading by reducing the amount of radiant energy absorbed and stored by built surfaces, through evapotranspiration by converting water in plants to vapor which cools the air and through wind speed reduction which reduces the amount of outside air that infiltrates into interior spaces (Heisler, 1986). Studies have shown that increasing tree cover in a city by 10%, may reduce the total energy for heating and cooling by 5 to 10% (Sorensen et al., 1997).

2.2.2.3.2 Increasement of property value

While not considered as important as some of the benefits discussed above, the aesthetics of urban green areas can be a meaningful benefit to many urban residents (Sorensen et al., 1997). A study by J. R. Wolch et al. (2014) suggests that urban greenery can inflate property values. Even small green space decorations may drive up property prices in urban cores where densities are highest, parks are fewer and temperatures are the hottest (J. R. Wolch et al., 2014). In general, areas of the city with enough greenery are aesthetically pleasing and attractive to residents as well as investors. When vacant, garbage dumps are replaced by attractive parks for example, the residents' quality of life as well as the value of their property increases (Sorensen et al., 1997).

2.3 Economic valuation of environmental goods

2.3.1 Concept

Value estimation in general involves determining the marginal willingness-to-pay (WTP) curves for environmental services. WTP can be defined as the maximum amount an individual would be willing to pay to secure a certain change (Hanemann, 1991). If these ecosystem services would be a purchasable good in a functioning market, determining these curves would be a standard econometric problem. However, most of environmental resources have the same characteristics as public goods, being non-excludability (once the good has been provided to an individual, others cannot be prevented from making use of the good) and non-rivalry (one person's use does not diminish the use that others can make of the good). The public good character of many environmental services creates the needs for economic valuation methods (Freeman III, Herriges, & Kling, 2014).

More specifically, a good or service has an economic value if it has an effect to humans' wellbeing (Atkinson & Mourato, 2006). When choosing between 2 goods, people will have preferences towards the good that makes their wellbeing better than the other one or in other words maximizes utility. These preferences are measured through people's WTP. Furthermore Freeman III et al. (2014) mention that individuals are the best judgers of their own welfare which means it can only be measured by observing individuals' decisions and choices among goods and services. By using the

WTP (or WTA i.e. willingness to accept a compensation for a loss) measure, the maximum amount of money that individuals are willing to pay in order for a change in environmental goods to occur can be defined.

2.3.2 Welfare measures

According to Freeman III et al. (2014), there are five different ways to measure the changes in welfare mentioned before: Marshalian's consumer surplus and four different Hick's welfare measures (compensating variation, equivalent variation, compensating surplus and equivalent surplus). Without going into detail, the (in)appropriateness of each measure for this research will be discussed shortly.

The Marshalian's consumer surplus is based on Marshalian's demand curves and the changes in consumer surplus. According to this method, the consumer's surplus is explained as the gains derived by an individual over and above the price he pays for a good. In other words, an individual derives excess benefits by paying more than he already pays in order to purchase a good. However this method does not measure a gain or loss that can be employed in a potential compensation test, which is why this measure is flawed as a welfare indicator (Freeman III et al., 2014).

In contrast, the compensating variation and equivalent variation do represent relevant welfare measures that are both based on a change in prices. Compensating variation utilizes the original level of welfare as a reference point and considers a price increase or fall. For a price increase the compensating variation defines the minimum payment that that an individual would be WTA to prevent a utility decrease. In case of a price fall on the other hand, it describes the maximum WTP for the right to purchase the good at the new price level (Atkinson & Mourato, 2006). In other words, it can be seen as an index of utility that assigns the same monetary value to all changes that result in the same final utility level (Morey, 1984). Equivalent variation is based on the new level of welfare. In the case that price falls, it measures the WTA to sacrifice or to voluntarily avoid the price drop. When price increases, it measures the WTP in order to avoid this price increase (Atkinson & Mourato, 2006). Unlike compensating variation, equivalent variation measures the offsetting income change necessary to prevent a utility change (Freeman III et al., 2014).

The problem of compensating variation and equivalent variation for applied welfare economics is the fact that they are based on unobservable demand functions. In contrast to these welfare measures, compensating surplus and equivalent surplus are based on a change in quantity/quality of goods instead of on a price change (Freeman III et al., 2014). They can be interpreted in the same manner as compensation and equivalent variation respectively. However, the most relevant welfare measure for this research is the compensating surplus, since the status quo is the reference point and there is a change in quantity/quality of urban greenery. Therefore, individuals' WTP for these changes will be observed. Past research e.g. Morrison, Bennett, Blamey, and Louviere (2002) has utilised compensating surplus as a value estimate and define it as 'the value of a discrete change in environmental quality'.

2.3.3 Economic valuation methods

2.3.3.1 Total economic value

In order to discuss the various methods of economic valuation it is important to understand the different TEV (Total Economic Value) components shown in figure 1 (Laurila-Pant, Lehikoinen, Uusitalo, & Venesjärvi, 2015). The total value of environmental assets includes both use and non-use values (Pagiola, Bishop, & Von Ritter, 2004). The use value is further divided into direct, indirect and option values. For environmental ecosystem services in general, direct benefits include food and timber to even medication. Examples of indirect values are the filtration of natural water, filtering the air and protection from storms. Optional values can be defined as the option to use ecosystem goods and services in the future (Laurila-Pant et al., 2015). On the other hand, non-use values can be divided into bequest values (benefits from ensuring that ecosystem services will be preserved for future generations) and existence or passive use values (a loss would be felt by individuals, although they don’t use it) (Pearce & Moran, 1994).

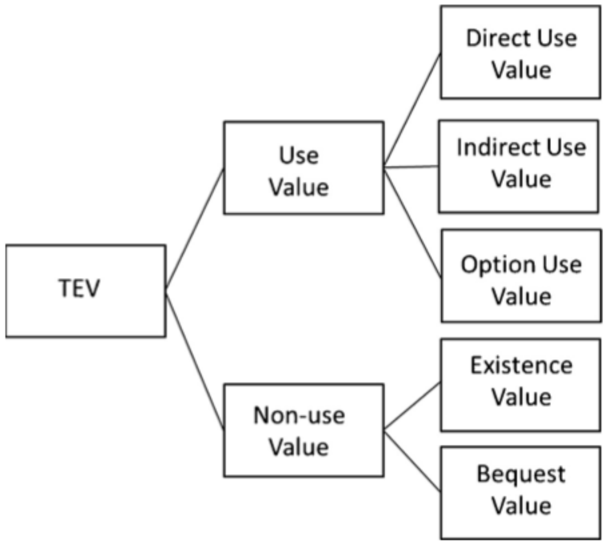

Figure 1: Total Economic Value

Usually, a distinction can be made between data coming from directly observing individuals’ behaviour, called revealed preferences (RP) and data coming from respondents’ answers to hypothetical questions or stated preferences (SP) (Haab & McConnell, 2002). The valuation of use values can be done by both RP and SP methods. However, the valuation of non-use values can only be done by the use of SP techniques, because they do not have a market and consequently no behaviour can be observed. (Freeman III et al., 2014). For this thesis, a SP approach will be used to estimate the value of environmental ecosystem services. However, both techniques will be discussed to gather an understanding of both techniques as well as the difference between them.

2.3.3.2 Revealed preferences

Although environmental goods do not have market prices, their quantity and quality will affect the decisions of individuals for other market goods and services. Without having direct prices for environmental goods, their value can be interfered by using consumer preferences (Remoundou & Koundouri, 2009). RP methods cope with this problem by using observations of how individuals behave in real life (Freeman III et al., 2014). In this manner, RP methods quantify the influence of preferences for non-market goods on actual markets for other goods (Atkinson & Mourato, 2006). These methods utilise an individual's demand for private goods to estimate their demand for public goods (Rusche, Wilker, Blaen, & Benning, 2013) by some type of substitute or complementary relationship between environmental and market goods and services (Freeman III et al., 2014). The two most prevalent approaches of revealed preferences valuation that have been identified from the literature are the travelling cost method and hedonic pricing method (Rusche et al., 2013).

2.3.3.2.1 Travel cost method

The travelling cost method (TCM) assumes a relation between the use of a public good and the costs related to its use. The method derives the value for recreation sites like national parks and beaches from the costs that are expressed in the market for trips to the specific area (Sukhdev, 2008). The required information, the amount of visits per individual/household and the associated travel costs, is usually gather via surveys on site (Hanley, Shogren, & White, 2013). These travel costs include all monetary costs such as fares, petrol costs, depreciation of the vehicle as well as the cost of time spent travelling, including opportunity costs of time (Rusche et al., 2013). Variation of travel costs is caused by people living at different distances from the site, which means that travel costs are low for people near the site and high for people living further away (Parsons, 2003). However, a range of problems can be identified by applying the TCM. The most significant issue is caused by multiple purpose trips, for example when tourists combine trips to a recreational site with trips to other destinations. Additionally only use values are captured and non-use values are not covered when TCM is applied (Rusche et al., 2013). Variations to this model like multiple site models and zonal travel cost methods can be applied.

2.3.3.2.2 Hedonic pricing method

The hedonic pricing method (HPM) uses information that is available on the demand elements for a market good to identify the value for a public good (Sukhdev, 2008). It is based on the assumption that a combination of different elements determine the price of a market good and describes its character (Gronemann & Hampicke, 1997). For property prices, this includes factors such as location, size, number of rooms and environmental characteristics like air quality, landscape, proximity to green areas (Rusche et al., 2013). However, the value of these individual features can't be observed directly. By using the HPM, the influencing effect of these characteristics on the overall price can be measured (Monson, 2009). In order to do so the implicit prices of the characteristics are estimated, which means that the price difference of two properties with the exact same characteristics, except for the one of interest, is calculated (Rusche et al., 2013). Like TCM, some practical implications arise when implementing HPM. These include the need for a large data set, multicollinearity due to co-variety of characteristics and the ability to solely measure use values (Atkinson & Mourato, 2006).

2.3.3.3 Stated preferences

To determine the WTP of urban greenery or other kinds of environmental aspects, a SP analysis is commonly used. SP methods evaluate environmental goods by using data coming from the responses to questions about hypothetical situations such as "Would you pay €X for …?", "What is the most you would be willing to pay for …?" or "Which of the following alternatives do you prefer …?" (Freeman III et al., 2014). In other words, SP approaches are based on a survey to create a hypothetical payment scenario (Rusche et al., 2013). A market and a demand is simulated for ecosystem services to reveal the WTP (or WTA) for hypothetical changes in the provision of these services and assign a monetary value. SP methods are the only techniques that are capable to evaluate non-use values because they are based on a hypothetical and not a real market (Bateman et al., 2002). They can be divided into two major methods: the contingent valuation method and choice modelling.

2.3.3.3.1 Contingent valuation

According to Atkinson and Mourato (2006), the contingent valuation (CV) method is the most popular stated preference method. For every CV study, the development of a questionnaire is key (Rusche et al., 2013). Within this questionnaire, respondents are asked about their maximum WTP (or minimum WTA a compensation) for a certain hypothetical increase or decrease in the level of a specific good (Mogas, Riera, & Bennett, 2002). Hanley (2016) discusses 4 different ways in which the CV method can be implemented in reality. Firstly, respondents can be asked about their WTP freely through 'open-ended questions'. In the 'bidding game method', respondents are asked whether they are prepared to pay a certain amount and as long as they answer with "yes", the researcher will keep on raising the amount. Thirdly, in the 'payment card' method, people choose between different amounts the one they are willing to pay. The last method, 'dichotomous choice', is comparable to the bidding game method. Additionally, if the respondent answers with "no", the researcher decreases the amount (double-bounded).

2.3.3.3.2 Choice modelling

Choice modelling (CM) is a SP valuation method that was originally developed for marketing and transport applications (Louviere & Hensher, 1982). In recent years, it has gained popularity in research towards environmental economics (Morrison & Bennett, 2000). In a CM application, respondents are presented with several choice sets, each containing different alternative goods. These alternatives consist of a combination of multiple attributes, with each attribute taking on a value or level (Mogas et al., 2002). In cases where environmental problems are complex CM methods tend to be useful because they can value the total change of a multi-dimensional good as in CV, but also because they're able to measure marginal or unit values for each of the attributes of environmental goods (Atkinson & Mourato, 2006). This enables researches not only to uncover the change in each of the attributes, but also the total change in the multi-dimensional good (Atkinson & Mourato, 2006). This is an important advantage of CM compared to CV methods, although they are quite similar in application, structure and content (Mogas et al., 2002). Furthermore, respondents are allowed to indirectly state their WTP in comparison to directly in CM surveys.

Atkinson and Mourato (2006) define four variants of CM according to their way of measuring respondents' benefits: contingent ranking, contingent rating, paired comparisons and choice experiments. In contingent ranking respondents are asked to rank the different alternatives. Contingent rating demands that respondents assess the alternatives with a certain rating (e.g. 1-10). Thirdly, paired comparisons requests respondents to choose an alternative out of a set of two and give it a score as in contingent rating. Respondents in choice experiments are asked to choose between two or more alternatives (where one is the status quo). Since this technique is the main focus in this paper, it will be discussed further upon in the next paragraph.

2.3.3.4 Choice Experiments

2.3.3.4.1 Concept

A relatively new method in the category of CM-methods can be referred to as choice experiments (CE). This approach is in essence a structured method of data generation, which requires a careful design of choice tasks that help reveal the factors influencing choice (Hanley et al., 1998). A careful definition of the attribute level and ranges is required, such that the attribute space is relevant concerning the policy questions asked. Different bundles of environmental non-market goods, with their own specific attributes, characteristics and levels are described and the respondents are asked to choose between them to estimate the WTP of a certain (environmental) good (Hanley et al., 1998). The CE-approach is based on Lancaster's consumer theory (Bateman et al., 2002) and the random utility theory (RUT) (Manski, 1977).

2.3.3.4.2 Lancaster's consumer theory

Lancaster's consumer theory states that goods possess or give rise to multiple characteristics in fixed proportions and that consumers' preferences are based on these characteristics instead of the goods themselves. Consumers do not necessarily derive utility from the good itself, but from its intrinsic characteristics instead (Lancaster, 1966). Bateman et al. (2002) give the example of a forest, which can be described by attributes like the age of the trees, the diversity in trees and recreational opportunities. However, it is impossible to describe everything in terms of attributes and its characteristics. In particular, there are also more complicated characteristics that cannot be observed, but do influence individual's utility. This missing point is covered through the random utility theory (Bateman et al., 2002).

2.3.3.4.3 Random utility theory

The Random Utility Model (RUM) states that consumers derive utility from the characteristics of a product, rather than from the product itself (Lancaster, 1966). Consequently, an individual's utility for a certain good is stated by a utility function where the utility depends on the characteristics of the good. Some of these characteristics are unobservable to the researcher, which causes the conventional utility function to be broken down into two parts. A deterministic part, which is assumed to be common for everyone given the same product characteristics and attributes and a stochastic, unobservable part, which includes factors that aren't shown and are not possible to elicit from the survey. In addition to the attributes of the good, socio-demographic characteristics could be added as well. Respondents are assumed to maximise their utility and therefore choose the alternative with the highest utility. Furthermore, the RUM can be associated with consumer choice theory. If the choice set involves two alternatives of a product, a binary logit model is required. When the model is extended to more than two alternatives, multinomial or mixed logit models are required (Bateman et al., 2002).

2.3.3.4.4 Critiques

In choice experiments it is very important that the information provided to survey respondents is strongly accurate within non-market valuation (Bateman et al., 2009). According to Munro and Hanley (2001), individuals form their preferences in response to the information provided concerning the goods in question. Especially concerning the valuation of non-market goods, information plays an important role in the formation of preferences because of the lack of experience. An increasing concern of choice experiments has been the comprehension (Matthews et al., 2017) or 'evaluability' of the information provided (Hsee, 1996). In other words, people need to understand what they are valuing. If respondents do not entirely comprehend or imagine how their choices would affect them in real life, results will not obtain external validity (Matthews et al., 2017) In this case, uncertainty about the non-market good will increase the valuation variability and potentially introduce or enhance uncertainty and biases (Bateman et al., 2009).

2.4 Respondent uncertainty in stated preference studies

2.4.1 Hypothetical bias

One of the major criticisms of choice experiments is the fact that the choices are being made in hypothetical markets. Since these experiments are hypothetical both regarding the payment and the provision of the good, it is uncertain whether the choices the respondent states (in a hypothetical setting) would match the choices in real life (Murphy, Allen, Stevens, & Weatherhead, 2005). The difference in the choices made by individuals in hypothetical settings compared to real life settings is often described as the result of hypothetical bias (Fifer, Rose, & Greaves, 2014). Another source of (hypothetical) bias arises when respondents are asked to state a maximum WTP for a good or service, while they don't have to actually pay for it (Aadland & Caplan, 2003). Previous studies have found that respondents generally report a higher WTP in hypothetical payments than in actual payments (Champ, Moore, & Bishop, 2009), leading to upwardly biased WTP estimates (Whitehead & Cherry, 2007). One of the many approaches that have been used with the aim to measure this bias is to use the self-reported (un)certainty of respondents (Olsen et al., 2011). Specifically in CV and CE studies, the mitigation of hypothetical bias is an important application of respondent uncertainty (Ku & Wu, 2018).

2.4.2 Respondent uncertainty

Responding to hypothetical questions about WTP for a non-market good can be challenging in numerous ways due to uncertainty as to the exact value of a good to the respondent, the misunderstanding of words and sentences in the survey or simply unfamiliarity to the good in monetary terms (Olsen et al., 2011) and give rise to preference or choice uncertainty (Li & Mattsson, 1995). Preference uncertainty is closely related to the complexity of choice tasks. Respondents are likely to be more certain about their choices when choice tasks are easier (Dekker, Hess, Brouwer, & Hofkes, 2013). Bradley and Daly (1994) find that an increase in complexity results in a reduction of the scale parameter of the RUM model causing an increase in random decisions and consequently may cause problems for the estimation of the WTP in choice experiments. Wang (1997) hypothesized that respondent uncertainty can be characterized by the difference between the true WTP and the indicated payments in the survey, where even small differences indicate that a respondent's preference is vague and uncertainty is high. In recognition of this, several SP studies have tried to obtain a measure of the degree of (un)certainty that is perceived by the respondent while answering valuation questions (Olsen et al., 2011).

2.4.3 Self-reported certainty in stated preference studies

One of the approaches to measure uncertainty is to use respondents' self-reported uncertainty through adding follow-up questions in which respondents are allowed to express their uncertainty about a decision (Li & Mattsson, 1995). This approach involves the respondent to make a decision first, before stating their choice certainty in a post-decisional setting, either in the form of a numeric scale or text statements (Olsen et al., 2011). According to Akter, Bennett, and Akhter (2008), the numeric certainty scale (NCS) and polychotomous choice (PC) method are two widely used techniques of measuring preference uncertainty through follow-up questions. In the NCS method, the valuation question is followed up by a numeric scale where respondents are asked to state their certainty about the decision they just made. In the PC method respondents are asked to express their uncertainty by choosing from a set of responses like "I will definitely pay", "I will probably pay", "maybe I will pay" . Various studies e.g. Lundhede, Olsen, Jacobsen, and Thorsen (2009) have used this self-reported choice certainty as an explanatory variable in the utility functions which allowed the model to control for choice task complexity. These authors suggested numerous ways to recode the data or to include uncertainty statements for all respondents directly into the random utility model. Other papers have tried to explain self-reported certainty based on the utility differences derived from an estimated indirect utility function. Inspired by Wang (1997), the respondent's stated certainty is hypothesized to increase with the utility difference, which means that uncertainty would be high for indicated payments close to the individual's true WTP and low for payments that are significantly smaller or larger than the true WTP (Tu & Abildtrup, 2016).

A study by Akter, Brouwer, Brander, and Van Beukering (2009) concludes that using the information provided by respondents about their experienced uncertainty and modelling this information is considered as a promising procedure for welfare estimation in CV studies. Several authors, e.g. Li and Mattsson (1995) and Alberini, Boyle, and Welsh (2003) applied some sort of recoding or truncation of respondent answers to calibrate the stated WTP to the actual level and consequently to deal with uncertainty in CV studies. Papers by Champ, Bishop, Brown, and McCollum (1997) and Welsh and Poe (1998) applied a direct recoding of answers from 'yes' to no'. In a more recent study, Morrison and Brown (2009) attempted to reduce hypothetical bias by discarding all choices with stated uncertainty above some cut-off point. According to Lundhede et al. (2009), these recoding methods are not significant. Because they either change respondent's stated preferences or leave out information, none of them are considered satisfactory in handling uncertain answers. To circumvent the recoding issue, another approach has been to explicitly include the self-reported certainty as an explanatory variable in the model. Loomis and Ekstrand (1998) incorporated stated certainty levels of 'yes' answers into the likelihood function and proposed an asymmetric uncertainty model. The studies above explain variations in the scale of the utility function as a result of self-reported decision uncertainty (Dekker et al., 2016).

An alternative econometric modelling approach exist in the context of self-reported certainty. This method utilizes utility differences as an explanatory variable in a model with self-reported certainty serving as the response variable. This method requires an estimation of the choice model, without controlling for respondent uncertainty, and calculating the utility level for each alternative in the choice set for each individual. The utility difference, which can be defined as the difference in utility between the chosen alternative and the best alternative to that, is then used as an explanatory variable in a model with the self-reported certainty as the response variable (Olsen et al., 2011). This approach allows researchers to study the relationship between utility differences and choice uncertainty, as well as evaluating the effect of survey design factors and respondent characteristics on perceived certainty in choice (Olsen et al., 2011). By treating decision uncertainty as a latent variable, the impact of decision uncertainty on both the response of the choice task and the self-reported certainty question can be taken into account (Dekker et al., 2016)

The later approach, which is the method of choice in this study, has been used and studied in several recent papers. A study by Olsen et al. (2011) indeed points to the utility difference in choice sets as a potential key to model variance heterogeneity effects of uncertainty across choice sets. Ku and Wu (2018) provide evidence to support this hypothesis. Tu and Abildtrup (2016) use utility differences as an explanatory variable in a model with self-reported certainty as the response variable and suggest that a respondent's choices are more deterministic if he/she feels certain about their choices. Finally, a study by Brouwer, Dekker, Rolfe, and Windle (2010) constructs a self-reported certainty model in the same fashion and include respondents characteristics and design characteristics as well as utility differences. The latter was found to significantly influence self-reported certainty in a positive way, supporting previously discussed studies.

2.4.4 Effects of presentation formats on uncertainty

2.4.4.1 Visualisation

There is a growing agreement that the most effective way to enhance the comprehension and evaluability in choice experiments is via the use of visual stimuli and presenting the information in visual form, making it more realistic (Krupnick, 2006). Visualisations such as photographs, maps, diagrams have proven to aid respondent's comprehension (Matthews et al., 2017). Corso, Hammitt, and Graham (2001) show that the sensitivity of the WTP of respondents was improved when using visual aids rather than using only text. Lipkus and Hollands (1999) show that visual information outperforms numeric data as a basis for an accurate comprehension of data. In general, the use of these visualisations to convey information to respondents in choice tasks has been identified by multiple authors as a possible method to enhance realism, evaluability and therefore the validity of the data (Patterson et al., 2017).

2.4.4.2 Virtual reality

The biggest part of past research on the use of visual stimuli has been focused on static visualisations. Alternatively, dynamic computer-generated 3D-environments, often referred to as virtual environments (VE) or virtual reality (VR) can be used (Matthews et al., 2017). Despite the fact that these virtual environments have been applied in games and the design of building, their use in non-market valuation is limited and more recent (Matthews et al., 2017). This valuation methodology, referred to as virtual reality choice experiments (VRCE) directly addresses the critiques on evaluability in choice experiments by visualising the attribute levels in each choice set. (Bateman et al., 2009). According to Fiore, Harrison, Hughes, and Rutström (2009), one of the major benefits of this VR-approach is the incorporation of a wider and more natural context, which allows moving away from the highly focused and abstracted environment of typical economic experiments. Bateman et al. (2009) conclude that compared to text-only presentation, preferences elicited in VR treatments are less variable and gain-loss asymmetry is significantly reduced. In other words, the greater evaluability of VR presentation reduces judgement error.

2.4.4.3 Sensory stimuli

Within virtual environments, comprehension and evaluability can be increased even more by increasing the modalities of sensory inputs. These sensory stimuli can range from auditory to tactile stimuli or any combinations (Dinh et al., 1999). According to Bystrom et al. (1999) the sense of presence is dependent on the degree to which spatial, tactile and auditory transformations of objects in a VR environment are similar to these transformations in the real world. Within this particular research sounds are included in the form of ambient sounds to the VR environment. Past research has shown that additional sensory input and in particular sounds can increase the sense of presence in a virtual environment (Dinh et al., 1999). Accurately reproducing sounds from the real world appears to be a necessary element to fully capture the realism of a mediated environment (Freeman & Lessiter, 2001).

2.4.4.4 Presence

A major goal of the use of VRCE's is to create virtual environments that bring about a sense of presence in participants (Bystrom et al., 1999). Past research around presence has shown a highly positive correlation between a sense of presence and the level of realism: the greater the sense of presence, the greater the level of realism (Barfield & Hendrix, 1995). VR environments in particular allow researchers to manipulate stimulus inputs so that the respondent's sensorimotor illusion of being 'present' is being maximized (Bohil, Alicea, & Biocca, 2011). 'Presence' in virtual environments has been defined as 'the degree to which participants feel that they are somewhere other than where they physically are when they experience the effects of a computer-generated simulation' (Barfield, Zeltzer, Sheridan, & Slater, 1995) or simply as 'the sense of being there'. An enhanced feeling of presence makes the experience more meaningful and realistic, therefore reducing choice uncertainty (Witmer & Singer, 1998).

According to Witmer and Singer (1998), both involvement and immersion are necessary for a respondent to experience presence. Involvement is a psychological state that can be defined as 'a consequence of focussing one's attention on a coherent set of stimuli or meaningfully related activities and events'. Respondents can become more involved in the VR experience as they focus more on the stimuli, causing an increased sense of presence in the VR (Witmer & Singer, 1998). Immersion refers to what the overall VR system can deliver: the frame-rate, latency, the realism of what is displayed and the number of sensory systems it stimulates (Sanchez-Vives & Slater, 2005). In Slater's model, immersion is categorized as a quantifiable aspect of technology, determined by the extent to which displays are inclusive, extensive, surrounding and vivid (Slater & Wilbur, 1997). Identical to involvement, a VR environment that produces a greater sense of immersion will produce higher levels of presence (Bystrom et al., 1999).

3 Methodology

3.1 Choice model

The choice model relies on the RUM by D. McFadden (1973), where the utility of a good can be described as a function of its attributes and people choose among goods by evaluating their attributes (Olsen et al., 2011). The basic idea of RUM is the assumption that an individual's utility cannot be observed with certainty and that it should be treated as a random variable because individuals only know their own true utility function. As mentioned before, some more complicated characteristics are unobservable and random. For utility to become a random variable, it is broken down into two parts: an observable, deterministic part and an unobservable, random part. Consequently, for a certain individual (i), the utility associated with each alternative (n) can be written as:

$$U_{in} = \beta_n ASC_n + \beta x_{in} + \varepsilon_{in} \qquad (1)$$

also known as the conditional or multinomial logit model. Where ASC_n is an alternative-specific constant, β is a vector of utility weights, homogenous across customers and x_{in} is a vector of explanatory variables, observed by the analyst. These include attributes of the alternatives, socio-economic characteristics of the respondent and descriptors of the decision context and the choice task itself in a certain choice situation (number of choice situations, number of alternatives, attribute ranges, data collection method) (Hensher & Greene, 2003). The error term ε_{in} can be motivated as consumer heterogeneity in tastes for unobserved product attributes as well as missing attributes, measurement errors and proxy variables (Bateman et al., 2002). Any specific respondent will choose an option over an alternative option in the choice set if the utility associated with that option is higher than the utility associated with the alternative option.

Since the error terms cannot be observed, it is important to at least define their distribution in order to express the probability of choosing an alternative. Assuming that the error term is identically and independently distributed (IID) extreme value type 1, the conditional logit probability of individual i choosing alternative n out of j alternatives is given by:

$$P_{in} = \frac{e^{\beta x_{in}}}{\Sigma_j e^{\beta x_{ij}}} \qquad (2)$$

The assumption of independence of the error term implies that including/omitting other alternatives or changes in the attributes of any alternative should not affect the probability of an option being chosen and is referred to as the property of the Independence of Irrelevant Alternatives (IIA) (D. L. McFadden, 1984). For a better explanation of this IIA property, Train (2009) defines the ratio of logit probabilities for any alternatives n and k as:

$$\frac{P_{in}}{P_{ik}} = \frac{e^{\beta x_{in}}/\Sigma_j e^{\beta x_{ij}}}{e^{\beta x_{ik}}/\Sigma_j e^{\beta x_{ij}}} = \frac{e^{\beta x_{in}}}{e^{\beta x_{ik}}} = e^{\beta x_{in} - \beta x_{ik}} \qquad (3)$$

This equation shows that the probabilities of choosing these alternatives are not affected from the existence of other alternatives and their attributes. This property can be an important strength but at the same time a limitation of this model. In cases where the IIA property holds, significant advantages can be gained in terms of an accurate representation of reality (Train, 2009). However, in many cases this IIA property can be both too restrictive and unrealistic.

One model that relaxes IIA property is the mixed logit model (Fiebig, Keane, Louviere, & Wasi, 2010), which allows for a much higher flexibility. When using this model, the assumption that the coefficients are the same for all individuals is relaxed. In contract to the multinomial logit model, which assumes heterogeneity in respondents' preferences, mixed logit models take heterogeneity in account (Dahlberg & Eklöf, 2003). The most commonly used form of mixed logit is known as the random parameters logit model (Train, 2009), which treats parameters (β) as random parameters instead of fixed parameters and assumes them to vary randomly in the population (Hensher & Greene, 2003). However, this model will not be utilised in this study.

3.2 Utility differences

In the next step, the estimated model (1) is used to calculate the expected average utility of each alternative in each choice set for each individual. The expected utility difference, UD, between the alternative chosen n and the best alternative of the two alternatives left (either k or l), i.e. for each choice set:

$$UD = E\big(U_{in}(ASC_n, x_{in}, \varepsilon_{in})\big) - \max\,\big\{E\big(U_{ik}(ASC_k, x_{ik}, \varepsilon_{ik})\big)\,;\; E\big(U_{il}(ASC_l, x_{il}, \varepsilon_{il})\big)\big\}$$

$$UD = \beta_n ASC_n + \beta x_{in} - \max\{(\beta_k ASC_k + \beta x_{ik})\,;(\beta_l ASC_l + \beta x_{il})\} \qquad (4)$$

As described by equation (4), the expected aggregate utility of each alternative is calculated by multiplying the estimated utility weights with the corresponding attribute levels. The utility differences are then used as an explanatory variable in a model with the self-reported level of certainty in choice as the dependent variable. Remember that respondents are assumed to be more certain about their choice if the UD between alternatives is bigger.

3.3 Self-reported choice certainty model

A panel data set consists of both a cross-sectional and a time-series dimension. In other words, the same individuals, families, firms or states amongst others are followed across time. This structure allows researchers to look at dynamic relationships, which cannot be achieved through the use of a single cross section. Furthermore, a panel dataset also allows to control for unobserved cross section heterogeneity (Wooldridge, 2010). Because the dataset for this thesis contains multiple observations for multiple individuals, a panel data structure of the dataset is exploited. In general, a basic model for panel data can be written by:

$$Y_{in} = \beta x_{in} + \alpha_i + u_{in} \qquad \text{n} = 1,2 \ldots \text{N} \qquad (5)$$

Where x_{in} is a vector which can contain variables that change across n but not i, change across i but not n or change across both i and n. α_i is the unobserved effect, often referred to as unobserved component, unobserved heterogeneity or in the case of individuals: individual heterogeneity. u_{in} are called idiosyncratic errors, because these vary across both i and n. The unobserved heterogeneity can be treated in two ways, as a random effect or as a fixed effect. A big difference between the fixed effects (FE) model and random effects (RE) model is the fact that the FE model allows correlation between fixed effects and the explanatory variables, while the RE model does not (Wooldridge, 2010).

Consequently, the key consideration between choosing a RE or a FE approach is whether x_{it} and c_i are correlated. If there is any correlation between them, the estimations from the random effects model would be biased and a fixed effects model is preferred. In order to test for this correlation, a Hausmann test can be conducted (Wooldridge, 2010). More specifically if the null hypothesis is rejected, indicated by a p-value less than 0.05, fixed effects is preferred over random effects and vice versa.

After deciding between a random and fixed effects model, the next step is to construct the model. As mentioned before, respondents' self-reported certainty is the dependent variable and in general, the model can be written by:

$$CERT_{in} = \beta x_{in} + \alpha_i + u_{in} \qquad (6)$$

Where $CERT_{in}$ is the self-reported certainty of respondent i for choice set n, x_{in} is a set of explanatory variables for respondent i in set n, including both respondent and design characteristics, which may affect respondents' certainty level in each choice. As mentioned in equation (5), α_i is the individual heterogeneity of respondent i and u_{in} is the error term.

4 Research design

4.1 Experiment

The experiment was conducted at Hasselt University over the course of two weeks or ten days (each day consisted of three different time slots). Upon arrival, the respondents were randomly assigned to one out of three survey modes, being a text, video or virtual reality survey. In total, 180 respondents were gathered, meaning 60 for each survey mode. Upon completion, the respondents who did the text or video survey, which took about 20 minutes, were able to use a VR setup outside of the survey room to still allow them to experience a VR environment. The respondents who did the VR experiment, which took around 45 minutes, were firstly given some brief instructions on how to use the setup. Afterwards, they were instructed on the course of the experiment, more specifically on when they were required to take off the VR headset and answer the questionnaire on the computer. At all times, an assistant was available for each respondent in the VR experiment to follow their progress and offer help if necessary. The VR installation from Oculus consisted of a controller, two sensors, a headset and a computer (see Appendix A). Note that the questionnaire was answered on a different computer. The environment was made with the software program Unity and was developed by Ilias Mokas. The questionnaire was made in Qualtrics for the three survey modes.

4.2 Survey

The survey itself consisted of three main sections. The first section started with a short introduction and gave some background information about the choice sets as well as asking some general questions about the attitude of the respondents towards urban green and how it affects them. In the introductory guidelines, it was emphasized that the respondents had to imagine being a resident of the street described/shown to them. Furthermore, the different choice sets had to be judged independently and the respondents had to bear in mind their household income as well as other expenses they have to make. In the second section, the respondents were presented with the actual choice sets. Based on a Bayesian fractional factorial design, twelve unique alternatives out of a total of 64 alternatives were chosen. Each choice set consisted of three alternatives, of which one was the no management/status quo scenario. Each alternative was paired up with a monthly cost to be paid, the status quo scenario would not cost anything. Once the respondent choose their preferred scenario, they were asked about their certainty of the choice on a scale from 0-10. In the text survey, the scenarios were presented to the respondent in plain text, which described the combination of the different variables in each scenario (see Appendix B). In the video on the other hand, respondents were shown a video in which they flew through the street with urban green (see Appendix C). In the virtual reality experiment, the respondents were able to wander through the scenario's in a virtual environment including ambient sounds. In the VR, the status quo/no management scenario was only shown once, as the first scenario to the respondents, followed up by a combination of two scenario's in each choice set (see appendix D). In order to assure that responses in later questions were not affected by earlier questions in a systematic way, the order of choice sets was randomized, therefore effects such as framing and anchoring were cancelled out across individuals (Czajkowski, Giergiczny, & Greene, 2014). Consequently, every respondent was facing the same choice sets but in a different order. In the third and final section, respondents were asked some personal and sociodemographic questions for statistical purposes.

4.3 Variables

4.3.1 Choice sets

Three types of urban green reanimating practices were selected to vary throughout the twelve choice sets: street trees, side-street lower vegetation and street design. Each alternative, which consisted of a certain combination of those variables, was paired up with a fourth variable, being the cost per month per resident to finance a specific scenario. The variables as well as their possible values are summarized in table 1.

Variable	**Level**
Street trees	Many high-canopy trees, few high-canopy trees, many low-canopy trees and few low-canopy trees
Lower vegetation	Many planters with evergreen plants and shrubs and few green planter with evergreen plants and shrubs
Street design	Green on one side and green on both sides
Cost per month	€0, €5, €10, €20 and €50

Table 1: variables in choice sets

4.3.1.1 Street tree spacing & canopy

To manage street trees, both tree spacing and tree canopy can be alternated. Tree spacing simply refers to the space between a tree and the tree next to it. The canopy of a tree is the shaded area under the tree created by the leaves and branches. Based on these two characteristics, four different green design interventions were designed:

- many high-canopy trees (figure 2)
- many low-canopy trees (figure 3)
- few-high canopy trees (figure 4)
- few low-canopy trees (figure 5)

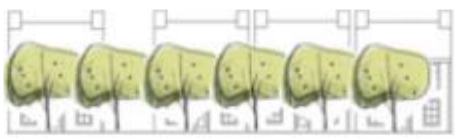

Figure 2: many high-canopy trees

Figure 3: many low-canopy trees

Figure 4: few high-canopy trees

Figure 5: few low-canopy trees

4.3.1.2 Side-street lower vegetation

Lower vegetation in the form of plants and shrubs is not only used to beautify the urban landscape, but possesses some practical functions like reducing and controlling the flow of stormwater as well. It was mentioned that this vegetation would keep it's green leaves throughout the year. In this category, two green design interventions were possible:

- many planters with evergreen plants and shrubs (figure 6)
- few green planter with evergreen plants and shrubs (figure 7)

Figure 2: many planters

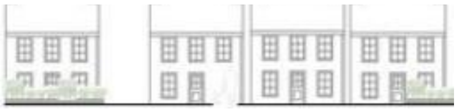

Figure 3: few planters

4.3.1.3 Street design

The two categories of side green previously discussed (trees and lower vegetation) can be accommodated either from one side or both sides of the streets. This design primarily affects the aesthetics of the road. The two possible interventions in this category are:

- green on both sides (figure 8)
- green on one side (figure 9)

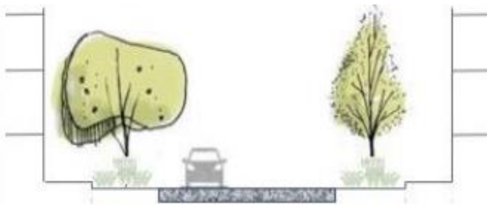

Figure 4: green on both sides

Figure 5: green on one side

4.3.1.4 Cost

To increase urban greenery, respondents had the choice to pay a monthly fee to support the local authorities. For this particular research, the fee was added to the municipality tax and the money raised would go to a strategic program for urban green infrastructure development. Five different fees were possible:

- €0 euro each month (no-management)
- €5 euro each month (equals €60 each year)
- €10 euro each month (equals €120 each year)
- €20 euro each month (equals €240 each year)
- €50 euro each month (equals €600 each year)

4.3.2 Self-reported choice certainty model

For the self-reported choice certainty model two types of explanatory variables, both respondent characteristics as well as experimental design factors are included in the survey. These variables and their possible levels are given in table 2.

Variable	Level
Respondent characteristics	
Male	1 if male; 0 if female
Age	18-99
Education	Less than high school; high school graduate; bachelor's degree; master's degree; doctoral degree
Employed	1 if employed; 0 if student, retired, looking for work, unable to work
Income	Less than €1000; €1000-€1999; €2000-€2999; €3000-€3999; €4000-€4999; €5000-€5999; more than €6000
Pedestrian	1 if main transport mode in cities is on foot; 0 if not
Organization	1 if part of an environmental organization; 0 if not
Utility difference (UD)	-2,7031 - 2,1696
Necessary	0-10
Wellbeing	0-10
Design characteristics	
Choice set number (Chnumber)	1-12
Virtual reality (VR)	1 if respondent used VR survey; 0 if not
Video	1 if respondent used video survey; 0 if not
Text	1 if respondent used text survey; 0 if not
Average cost (Avgcost)	The average cost of scenario a and scenario b
Green scenario (Greenscenario)	1 if respondent choose either scenario a or b; 0 if not

Table 2: respondent and design characteristics

For the variable *Employed*, both part-time and full-time employed respondents were included. Furthermore, *Income* was defined as the average monthly net income of the entire household. The variables *Necessary* and *Wellbeing* were obtained through two warm-up questions, asking about the necessity of urban green and its ability to improve the wellbeing of citizens respectively.

4.4 Actual models

4.4.1 Choice model

Based on equation (1), the utility for each alternative in each choice set for all respondents was calculated by:

$$U_1 = 1.131ASC_1 - 0.066PRICE_1 + \ 0.494MH_1 + 0.637FH_1 + 0.595ML_1 + 0.185MP_1 + 1.124BS_1 \quad (7)$$

$$U_2 = 1.974ASC_2 - 0.066PRICE_2 + \ 0.494MH_2 + 0.637FH_2 + 0.595ML_2 + 0.185MP_2 + 1.124BS_2 \quad (8)$$

$$U_3 = -0.066PRICE_3 \quad (9)$$

Where:

MH = 1 if the scenario contains many high trees;

FH = 1 if the scenario contains few high trees;

ML = 1 if the scenario contains many low trees;

MP = 1 if the scenario contains many low-vegetation planters;

BS = 1 if the scenario contains urban green on both sides of the street

4.4.2 Utility differences

Based on equation (4), the utility difference for each choice set for all respondents is then calculated by taking the utility of the chosen alternative and subtracting the highest utility of the two alternatives left:

$$UD_1 = U_1 - \max\{U_2; U_3\} \quad (10)$$

$$UD_2 = U_2 - \max\{U_1; U_3\} \quad (11)$$

$$UD_3 = U_3 - \max\{U_1; U_2\} \quad (12)$$

Where UD_1, UD_2 or UD_3 is included as an explanatory variable in the self-reported choice certainty model if respectively alternative 1, 2 or 3 is chosen. If the respondent choose the alternative with the highest utility, the utility difference is positive whereas the respondent choose an alternative other than the one with the highest utility, the utility difference is negative.

4.4.3 Self-reported choice certainty model

Before constructing the actual self-reported choice certainty model, some tests were conducted to find the most appropriate model. First of all, multicollinearity between the dependent variables was tested for. Since the study includes different types of variables (binary, ordinal and continuous), different measures of correlation had to be applied. For the correlation between continuous - ordinal, continuous – continuous and ordinal – ordinal, spearman's ρ (rho) was applied (see Appendix E1). For the correlation between binary – binary and binary – ordinal, Cramer's V was applied based on contingency tables (see Appendix E2). Finally, for the correlation between binary – continuous, the point-biserial correlation was utilised (see Appendix E3). These tests reveal a high correlation (0.7008) between *Necessary* and *Wellbeing*, so it was decided to leave out *Wellbeing*. Furthermore, a high correlation between *Employed* and *Education* (0.6488) was found, so *Education* was left out. Thirdly, a high correlation between *Average cost* and *Green scenario* (0.6136) was found, so *Green scenario* was left out. To be certain that no multicollinearity exists between the remaining variables, the Variance Inflation Factor (VIF) was calculated as well. Generally speaking, a VIF higher than 5 represents high correlations. Based on the results of the test (see Appendix F), no multicollinearity exists in the data. Secondly, heteroskedasticity if tested for as well. This refers to the situation where the variability of a variable is unequal across the range of values of a second variable that predicts it. If heteroskedasticity is present it can produce biased and misleading parameter estimates. Based on the results a Breusch-Pagan test for heteroskedasticity (see Appendix G), the null hypothesis (homoskedasticity) is rejected (p = 0.000) implying the presence of heteroskedasticity. To correct for this, the *Robust* command is added to the regression in Stata. Finally, a Wooldridge test is conducted to check for serial correlation in the data. In panel data, serial correlation biases the standard errors and causes the results to be less efficient. Based on the results of this test, we accept the null hypothesis of no serial correlation (p = 0.1344) (see Appendix H).

As described in section 3.4, the next step is to conduct a Hausman test to decide whether a RE or a FE model is appropriate. The result indicate that the null hypothesis cannot be rejected (p = 0.999) and therefore the RE model is consistent (see Appendix I). The model, based on equation (6) and referred to as **model 1** can be written by:

$$CERT_{in} = \beta_1 Male + \beta_2 Age + \beta_3 Employed + \beta_4 log(Income) + \beta_5 Organization + \beta_6 Pedestrian + \beta_7 Necessary + \beta_8 UD + \beta_9 Avgcost + \beta_{10} Chnumber + \beta_{11} VR + \alpha_i + u_{in} \quad (13)$$

This model will be used to test the main hypotheses. In order to test the sub hypotheses, some small adjustments will be made to this model. Hypothesis 1a will be tested by adding the variable *Video* to the main model causing the variable *Text* to become the reference category. This model will be referred to as **model 2**:

$$CERT_{in} = \beta_1 Male + \beta_2 Age + \beta_3 Employed + \beta_4 log(Income) + \beta_5 Organization + \beta_6 Pedestrian + \beta_7 Necessary + \beta_8 UD + \beta_9 Avgcost + \beta_{10} Chnumber + \beta_{11} VR + \boldsymbol{\beta_{12} Video} + \alpha_i + u_{in} \quad (14)$$

Comparably, in order to test hypothesis 1b, the variable *Text* is added to the main model causing the variable *Video* to become the reference category. This model will be referred to as **model 3**:

$$CERT_{in} = \beta_1 Male + \beta_2 Age + \beta_3 Employed + \beta_4 log(Income) + \beta_5 Organization + \beta_6 Pedestrian + \beta_7 Necessary + \beta_8 UD + \beta_9 Avgcost + \beta_{10} Chnumber + \beta_{11} VR + \boldsymbol{\beta_{12} Text} + \alpha_i + u_{in} \quad (15)$$

5 Results

5.1 Sample characteristics

The sample for the choice experiment comprised 180 respondents, more specifically 60 respondents for each survey mode. Table 3 shows a selection of socio-demographic characteristics for the sample which were acquired through follow-up questions after the actual choice experiment and compares them to the population characteristics from Belgium. Overall, people in the sample are on average 8 years younger compared to the population. Furthermore, the amount of people with a high school degree or less is significantly lower and the mean monthly household income is higher in the sample. These differences can be devoted to the fact that the survey was held in academic surrounding containing well-educated respondents.

Variable	**Sample statistics**	**Population statistics**
Mean age	33.7	41.7 ([2] , 2019)
Gender (% male)	49.4%	49.2% ([1] , 2018)
% with high school degree or less	16.11%	67.27% ([1] , 2018)
Employment rate	62.23%	65.2% ([1] , 2018)
Average people in household	2.99	2.30 ([3] , 2017)
Average net monthly household income	€3700	€2034 ([3] , 2017)

Table 3: socio-demographic statistics
[1] = acquired from Statbel; [2] = acquired from Statista; [3] = acquired from Eurostat

Respondents were also asked a number of general questions to gauge their attitude towards urban green spaces. The results indicate that respondents had a positive attitude towards urban greenery in general. When asked about the necessity and the contribution towards well-being of citizens of urban green spaces, respondents reported an average score of 8.8 and 8.7 respectively on a scale of 0 to 10. A 5-point Likert scale was utilised to look at the attitude of respondents towards certain benefits and downsides of urban green. The results, as shown in table 4, indicate that on average respondents strongly agreed that urban greenery improves street-level air quality, improves the beauty of the neighbourhood, increases biodiversity and contributes to better health. Respondents also agreed that urban greenery reduces wind speed, reduces noise from the street, keeps their house shaded and cool and prevents water runoff problems. On the other hand, respondents only disagreed that urban green bothers them when their leaves fall. Concerning the contribution to community safety and the damagement of the pavement, a neutral attitude towards urban greenery was found.

Variable	Median response
Urban green spaces…	
Improve street-level air-quality	1 (= **strongly** agree)
Reduce wind speed	2 (= somewhat agree)
Improve the beauty of the neighbourhood	1 (= **strongly** agree)
Bother me when their leaves fall	4 (= somewhat disagree)
Reduce noise from the street	2 (= somewhat agree)
Keep my house shaded and cool	2 (= somewhat agree)
Increase biodiversity	1 (= **strongly** agree)
Prevent water runoff problems	2 (= somewhat agree)
Contribute to better health	1 (= **strongly** agree)
Contribute to community safety	3 (= neither agree nor disagree)
Damage the pavement	3 (= neither agree nor disagree)

Table 4: respondent attitude towards urban green

5.2 Modelling determinants of respondent certainty

In this section, we turn to the self-reported choice certainty results. To explore what drives choice certainty, the self-reported choice certainty from the survey was regressed on a number of possible explanatory factors in a random effects model. An explanation of the variables can be found in section 4.3.2, table 2. In all of the three models, the R^2 (goodness of fit) indicates that the model provides a reasonably good description of the dataset. Other papers using virtual reality e.g. Birenboim et al. (2019) also deal with an R^2 ranging between 0.1 and 0.2.

The results of the first model (**model 1**) are reported in table 5. It is found that being employed decreases the self-reported certainty, while having a higher income increases the self-reported certainty. Respondents who are part of an environmental organization on the other hand feel less certain about their answers. Furthermore, respondent's self-reported certainty increases with the UD's, implying that respondents feel more certain where there is a bigger UD between alternatives. Looking at the design characteristics, a higher average cost of scenario a and scenario b makes respondents feel less certain about their choices. Finally, respondents who took part in the VR experiment report a higher self-reported certainty compared to respondents who took part in the text-based or video-based experiment.

As mentioned in section 4.4.3, two sub-models were created to test the sub hypotheses for this study. The results of the first sub-model (**model 2**) are reported in table 5. In this model, the self-reported certainty of both respondents in the VR experiment as well as respondents in the video-based experiment is compared to respondents in the text-based experiment. Results show that the use of VR does increase respondent's certainty compared to text-based surveys. However, video-based surveys do not show a significant improvement in certainty over text-based surveys. The results of the second sub-model (**model 3**) are reported in table 5. Similar to the previous model, the self-reported certainty of respondents in the video-based survey is now used as the reference category. Results show that the use of VR does not significantly increase the self-reported certainty of respondents compared to video-based surveys.

	Model 1		Model 2		Model 3	
Variable	Estimate	S.E.	Estimate	S.E.	Estimate	S.E.
Respondent characteristics						
Male	-.01808	.14585	-0.16795	.14514	-0.16795	.14514
Age	.001	.00428	.00102	.00426	.00102	.00426
Employed	-.28948*	.14342	-2.99951*	.14543	-2.99951*	.14543
Log(Income)	.27918*	.12758	.27540*	.12742	.27540*	.12742
Pedestrian	-.22574	.14265	-.23534	.14249	-.23534	.14249
Organization	-.52699**	.18450	-.53527**	.18377	-.53527**	.18377
UD	.32952***	.03469	.32880***	.03466	.32880***	.03466
Necessary	.13716	.07250	.14212	.07327	.14212	.07327
Design characteristics						
Chnumber	.01141	.00940	.01141	.00905	.01141	.00905
VR	.29716*	.13795	.36699*	.16714	.23172	.16711
Video			.13528	.17843		
Text					-.13527	.17884
Avgcost	-.00928**	.00321	-.00930**	.00321	-.00930**	.00321
Constant	4.5981***	1.0956	4.5276***	1.0969	4.6629***	1.0827
Between R^2	0.1385		0.1415		0.1415	

Table 5: Self-reported choice certainty determinants
**** indicates significance at the 0.001 level; ** at the 0.01 level; * at the 0.05 level*

6 Discussion

6.1 Summary of findings

The first and main hypothesis *'Respondents report less uncertainty about their decisions in a virtual reality experiment compared to experiments based on traditional survey methods'* is confirmed through the first model, since *VR* reports a positive statistically significant coefficient. As expected, following the statement of Fiore et al. (2009) this means the use of VR creates a wider and more natural context, allowing respondents to experience an enhanced feeling of presence and realism causing a reduction in choice uncertainty. To look further into this hypothesis, it was divided into two sub hypotheses. This allowed us to test whether the use of VR reported a significant improvement in choice certainty compared to both text- and video-based surveys. The first sub hypothesis *'Respondents report less uncertainty about their decisions in a virtual reality experiment compared to a text-based experiment'* is confirmed in the results of the second model, since *VR* reports a positive statistically significant coefficient in this model as well. However, the second sub hypothesis '*Respondents report less uncertainty about their decisions in a virtual reality experiment compared to a video-based experiment'* cannot be confirmed due to an insignificant coefficient. This interesting finding shows that researchers can significantly increase respondent uncertainty by using virtual reality instead of traditional text-based surveys.

Like Olsen et al. (2011), another point of interest was to provide further empirical evidence of the hypothesis of Wang (1997) that choice uncertainty increases as alternatives become less distinguishable from each other in terms of utility. The utility differences between the chosen and second-best alternative was therefore included in the models and significantly influences self-reported certainty in a positive way, supporting the findings of (Olsen et al., 2011) and confirming the second hypothesis: *'Respondents' stated certainty in choice increases with the utility difference between the alternative chosen and the best alternative to that'*. More specifically, the larger the utility difference, the more certain respondents are about their choice.

Furthermore, there is a significant effect of respondents' household *Income*: the higher the income level, the higher their self-reported certainty confirming the findings of Brouwer et al. (2010) and Olsen et al. (2011). A possible explanation could be the financial space of respondents with a higher household income to support certain initiatives. Respondents with a lower household income will be less eager to give up personal money, making them less certain. Employment has a negative influence on certainty, meaning that people who are *Employed* are less certain about their answers than respondents who still study, respondents who are retired, respondents who are unable to work and respondents who are looking for work. This could be explained by the financial conservatism of employed people, meaning they are more cautious about the way they handle their finances and invest their money in comparison to mainly students and retirees. *Organization* shows a negative relationship with choice certainty, people who are part of an environmental organization are less certain. This is a surprising and counterintuitive result since we expected members of an environmental organization to have a strong preference towards urban greenery, therefore expressing more certainty about their answers. In the same line as findings by Olsen et al. (2011), *Age* does not significantly influence self-reported certainty. Brouwer et al. (2010) however do find that self-reported certainty is significantly influenced by the age of respondents and conclude that older respondents are less certain. *Male* does not report a significant coefficient either, while papers by Olsen et al. (2011) and (Brouwer et al., 2010) do find a significant relationship between the gender of the respondent and their choice certainty. These papers both find that women tend to be less certain than men. A priori, we expected respondents who have a positive attitude towards urban green and respondents who mainly go on foot in cities to be more certain about their choices. However, *Necessary* and *Pedestrian* are found to have no significant effect on certainty in choice.

Another interest in this study was the impact of some design characteristics on self-reported choice certainty. Supporting the findings of Brouwer et al. (2010), *Avgcost* has a negative impact on choice certainty, implying that a higher price results in less certainty. That is, in choice sets where both alternatives a and b had a high cost price (for example €50), respondents tended to be less certain because they had to give up a bigger fraction of their income. Finally, it is a well-documented finding that as respondents evaluate more choice sets, initial instability of preferences may decrease (Bateman et al., 2009). Such an effect would cause respondent certainty to increase with the choice set number. However, the findings do not support this hypothesis and report an insignificant coefficient for *Chnumber*.

6.2 Limitations

Although the experiment was anonymous, respondents still might have felt that they were recorded which might have led to different answers in comparison to e.g. an online survey. Especially the respondents who did the virtual reality survey had an assistant behind them at all times which could lead to feeling extra pressure and giving more socially desirable answers. The environment in general was highly academic since the experiment was conducted at the University of Hasselt. Judging by the sample characteristics (section 5.1) the sample might not be an ideal representation of the population. On average respondents in the sample were younger, had a higher level of education and a higher net monthly household income compared to population statistics.

Another limitation of the experiment is the amount of respondents that participated. Due to time limitations, the relatively long duration of the experiment and the cost of conducting a virtual reality experiment, only 180 respondents each answering 12 choice sets were able to be gathered, equating to a total of 2160 observations. Other similar researches applying similar models e.g. Olsen et al. (2011) and Tu and Abildtrup (2016) include up to 6000 observations. Furthermore, some variables with a possible impact on certainty were not present in the survey. Learning, as described by Olsen et al. (2011) is related to respondents' familiarity with the respective good that is evaluated. In our case, prior experience with a virtual reality setup might have a significant impact on the certainty of respondents in the virtual reality experiment. Another interesting variable to include is the credibility of the proposed policy alternatives towards respondents. As shown by Brouwer et al. (2010), the credibility of presented alternatives can have a significant positive impact on choice certainty.

6.3 Further research

Following the limitations of this experiment, further research could be conducted in a more natural environment. Since the experiment focused on urban greenery in cities, it might seem straightforward to conduct the experiment in an actual city, allowing for a more representative sample. Regarding the organization of the experiment, it might be interesting to use a setup which allows for a more time-effective way of using virtual reality setup and an elevated amount of respondents. It would also be interesting to investigate other socio-demographic or design characteristics that might have a significant impact on self-reported certainty which were not included in this thesis or other similar papers.

7 Conclusion

In choice experiments, respondents are often not familiar with the task of responding to hypothetical questions concerning their willingness-to-pay for a non-market good. Due to the highly abstracted environments in which traditional choice experiments, like text-based or video-based surveys, are conducted respondent uncertainty can arise resulting in biased estimations of welfare measures. However, the use of virtual reality has shown to create a more natural context and consequently enhance presence and realism. In this research 180 respondents were randomly assigned to either a virtual reality, a text-based or a video-based choice experiment about urban green. After each out of twelve choice sets, respondents were required to state their certainty on a scale from 0 to 10 about the choice they just made. The self-reported choice certainty was then used as the dependent variable in a random effects model. Results show that the self-reported certainty of respondents who did the virtual reality survey significantly increases in comparison to respondents who did the text-based survey. However, self-reported certainty did not significantly increase compared to respondents who did the video-based survey. This result is particularly useful towards researchers and companies who seek to elicit respondent or customer preferences towards a non-market good through choice experiments.

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Appendix

Appendix A: VR installation from Oculus used for the experiment

Appendix B: Example of a choice set in the text-based survey

Case:

Now imagine that you are a resident of the street which at the moment has **no urban green.** The municipality is willing to improve the greenery design. **If the following options are the** only **available, which scenario would you prefer the most?**

	Scenario A	**Scenario B**	**No-management**
Tree spacing & canopy	few low-canopy trees	many high-canopy trees	none
Side-street lower vegetation	many planters	few planters	none
Green-street design	one side	both sides	none
Cost	€20	€10	none

I choose:

Scenario A	Scenario B	No management
○	○	○

Appendix C: Example of a choice set in the video-based survey

Case:

Now imagine that you are a resident of the street which at the moment has **no urban green.** The municipality is willing to improve the greenery design. **If the following options are the** only **available, which scenario would you prefer the most?**

Click on the play button to see the videos below

Scenario A	**Scenario B**	**No management**
€20	€10	None
		

I choose:

Scenario A	Scenario B	No management
○	○	○

Appendix D: Example of a choice set in the VR survey

Appendix E: Tests for collinearity

Appendix E1: Spearman's rho for correlation between: continuous-continuous, ordinal-ordinal and continuous-ordinal

	Avgcost	Age	Logincome	UD	Necessary	Wellbeing	Education	Chnumber
Avgcost	1.0000							
Age	0.0000	1.0000						
Logincome	0.0000	0.1356	1.0000					
UD	-0.2968	-0.0325	-0.0028	1.0000				
Necessary	0.0000	0.2605	0.0097	0.0109	1.0000			
Wellbeing	0.0000	0.2361	-0.1540	0.0084	0.7008*	1.0000		
Education	0.0000	0.4112	0.2103	0.0293	0.2102	0.1956	1.0000	
Chnumber	0.0279	0.0000	0.0000	-0.0150	0.0000	0.0000	0.0000	1.0000

Appendix E2: Cramer's V for correlation between: binary-binary and binary-ordinal

	Male	Employed	Organization	Vr	Video	Text	Pedestrian	Groenscenario
Male	1							
Employed	-0.0659	1.0000						
Organization	0.0393	0.0242	1.0000					
Vr	0.0314	0.0485	0.0875	1.0000				
Video	0.0079	0.0485	-0.0250	/	1.0000			
Text	-0.0393	-0.0970	-0.0625	/	/	1.0000		
Pedestrian	0.0882	-0.0343	-0.0556	0.1747	-0.0159	-0.1588	1.0000	
Greenscenario	-0.0011	-0.0329	0.0348	0.0404	-0.0348	-0.0057	0.0134	1.0000

	Male	Employed	Organization	Vr	Video	Text	Pedestrian	Groenscenario
Necessary	0.3711	0.2295	0.2152	0.1968	0.1846	0.1879	0.1972	0.1130
Wellbeing	0.3533	0.2116	0.2488	0.2133	0.3082	0.2422	0.1616	0.0782
Education	0.2200	0.6488*	0.0969	0.1582	0.1344	0.1498	0.1335	0.0682
Chnumber	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0546

Appendix E3: point-biserial correlation between binary and continuous variables

	Male	Employed	Organization	Vr	Video	Text	Pedestrian	Groenscenario
Age	0.0050	0.1344	0.2248	0.1301	-0.0701	-0.0599	-0.0287	0.0493
Logincome	0.0272	0.3113	0.0197	-0.0119	0.0473	-0.0355	-0.1487	-0.0080
Avgcost	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.6136*
UD	0.0178	-0.0047	0.0140	0.0754	0.0189	-0.0944	0.0155	0.2118

Appendix F: Variation Inflation Factors (VIF's) for the dependent variables

```
. estat vif
```

Variable	VIF	1/VIF
necessary	1.26	0.794124
loginc	1.15	0.869677
male	1.15	0.871341
employed	1.14	0.874501
age	1.14	0.876748
envorgYes	1.10	0.912342
UD	1.09	0.917080
avgprice	1.08	0.925643
transport_4	1.08	0.929478
vr	1.07	0.937831
chnumber	1.00	0.998746
Mean VIF	1.11	

.

Appendix G: Breusch-Pagan test for heteroskedasticity

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: fitted values of cert

         chi2(1)      =    40.57
         Prob > chi2  =   0.0000
```

Appendix H: Wooldridge test for serial correlation

```
Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
    F(  1,     179) =      2.262
           Prob > F =      0.1344
```

Appendix I: Hausman test

	Coefficients (b) fe	(B) re	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
chnumber	.0114107	.0114105	1.82e-07	.0001905
UD	.3287698	.3295224	-.0007526	.004779
avgprice	-.0092957	-.0092812	-.0000145	.0000996

```
                  b = consistent under Ho and Ha; obtained from xtreg
      B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test:  Ho:  difference in coefficients not systematic

              chi2(3) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                      =        0.02
            Prob>chi2 =      0.9990
```