Communicating urban density: Assessing the challenges and opportunities in the use of 3-D representation for public participation in planning

Syeda Laila Nargis

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______________________________________ Chair
Dr. Damon Matthews

______________________________________ Examiner
Dr. John Zacharias

______________________________________ Examiner
Dr. Juan Torres

______________________________________ Supervisor
Dr. Pierre Gauthier and Dr. Amin Hammad

Approved by ______________________________________
Dr. David Greene
Chair of Department

____
Dr. Brian Lewis
Dean of Faculty of Arts and Science

Date ______________________________________

Abstract

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The issue of urban densities is central for cities that aim at reducing their environmental footprints. As many cities are devising intensification policies that would significantly alter the spatial form, the demand for public participation in the planning process becomes more pressing. To meet this demand, specialists employ three dimensional (3-D) technologies that allow effective communication with non-specialists. Urban density is a complicated notion which is difficult to communicate to non-specialists.

The purpose of the present study is to identify some of the difficulties faced by specialists and non-specialists that wish to exchange a dialogue over urban density. It focuses on perception and cognition problems regarding density in 3-D digital representation. It endeavors more specifically to understand whether an active engagement with digital 3-D models displaying density changes favors a better cognition of specialists and non-specialists including those who come to the experiments with preconceived (false) conceptions.

The results show that there is a significant difference between active and passive engagement with 3-D models. The success rate of participants' actively interacting with the digital model is higher than that of their passive counterparts. By stressing the fact that an active engagement with 3-D digital modes favours a better cognition of urban density this study can contribute to the improvement of the methods and tools used to encourage the public participation to the planning debates pertaining to density.

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Finally, thank you to Almighty Allah literally, for everything.

Dedicated

To

My Mother

Who taught me to face the world boldly.

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Chapter 1

Introduction

The modern technological world gives people new opportunities to have a voice in public policy. This applies in particular to urban planning. Without public participation, one can argue that proper planning cannot be done. Traditionally, the “top down” approach for planning was the norm however; the “bottom up” approach has been gaining in popularity. In recent decades, politicians, planning professionals, developers, activists and citizens reshaped and redefined the planning process by expanding it. Planning theorists studied the public’s behavior as well as its concerns and involvement in the planning process (Haward and Gabrion, 2007). Planning is generally a complicated process whereby professional planners routinely use new technologies, such as three-dimensional (3-D) images to analyze and communicate trends of future development. Such technologies are not very user friendly for “non-specialists” that are called upon to form and share an opinion. In the last 20 years or so, technologists have been using 3-D environments in particular, to increase public participation. Planners are faced with challenges when trying to determine the most suitable mode of communication. One such challenge pertaining to cognition problems could arise when visualizing information on the built environment. Among the issues that need proper attention to ensure an improved public involvement, are perception and cognition problems pertaining to density.

This research aims to better understand the nature of some of the communication challenges faced by specialists and non-specialists wishing to engage in exchanges over effective urban transformation. More specifically, it explores some of the determinants affecting the communication of density, using 3-D graphical representation. The enquiry will rely predominantly on experimental research methods.

The first Chapter gives an introduction of the present study. Chapter 2 briefly reviews at first the public participation process and the background of the present study. This chapter describes the purpose, objectives and hypotheses of this research after that it sets about the tools, techniques and mode of communication that are currently used by specialists to communicate with non-specialists. A theoretical framework is also developed in this chapter about density and digital 3-D representations. Chapter 3 outlines the methodology of the research and focuses on the procedural details of the experiment. Chapter 4 presents the general and statistical analyses. Chapter 5 presents the results and a discussion. Finally Chapter 6 summarizes the findings in a conclusion and outlines recommendations.

Chapter 2

Theoretical framework

The purpose of the present research is to explore several communication problems and potential inconsistencies in what specialists intend to communicate and the actual information received by non-specialists. When using 3-D representations of the built environment technologists may tend to assume that non-specialists understand their illustrations or demonstrations, yet there could be a gap between specialists' and non-specialists' comprehension of the information being shared. In the last few decades, urban planners, architects and technologists have routinely used 3-D models to represent their work. In order to ensure effective public participation in planning consultation no doubt, this is potentially a very powerful tool. However, not all researchers are convinced of the effectiveness of the process and techniques that are used for public participation in planning consultations. Some researchers have started to identify shortcomings of the process and some are exploring new directions to control for these relatively "unknown" techniques in their methodologies (Zacharias, 2006).

Several modes of communication are commonly used for 3-D representation: active, passive, static, dynamic, 2-D, 3-D, local and Internet based, to name a few (Hammad and Gauthier 2007). We actually know very little about which mode of communication is more effective for the sharing of various types of spatial information between specialists and non specialists. The present research endeavors to shed light on the suitability of various modes of graphic communication aimed at ensuring a good communication of ideas between these groups. Specific shortcomings of 3-D representation are discussed in the literature on the subject. Generally, non-specialists have cognition problems regarding density. This problem sometimes applies to specialists also. Density is a confusing concept to begin with, especially when considering its many definitions. More importantly, the range and depth of both perception and cognition problems of density representation have not yet been properly mapped (Arza Churchman, 1999). In addition, preconceived (false) notions sometimes misguide participants to process information about density. This research will focus on some perception and cognition problems regarding density in 3-D digital representation. Specifically, it will endeavor to understand whether an active engagement with digital models displaying density changes favors better cognition of specialists and non-specialists including those who come to the experiments with preconceived (false) conceptions. A good understanding of information is essential for good communication between specialists and non-specialists wishing to exchange views over urban density.

2.1 Research objectives

The overall objective of this research is to better understand the communication challenges faced by specialists and non-specialists wishing to engage in exchanges over urban density. More specifically, it explores the effects of some of the factors that affect the perception and cognition of urban density as depicted in various digital representations.

Specific objectives

To determine if the mode of engagement (active or passive)* with 3-D digital models affects the specialists and non-specialists** cognitive performance in assessing urban density.

2.2 Hypothesis

The present research hypothesizes that:

- Active engagement with the data favors better cognition about urban density variation.

This research postulates

- That some people might confuse the notion of density with that of building heights. Such a factor was taken into account in this research.

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*Active engagement" refers to participants exploring and navigating the digital environment by themselves using a mouse. "Passive engagement" refers to the exposure to the 3-D dynamic digital representation, whereby the participants' interaction with the model is controlled.

**In the context of this research, the term specialist refers to an individual whose formal training entailed familiarization with mode of representation of the three-dimensional built environment, such as in the disciplines of Urban planning, architecture or engineering. The term non-specialists refer to the individual who do not have any formal training about three-dimensional environment.

2.3 Context of the research

In the early times of contemporary planning, citizens did not have many opportunities to take part in planning activities, but over the course of time, planning has become a more democratic process. Citizens and stakeholders now have the possibility to voice their concerns regarding community development. Public participation in planning has become more popular and even mandatory in some jurisdictions. Urban Planners and technologists have explored different formulae and tools to foster a better public involvement; 3-D representation being one of them. 3-D modals help people to understand both the built and natural environments and could be an valuable tool in the context of the planning process. Technical tools such as GIS, Google Earth, and Sketch Up, to name a few, allow people to create or interact with 3-D models, thus providing opportunities to participate in planning activities by forming and sharing opinions.

2.3.1 Public participation

The idea of citizen participation grew in the United States with the rise of the advocacy planning movement during the 1960s (Kurzman, 2000).

The importance of public participation cannot be ignored, however, the question remains on how to best pursue it. Jones discussed out some ways and means to guide how planners can democratically involve the public. According to him, non-professionals, professionals and others are responsible for shaping the future of a neighbourhood. If more people are involved and have a say in the planning process, especially local stakeholders, the decentralization of decision making will take place (Jones, 1990).

Sustainable development and participatory planning

Sustainable development and participatory planning are closely related. Without participatory planning, sustainable development can hardly be achieved. Participatory planning has been defined in many ways. Generally, it is considered to be "direct involvement of the public in decision making through a series of formal and informal mechanisms" (Day, 1997).

The World Commission on Environment and Development (1987) maintains that "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own" (WCED, 1987). Brown proposes a new definition, "Sustainable development is a progressive qualitative or quantitative change that ensures the vitality of living systems and the sustainable use of resources, while promoting synergy between nested social, economic and ecological systems through the use of multi-stakeholder participation in planning, decision-making and implementation processes with special attention being given to social equity and the processes through which individuals develop in qualitative terms" (Brown, 2006).

Participatory planning and democracy

Participatory planning and democracy correlate. Democracy ensures participatory planning and participatory planning supports democracy. Arnstein points out that the distribution of power is the key to real democracy (Arnstein, 2003).

Allowing access to the planning process, often a forbidden area for the public, can generate the feeling that the agency and government in general are trying to be more considerate of the public's voice and allow for more democratic processes (Tao Zhong et al., 2007).

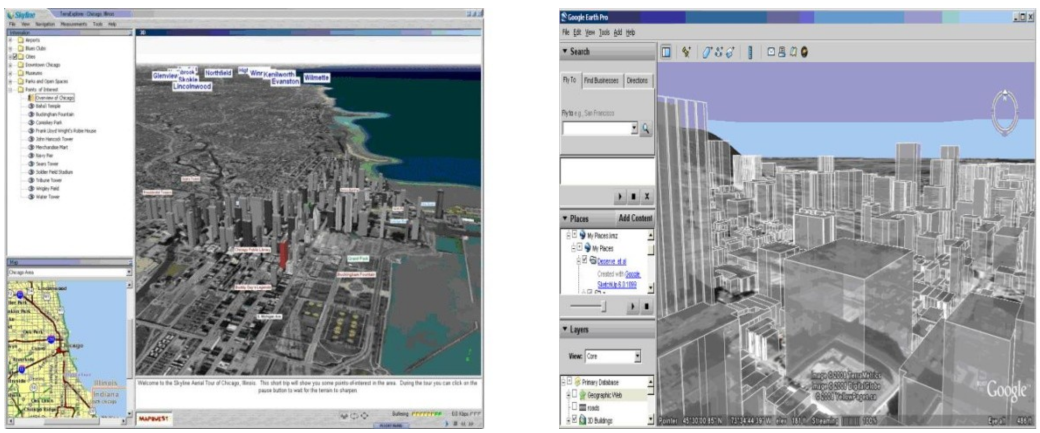
Traditional method of public participation

The traditional method of public participation is a process whereby people have access to information by using different media, such as two-dimensional (2-D) images (for example, report papers or posters), video presentations or physical small scale models. In the most rudimentary form of public participation, the information is exposed in a public venue such as the City Hall, where people can visit the exposition and give feedback by writing their comments in a notebook, for instance. Sometimes, an opportunity is provided to engage in detail dialogue with the planners or architects (Howard and Gabrion, 2007).

Some planners identified the limitations of this passive process and argued that it was insufficient in fostering the involvement of the citizens. Al-Kodmany remarked that such a passive process lacks visualization capabilities. Residents become confused and overwhelmed with information, particularly when trying to absorb and retain details about a future plan, instead of being able to apply their community knowledge and expertise. Furthermore, the Planning team may also become frustrated with a less than effective communication process (Al-Kodmany, 1998).

Visual representation for public participation

In the past 20 years, digital modes of representation have developed tremendously. When specialists felt that the traditional method of public participation was not working efficiently, they started thinking about alternatives. Digital visual representation became a new means of communication as visualization is a key element of participation (Joerin and Nembrini, 2005). However, planners must always be attentive to the fact that the participants may not be able to understand the visual models that they are presented with, digital models in particular. “Developers try to improve spatial perception for the user by creating improved visualization technologies” (Joerin and Nembrini, 2005).



(a) (b)

Figure 2-1: Virtual representation by Skyline Software Systems (a) and Terra Explorer (b) (Hammad and Gauthier, 2007).

Planners and the other professionals have started using 3-D images, GIS and animation routinely for their work. These technologies are seen as a great improvement over paper and pen sketches, but are they effective for communicating with non-specialists?

Technologists created different software’s for visualizing large-scale virtual environments. Figures 2-1(a) and (b) show virtual representations by different software.

Figure 2-1(a) represents Chicago, Illinois, USA and Figure 2-1(b) represents Concordia University, downtown campus in Montreal.

2.3.2 Available tools for virtual representation

Some available tools used by planners to create 3-D environments are available for free on the web. Google Earth, Sketch Up, GIS and CAD are some of these commonly used and user friendly tools. By using this software, specialists' even non-specialists can create and consult 3-D representations and take part in planning activities for instance.

Google Earth and Sketch Up

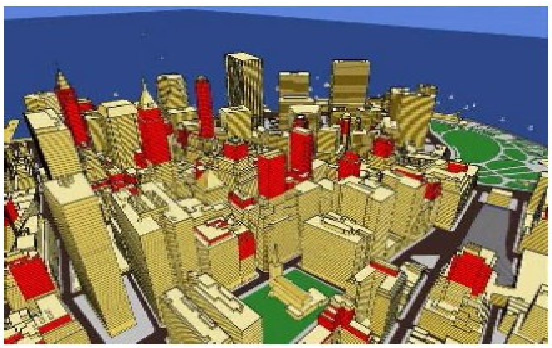
Google Earth provides Internet based satellite images of the Earth's surface. It supports 3-D data through Keyhole Markup Language (KML). Google Earth provides a bird's eye view of the Earth at a pretty high resolution that allows seeing built details for instance. Users can add any authentic feature and make it available for others. Google Earth also supports Sketch Up for 3-D modeling.

Sketch Up is a fairly commonly used software that allows architects, engineers, urban planners and the general public to create 3-D models easily and quickly. Theoretically, Sketch Up's has well organized features which makes 3-D communication easy for both specialists and non-specialists.

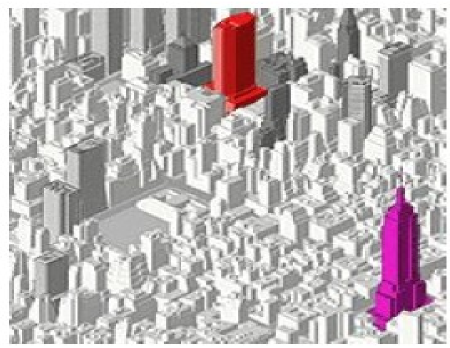
GIS and CAD

Geographic Information system (GIS) is a software which was designed to answer spatial queries using latitude and longitude data and other geographic information based on key information such as name, address, social security, zip code etc. (Sadagopan, 2000). It is an intelligent mapping system which can integrate map (graphic) data with attribute (tabular) data using different matching methods.

GIS is a very powerful tool that allows other to create and analyze vast amounts of information that can be displayed in maps and when needed, in 3-D. Different geographic information technologies can be employed for participatory activities (Howard and Gabbion, 2007*)*. If any spatial data or picture is hyperlinked with GIS, it can provide great support during planning demonstrations.



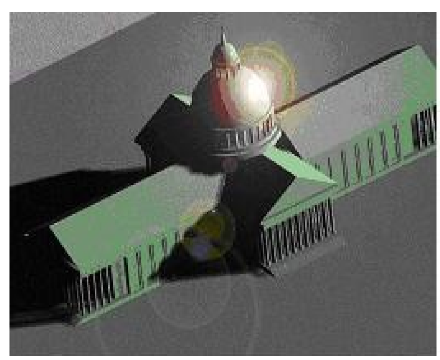
(a)



(b)

Outside Manhattan by 3-D GIS (Batty, 2006)

(c)



(d)

Full volumetric CAD modeling (Shiode, 2001)

Figure 2-2**:** 3-D GIS and CAD used to show various renditions of buildings.

When GIS is linked with a database, spatial and database information can be shown at a glance with one click. A spatial database must contain two types of information about the represented objects: geometric data and topological data. Geometric data contain information about the shape of the 2-D or 3-D objects, whereas topological data include the mathematically explicit rules defining the connectivity between spatial objects (Laurini and Thompson, 1992).

Computer aided design (CAD) is another powerful visual representation tool which can individually or together with GIS provide good quality maps. CAD files can be easily imported into GIS. Digitization can be done in CAD while the presentation can be done in GIS. Figure 2-3 (a) and (b) show the use of 3-D GIS in various renditions of the Manhattan cityscape. Figure 2-3 (c) and (d) show 3-D CAD models.

World Wide Web

The "World Wide Web" and Internet is one of the most important technological inventions over recent years. It has become a widely used communication media for carrying out all kinds of commercial, social and governmental activities. It has become an integral part of society quicker than any other previously new technology has, such as the television, telephone and automobile (Woolgar, 2002). According to their needs, people can access any information sites by using the web. As technology and internet content evolve in the world, people will be able to visualize a specific location by using Google Earth for instance. Such developments have obvious implications for public participation in planning.

2.3.3 Challenges of 3-D virtual representation

This section discusses some of the challenges pertaining to the assessment of the effectiveness of different modes of 3-D digital representation for non-specialists. Perception of scale and density is of particular importance.

General considerations

Links between sustainable development and public participation have become an unavoidable issue. However, to achieve the goal of effective public participation, there is a pressing need to address cognition problems associated with 3-D models. These problems hinder the exchange of ideas and good communication between specialists and non-specialists when they try to increase public participation in planning. Sustainable development practice dictates that the local population be consulted and participate in making decisions affecting their future. Any attempt to reform the way we inhabit our urban habitats requires that a broad consensus be reached. Such a consensus cannot be built without democratic access to information. First, we need to be aware of the challenges for effective public involvement. Once these are identified, it will become easier to meet them. Before the issues of perception and cognition of 3-D virtual rendering will be discussed, the ‘peripheral’ critical issues of high cost, age, education level and availability of technology will be addressed.

High cost

The creation of a virtual 3-D environment and a graphic representation involves using sophisticated software and hardware, which translates into a significant cost. Developed countries can manage the cost but it is difficult for developing countries to provide the required funds to install and run technology oriented demonstrations for public participations. The same rational applies when considering the use of such systems by the general population of developed countries. For instance, Geographic Information System (GIS) is one powerful tool for the production and representation of 3-D data but it has been criticized by some geographers and social scientists as being an elitist technology (Pickles, 1995). According to Al-Kodmany (1999), the cost of developing the GIS system is important.

Age and education level

Age and education level are also important issues for the use of new technologies for public participation. People of different ages and education levels do not respond similarly to technological planning demonstrations. Younger people may be more capable and interested in using technology, than older people are. Lack of familiarity with technology is another vital issue. A portion of the total population, especially older people and blue collar workers, may never have used a computer throughout their entire lives (Gaines, 2001).

Technological impediments (availability of technology and capability of citizens)

Access to computers could be a problematic factor for public involvement. Different groups of people can experience various problems regarding access. For instance, those who are financially unable to buy computer equipment, who are unwilling to connect to the Internet, who are challenged by technology or who are physically unable to use the medium (Richard, 2002). Richard mentioned that in some circumstances, technology has handed increasing power to those in authority while giving community organizations and the general public less of a say in the decision making process due to a lack of access to, and understanding of the technology. Furthermore, GIS and other commonly used software's in 3-D development require a lot of space in a computer, which often makes it slower in processing information such as loading images and overlaying thematic layers. Even technologically well informed people might not have the best adapted equipment to work with, or access, data generated by 3-D modeling specialists.

Flawed assumption (perception of scale and perception of density)

Density is an important issue in urban planning but it is a complex concept. The complexity arises in part from the inherent nature of the phenomena itself and in part due to different definitions of density that are used by specialists (Alexander. 1993). Critical misconceptions about scale and density are quite common. When non-specialists see a model or plan, sometimes they cannot visualize its scale accurately and sometimes they carry misunderstanding about its density. A constant density can be achieved by varying the space between buildings, thus driving up the height, (Zacharias & Stamps, 2004). This type of visual density calculation is not easy and it misleads participants. This potential gap in communication between specialists and non-specialists based on the flawed assumption hinders communication between those two groups. The problems associated with the perception of density are at the core of the present research and will be discussed briefly in the following sections.

2.4 Communicating urban densities: means and challenges

2.4.1 Elusive nature of the notions of density

An abundant urban planning literature is dedicated to the issues pertaining to the environmental crisis. It points to the high levels of green house gas emissions emanating from urban regions as well as to the impact of fossil energy-based transportation. Urban planners are now trying to tackle this situation by reforming transportation practices in order to reduce car-dependency and to foster the intensification of urban land use by increasing concentration of people and amenities in city centers and along transit lines. As a result, urban density is an intensively discussed issue. However, any purposeful attempt to implement social change entails communication, which presents a specific challenge in this field; the proposed changes or solutions (increased density, for example) must be represented in some legible way in order for well informed specialists and non-specialists to engage in a successful dialogue.

Density

The practice of urban planning deals with the distribution of people and their activities in the spaces they live in. It also deals with the materials objects in the built environment that houses people and their activities while allowing for the movement of people and goods.

In planning, the notion of density assumes different meanings and can refer to either the intensity of human occupation or the intensity of the built up space. Density is then translated in number of people, or number of dwellings square footage of buildings in a given land area. Density varies greatly depending on the base land area used in the density calculation. The parcel or site density is almost always higher than the neighborhood density because at a neighborhood scale, much land is included in the base land area calculation, which does not contain houses (Ann Forsyth, 2003). Discrepancies between actual and perceived density may be attributed to direct optical effect or visual memory of other building environment (Zacharias and stamps, 2004). Planners practice different types of density such as, Residential density which refers to the total number of residential units in a particular area of reference (e.g. ha, sq. k65m, sq. miles). Population density refers to the total number of people in a particular area of reference.

The notion of net density indicates the land dedicated to a specific land use, while excluding land not directly related to that usage (e.g. measuring the residential density of an area while excluding the space dedicated to public roads and parks).

Gross density on the contrary, refers to the density of a given area without any exclusion (i.e. including infrastructures such as streets, sidewalks and public spaces) (Alexander, Ernest 1993).The Floor area ratio (FAR) indicates the total Floor area of a building.

Why density is an issue

Density is a crucial issue in urban planning. "*Density* is a term that represents the relationship between a given physical area and the number of people who inhabit or use that area. It is expressed as a ratio of population size or number of dwelling units (the numerator) to area units" (Charchman, 1999).

Planners frequently discuss whether to increase or decrease density of a particular area, block or neighborhood. For this purpose, they use different types of density measures such as residential density, population density, floor area ratio (FAR), gross density and net density.

Aside from the aforementioned intricacies associated to the different definitions of density, relatively little is known about how non-specialists in particular process cognitively visual information designed to communicate density levels. Among other issues there is a gap between perception of density and actual density. Environmental cues representing people and their activities play critical roles in this perception of density (Rapoport, 1975).

The FAR for instance is an objective measure of the amount of built space on a parcel, but a similar FAR index can describe very different building spatial configurations. High rise building surrounded by generous open space for instance can produce the same FAR that tightly constructed mid or low rise buildings can. In such circumstances, the "perceived" density associated with the building height may or may not be contradict the objective density.

Reasons for misunderstanding density at the neighborhood level

Density is often understood in accordance with an individual's experience or preconceived ideas of the notion itself, which may be invalid. However, density calculations are rather complicated and may leave non-specialists confused and unable to visualize actual density. There are various reason for misconception of density like different units, different mode of presentations, preconceived notion etc.

Reasons behind misleading perceptions of density at the individual house level

In small scale representations, perception of density depends on different factors. In particular, shape, size, color and texture affect the perception of density. Furthermore, in such representations, personal comfort or feelings of privacy have been found to affect one's cognition of density. "Physical factors affect the perception of space and density. Studies of high–rise dormitories show that when the design involves long corridors as opposed to short corridors or suites, residents experience more crowding and stress" (Baum et al.,1987). In small scale, individuals' personal experience and expectations lead to their feelings regarding density. Surface detail has a minor effect in perceived density (Zacharias and stamps, 2004). According to McCarthy and Saegert (1979), "Living in a high-rise building may lead to a greater feeling of crowding". "Perception of crowding varies inversely with the brightness of a room" (Mandel et al., 1980). Kaya maintains that perception of crowding or density relates to one's gender (Kaya and Feyzan, 2001).

2.4.2 Virtual environment

Virtual Environment (VE) was created by specialists in order to generate better representation of complex architectural and urban realities. Wilson defines virtual environments as a "computer simulated 3-D environment that people interact with and explore in real time" (Wilson, 1999). Ian D. Bishop et al. observed that for a path choice a virtual environment is more effective over still images (Ian D. Bishop, JoAnna R.

Wherrett, David R. Miller, 2001). The technology for virtual world creation has dramatically increased our ability to capture salient aspects of environment and communicate them with the audience (Brian Orland, Kanjanee Budthimedhee and Jori Uusitalo, 2001). The virtual environment model can provide an opportunity to explore places that are otherwise inaccessible (i.e. in the past or the future), and provide a visual support alternatives which can help decision making (Kraak et. al., 1995).

Specialists developed different forms of 3-D VEs using projection screens, driving simulators and helmet-mounted displays to name a few. Immersive VEs are believed to be the most advanced form of digital 3-D representation. The VE offers great opportunities to involve the public into discussions with specialists. Some Research has found that desktop virtual environments increase efficiency in navigation when compared to immersive virtual environments (Jansen-Osmann p. & Weidenbauer, 2004).

Some research evidence suggests that sometimes users have problems navigating VEs when supplementary element like maps, land marks etc are not provided (Roy A. R., Stephen J. Payne and Dylan M. Jones, 1997). Their research suggests that landmark and familiar objects has great effect on virtual environment. The research findings of Williams Albert et al. also suggest that the way finding is difficult in a virtual environment without landmarks (Williams Albert, Ronald A. Rensink and Jack M. Deusmans, 1999). According to some researcher the virtual environment is sometimes so perfect that it does not reflect real scenario thus it misleads the end users. Brian et al. cautioned that if this technique has to go into central position in planning support much more evaluation, testing and development is essential (Brian Orland, Kanjanee Budthimedhee and Jori Uusitalo, 2001).

2.5 Modes of communication, a theoretical exploration

The field of urban planning requires frequent communication of complex spatial information between specialists (planners, engineers, architects, urban designers, etc.) and non-specialists (members of the public, community groups, government representatives, stakeholders, etc.). Planners spend much time presenting concepts, projects and plans with the goal of transmitting ideas or collecting feedback. Comprehension is essential to any useful exchange of ideas. Specialists who are unable to effectively communicate their ideas can confuse, intimidate or even anger non-specialists. A lack of understanding results in useless feedback and wasted time. Traditionally, visualization tools such as maps, physical models, photographs and artist renderings were commonly used to aid such communication. More recently, urban planners have begun to use computers to create visual representations such as digital photography; GIS generated digital 3-D models and virtual environments. The availability of new tools goes beyond the addition of new functions and amenities. It also fosters the evolution of the field of planning itself. "[T]he trend toward more interactive and participatory planning will have major repercussions on the way planning is practiced: planning will become more complex and increasingly dependent on information and communication technology instruments" (Geertman, 2001).

Sustainable development and the democratic process, as epitomized by participatory planning, require the most effective and well informed exchange of ideas. There are different modes of interaction for communication between specialists and non-specialists (Hammad and Gauthier, 2007). Hammad and Gauthier (2007) proposed a preliminary taxonomy that seeks to classify different modes of visual representation and integration with spatial data. Hammad and Gauthier's taxonomy is based on 4+1 pairs of opposition: 1. 2-D vs. 3-D representations; 2. Static vs. dynamic representation; 3.Synchronic vs. diachronic representation; 4.Passive vs. active mode of interaction; plus one is local vs. internet access interaction. The present research focuses on finding out which mode of engagement favours better understanding of 3-D representation for effective public participation.

2.5.1 Favorable mode for 3-D virtual environment

Different researchers work demonstrate or disproved the effectiveness of different modes of interaction as a suitable interaction method for a 3-D digital environment. Little is known about the suitability of a mode of interaction for density calculation. There are very limited empirical research efforts regarding urban density and 3-D representation. Therefore the discussion of 3-D environments and different modes of interaction can provide some idea about the focus of present research.

Active and passive interaction

In the past, the planning community mostly used passive modes of communication such as posters, technical papers, video presentations or small scale physical models to provide public demonstrations of plans. In such contexts citizens expressed their views through written comments or dialogues with planners (Kingston, 2002). A passive engagement system does not allow manipulating the information and thus significantly limits the citizens' ability to experience live interactions with plans and information.

Recently, there has been increased interest in introducing an active engagement system to allow more active and vivid interactions with planning information. Over the last two decades Visual Environments (VEs) as an investigating tool for spatial learning have grown significantly (Péruch & Gaunet, 1998; Wilson, 1997). Numerous researchers have shown that an active involvement may promote learning in both real and virtual environment (Wilson, 1999). Various software and hardware tools such as 3-D CAD models, Google Earth, Sketch up and the World Wide Web were developed, adapted and commercialized to allow a real time interaction with information systems.

Péruch, Gaunet, Giraudo, and Thinus-Blanc (1995) have observed that an active involvement of VEs produces a better testing environment for spatial memory and inference. Additionally, Williams, Hutchinson, and Wickens (1996) have noticed a superior route-following performance of an active group in compared to a passive one. Outcomes of several real world experiments also suggest that an active involvement can play a significant influence on correcting orientation and finding ways (Cohen & Cohen, 1985; Downs & Stea 1973; Foreman, Foreman, Cummings & Owens, 1990). Attree et al. (1996) have found that active participants performed better than passive observer participants on a test of spatial learning in a VE. An example of this is the fact that car passengers generally learn less than drivers about the layout of a town route (Appleyard, 1970).

However, not all researchers found advantages of activity over passivity (Ito & Matsunaga, 1990; Schwaartz, Perey &Azulay, 1975). For instance, Wilson, Foreman, Gillett, and Stanton (1997) failed to observe any significant differences between active and passive participants in two experiments assessing orientation and way-finding performance in VEs. Although they discussed several possible reasons for their outcomes, it appears that some relatively minor differences in procedure may affect their results of influence of activity. Wilson, Foreman, Gillett, and Stanton speculated that their results may be biased due to the fact that participants in both conditions were explicitly told that their spatial abilities would be subsequently tested. Under conditions where attention to the spatial learning task is high, it is possible that attention in passive subjects compensates for their lack of control and masks the expected beneficial effects of activity.

Both Satalich (1995) and Arthur (1996) also found that active participants had greater difficulty than passive participants on several tasks of spatial learning in a VE. These differences could also be due to several experimental parameters such as attention control, sensitivity to information, kinds of information available and kinds of activities involved (Péruch et al., 1995).

As a preferred mode of interaction, the advantage of active involvement for spatial memory and inference, way-findings, and route-following performance was proved and disproved by various researchers. The objective of the present research is to determine if the mode of engagement (active or passive) with 3-D digital models affects the cognitive performance in assessing urban density. This research will try to identify which mode is more favorable for specialist and non-specialist to cognize urban density information displayed in 3-D models.

Static vs. Dynamic

Both static and dynamic models are used in public presentations. Several studies have shown that space characteristics "are better integrated into an internal representation from dynamic rather than from static visual information" (Péruch et al., 1995). According to Kaplan and Kaplan (1989) a dynamic scene is high in mystery. However, Zacharias points out that some potential weaknesses of using virtual environments especially those consist of photographs[1].

Researchers in the environment-behavior area have also long stressed the usefulness of dynamic simulations of the environment (Appleyard, Lynch, & Myer, 1964; Lynch, 1960; Thiel, 1970, 1997). This concern was a major impetus behind the design and construction of the Berkeley Simulation Laboratory. In this facility researchers and designers can produce filmed trips through scale model environments (Appleyard & Craik, 1974). In one of the tests in this simulator, the dynamic communication proved more favorable in comparison to a static approach (Bosselmann & Craik, 987). These findings helped to justify the use of dynamic displays in environmental perception research (see Heft,1983, 1996). However, whether the apparent differences between static

[1] "Photos may well be highly reliable surrogates for preferences in the real environment, but do not provide a sense of spatial relationship…" thus, the use of photos "cannot likely be used with confidence as a surrogate for predicting behaviour in the real world" (Zacharias, 2001).

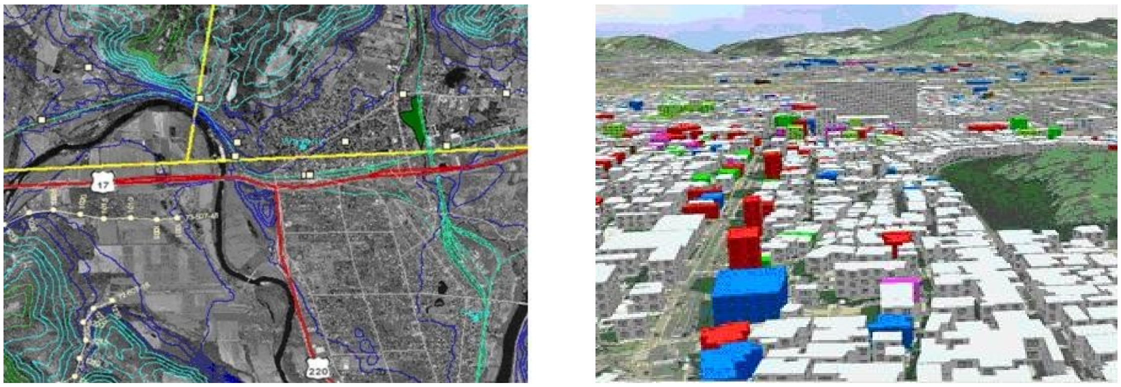
and dynamic displays are of any consequence for the resulting research literature is an important issue.

Heft & Nasar examined several differences between static (freeze frames of route segments) and dynamic (videotaped segments taken along a route) virtual environments. "Results indicated that assessments of static displays do not simply parallel those of dynamic displays" (Heft & Nasar, 2000, p.301). "Investigations of some environmental variables using static displays with the assumption that perceivers' reactions to these displays will be identical to their reactions to dynamic displays, and by extension to environments in situ, rest on unwarranted assumptions"
(Heft & Nasar, 2000).

2-D vs. 3-D representation

2-D and 3-D are two types of geographic representation medium. More widely used mediums are 2-D such as maps (Blades and Spencer, 1987). The 3-D computer simulation is relatively a new medium for spatial information presentation (O. Neil, 1992, Wilson and Foreman, 1993). During the past decade several studied have investigated spatial orientation (Levine 1982, Rossano and Warren 1989) and most of them have compared the maps and navigation through space.

A person who views a map from only one perspective can typically use the information provided on the map better in the orientation in which it was originally created or learned (Warren, Scott and Medley. 1992). According to Thalku and Wilson (1996), navigating in computer simulated space and real space lead to a similar kind of spatial knowledge. Recently, GIS has been used to represent geographic settings and can be categorized into 2-D or 3-D GIS (Figure 2-3).



(a) 2-D GIS (b) 3-D GIS

Figure 2-3: 2-D and 3-D GIS maps (Mozaffare, 2006).

The 2-D GIS database contains only X and Y axes. However, the 3-D GIS has a 3-D data structure which represents both the geometry and topology. The 3-D GIS allows a 3-D spatial analysis as well. 2-D and 3-D representations can also be created with Sketch Up and Google Earth. Some researchers prefer 3-D for visual representation while few still choose the 2-D version.

Synchronic vs. Diachronic

A synchronic pattern shows a variety of spatial combinations pertaining to a plan at some given point in time.

A diachronic pattern shows the evolution of a built environment or plan. Thus, with respect to spatial representation, the diachronic axis allows the user to go back and forth in time and observe features of the model as it changes over time. This sort of presentation helps participants to see urban developments in different times allowing them to see past, present and future plans.

Local vs. Internet

Both local and Internet based communication can be an effective tool for citizen participation. The success of Internet based communication depends upon the availability of technology. In some places where technology is not developed or computer literacy is low, local demonstrations will be more effective than Internet based systems.

2.6 Conclusion of the theoretical framework

In conclusion, it can be said that effective public participation depends on different factors and modes of representation; 3-D visualization is one of them. However, not all researchers are convinced of the effectiveness of this concept and some have begun testing the strengths and weaknesses of virtual models (Heft & Nasar, 2000). Others are aware of its limitations and try to control these in their methodologies (Zacharias, 2006). Future research should focus on how these limitations can be overcome or minimized. The present research aims to identify ways to mitigate some of these limitations. Particularly, those related to cognition problems of density and suitable modes of communication for both specialists and non-specialists.

There is not much empirical research studying cognition problems of density (Zacharias and Stamps, 2004). There is, however, an abundance of literature on how to increase or decrease density, but little was conducted about how best to communicate urban densities to non-specialists. This is an important area requiring attention in order to increase public involvement in the planning process. The present research will identify the reasons leading to misconceptions of density and which modes of representation are more effective for both specialists and non-specialists in their exchange of information. As such, it will help to ensure a better involvement of the public in the planning process through 3-D visualization.

2.6.1 Limitation of the research

Technologists use different modes of communication for 3-D representations and are faced with numerous perception problems. Due to a shortage of time, the present research considers only certain modes of communication, such as, active vs. passive while perception problems take the form of density. A further limitation of the present research is that all the participants are within a particular age group. They are all students, thus different age groups and their effects on performance cannot be measured.

Chapter 3

Research Methodology

3.1 Participants

Sixty Concordia University undergraduate students make up the participants of the present study. Among them, 30 (50%) are third or fourth year students in the Department of Geography, Planning and Environment. For the purposes of this research, they are considered "specialists" due to the experience and knowledge they have gained during their studies. They have become familiar with 3-D models in addition to various planning concepts and processes including those relating to scale and density. The remaining 30 participants are from other departments, thus have not gained academic or technical knowledge about built environments in urban planning. The planning students serve as "surrogates" for planning specialists whereas the non-planning students serve as "surrogates" for the general public or non-specialists. Volunteer participants have been recruited through the use of posters and either indirect or direct solicitation. Written consent forms have been collected to satisfy the University's ethics requirements.

3.2 Research design

The main comparison considers how different modes of presentation affect the ability of the participants to cognize the information about density changes. The result indicates which mode favours a better understanding of density. This research follows an experimental design.

Variables

The dependent variables in this research are cognition levels of density in 3-D digital representation. The independent variables are the modes of interaction (active vs. passive) and any previously acquired knowledge on planning. Density is considered to be a moderating variable. The control variables are the details of the built environment (e.g. building pattern, colors, road network, etc.) as well as demographic factors (e.g. age, socio-economic status and general computer literacy).

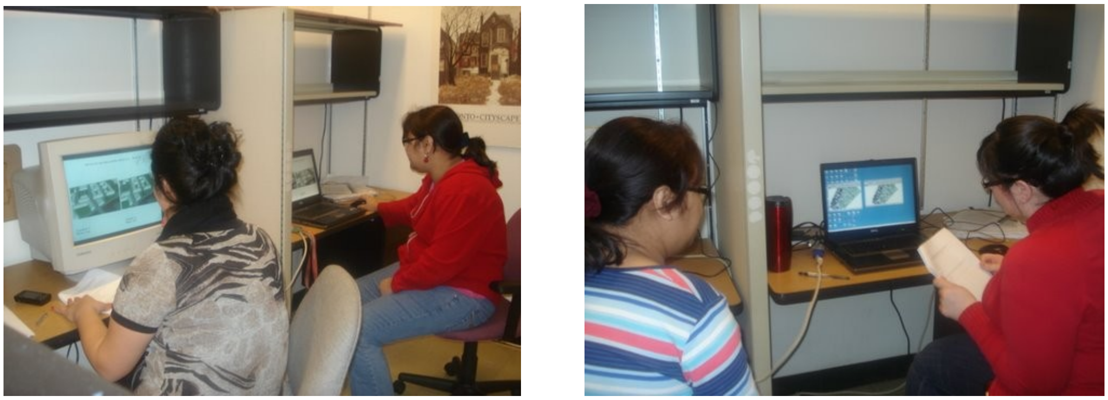
3.2.1 Research Procedure

The 60 participants were divided into two major groups: the active participant group and the passive participant group. In each group, 15 were deemed "specialists' and 15 "non-specialists".

Participants	Mode of interaction	No of participants
Active	Active specialists group	15
	Active non-specialists Group	15
Passive	Passive specialists group	15
	Passive non-specialists group	15
Total participants		60

Table3-1: Breakdown of participants' categories and their number.

This research is comprised of an experiment with five sets of 3-D models and a questionnaire. In both groups, half of the participants experience active interaction and the other half experience passive interaction**.** These models were shown to the participants by means of a 21 inch flat screen monitor. Each set of models displayed a 'before and after' scenario. Both scenarios were presented in a side by side dynamic mode. Figure 3-1 (a) and (b) is showing the side by side dynamic mode representation during test.



(a) (b)

Figure 3-1: Side by side model presentation through dynamic mode (Picture taken during the Test).

A questionnaire allowed for the collection of basic demographic data of the participants as well as the assessment of participants' ability to cognize density in 3-D environment. During the experiment, each participant received a 3 minute introduction and was then given 5 minutes to complete the questionnaire. Afterwards, five different tests of 2 minutes each were administered. In total, each participant spent about 20 minutes in the experiment.

Five test models were prepared to measure the participants' ability to cognize density. The first test was designed based on the postulate that some people's performance will be affected by their preconceived false perceptions about density. In this test, the only spatial variable that was changed was height; the other variables were kept constant (built up areas, built environments and modes of communication). This test was shown by pre-determined passive routes and it was dynamic. Furthermore, the model was presented passively in order to keep all variables constant. In addition, all external factors that could have influenced the results were controlled. The results were collected in order to identify participants who might hold false assumptions regarding the notion of built density.

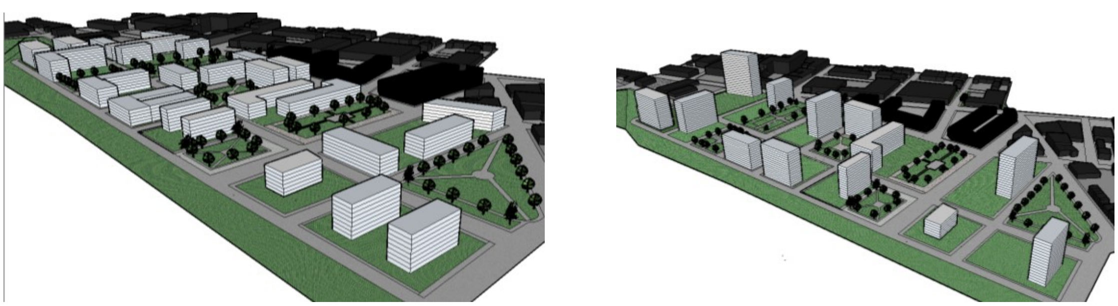
The other four tests were conceived to gradually raise the level of difficulty, which allowed for the measuring of the participants' ability to cognize the variation of density. To achieve this, various spatial variables in the built environment were changed (building height, width and open space). Each test was performed in either the active or passive engagement mode. With respect to the first hypothesis, the performance results of the active and passive participant groups were compared. They determined whether or not active engagement with the 3-D model favored better cognition for both specialists and non-specialists.

3.2.2 Research materials

The present study used 3-D models, a questionnaire and a computer to conduct the experimental tests. Five sets of 3-D neighborhood models were created for presentation by using Sketch Up Pro software. Each set contained a 'before and after scenario'. These digital environments were shown in active and passive modes by using a laptop computer and dual displays output to a 21-inch, flat screen monitor. The tests results were indicative of the participants' performance level in relation to the respective mode of engagement with the various dynamic 3-D representations of the built environment.

The active interaction group's participants used a mouse by themselves to explore the environment while the passive interaction group's participants were presented a pre-determined fly-over animation of the same area. Each participant of both interaction groups performed 5 tasks, in which their performance in assessing changes of density was measured.

Test 1 was made up of two figures; the first, Figure 3-2 (a), displayed a low rise area while the second, Figure 3-2(b), depicted a high rise area. The height contrast between the two slides was sharp. For the first test, the building heights were changed but in both Figures 3-2(a) and (b) the density remained the same. This was designed to assess whether or not participants held false perceptions regarding height and density. For this test, only a passive mode of interaction was used.

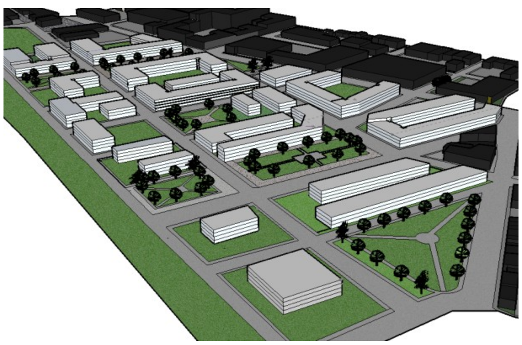


(a) Low rise same density (b) High rise same density

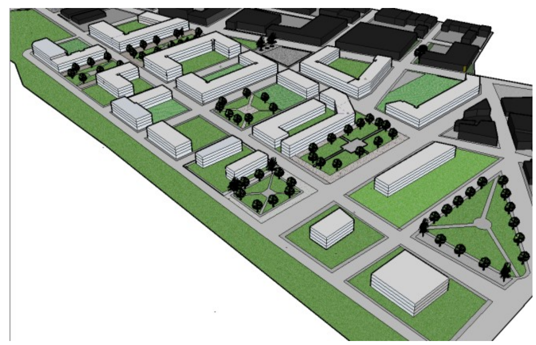
Figure 3-2: Static pictures from the animations used for Test 1 (before and after scenarios).

In tests 2, 3, and 4, building heights, coverage area and densities were changed in each of the before and after scenarios but for Test 5 density was same for both scenario. For each test, 15 participants were actively engaged with the models while 15 saw the animations passively. The test results allowed for a comparison to be made between the participants' ability to cognize density while engaged either actively or passively.

In Test 2, the density in Figure 3-3 (a) was higher than that of 3-3 (b). The density in 3-3 (b) was lower due to the removal of some building parts. The density variation between these two scenarios was 10%.



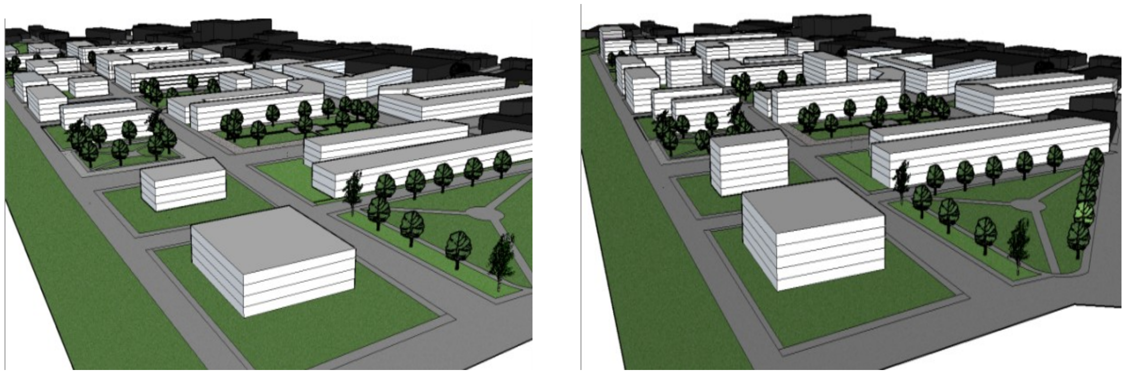
(a) high-density



(b) low density

Figure 3-3: Static pictures from the animations used for Test 2 (before and after scenarios).

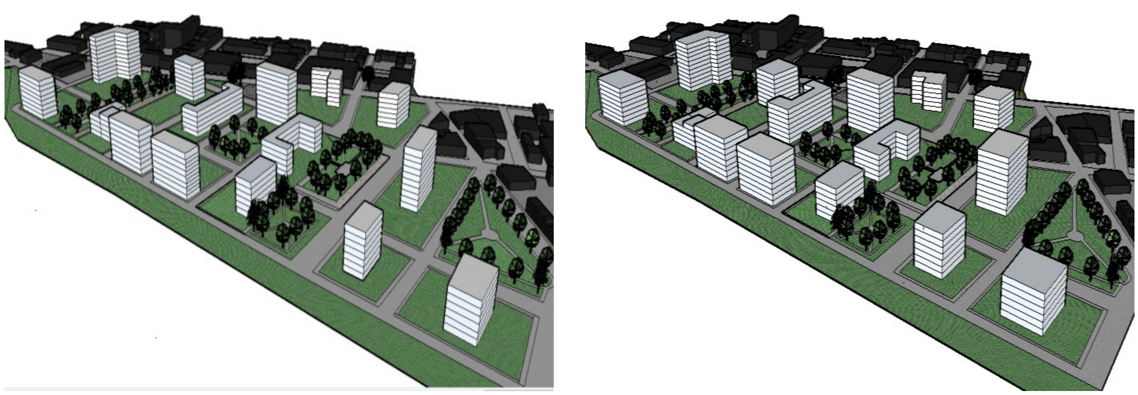
In Test 3, Figure 3-4 (a) displayed a lower density than that of 3-4 (b). The higher density in 3-4 (b) was achieved by slightly raising the building height. Each building represented in 3-4 (b) contained two floors more than those found in 3-4 (a). The increase in density was 50%. In both passive and active engagement modes, the test models were the same so that the results of the tests would clearly reflect the performance of both the active and passive groups' participants



(a) Low rise low density (b) High rise high-density

Figure 3-4: Static pictures from the animations used for Test 3 (before and after scenarios).

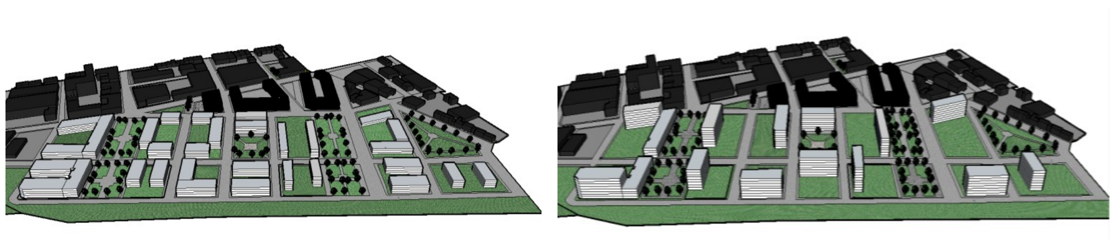
In Test 4, Figures 3-5 (a) and (b) displayed high rise buildings; however, 3-5 (a) represented a lower density than 3-5 (b). Greater density was achieved by increasing the individual building size in slide 3-5 (b). The overall density increase was 45%.



(a) Less building coverage, less density. (b) More building coverage, more density.

Figure 3-5: Static pictures from the animations used for Test 4 (before and after scenarios).

Test 5, Figures 3-6 (a) and (b) contained the same density. The height contrast between the two slides was moderate, meaning a comparison was made between low rise and medium height built environments. Open space design and placement was different for both scenarios. Active and passive participants took part in both tests with the same model. Thus, the results are expected to indicate which mode of involvement provides a better performance.



(a) Low rise same density (b) Medium rise same density

Figure 3-6: Static pictures from the animations used for Test 5 (before and after scenario).

See Appendix-A for a sample of the questionnaire given to participants and Appendix-B for the calculation sheets.

3.2.3 Questionnaire preparation

The questionnaire contained two parts. The first part was designed to gather general demographic information about the participants' gender, age group, educational level and computer proficiency.

The first and second questions pertain directly to the participant's gender and age group. All the participants were selected from Concordia University's student to control the socio-economic status, education level and computer literacy.

From the third question, the "specialists" and "non-specialists" for the purpose of the present research are inferred. The fourth question determines whether significant exposure to 3-D computer games affects the participant's cognitive performance regarding density.

The second part of the questionnaire is comprised of five tests for five models. The number one test question (Q.5) designed to determine whether some participant's performance would be affected by a preconceived false perception regarding density. As such, one test model was created. This model depicted a 'before and an after' situation in which the building height was changed without altering its total density. Question 5 was phrased in such a way to ensure that all participants shared a common understanding of the notion of urban density as defined in the present research. The participants that might hold false pre-conceived notions were made aware that the presence of high rise buildings does not always translate into a higher density.

The following notes were incorporated into the questionnaire:

- **Question 5: Note:** Density in the built environment is determined by the total floor area of buildings in relation to the size of land. Therefore, high density environments can indistinctively be produced by high or low rise buildings.

Number two to five test had seven questions related to four tests. For Tests 2, 3 and 4 each test was made up of a 'before and after' scenario. The sequence of the tests was arranged to gradually raise the level of difficulty and each test was comprised of two questions. The first question asked directly which scenario, the before or the after, had a higher density. The second question asked participants to assess the percentage of density change. Four possible answers were offered for each whereby only one was correct. Test 5 depicted the same density for both the before and after scenarios. There is only one question for Test 5.

Half (50%) of the participants were actively engaged for these four tests while the other half passively experienced a pre-determined route. The results of these four tests provided information regarding the first hypothesis - whether or not active engagement favors better cognition about urban transformation.

For better clarification the following notes were added before question nine:

- **Question 9: Note:** Density in the built environment is determined by the total floor area of buildings in relation to the size of land. Therefore, the same density in built environments can produce a different amount of open space.

3.2.4 Model preparation and presentation

Many factors came into play during the course of the 3-D model development. For instance, which software should be used? Will education level and age hinder an understanding of the 3-D models? Should a fictitious model be prepared or should a real area map be utilized? Should the map be linked with Google Earth? What type of colors should be used? In depth research and support offered by the literature in the field influenced the decisions made regarding the above questions.

There is an abundance of software available for 3-D model development. Some are very sophisticated while some are user friendly. Some are costly and some are inexpensive or even free. Technical planners usually use GIS (ARC INFO, ARC VIEW or ARC GIS) for 3-D development. However, these are proven difficult to use for those not familiar with them. Moreover, they are quite costly. The ultimate goal of the present research was effective public participation. Thus, choosing less costly and user friendly software was deemed a priority. Sketch Up Pro software was selected as it met these requirements. Furthermore, Sketch Up can be easily linked with Google Earth, which is free and downloadable software. Even participants with a low proficiency in computers can successfully navigate an area with ease by using this uncomplicated software. Therefore, neither education level nor cost would affect the present study. Sketch Up proved to be a suitable software choice for 3-D model development, which in turn may help to increase effective public participation.

When deciding whether to use a real area map or a fictitious one, the pros and cons were weighed. A real area map can be helpful in that participants can locate the area and be oriented by natural cues. At the same time it might divert the participants attention from the main tasks. In consequence, areas without a real map location were selected for the present research. Standard colors were used for model development.

3.2.5 Pre-test

The static and dynamic views, colors and the design of the virtual environment was established following multiple pre-tests. Several environments were created using different levels of complexity of concept and layout, as well as various colors. These issues were taken into consideration during the design and exploration of the final environment. The following amendments were done after the pre-tests:

Model preparation

(a) For better understanding of Tests 1 and 5, the total block number was reduced.

Reason: Test 1 and 5 are a little complicated compared than the other three tests. The pre-test revealed that so many blocks made it more difficult to concentrate. As a result, one row containing three blocks was removed leaving the model with two rows of buildings opposed to the rows initially designed.

(b) Density on a block per block basis was made the same.

Reason: In earlier models, the total density of models 5-a, 5-b, 9-a and 9-b was the same. During pre-test, participants exhibited difficulties in calculating the density of an area as a whole. Once the block per block basis density was made the same for both tests (Tests 1 and 5) the models became easier to understand.

(c) Some blocks were redesigned to simplify the building geometry.

Reason: Pre-test feedback indicated that participants were not comfortable with complex building geometry. Their focus went towards the building pattern rather than density. To mitigate this problem building geometry was made simpler.

Model presentation

The initial model was designed with only a 45 degree bird's eye view. The pre-test results suggested that the bird's eye view of the presentation was not enough to understand the actual density. Participants needed to see it more closely to count the floors. In consequence, the presentation sequence was prepared by combining the bird's eye view with a zoom in view on a block per block basis.

General talk with participants

It was learned during the pre-test that participants needed a brief description about the test. Reading the questionnaire alone was insufficient in enhancing perception. Thus, it was decided that there would be a general explanation before starting the test. Each participant would be given a short description of the test materials and sequences.

Questionnaire correction

The initial questionnaire had only one question about density through which the participant's ability to understand the exact ratio of density change was assessed. The pre-test identified that this was particularly difficult for non-specialists. As a result, a new question was added for each test. This question aimed at evaluating the general understanding of density change rather than the exact ratio of density change.

In order to avoid a conflict between the two questions, which model has higher density had been mentioned in the second question**.** The questionnaire was designed in such a way that participants were forced to answer the questions in order, one at a time, without being able to see the one that came next. Once the page was turned, they were not permitted to go back and change their previous answer.

3.2.6 Testing

Participants were assigned to one of two groups, active or passive, according to the order in which they signed up to participate in the experiment.

When participants entered the room where they were to be shown the virtual environment, they were asked to read and sign a consent form explaining the nature of the experiment. All participants were warned about the risk of after-effects (such as motion-sickness), and were told they could request that the experiment be stopped at any time, for any reason. They were then informed they would explore a virtual environment and that they would have to complete a questionnaire after the presentation. Participants were also told that their only responsibility was to explore the virtual 3-D environment tour actively or passively and to answer some questions related to density. Extra time was allotted for participants to ask questions or discuss the research project once their tasks had been completed. The participants were tested individually.

Participants sat at a table in front of a flat-screen monitor and were asked to adjust their seat so that they were at a comfortable level for viewing the monitor. The researcher sat beside the participants with another monitor. Once the participant had indicated that he or she was ready, the researcher began the test with either the pre-defined point of the built environment or by simply allowing the participant to explore the environment by him or herself (where applicable).

There were no set time limits to complete the tasks; however, the researcher endeavoured that each participant finish within 30 minutes.

Chapter 4

Analysis

In this section, the data is analyzed separately, starting with the general analysis followed by the statistical analysis.

The thesis questionnaire was divided into two parts. The first part contained general information regarding participants' age, sex, category (specialist or non-specialist) and their 3-D computer game experience. The second part consisted of five tests for five models. Models one and five had a single question whereas models two, three and four had two questions each. In total, the second part was made up of eight questions for the five models. Here, participants were separated by their category (specialist or non-specialist) as well as their participatory level of interaction, taking part in either the active or the passive interaction group for the five tests. These tests provided distinct types of data.

4.1 General analysis

Age: All participants were Concordia University students. Most of them were from the same educational background and age group. Figure 4-1 illustrates 95% participants that means 57 among 60 participants were in between 18 to 30 years of age and only 20 % means 3 participants were more than 31 years old. All were either 3rd or 4th year students. This similar educational and age background ensures the participants' comparable computer skills and knowledge about density. All participants were carefully selected to neutralize external effects on their density cognition.

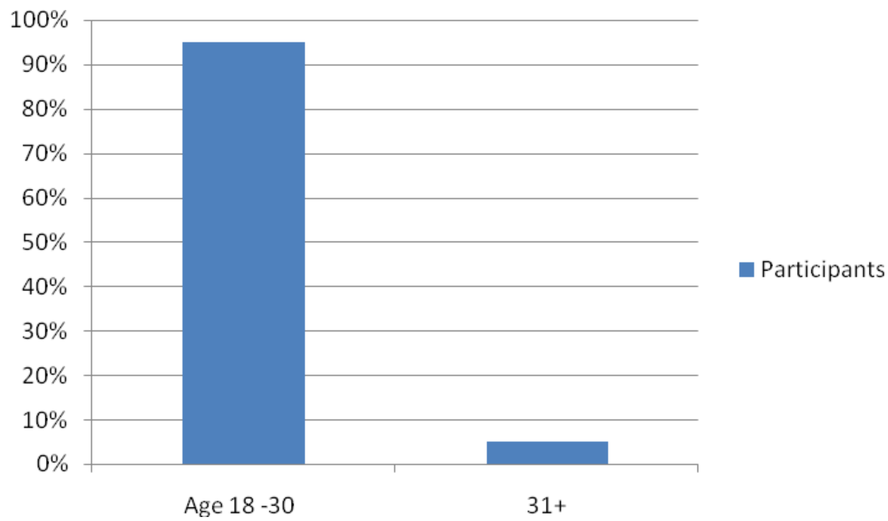


Figure 4-1: Participants, age group.

Gender: Figure 4-2 illustrate that among all participants 53% of the participants were male and 47% were female.

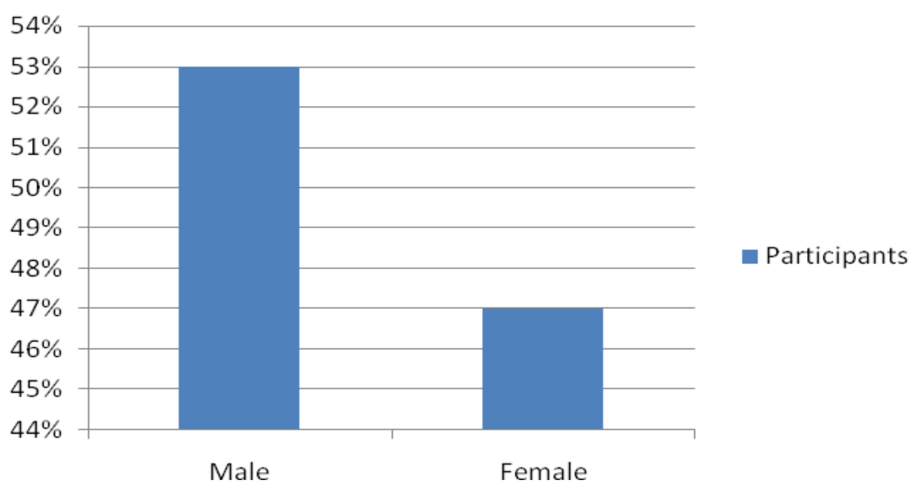


Figure 4-2: Participants gender.

In seven out of eight questions male participants performed better than female participants. Figure 4-3 illustrates that. Furthermore of the six participants who gave correct answer of all questions, four of them were male.

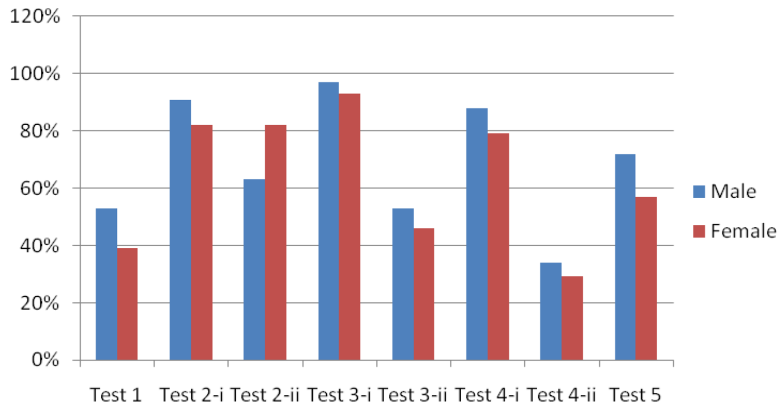


Figure 4-3: Male and female participants' percentage of success rate.

Thus, the questionnaire analysis suggests that male participants' performance may be comparatively better than that of their female counterparts.

3-D Computer game playing experience: Participants were asked how frequently they usually play 3-D computer games. This question was designed to evaluate whether 3-D computer game playing experience had any effect on the results of the present study.

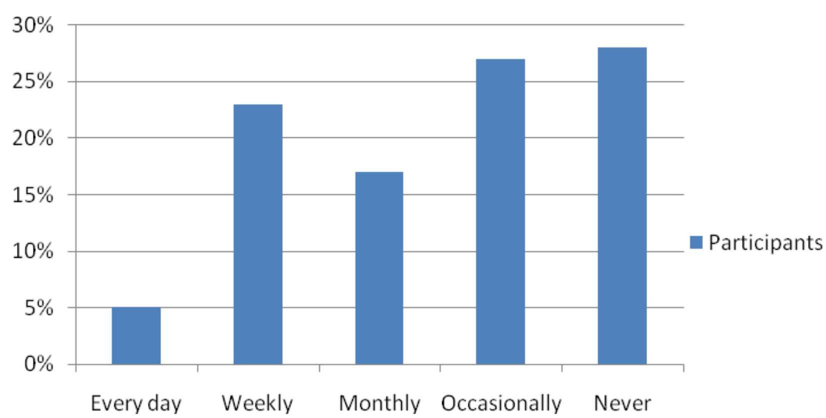


Figure 4-4: Percentage of participants who play 3-D computer games by different frequencies.

Figure 4-4 illustrate that, the results were distributed across different categories and indicated that most of the participants did not play 3-D computer games on a regular basis.

The critical finding here is that those who play 3-D computer games everyday they performed far better compared to the others.

	Total participants	Successful participants number and percentage in each test							
		Test 1	Test 2-i	Test 2-ii	Test 3-i	Test 3-ii	Test 4-i	Test 4-ii	Test 5
Every day	3	3 (100%)	3 (100%)	3 (100%)	3 (100%)	3 (100%)	3 (100%)	3 (100%)	3 (100%)
Weekly	14	8 (57%)	13 (92%)	8 (57%)	13 (93%)	10 (71%)	12 (86%)	7 (50%)	12 (85%)
Monthly	10	7 (70%)	10 (100%)	7 (70%)	9 (90%)	7 (70%)	10 (100%)	2 (20%)	7 (70%)
Occasio-nally	16	6 (37%)	13 (81%)	13 (81%)	16 (100%)	2 (13%)	12 (75%)	1 (6%)	8 (50%)
never	17	4 (23%)	13 (76%)	12 (71%)	16 (94%)	7 (41%)	13 (76%)	5 (29%)	9 (53%)
	60	28	52	43	57	29	50	18	39

Table 4 -: Success rate of 3-D computer games playing participants.

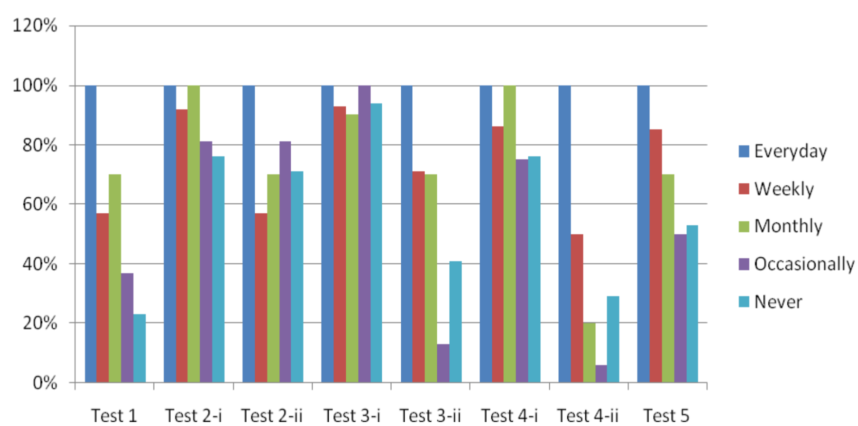


Figure 4-5: Success rate of participants who play 3-D computer games by different frequencies.

This finding suggests that 3-D computer game experience is an important criterion in understanding density change in 3-D models. Table 4-1 and Figure 4-5 show that the participants who play 3-D computer games most frequently exhibited a 100% success rate. That of those who play occasionally or never was much lower in most cases.

Specialists' and non-specialists' performances for each test

The present study's participants were equally divided into specialists and non-specialists. The questionnaire survey analyses revealed, as expected, that specialists' performance was better in almost all tests. Only in one question specialists did not perform better. This can be considered an exception.

Correct answer by	Test 1	Test 2-i	Test 2-ii	Test 3-i	Test 3-ii	Test 4-i	Test 4-ii	Test 5
Specialists	57%	93%	70%	100%	70%	97%	34%	72%
Non-Specialists	37%	84%	72%	94%	30%	74%	30%	60%

Table 4-2: Percentage of specialists and non-specialists who gave correct answers.

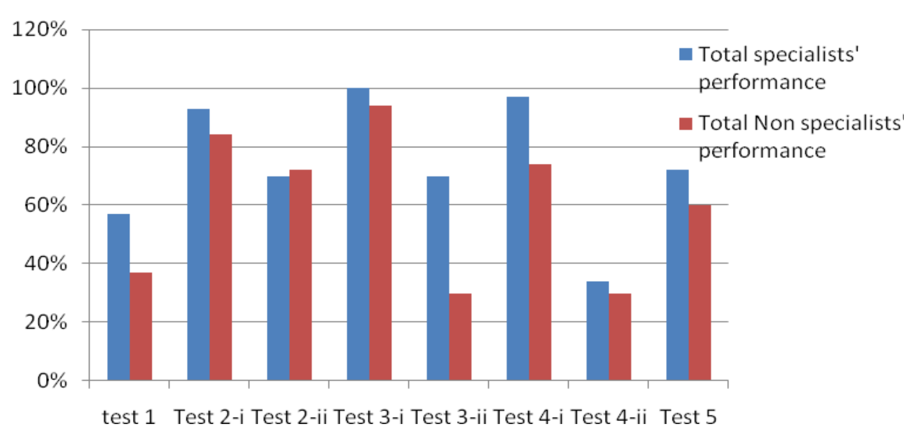


Figure 4-6: Total specialists' and non-specialists' performance.

The data in Table 4-2 and Figure 4-6 indicate that specialists' performance is comparatively better than that of non-specialists.

Active vs. passive interaction performance (without considering specialists or non-specialists) for each test

Participants of this research were engaged in two modes of interaction: active and passive. The findings revealed that active interaction participants did well in all tests.

Active vs. passive interaction performance for each test

Correct answer by	Test 2-i	Test 2-ii	Test 3-i	Test 3-ii	Test 4-i	Test 4-ii	Test 5
Passive interaction	84%	66%	96%	46%	78%	26%	60%
Active interaction	94%	76%	96%	52%	93%	37%	73%

Table 4-3: Participants correct answer through passive and active interaction.

These findings support hypothesis one- "active engagement favors better cognition about

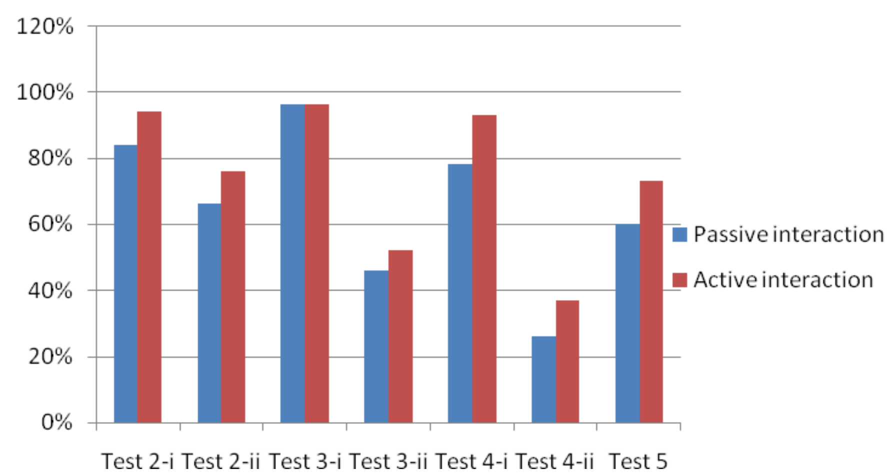


Figure 4-7: Percentage of correct answers given by participants through passive and active interaction.

urban transformation".Tables 4-3 and Figure 4-7 show a overall comparative results of active and passive participant interactions, followed by the specialist's and non-specialist's active and passive interaction results, respectively. Overall, the results of the active interaction tests are better or equal to those of the passive interaction tests. This suggests that active interaction favours a better perception of density.

The comparative result of test 1 and test 5 gives a more clear result of this finding. Test 1 was conducted through passive interaction mode and test 5 was conducted through both active and passive mode. The before and after scenario of test 1 had the same density. Like Test 1, Test 5 was designed according to same manner. The success rate of Test 5 is much higher than Test 1. Among 60 participants 28 participants gave correct answer for Test 1and 40 participants gave correct answer for Test 5., which suggests that active engagement produce higher success rate than passive mode. Figure 4-8 showing the findings.

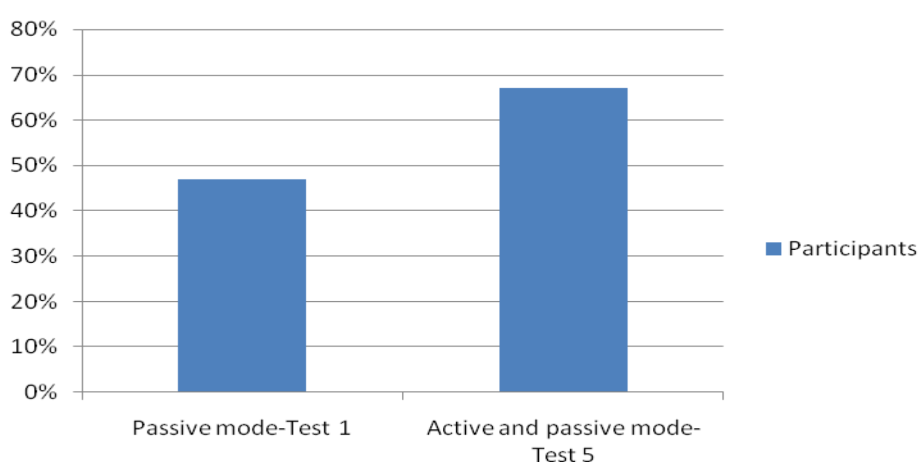


Figure 4-8: Percentage of correct answers given by participants through Test 1 and 5.

Specialists' passive vs. active interaction performance for each test

Correct answer by	Test 2-i	Test 2-ii	Test 3-i	Test 3-ii	Test 4-i	Test 4-ii	Test 5
Specialists' passive interaction	87%	73%	100%	67%	93%	33%	67%
Specialists' active interaction	100%	67%	100%	73%	100%	33%	80%

Table 4-4: Specialists correct answers through passive and active interactions.

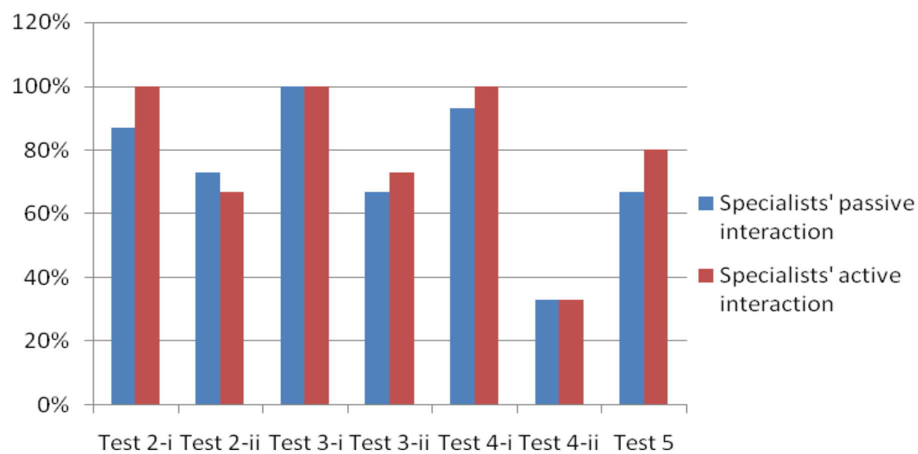


Figure 4-9: Percentage of correct answers given by specialists' through passive and active interactions mode.

Figure 4-9 illustrates the specialists' passive and active interaction performance results. Active interaction performance is equal to or better than passive interaction in all tests with one exception; in Test 2-ii, passive interaction results are superior.

Non-specialists' passive vs. active interaction performance for each test

Correct answer by	T 2-i	T 2-ii	T 3-i	T 3-ii	T 4-i	T4-ii	T-5
Non-specialists' Passive interaction	80%	60%	93%	27%	60%	20%	53%
Non-specialists' active interaction	87%	87%	93%	33%	87%	40%	67%

Table 4-5: Non-specialists correct answers through passive and active interactions.

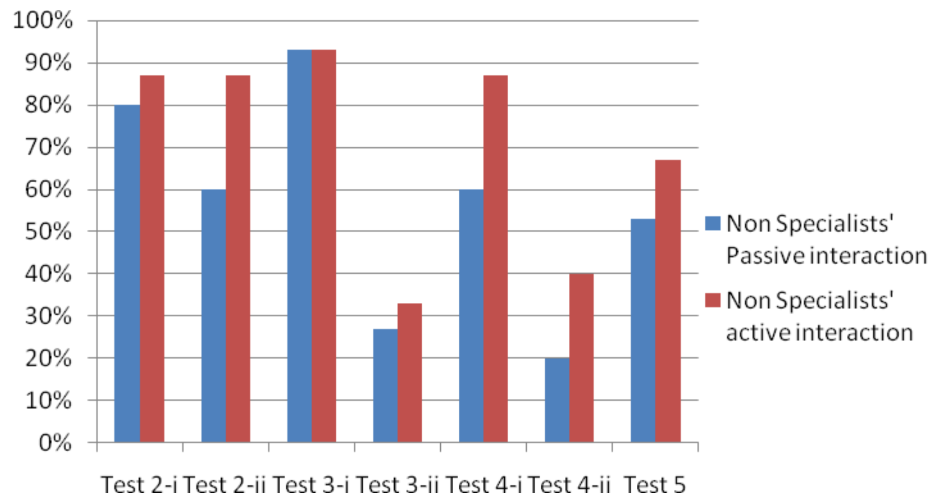


Figure 4-10 Percentage of correct answers given by non-specialists' through passive and active interactions.

Table 4-5 and Figure 4-10 demonstrate comparative results of non-specialists' passive and active interaction performances. Active interaction is better or equal to that of passive interaction results. This finding supports first hypothesis.

Specialists' passive vs. non-specialists' active interactions performance for each test

According to the present findings, specialists' performance is comparatively better than non-specialists. It is expected that specialists' level of knowledge regarding density and 3-D environments be superior to that of non-specialists; however, one critical finding of the present study suggests that, the non-specialist group's active interaction is equal or comparatively better than the specialist's group's passive interaction. It suggests that despite less experience, performance could be enhanced with active participation. This result adds weight to the evidence that active engagement may be better than passive interaction. Table 4-6 and Figure 4-11 represent this finding.

Specialists' passive vs. non-specialists' active interaction performance

Correct answer by	Test 2-i	Test 2-ii	Test 3-i	Test 3-ii	Test 4-i	Test 4-ii	Test 5
Specialist passive participants	87%	73%	100%	67%	93%	33%	67%
Non-specialist active participants	87%	87%	93%	33%	87%	40%	67%

Table 4-6: Number of correct answers given by specialist passive and non-specialist active participation.

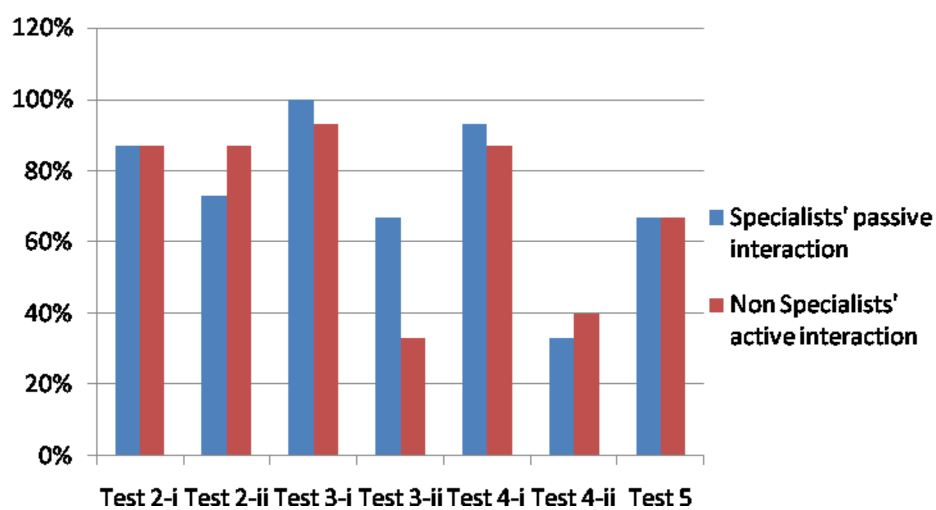


Figure 4-11: Number of correct answers given by specialist passive and non- specialist active participants.

Analysis for research postulate

The first test was designed to deal with a potential confusion between the notions of built density and of building height. The following note regarding density definition was added in this test to give an idea about density to participants.

Note: Density in the built environment is determined by the total floor area of buildings in relation to the size of land. Therefore, high density environments can indistinctively be produced by high or low rise buildings.

Only building height was manipulated in this test to identify which factors were affecting perception of density. All other factors were kept the same, including the mode of interaction (passive). Test 1-a consisted of low rise buildings while 1-b had high rise buildings; however, their densities were identical.

47% of the participants gave the correct answer while 53% offered a wrong one. Figure 4-12 illustrate that.

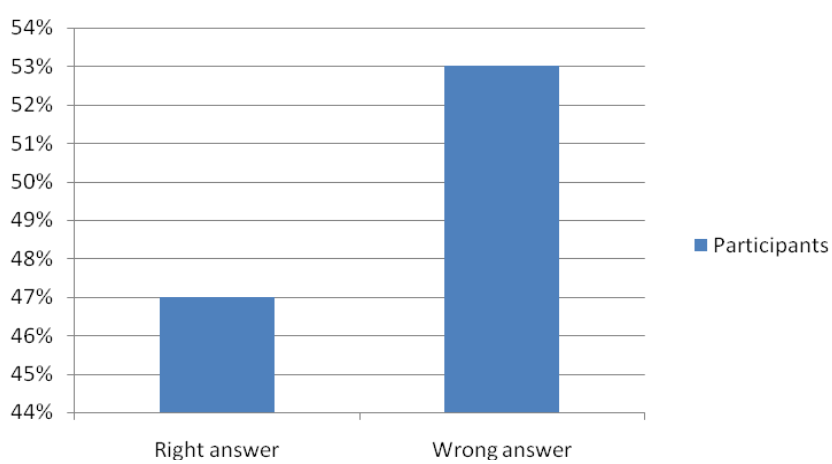


Figure 4-12**:** Number of participants who gave right or wrong answer.

The difference between the right answers and wrong answers is not significant. Statistical analysis also support that the preconceived false perception matters, but not much.

The critical analysis is that, among all participants 23% of them thought that Test 1-b displayed a higher density than Model 1-a and 30% thought Test 1-b exhibited a lower density than Test 1-a.

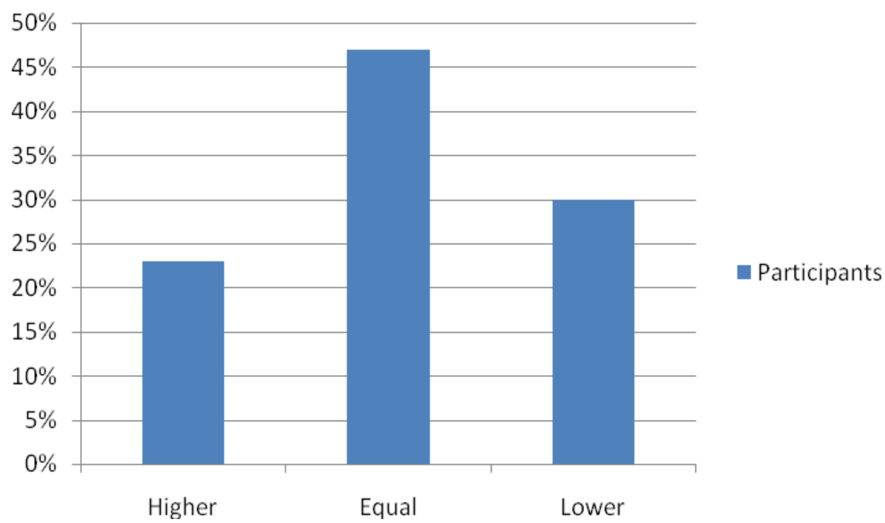


Figure 4-13: Percentage of participants who perceived that the density of the two models

A big number of participants that means 47% thought both Test had the same density, which is correct answer. Figure 4-12 illustrate the findings. So this result also indicates that preconceived false notion does not affect much on result.

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4.2 Statistical analysis

Analysis method

For statistical analysis t test and F test were done by using Minitab software. The main objective of the thesis is to identify which mode of interaction (active or passive) is more favourable for participants to recognize density change in 3-D environment.

The research goal is individual variable testing. The t test is very effective for individual significance testing. For this analysis, the simple linear regression model is used.

In order to determining whether the correct answer depends on the condition of being specialists or non-specialists an effect size analysis was done. Moreover for the postulates another Chi-Square Test was done.

F test

An F test, based on the F probability distribution, can also be used to test for significance in regression. With only one independent variable, the F test will provide the same conclusion as the t-test, if the test indicates $\boldsymbol{\beta_1 \neq 0}$, the F tests will also indicate a significant relationship. But with more than one independent variable, only the F test can be used to test for an overall significant relationship.

1. Test 1 result analysis

Testing if being a specialists significantly effect on the correctness of answer for Test 1

For Test 1 analyses, the hypothesis is,

$\boldsymbol{H_o : p_1 = p_2}$

$\boldsymbol{H_a : p_1 \neq p_2}$

Sample proportion for correct answer of specialist

$\widehat{p_1} = \frac{x_1}{n_1} = \frac{17}{30}$

Sample proportion for correct answer of non-specialist

$\widehat{p_2} = \frac{x_2}{n_2} = \frac{11}{30}$

Test statistics

$$Z = \frac{\widehat{p_1} - \widehat{p_2}}{\sqrt{\frac{\hat{p}_1(1-\hat{p}_1)}{n_1} + \frac{\hat{p}_2(1-\hat{p}_2)}{n_2}}}$$

$$= \frac{\frac{17}{30} - \frac{11}{30}}{\sqrt{\frac{\frac{17}{30}(1-\frac{17}{30})}{30} + \frac{\frac{11}{30}(1-\frac{11}{30})}{30}}}$$

$$=1.58$$

From appendix C (f), p-value is 0.113 Reject Ho at level 0.05. There is no significant different between specialist and non-specialist on correctly answering Test 1.

The mode of interaction of this test was passive. Through this test we were trying to identify the performance of specialists and non-specialists. Here only one variable was changed that is training about urban planning. We assumed that trained people will have less preconceived false notion. The result indicates that specialness does not have enough affect on result. According to result we can say being specialist or non-specialist does not matter a lot. In a context where a definition of density was provided to the participants the results indicate the preconceived false notion does not have enough effect on perception. At the same time because of the lack of enough evidence we cannot say which factor is effecting on the result. For that purpose further research could be done.

1.1Chi square test for the Test 1(postulates)

Test whether there is a significant difference between the percentages of answering test 1 correct and wrong.

$Ho: p_c = p_w$

$Ha: p_c \neq p_w$

Test statistic

$$Z = \frac{\widehat{p_1} - \widehat{p_2}}{\sqrt{\widehat{p_{pool}}(1 - \widehat{p_{pool}})(\frac{1}{n_1} + \frac{1}{n_2})}}$$

Test statistic, Z=-0.73 is highlighted at the bottom of the Minitab output, as is the observed significance level (p-value) of the test. Since p-value =0.464 is greater than significance level 5%, we do not reject Ho.

According to appendix C (m), we conclude percentage of answering test 1 correctly is not significantly different from the percentage of answering test 1 wrongly.

2. Testing if gender significantly effects on the correctness of answer (all question together)

This analysis is based on test one to five. The simple linear regression model is $y = \beta_0 + \beta_1 x_1 + \epsilon$. If x and y are linearly related, we must have $\beta_1 \neq 0$. Following is the hypotheses which use to test for the parameter β_1.

$\boldsymbol{Ho}: \boldsymbol{\beta_1 = 0}$

$\boldsymbol{H_a}: \boldsymbol{\beta_1 \neq 0}$

Ho: Correctness of answer does not depend on Gender.

Ha: Correctness of answer does depend on Gender.

Test statistic $t = \frac{b_1}{s_{b_1}}$

Rejection rule:

p-value approach: Reject Ho if p-value$\leq \alpha$

The estimated regression model is $y = b_0 + b_1 x_1$

where

$y = number\ of\ correct\ answers$

$b_0 = the\ y - intercept\ of\ the\ regression\ line$

$b_1 = the\ slope\ of\ the\ estimated\ regression\ line$

$x_1: Gender\ (male = 1, female = 0)$

If Ho is rejected, we will conclude that $\beta_1 \neq 0$ and it indicate statistically significant relationship exist there between the two variables. However, if Ho cannot be rejected, we will have insufficient evidence to conclude that a significant relationship exists.

From Appendix C (a), t test statistic for coefficient of gender is 1.12, p-value is 0.267. Do not reject Ho since p-value is greater than 0.05. It concludes that gender does not have significant effect on the correctness of answer.

3. Testing if frequency of playing 3-D video game significantly effects on the correctness of answer.

This analysis is based on test one to five. The frequency of computer game playing experience was analyzed for each test. The simple linear regression model is $y = \beta_0 + \beta_4 x_4 + \epsilon$. The following is the hypotheses which use to test for the parameter β_4

$\boldsymbol{Ho: \beta_4 = 0}$

$\boldsymbol{H_a: \beta_4 \neq 0}$

Ho: Frequency of playing videogame is not significant to correctness.

Ha: Frequency of playing video game is significant to correctness.

The estimated regression model is $y = b_0 + b_4 x_4$

x_4: *Frequency of playing video game (Never= 0, occasionally= 1, monthly=2, weekly=3, daily=4)*

From Appendix C (e), t test statistic for coefficient of activeness is 4.86, p-value is 0.000. Reject Ho since p-value is less than 0.05. It concludes that frequency of playing video game has significant effect on the correctness of answer.

4. Testing if Specialness (urban planning training) significantly effect on the correctness of answer.

This analysis is based on test one to five. The simple linear regression model is $y = \beta_0 + \beta_2 x_2 + \epsilon$. The following is the hypotheses which use to test for the parameter β_2.

$\boldsymbol{Ho: \beta_2 = 0}$

$\boldsymbol{H_a: \beta_2 \neq 0}$

Ho: Specialness is not significant to correctness.

Ha: Specialness is significant to correctness.

The estimated regression model is $y = b_0 + b_2 x_2$

Where

$x_2: Specialness(Specialist = 1, non - Specialist = 0)$

From Appendix C (b), t test statistic for coefficient specialist is 2.87, p-value is 0.006. We reject Ho since p-value is less than 0.05. It concludes that Specialness has significant effect on the correctness of answer.

5 (i). Testing if activeness significantly effect on the correctness of answer, for specialists.

The simple linear regression model is $y = \beta_0 + \beta_3 x_3 + \epsilon$. The following is the hypotheses which use to test for the parameter β_3.

$\boldsymbol{Ho}: \boldsymbol{\beta_3 = 0}$

$\boldsymbol{Ho}: \boldsymbol{\beta_3 \neq 0}$

Ho: Activeness is not significant to correctness of specialist.

Ha: Activeness is significant to correctness of specialist.

The estimated regression model is $y = b_0 + b_3 x_3$

$x_3: Activenss(Active\ = 1, Passive\ = 0)$

From Appendix C ©, t test statistic for coefficient of activeness is 1.61, p-value is 0.119. The result do not reject Ho since p-value is greater than 0.05. It concludes that activeness does not have any significant effect on the correctness of a Specialist. It indicates that for specialist being active or passive does not matter a lot.

Activeness is one indicator variable, "Active=1", "Passive=0", one variable, one test, one p-value, There is not any p-value for passive specialist, because "active" and "passive" is one variable.

5 (ii). Testing if activeness significantly effect on the correctness of answer for non-Specialists

The simple linear regression model is $y = \beta_0 + \beta_3 x_3 + \epsilon$. The following is the hypotheses which use to test for the parameter β_3.

$\boldsymbol{Ho}: \boldsymbol{\beta_3 = 0}$

$\boldsymbol{Ho}: \boldsymbol{\beta_3 \neq 0}$

Ho: Activeness is not significant to correctness of non-specialist.

Ha: Activeness is significant to correctness of non-specialist.

The estimated regression model is $y = b_0 + b_3 x_3$

$x_3: Activenss(Active = 1, Passive = 0)$

From Appendix C (d), t test statistic for coefficient of activeness for non-specialist is 2.13, p-value is 0.043. Reject Ho since p-value is less than 0.05. It concludes that activeness has significant effect on the correctness of answer of a non-specialist. It indicates for non specialists being active or passive has an important role. From general analysis we saw that non specialist's performance is comparatively better when they use active interaction mode. Statistical analysis supports that.

Activeness is one indicator variable, "Active=1", "Passive=0", one variable, one test, one p-value, There is not any p-value for passive non-specialist, because "active" and "passive" is one variable.

6. Effect size analysis for total performance of specialists vs. non-specialists

	Answer of Correct	Answer of Incorrect	Total
Specialists	178	62	240
Non-specialists	144	96	240
Total	322	158	480

Table 4.7: Effect size analysis.

In order to determining whether the proportion of answer the question correctly depends on condition of being specialists, chi-square used in analysis of categorical data. The condition required for valid chi-square test are multinomial experiment and the expected cell counts are all greater than or equal to 5. The null and alternative hypothesis we want to test are

Ho: Performance is independent on the condition of being specialists

Ha: Performance is dependent on the condition of being specialists

The expected count for each cell is $E_{ij} = \frac{R_i C_j}{n}$

where $R_i = total\ for\ row\ i,\ C_j = total\ for\ column\ j, and\ n = sample\ size.$

Test statistic $\chi^2 = \sum\sum\frac{(n_{ij}-E_{ij})^2}{E_{ij}}$

Degree of freedom $df = (r-1)(c-1)$

where $r = number\ of\ rows\ and\ c = number\ of\ columns$

Test statistic, χ^2= 10.907 is highlighted at the bottom of the Minitab output, as is the observed significance level (p-value) of the test. Since p-value =0.001 is less than significance level 5%, we reject Ho; that is,

According to appendix C (m) we conclude the performance of answering the question correctly depends on being specialists.

Results:

Each test results are shown below as a tabular form.

Test	Result, P value	P > .05	Remarks
Effect of Gender on result	0.267	Yes	Not-Significant
Effect of 3-D game playing experience on result	0.000	No	Significant
Specialists Performance	.006	No	Significant
Active Specialists performance	.119	Yes	Not-Significant
Active Non-specialists performance	.043	No	Significant
Specialist/non-specialists performance for Test 1	.113	Yes	Not-significant

Table 4-7: Statistical result of the data analysis.

Testing for Multi Co-linearity

We use the term independent variable in regression analysis to refer to any variable being used to predict or explain the value of the dependent variable. The term does not mean, however, that the independent variables themselves are independent in any statistical sense. On the contrary, most independent variables in a multiple regression model are correlated to some degree with one another.

Statisticians have developed several tests for determining whether multi co-linearity is high enough to cause problems. According to rule of thumb test, multi co-linearity is a potential problem if the absolute value of the sample correlation coefficient exceeds 0.7 for any two of the independent variables.

We consider the sample correlation coefficients between each pair of variables. The following correlation matrix shows (appendix C (g) the sample correlation between correctness of answer and frequency of playing 3-D games is 0.538., so the best predictor of correctness to answer is frequency of playing 3-D games because it has the highest sample correlations coefficient.

The sample correlation of specialness is the second best predictor because the sample correlation between correctness of answer and specialness is 0.352.

There is a moderate multi co-linearity problem between 2 independent variables.

Testing for overall multiple regression model

The objective is to use the data to develop an estimated regression equation that provides the best relationship between the dependent and independent variables.

The estimated multiple regression model

$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4$

$y = number\ of\ correct\ answers$

b_0, b_1, b_2, b_3, b_4 *are the estimate of* $\beta_0, \beta_1, \beta_2, \beta_3, \beta_4$

x_1: *Gender* (*male* = 1, *female* = 0)

x_2: *Specialness (Specialist* =1, *Non-specialist* =0*)*

x_3: *Activeness* (*Active* = 1, *Passive* = 0)

x_4: *Frequency of playing video game (Never= 0, occasionally*= 1, *monthly*=2, *weekly*=3, *daily*=4*)*

F-test for overall significance

$\boldsymbol{Ho: \beta_1 = \beta_2 = \beta_3 = \beta_4 = 0}$

Ha : One or more of the parameters is not equal to zero

Test statistic $F = \frac{MSR}{MSE}$

Rejection rule:

p-value approach: Reject Ho if p-value$\leq \alpha$

From Appendix C (h), the estimated regression equation is

Correctness of answer = 3.70 - 0.014 gender + 0.971 specialness + 0.620 activeness+ 0.544 frequency

F-ratio from ANOVA is 9.59, p-value is 0.000 and the overall model is significant at level 0.05.

According to appendix C (h) the four variables multiple regression model has an adjusted coefficient of determination 36.8. Only 36.8% of total variation of y can be explained by the model. We still have 63.2% total variation cannot be explained by the model.

The p-values for the t-tests of individual parameters show that only specialness and frequency are significant at level 0.05, given the effect of all the other variables. The p-value of the t-tests of gender and activeness are greater than 0.05, therefore, gender and activeness are not significant. Hence, we might be inclined to investigate the results that would be obtained if we just use specialists and frequency.

Testing for the reduced model (2 variables)

We now analysis the reduced model with only 2 major independent variables specialness and frequency. According to appendix C (i), we conclude that the estimated regression equation has an adjusted coefficient of determination of 35.4%, which, although not quite as good as that with 4-variable estimated regression equation, is high.

Variable selection procedures

In order to find the best estimated regression, we would like to find all possible regressions by stepwise regression. Stepwise regression procedure begins each step by determining whether any of the variables already in the model should be removed. It does so by first computing an F statistics and a corresponding p-value for each variable in the model. The level of significance for determining whether an independent variable should be removed from the model is referred to in Minitab as alpha to remove. If the p-value for any independent variable is greater than alpha to remove, the independent variable with the largest p-value is removed from the model and stepwise regression procedure begins a new step.

If no independent variable can be removed from the model, the procedure attempts to enter another independent variable into the model. It does so by first computing an F-statistics and corresponding p-value for determining whether an independent variable should be entered into the model which is referred to in Minitab as alpha to enter.

The independent variable with smallest p-value is entered into the model provided its p-value is less than Alpha to enter. The procedure continues in this manner until no independent variables can be deleted from or added to the model.

The following shows the result obtained by using the Minitab stepwise regression procedure using values 0.05 for alpha to remove and 0.05 for alpha to enter. According to appendix C (j), the variables in the final model are frequency and specialness and the corresponding p-values are 0.000 and 0.007, respectively. The R-square (adjusted) is 35.44%

Best-subsets regression

Stepwise regression is an approach to choosing the regression model by adding or deleting independent variables one at a time. None of them guarantees the best model will be found for a given number of variables. Hence, the best-subsets regression model that enables the user to fin, given a specified number of independent variables, the best regression model.

The criterion used in determining which estimated regression equations are best for any numbers of predictors is the value of the adjusted coefficient of determination. It is found that according to Appendix C (k) and the model with Specialness and Frequency has an adjusted R-sq =34.7% and the model with specialness and activeness and frequency with adjusted R-sq=44.6%.

The model of 3 variables only has 0.9% improvement for adjusted R-sq. We prefer the simple model with specialness and frequency which is identical to the stepwise regression procedure.

Chapter 5

Results and discussion

5.1 Results

The research data analysis findings suggest that active engagement with 3-D digital models affects the participants' cognitive performance in assessing urban density levels for both specialists and non-specialists. Analysis also suggests that preconceived false perceptions do not affect participants' cognition significantly.

5.2 Discussion

This research was made up of nine questions. Some of them helped to validate the hypotheses and some helped to provide supporting factors, which affected these results. The first test was designed for the postulates. It had two simulations of built environments presenting identical densities. Participants took part in this test in passive mode only. The results of the general and statistical analyses indicate that false conceptions held about urban density do not significantly affect the cognition of the information conceived in the 3-D representations.

Questions were designed to test the active and passive interaction performances of the participants. The general and statistical results suggest that for both specialists and non-specialists active engagement increases the probability of getting the correct appreciation of the density variation. In case of non-specialists the impact of active engagement was more effective tool in enhancing participants' performance in the assessment of density change in 3-D environments. In conclusion, it can be said that in most cases, active interaction proved more effective resulting in a significant effect on performance.

Separate analyses for all the questions' aggregated were also conducted. This overall analysis indicates that active engagement and being a specialist can increase the probability of giving the correct answers.

Through questionnaire analysis, the research attempted to identify the effects of other factors that may have influenced the overall results. Among them, gender, 3-D computer game playing experience and participants' professions (e.g. being a specialist or non-specialist) was remarkable. The findings indicate that gender has little effect on the test results. That is to say, according to statistical analysis being male or female does not have a significant difference on the tests' outcome. Computer game playing experience was also investigated. The research analysis showed that those who play 3-D computer games everyday performed significantly better than those who do not. The data indicate that experience or practice with computer games is an important factor affecting the ability to cognize a variation of density in a 3-D virtual environment.

Chapter 6

6.1 Conclusion

Several modes of communication are commonly used for 3-D representation: active, passive, static, dynamic, 2-D, 3-D, local and Internet based, to name a few. We actually know very little about which mode of communication is more effective for the sharing of various types of spatial information between specialists and non specialists (Hammad and Gauthier 2007). According to the thesis result among active vs. passive interaction active interaction proved better. The result gave indication that active involvement is more effective for non-specialists than for specialists.

The results may add to the debate about the importance of active exploration of 3-D environment for acquiring knowledge about urban density. Some researcher did not found active involvement better over passive (like LiIto & Matsunaga, 1990; Schwaartz, Perey &Azulay, 1975). Wilson, Foreman, Gillett, and Stanton (1997) failed to find any significant differences between active and passive interaction. This thesis results, together with those of Péruch & Gaunet, (1998); Williams, Hutchinson, and Wickens (1996) suggest that active engagement is preferable than passive engagement.

All researchers are not convinced of the concept of virtual models and some have begun testing the strengths and weaknesses of those models (Heft & Nassar, 2000). Others are aware of its limitations and try to control these in their methodologies (Zacharias, 2006). The present research can contribute to improvement of the methods and tools used to encourage the public participation in the planning debate regarding density.

The result also gives indication that participants who have 3-D game playing experience can understand 3-D environment easily. The findings are helpful if one wishes to improve 3-D representation to foster public participation in urban planning. Density is a crucial issue in urban planning. Fisher et. al point to the fact that high rise does not mean high-density. The same number of building units or the same FAR can be achieved through different designs (Fisher et al, 2003). According to McCarthy and Saegert (1979), "Living in a high-rise building may lead to a greater feeling of crowding. The thesis postulate result does not support Mc,Carthy and Saegert concept rather it indicates in favor of Fisher et al.'s findings. The present research finding indicates that preconceived perceptions regarding height and density do not significantly affect participants' cognition.

Sustainable development and participatory planning are closely related. Planning is generally a complicated process since the 1960s professional planners routinely using 3-D technologies, to communicate with non-specialists (Kurzman, 2000). Planners are faced with challenges when trying to determine the most suitable mode of communication. However, planners must always be attentive to the fact that the participants may not be able to understand the visual models that they are presented with, digital models in particular (Joerin and Nembrini, 2005). The present research findings can help to understand some of the challenges faced by planners and citizens wishing to exchange their views over urban transformation and some ways to resolve the challenges.

The research illustrates that well adapted tools and methods can help participants to grasp complex spatial information pertaining to density.

6.2 Limitation and future works

There are numerous factors that could have been included in the present research; however, due to research scope and time, only one communication mode alternatively active versus passive was considered.

A portion of the total population, especially older people and blue collar workers, may never have used a computer throughout their entire lives (Gaines, 2001). A limitation of the present research is that all the participants are within a particular age group. They are all university students. Thus, the impact of age of familiarity with digital environments on performance could not be measured. This element may bring interesting findings in future research.

Furthermore, the sample size of the participants amounted to 60 individuals. During analysis, only the correct answers given by specialists and non-specialists were considered. In consequence, that number was always less than 60. Because of the small amount of data, some kinds of statistical analyses were not possible. This meant that the present research could only use F-Test, t test and chi square test. A larger sample ought to be considered for further studies of this kind.

This present study measured only active and passive modes of interaction in order to assess which of the two favors a better understanding of density in 3-D environments.

There is the possibility that some independent variables influenced the results – variables that could not be reliably detected here. Future research could be designed to identify those variables.

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Appendix: A

Communicating urban density: assessing the challenges and opportunities in the use of 3D representation for public participation in planning.

Question.1

Are you?

☐ Male ☐ Female

Question.2

What age groups do you belongs to?

- ☐ 18-25
- ☐ 26-30
- ☐ 31-40
- ☐ 40+

Question.3

Have you received college or university level training in any of the following fields: Urban Planning, Architecture, Engineering or digital 3-D modeling?

☐ Yes ☐ No

Question.4

How frequently did you play 3-D computer games in the last 5 years?

- ☐ Every day
- ☐ A few hours a week
- ☐ A few hours a month
- ☐ Occasionally only
- ☐ Never

Now you will see two passive, dynamic and pre determined route of a neighborhood. In each test you can see before and after situation of the same area. Through these tests you have to assess and answer increased or decreased density related questions.

Question- 5

Note: Density in the built environment is determined by the total floor area of buildings in relation to the size of land. Therefore,

-High density environments can indistinctively be produced by high or low rise buildings.

See question five, model 1(a & b). In your opinion , does model "b" display a

- ☐ Significantly higher density than model "a"
- ☐ Slightly high density than model "a"
- ☐ Equal density with model 'a'
- ☐ Slightly lower density than model "a"
- ☐ Significantly lower density than model "a"

Now you will go through four tests. Among the participants 50% participants will see a passive, dynamic tour and rest 50 % will explore it actively. After each test please answer one set of questions. Through this test you have to assess and answer increased or decreased density related questions

☐ Active participant ☐ Passive participant

Question.6 (i)

See question six, model 2 (a & b). In your opinion , which one has higher density

- ☐ model "a"
- ☐ model "b"

Question.6 (ii)

In model 2"b" the density is lower than model "a". In your opinion what is the percentage of density decrease from model "a" to model "b"?

- ☐ 10%
- ☐ 30%
- ☐ 50%
- ☐ 70%

Question.7 (i)

See question seven, model 3 (a & b). In your opinion , which one has higher density

- ☐ model "a"
- ☐ model "b"

Question.7 (ii)

In model 3 “b” the density is higher than model “a”. In your opinion what is the percentage of density increase from model “a” to model “b”?

- ☐ 10%
- ☐ 25%
- ☐ 50%
- ☐ 75%

Question.8 (i)

See question eight, model 4 (a & b). In your opinion , which one has higher density

- ☐ model “a”
- ☐ model “b”

Question.8 (ii)

In model 4"b" the density is higher than model "a". In your opinion what is the range of density increase from model "a' to model "b"?

- ☐ 5%
- ☐ 15%
- ☐ 45%
- ☐ 65%

Question- 9

Note: Density in the built environment is determined by the total floor area of buildings in relation to the size of land. Therefore,

- The same density in built environment can produce a different amount of open space.

See question nine, model 5 (a & b). In your opinion , does model "b" display a

- ☐ Significantly higher density than model "a"
- ☐ Slightly high density than model "a"
- ☐ Equal density with model 'a'
- ☐ Slightly lower density than model "a"
- ☐ Significantly lower density than model "a"

Calculation sheet for models **Appendix: B**

1(a) High Rise same density

Building No	Length	Width	floor area(sq. m)	no of floor	Total sq. m of the building
1	41.8	17	710.6	16	11369.6
2	63.73	20	1274.6	18	22942.8
3	38.14	20	762.8	6	4576.8
4	42.32	13.18	557.7776	14	7808.8864
5	92.49	20	1849.8	10	18498
5	16.76	20	335.2	10	3352
6	54	20	1080	16	17280
7	54	20	1080	18	19440
8	48	20	960	15	14400
9	54.12	18.14	981.7368	12	11780.8416
10	40	20	800	14	11200
11	55.24	20	1104.8	16	17676.8
12	55.41	20	1108.2	24	26596.8
13	61.25	24.53	1502.4625	16	24039.4
				Total density	**210961.928**

1(b) low rise same density

Building No	Length	Width	**floor area(sq. m)**	**no of floor**	**Total sq. m of the building**
1(a)	41.8	17	710.6	8	5684.8
1(b)	41.8	17	710.6	8	5684.8
2(a)	63.73	20	1274.6	6	7647.6
2(b)	63.73	20	1274.6	6	7647.6
2(3)	63.73	20	1274.6	6	7647.6
3	38.14	20	762.8	6	4576.8
4(a)	42.32	13.18	557.7776	7	3904.4432
4(b)	42.32	13.18	557.7776	7	3904.4432
(a)	92.49	20	1849.8	5	9249
5(a)	16.76	20	335.2	5	1676
5(b)	92.49	20	1849.8	5	9249
5(b)	16.76	20	335.2	5	1676
6(a)	54	20	1080	8	8640
6(b)	54	20	1080	8	8640
7(a)	54	20	1080	6	6480
7(b)	54	20	1080	6	6480
7(c)	54	20	1080	6	6480
8(a)	48	20	960	5	4800
8(b)	48	20	960	5	4800
8(c)	48	20	960	5	4800
9(a)	54.12	18.14	981.7368	6	5890.4208
9(b)	54.12	18.14	981.7368	6	5890.4208
10(a)	40	20	800	7	5600
10(b)	40	20	800	7	5600
11(a)	55.24	20	1104.8	8	8838.4
11(b)	55.24	20	1104.8	8	8838.4
12(a)	55.41	20	1108.2	6	6649.2
12(b)	55.41	20	1108.2	6	6649.2
12©	110.82	20	2216.4	6	13298.4
13(a)	61.25	24.53	1502.4625	8	12019.7
13(b)	61.25	24.53	1502.4625	8	12019.7
				Total density	**210961.928**

1(a) and (b) both have same density

1(a) density = **210961.928**

1(b) density = **210961.928 .**

2(a) High density

Bld. No	Length	Width	**floor area(sq. m)**	**no of floor**	**Total sq. m of the bld.**
1	38.56	40.7	1569.392	4	6277.568
2	32.62	18.3	597.9246	4	2391.6984
3	95	16	1518.1	4	6072.4
4	138.8	18.5	2561.598	3	7684.794
5	107	18.5	1974.15	3	5922.45
6	55.43	18.5	1022.6835	3	3068.0505
7	85.64	18.5	1580.058	3	4740.174
8	40.49	12.2	492.3584	4	1969.4336
9	45.48	11	500.28	4	2001.12
10	85.35	22	1877.7	3	5633.1
11	85.13	12	1021.56	4	4086.24
12	52.12	21	1094.52	4	4378.08
13	63.45	15.7	994.896	4	3979.584
14	38.97	15.7	611.0496	4	2444.1984
15	92	15.7	1442.56	4	5770.24
16	49.83	18.5	919.3635	4	3677.454
17	32.12	20	641.4364	4	2565.7456
18(a)	49.81	18.5	921.485	4	3685.94
189b)	49.81	18.5	921.485	4	3685.94
19	49.94	18.2	910.4062	4	3641.6248
20	25.83	23	594.8649	3	1784.5947
21	49.15	19.7	968.7465	3	2906.2395
22	73.36	18.5	1353.492	4	5413.968
23	49.83	21.4	1063.8705	4	4255.482
24	51.43	18.5	948.8835	4	3795.534
25	49.83	18.5	919.3635	4	3677.454
26	43	29.6	1273.66	3	3820.98
27	49	18.8	919.73	4	3678.92
27(b)	44.03	15	660.45	4	2641.8
28	27.63	18.8	518.6151	4	2074.4604
29	49.68	21.4	1062.1584	4	4248.6336
30	68.77	18.8	1290.8129	4	5163.2516
31	49.68	18.8	932.4936	4	3729.9744
31(a)	40.41		15	4	60

32	54.44	18.8	1021.8388	3	3065.5164
33	103.8	18.5	1915.6635	4	7662.654
34	57.1	21.6	1232.789	4	4931.156
35	56.52	23.1	1303.9164	4	5215.6656
36	63.49	15.7	998.0628	3	2994.1884
37	56.37	22.8	1285.236	4	5140.944
			Total	**density**	159937.2519

2(b) Some building missing low density

Building No	Length	Width	floor area(sq. m)	no of floor	Total sq. m of the building
1	38.56	26.2	1009.5008	4	4038.0032
2	32.62	18.3	597.9246	4	2391.6984
3	95	16	1518.1	4	6072.4
4	123.1	18.5	2271.7485	3	6815.2455
5	107	18.5	1974.15	3	5922.45
6	35	18.5	645.75	3	1937.25
7	85.64	18.5	1580.058	3	4740.174
8	40.49	12.2	492.3584	4	1969.4336
9	45.48	11	500.28	4	2001.12
10	85.35	22	1877.7	3	5633.1
11	85.13	12	1021.56	4	4086.24
12	52.12	21	1094.52	4	4378.08
13	63.45	15.7	994.896	4	3979.584
14	0	0	0		
15	92	15.7	1442.56	4	5770.24
16	49.83	18.5	919.3635	4	3677.454
17	32.12	20	641.4364	4	2565.7456
18(a)	49.81	18.5	921.485	4	3685.94
189b)	24.96	18.5	461.76	4	1847.04
19	49.94	18.2	910.4062	4	3641.6248
20	25.83	23	594.8649	3	1784.5947
21	49.15	19.7	968.7465	3	2906.2395
22	73.36	18.5	1353.492	4	5413.968
23	49.83	21.4	1063.8705	4	4255.482
24	20	12	240	4	960

25	49.83	18.5	919.3635	4	3677.454
26	43	29.6	1273.66	3	3820.98
27	49	18.8	919.73	4	3678.92
27(b)	0	0	0		
28	27.63	18.8	518.6151	4	2074.4604
29	49.68	21.4	1062.1584	4	4248.6336
30	68.77	18.8	1290.8129	4	5163.2516
31	49.68	18.8	932.4936	4	3729.9744
31(a)	20	12	240	4	960
32	54.44	18.8	1021.8388	3	3065.5164
33	103.8	18.5	1915.6635	4	7662.654
34	57.1	21.6	1232.789	4	4931.156
35	56.52	23.1	1303.9164	4	5215.6656
36	63.49	15.7	998.0628	3	2994.1884
37	56.37	22.8	1285.236	4	5140.944
			Total density		146836.9057

Decrease 8.19%

Density decrease around 10% from 2(a) to 2(b).

2(a) density = 159937.2519

2(b) density = 146836.9057

3(a) Two floor lower height, low density

Building No	Length	Width	floor area(sq. m)	no of floor	Total sq. m of the building
1	38.56	40.7	1569.392	4	6277.568
2	32.62	18.3	597.9246	4	2391.6984
3	95	16	1518.1	4	6072.4
4	138.8	18.5	2561.598	3	7684.794
5	107	18.5	1974.15	3	5922.45
6	55.43	18.5	1022.6835	3	3068.0505
7	85.64	18.5	1580.058	3	4740.174
8	40.49	12.2	492.3584	4	1969.4336
9	45.48	11	500.28	4	2001.12
10	85.35	22	1877.7	3	5633.1
11	85.13	12	1021.56	4	4086.24
12	52.12	21	1094.52	4	4378.08
13	63.45	15.7	994.896	4	3979.584
14	38.97	15.7	611.0496	4	2444.1984
15	92	15.7	1442.56	4	5770.24
16	49.83	18.5	919.3635	4	3677.454
17	32.12	20	641.4364	4	2565.7456
18(a)	49.81	18.5	921.485	4	3685.94
189b)	49.81	18.5	921.485	4	3685.94
19	49.94	18.2	910.4062	4	3641.6248
20	25.83	23	594.8649	3	1784.5947
21	49.15	19.7	968.7465	3	2906.2395
22	73.36	18.5	1353.492	4	5413.968
23	49.83	21.4	1063.8705	4	4255.482
24	51.43	18.5	948.8835	4	3795.534
25	49.83	18.5	919.3635	4	3677.454
26	43	29.6	1273.66	3	3820.98
27	49	18.8	919.73	4	3678.92
27(b)	44.03	15	660.45	4	2641.8
28	27.63	18.8	518.6151	4	2074.4604
29	49.68	21.4	1062.1584	4	4248.6336
30	68.77	18.8	1290.8129	4	5163.2516
31	49.68	18.8	932.4936	4	3729.9744

31(a)	40.41		15	4	60
32	54.44	18.8	1021.8388	3	3065.5164
33	103.8	18.5	1915.6635	4	7662.654
34	57.1	21.6	1232.789	4	4931.156
35	56.52	23.1	1303.9164	4	5215.6656
36	63.49	15.7	998.0628	3	2994.1884
37	56.37	22.8	1285.236	4	5140.944
				Total density	**159937.2519**

3(b) two floor high, high density

Building No	Length	Width	**floor area(sq. m)**	**no of floor**	**Total sq. m of the building**
1	38.56	40.7	1569.392	6	9416.352
2	32.62	18.3	597.9246	6	3587.5476
3	95	16	1518.1	6	9108.6
4	138.8	18.5	2561.598	5	12807.99
5	107	18.5	1974.15	5	9870.75
6	55.43	18.5	1022.6835	5	5113.4175
7	85.64	18.5	1580.058	5	7900.29
8	40.49	12.2	492.3584	6	2954.1504
9	45.48	11	500.28	6	3001.68
10	85.35	22	1877.7	5	9388.5
11	85.13	12	1021.56	6	6129.36
12	52.12	21	1094.52	6	6567.12
13	63.45	15.7	994.896	6	5969.376
14	38.97	15.7	611.0496	6	3666.2976
15	92	15.7	1442.56	6	8655.36
16	49.83	18.5	919.3635	6	5516.181
17	32.12	20	641.4364	6	3848.6184
18(a)	49.81	18.5	921.485	6	5528.91
189b)	49.81	18.5	921.485	6	5528.91
19	49.94	18.2	910.4062	6	5462.4372
20	25.83	23	594.8649	5	2974.3245
21	49.15	19.7	968.7465	5	4843.7325
22	73.36	18.5	1353.492	6	8120.952
23	49.83	21.4	1063.8705	6	6383.223
24	51.43	18.5	948.8835	6	5693.301

25	49.83	18.5	919.3635	6	5516.181
26	43	29.6	1273.66	5	6368.3
27	49	18.8	919.73	6	5518.38
27(b)	44.03	15	660.45	6	3962.7
28	27.63	18.8	518.6151	6	3111.6906
29	49.68	21.4	1062.1584	6	6372.9504
30	68.77	18.8	1290.8129	6	7744.8774
31	49.68	18.8	932.4936	6	5594.9616
31(a)	40.41		15	6	90
32	54.44	18.8	1021.8388	5	5109.194
33	103.8	18.5	1915.6635	6	11493.981
34	57.1	21.6	1232.789	6	7396.734
35	56.52	23.1	1303.9164	6	7823.4984
36	63.49	15.7	998.0628	5	4990.314
37	56.37	22.8	1285.236	5	6426.18
				Total density	**245557.3231**
				increase 53.53	

Model 3(b) density is around 50% greater than 3(a) 159937.2519

3(a) density = **159937.2519** 3(b) density = **245557.3231**

4(a) Less width buildings low density

Building No	Length	Width	floor area(sq. m)	no of floor	sq. m of each building
1	27.92	17.7	494.184	6	2965.104
2	23.4	13.41	313.794	7	2196.558
3	33.18	12.74	422.7132	10	4227.132
4	28.33	16.12	456.6796	7	3196.7572
5(a)	19.99	8.6	171.914	6	1031.484
5(b)	25	12.32	308	6	1848
6	36.06	13.35	481.401	11	5295.411
7A	23.81	11.88	282.8628	5	1414.314
7B	32.08	8.16	261.7728	5	1308.864
7C	23.81	8.08	192.3848	5	961.924
8	29.24	13.48	394.1552	6	2364.9312
9	36.06	13.35	481.401	8	3851.208
10	36.14	13.44	485.7216	8	3885.7728
11A	19.66	8.75	172.025	5	860.125
11B	45.5	9.66	439.53	5	2197.65
11C	19.61	7.15	140.2115	5	701.0575
12	26.95	16.23	437.3985	8	3499.188
13	23.63	13.51	319.2413	4	1276.9652
14	32.15	13.35	429.2025	4	1716.81
15(a)	29.89	16.47	492.2883	11	5415.1713
15(b)	23.75	11.89	282.3875	11	3106.2625
16	40.87	16.38	669.4506	8	5355.6048
		Total density			**58676.2945**

4(b) More width buildings, more density

Building No	Length	Width	floor area(sq. m)	no of floor	sq. m of each building
1	27.92	25.22	704.1424	6	4224.8544
2	23.4	20.37	476.658	7	3336.606
3	33.18	23.34	774.4212	10	7744.212
4	28.33	22.78	645.3574	7	4517.5018
5(a)	19.99	17.78	355.4222	6	2132.5332
5(b)	25	13.72	343	6	2058
6	36.06	19.34	697.4004	11	7671.4044
7A	23.81	14	333.34	5	1666.7
7B	32.08	10.89	349.3512	5	1746.756
7C	23.81	11.9	283.339	5	1416.695
8	29.24	19.3	564.332	6	3385.992
9	36.06	22.11	797.2866	8	6378.2928
10	36.14	22.19	801.9466	8	6415.5728
11A	19.66	11.84	232.7744	5	1163.872
11B	45.5	10.89	495.495	5	2477.475
11C	19.61	14	274.54	5	1372.7
12	26.95	28.74	774.543	8	6196.344
13	23.63	13.45	317.8235	4	1271.294
14	32.15	13.41	431.1315	4	1724.526
15(a)	29.89	16.96	506.9344	11	5576.2784
15(b)	23.75	20.71	491.8625	11	5410.4875
16	40.87	24.62	1006.2194	8	8049.7552
		Total density			**85937.8525**

Model 4(b) density is around 45% greater than 4(a) 159937.2519

3(a) density = **58676.2945**

3(b) density = **85937.8525**

5(a) More large open space same density

Building No	Length	Width	floor area(sq. m)	no of floor	Total sq. m of the building
1	41.8	17	710.6	10	7106
2(a)	53	22	1166	5	5830
2(b)	53	22	1166	10	11660
3(a)	63	20	1260	4	5040
3(b)	63	20	1260	8	10080
4	83.98	13	1091.74	8	8733.92
5	48.11	11	529.21	10	5292.1
6	54	20	1080	8	8640
7	54	20	1080	13	14040
8	75	20	1500	8	12000
9	54.12	18.14	981.7368	8	7853.8944
10	48	20	960	8	7680
11	70.89	20	1417.8	8	11341.6
12(a)	68.7	20	1374	8	10992
12(b)	61.25	25	1531.25	8	12250
13(a)	107.5	20	2150	8	17200
13(b)	61.08	23.46	1432.9368	8	11463.4944
				Total density	**167203.0088**

5(b) less open space same density

Building No	Length	Width	floor area(sq. m)	no of floor	Total sq. m of the building
1(a)	41.8	17	710.6	5	3553
1(b)	41.8	17	710.6	5	3553
2(a)	53	22	1166	5	5830
2(b)	53	22	1166	5	5830
2©	53	22	1166	5	5830
3(a)	63	20	1260	4	5040
3(b)	63	20	1260	4	5040
3(c)	63	20	1260	4	5040
4(a)	83.98	13	1091.74	4	4366.96
4(b)	83.98	13	1091.74	4	4366.96
5(a)	48.11	11	529.21	5	2646.05
5(b)	48.11	11	529.21	5	2646.05
6(a)	54	20	1080	4	4320
6(b)	54	20	1080	4	4320
7(a)	54	20	1080	6	6480
7(b)	54	20	1080	7	7560
8(a)	37.5	20	750	4	3000
8(b)	75	20	1500	4	6000
8(c)	37.5	20	750	4	3000
9(a)	54.12	18.14	981.7368	4	3926.9472
9(b)	54.12	18.14	981.7368	4	3926.9472
10(a)	48	20	960	4	3840
10(b)	48	20	960	4	3840
11(a)	35.44	20	708.8	4	2835.2
11(b)	35.44	20	708.8	4	2835.2
11 (c)	70.89	20	1417.8	4	5671.2
12(a)	68.7	20	1374	4	5496
12(b)	68.7	20	1374	4	5496
12©	61.25	25	1531.25	4	6125
12(d)	61.25	25	1531.25	4	6125
13(a)	107.5	20	2150	4	8600
13(b)	107.5	20	2150	4	8600
13(c)	61.08	23.46	1432.9368	4	5731.7472
13(d)	61.08	23.46	1432.9368	4	5731.7472
				Total density	**167203.0088**

1(a) and (b) both have same density

5(a) density =**167203.0088**

5(b) density = **167203.0088.**

Appendix: C(a)

Calculation sheets for statistical analysis

Minitab output of regression model of predicting model of correctness of answer from gender

Regression Analysis: Correctness of Answer versus Gender

The regression equation is
Correctness of Answer = 5.07 + 0.471 Gender

Predictor	Coef	SE Coef	T	P
Constant	5.0741	0.3116	16.28	0.000
Gender	0.4714	0.4201	1.12	0.267

S = 1.61903   R-Sq = 2.1%   R-Sq(adj) = 0.4%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	3.300	3.300	1.26	0.267
Residual Error	58	152.034	2.621		
Total	59	155.333			

Unusual Observations

Obs	Gender	Correctness of Answer	Fit	SE Fit	Residual	St Resid
18	1.00	2.000	5.545	0.282	-3.545	-2.22R
53	0.00	1.000	5.074	0.312	-4.074	-2.56R

Appendix C (b)
Minitab output of regression model of predicting model of correctness of answer from Specialness

Regression Analysis: Correctness of Answer versus Specialness

The regression equation is
Correctness of Answer = 4.77 + 1.13 Specialness

Predictor	Coef	SE Coef	T	P
Constant	4.7667	0.2796	17.05	0.000
Specialness	1.1333	0.3955	2.87	0.006

S = 1.53166   R-Sq = 12.4%   R-Sq(adj) = 10.9%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	19.267	19.267	8.21	0.006
Residual Error	58	136.067	2.346		
Total	59	155.333			

Unusual Observations

Obs	Specialness	Correctness of Answer	Fit	SE Fit	Residual	St Resid
18	1.00	2.000	5.900	0.280	-3.900	-2.59R
33	0.00	8.000	4.767	0.280	3.233	2.15R
41	0.00	8.000	4.767	0.280	3.233	2.15R
53	0.00	1.000	4.767	0.280	-3.767	-2.50R

R denotes an observation with a large standardized residual.

Appendix C ©
Minitab output of regression model of predicting model of correctness of answer from Activeness for Specialist
Regression Analysis: Correctness of Answer_1 versus Activeness_1

The regression equation is
Correctness of Answer_1 = 5.47 + 0.867 Activeness_1

Predictor	Coef	SE Coef	T	P
Constant	5.4667	0.3813	14.34	0.000
Activeness_1	0.8667	0.5393	1.61	0.119

S = 1.47680   R-Sq = 8.4%   R-Sq(adj) = 5.2%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	5.633	5.633	2.58	0.119
Residual Error	28	61.067	2.181		
Total	29	66.700			

Unusual Observations

Obs	Activeness_1	Correctness of Answer_1	Fit	SE Fit	Residual	St Resid
18	0.00	2.000	5.467	0.381	-3.467	-2.43R

Appendix c (d)
Minitab output of regression model of predicting model of correctness of answer from Activeness for Non-Specialist

Regression Analysis: Correctness versus Activeness_2

The regression equation is
Correctness = 4.20 + 1.13 Activeness_2

Predictor	Coef	SE Coef	T	P
Constant	4.2000	0.3771	11.14	0.000
Activeness_2	1.1333	0.5333	2.13	0.043

S = 1.46059   R-Sq = 13.9%   R-Sq(adj) = 10.8%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	9.633	9.633	4.52	0.043
Residual Error	28	59.733	2.133		
Total	29	69.367			

Unusual Observations

Obs	Activeness_2	Correctness	Fit	SE Fit	Residual	St Resid
23	0.00	1.000	4.200	0.377	-3.200	-2.27R

R denotes an observation with a large standardized residual.

Appendix c (e)
Minitab output of regression model of predicting model of correctness of answer from frequency of playing video game

Regression Analysis: Correctness of Answer versus frequency

The regression equation is
Correctness of Answer = 4.34 + 0.643 frequency

Predictor	Coef	SE Coef	T	P
Constant	4.3365	0.2714	15.98	0.000
frequency	0.6431	0.1322	4.86	0.000

S = 1.37914 R-Sq = 29.0% R-Sq(adj) = 27.8%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	45.016	45.016	23.67	0.000
Residual Error	58	110.317	1.902		
Total	59	155.333			

Unusual Observations

Obs	frequency	Correctness of Answer	Fit	SE Fit	Residual	St Resid
11	0.00	8.000	4.337	0.271	3.663	2.71R
18	1.00	2.000	4.980	0.192	-2.980	-2.18R
33	5.00	8.000	7.552	0.490	0.448	0.35 X
41	5.00	8.000	7.552	0.490	0.448	0.35 X
53	0.00	1.000	4.337	0.271	-3.337	-2.47R

R denotes an observation with a large standardized residual.
X denotes an observation whose X value gives it large leverage.

Appendix c (f)

Sample	X	N	Sample p
1	17	30	0.566667
2	11	30	0.366667

Difference = p (1) - p (2)
Estimate for difference: 0.2
95% CI for difference: (-0.0473435, 0.447343)
Test for difference = 0 (vs not = 0): Z = 1.58 P-Value = 0.113

Fisher's exact test: P-Value = 0.195

Appendix C (g)

Correlation matrix

Correlations: Correctness of Answer, Gender, Specialness, Activeness, frequency

	Correctness	Gender	Specialness	Activeness
Gender	0.146			
Specialness	0.352	0.101		
Activeness	0.311	0.101	-0.000	
frequency	0.538	0.220	0.111	0.260

Appendix C (h)
Minitab output of regression model of predicting model of correctness of answer from all four varaibles

Regression Analysis: Correctness of A versus Gender, Specialness, Activeness, Frequency

The regression equation is
Correctness of Answer = 3.70 - 0.014 Gender + 0.971 Specialness
+ 0.620 Activeness + 0.544 frequency

Predictor	Coef	SE Coef	T	P
Constant	3.7014	0.3436	10.77	0.000
Gender	-0.0137	0.3446	-0.04	0.968
Specialness	0.9714	0.3364	2.89	0.006
Activeness	0.6204	0.3455	1.80	0.078
frequency	0.5442	0.1314	4.14	0.000

S = 1.28992 R-Sq = 41.1% R-Sq(adj) = 36.8%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	4	63.819	15.955	9.59	0.000
Residual Error	55	91.515	1.664		
Total	59	155.333			

Source	DF	Seq SS
Gender	1	3.300
Specialness	1	17.878
Activeness	1	14.082
frequency	1	28.559

Unusual Observations

Obs	Gender	Correctness of Answer	Fit	SE Fit	Residual	St Resid
11	1.00	8.000	5.280	0.428	2.720	2.24R
18	1.00	2.000	5.203	0.335	-3.203	-2.57R
53	0.00	1.000	3.701	0.344	-2.701	-2.17R

R denotes an observation with a large standardized residual.

Appendix C (i)

Minitab output of estimated regression equation with only Specialness and frequency.

Regression Analysis: Correctness of Answer versus Specialness, frequency

The regression equation is
Correctness of Answer = 3.92 + 0.952 Specialness + 0.604 frequency

Predictor	Coef	SE Coef	T	P	VIF
Constant	3.9215	0.2961	13.25	0.000	
Specialness	0.9522	0.3387	2.81	0.007	1.013
frequency	0.6037	0.1257	4.80	0.000	1.013

S = 1.30374   R-Sq = 37.6%   R-Sq(adj) = 35.4%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	2	58.448	29.224	17.19	0.000
Residual Error	57	96.885	1.700		
Total	59	155.333			

Source	DF	Seq SS
Specialness	1	19.267
frequency	1	39.181

Unusual Observations

Obs	Specialness	Correctness of Answer	Fit	SE Fit	Residual	St Resid
11	1.00	8.000	4.874	0.320	3.126	2.47R
18	1.00	2.000	5.477	0.254	-3.477	-2.72R
33	0.00	8.000	6.940	0.511	1.060	0.88 X
41	0.00	8.000	6.940	0.511	1.060	0.88 X
53	0.00	1.000	3.921	0.296	-2.921	-2.30R

R denotes an observation with a large standardized residual.
X denotes an observation whose X value gives it large leverage.

Appendix C (j)
Minitab output of stepwise regression
Stepwise Regression: Correctness of A versus Gender, Specialness, ...

Alpha-to-Enter: 0.05 Alpha-to-Remove: 0.05

Response is Correctness of Answer on 4 predictors, with N = 60

Step	1	2
Constant	4.337	3.921
frequency	0.64	0.60
T-Value	4.86	4.80
P-Value	0.000	0.000
Specialness		0.95
T-Value		2.81
P-Value		0.007
S	1.38	1.30
R-Sq	28.98	37.63
R-Sq(adj)	27.76	35.44
Mallows Cp	10.3	4.2

Appendix C (k)
Minitab outputs of Best Subsets regression

Best Subsets Regression: Correctness versus Gender, Specialness, ...

Response is Correctness of Answer

Vars	R-Sq	R-Sq(adj)	Mallows Cp	S	Gender	Specialness	Activeness	Frequency
1	35.8	34.5	10.6	1.1837			X	
1	14.6	13.0	30.6	1.3645		X		
2	45.8	43.7	3.1	1.0976		X	X	
2	37.1	34.7	11.4	1.1826			X	X
3	47.7	44.6	3.4	1.0891		X	X	X
3	46.1	42.9	4.9	1.1055	X	X		X
4	48.1	43.9	5.0	1.0961	X	X	X	X

Appendix C (L)

Minitab outputs of Total performance of specialists vs. non-specialists

Chi-Square Test: C1, C2

Expected counts are printed below observed counts

Chi-Square contributions are printed below expected counts

	C12	C13	Total
1	178	62	240
	161.00	79.00	
	1.795	3.658	
2	144	96	240
	161.00	79.00	
	1.795	3.658	
Total	322	158	480

Chi-Sq = 10.907, DF = 1, P-Value = 0.001

Appendix C (m)

Minitab outputs for test 1 (postulates)

Sample	X	N	Sample p
1	28	60	0.466667
2	32	60	0.533333

Difference = p (1) - p (2)

Estimate for difference: -0.0666667

95% CI for difference: (-0.245188, 0.111855)

Test for difference = 0 (vs not = 0): Z = -0.73 P-Value = 0.464

Fisher's exact test: P-Value = 0.584