Technology Adoption of InnovViz 2.0 : A Study of Mixed-Reality Visualization and Simulation System for Innovation Strategy with UTAUT Model

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Abstract

InnovVizwas designed and developed anew as avisualization and simulationtool to present innovation and strategy information. The InnovViz system employs two key types of technology, namely mixed reality (MR) and neural network (NN). An experiment was conducted to examine the usability, acceptance and possible adoption of this new system. Participants comprised 4 experts from 4 top performing entrepreneurial firms and 161 master degree students from 2 leading universities. The study used a modified UTAUT model and a cognition and perception model. The results revealed that when the InnovViz was introduced, the key drivers to adoption are Facilitating Conditions (FC) and Voluntary to Use (VOL). Adequate knowledge and sufficient resources were found to strongly affect FC construct. The expert's rating of a firm's innovation and performance was more congruent with senior students with a technology-background than with a finance and accounting-background. InnovViz was seen as providing complex information with an ease of use and usefulness for showing data and assessment. Among the three types of visuals depicted by InnovViz, experts rated their usefulness in descending order as follows: Cube, Tetrahedron and Saturn. Finally, experts found backward simulation to be slightly more useful for assessment than forward simulation.

Keywords : Strategy, Innovation, Visualization, Mixed Reality, Technology Adoption

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1. Introduction

Both innovation and strategy are significant to a firm's competitive advantage [Nilsson and Johansson, 2006; Paliwal and Kumar, 2009]. Strategic management consists of four general processes : analysis, formulation, implementation and control [Balaji, Chakravarthy, Doz, 1992; Hitt et al., 2011; Pettigrew, 1992; Van de Ven, 1992]. Although innovation can vary from one firm to another, its processes mainly cover idea generation, idea evaluation and selection, feasibility, prototyping, market testing and commercialization [Microsoft Corporation, Innovation Management Process, 2007; Project Leaders International (PLI), 2011; Savetpanuvong et al., 2010; Tidd and Bessant, 2009]. Both strategy and innovation processes are highly critical to a firm's success, however, many companies fail to translate innovation and strategy from an analysis sub-process to an implementation sub-process [Christensen and Donovan, 2011; Kaplan and Norton, 1996; Kaplan, and Norton, 2004]. Normally analysis sub-process employs tools such as spreadsheets and presentation software. These tools have limited communicative visuals in presenting key information from large amount of data. The existing visuals are not very effective in drawing attention to and collaborating with group decision making [Savetpanuvong et al., 2010]. For instance, summary analyses of external and internal factors are often carried out by weighted score techniques with tables and numbers first and are then presented by graphs of profit trends, market share, etc. Spreadsheet software is also used for popular techniques in planning such as what-if and Monte-Carlo simulation. However, spreadsheet and presentation software, as of now, has a limited capability because it provides only two-dimensional (2D) graphs or three-dimensional graphs on a two-dimensional screen (3D on 2D). A real 3D image cannot be incorporated into the presentation of strategic and innovation management processes using a spreadsheet tool.

One promising technology, mixed reality (MR), also known as Augmented Reality (AR), allows 3D objects to be naturally interacted with users. 3D MR-based objects are expected to reduce the cognitive load of managers because users can control virtual objects with physical reality. Though previous studies have found 3D graphs to be associated with slower decision times and reliable performance decrements [Carswell, 1991; Fischer, 2000], 3D rotational visuals have been found to make the best prediction in terms of decision accuracy by novice users who deal with complex, multidimensional accounting data [Brath and Peters, 2005; Dull and Tegarden, 1999; Kumar and Benbasat, 2004; Tanlamai et al., 2010]. Nevertheless, in the authors' knowledge, there are no commonly agreed standards for 3D objects to represent abstract terms such as strategy or innovation. Neither are there any typical visual metaphors to represent various management concepts such as economy of scale, economy of scope, economy of speed, superiority and so on [Savetpanuvong et al., 2010; Savetpanuvong et al., 2011].

Another promising technology increasing competitive advantage withsimulation is the neural network (NN). The neural network is a black-box modeling technique that is capable of learning relationships between variables without prior assumptions [Savetpanuvong and Tanlamai, 2008; Savetpanuvong and Tanlamai, 2009]. NN has been used extensively in various applications [Akyol and Bayhan, 2007; Liao, 2005; Paliwal and Kumar, 2009; 6Kaplan, and Norton, 2004; Wong and Monaco, 1995; Wong and Selvi, 1998]. However NN outputs are almost always represented as a matrix of coefficients of transfer function. This kind of model representation is difficult to interpret and requires specific types of visualizations to ease users' understanding.

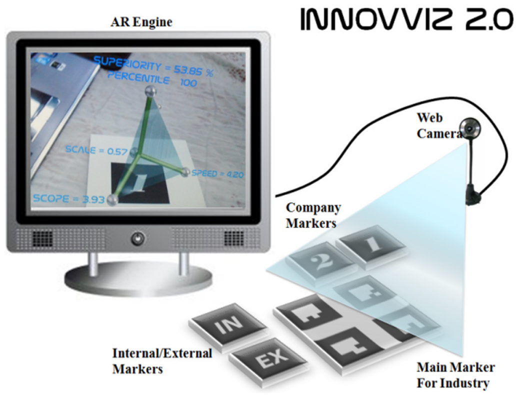
In order to improve the way innovation and strategic planning process operate, the authors developed software entitled InnovViz. The InnovViz integrates two types of technology, MR and NN, to allow managers and entrepreneurs to analyze information more effectively and usefully by providing visuals with MR and simulation engines with NN.

This researchexamines the technology adoption of InnovViz version 2.0 using the Unified Theory of Acceptance and Use of Technology (UTAUT) model [Tufte, 2011]. UTAUT model has been selected over other models because, ithas integrated disparate theories in psychology and organization and it has been designed and robustly tested extensively on information technology adoption. Specifically, the present research examines the extent of user's adoption on three originally constructed visuals for the InnovViz software.

In the next section, literature regarding MR and NN technology will be presented. A brief description of the InnovViz will be provided together with a depiction of visual representations of innovation and strategy.

2. Mixed Reality (MR)

Numerous applications including entertainment, education, and architecture are now enhanced by MR technology. MR has grown-rapidly because of its ability tocombine real images with virtual images, in contrast to virtual reality (VR) which only introduces computer-generated objects to users [Kirner and Kirner, 2006; Maad et al., 2008; Milgram and Kishino, 1994]. MR presents three-dimensional data which is expected to provide interactive visualization with a higher involvement from the user through a merger of physical and virtual world. Thus far, Augmented Reality (AR) is a term-more generallyreferred to than MR [Tanlamai et al., 2010].



<Figure 1> Hardware, Software, and MR Accessories [Savetpanuvong et al., 2011]

As shown in <Figure 1>, MR application requires computer hardware with a webcam and markers. The markers will be detected by a webcam and are processed by a MR application that will render 3D visuals on a computer screen. The MR feature being employed in this study usesprinted markers. Nevertheless, recent development in mobile and multi-touch technology has brought MR and AR into other mainstream applications. Latest MR applications can be used with smart phones like iPhonesor electronic readers like aniPad to replace paper-based markers and to show augmented reality images with mobility and security [Milgram and Kishino, 1994; Tanlamai, 2010].

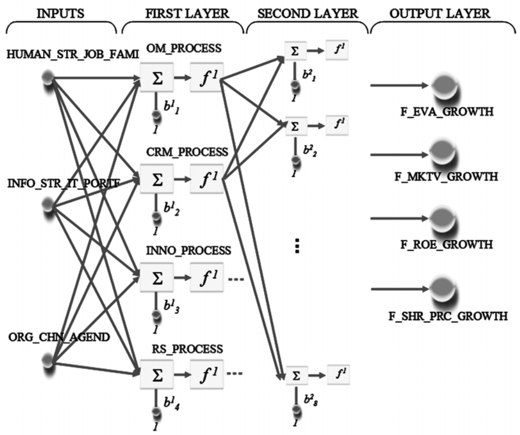
Based on previous findings of 2D versus 3D, a recent study conducted by Tanlamai et al., in 2010, suggested that a 3D graph constructed with MR technology was usable and did not create misperception or decision biases on financial and accounting data [Tanlamai et al., 2010; Amer, 2005; Amer and Ravindran, 2010; Benbasat and Dexter, 1998]. The present study aims to test similar relationships using data within the context of innovation and strategy. An Experiment was carried out to examine whether a set of novel visualswith MR technology would be usable and accepted by business experts and general users.

3. Neural Network (NN) Simulation

Neural network (NN) is a soft-hypotheses forecasting method which imitates the way humans process information using input-output transfer function with bias [Liao, 2005; Paliwal and Kumar, 1992]. It is one of the artificial intelligence techniques that draws on computing algorithms to learn data without prior knowledge like rule extraction [Savetpanuvong and Tanlamai, 2008; Savetpanuvong and Tanlamai, 2009]. The technique has long been used in financial management and engineering literature [Akyol and Bayhan, 2007; Liao, 2005; Paliwal and Kumar, 2009; 6Amer and Ravindran, 2010; Wong and Monaco, 1995; Wong and Selvi, 1998], however, its application to the management of strategy and innovation is still very limited [6Amer and Ravindran, 2010; Wong and Monaco, 1995; Wong and Selvi, 1998]. Strategy and innovation scholars use classical statistical methods to study phenomenon in management. The methods include multiple linear regression (MLR), structural equation modeling (SEM) [Williams et al., 2004], and SEM with partial least squares (PLS) technique [Hulland, 1999]. These techniques are based on the assumption of a linear relationship between variables whichdoes not reflect the real-world phenomena of nonlinearity.

In 2006 and 2010, Wang and Chien developed NN software to explore the relationship of input-output variables within a Taiwanese manufacturing setting [Chien et al., 2010; Wang and Chien, 2008]. However, the results showed variables in numerous aspects andwere too difficult to understand because no visualization wasincorporated. To datetheir neural network software has not been usedcommercially in forecasting.

For NN software packages that have been successfully commercialized, themajorityare in the field of manufacturing and finance, for example, production control, stock trading, credit scoring, foreign exchange, game theory, and so on. Nevertheless, the use of NN in innovation and strategic management domain has not been commercially available. Thus, the present study also attempts to examine which antecedents affect NN-based information system adoption. InnovViz employs an NN architecture as depicted in <Figure 2>.



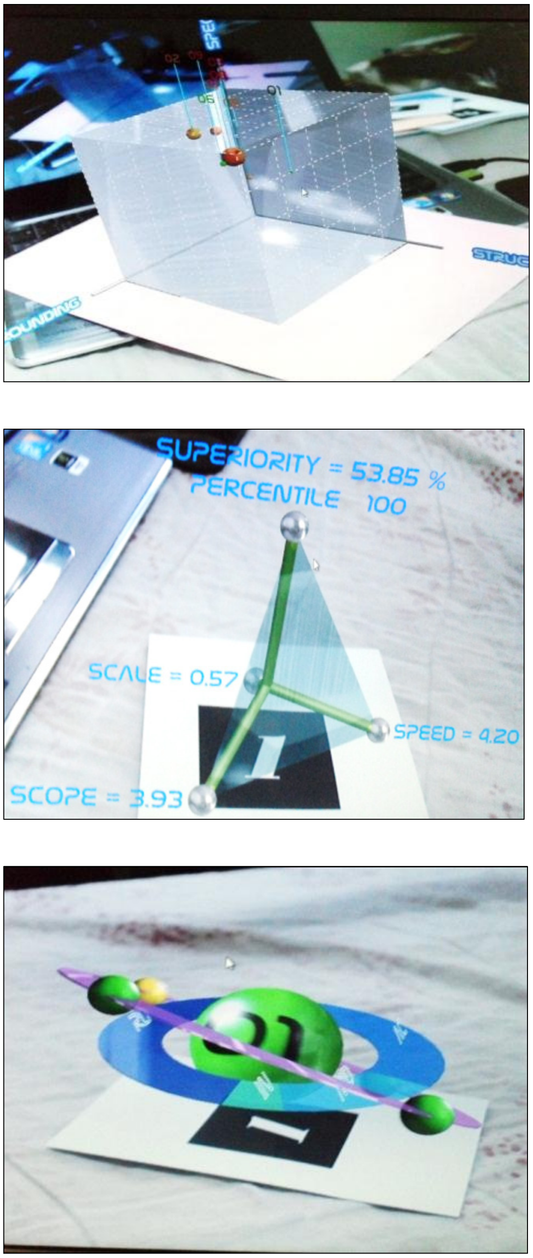
〈Figure 2〉 Neural Network Architecture

4. InnovViz 2.0

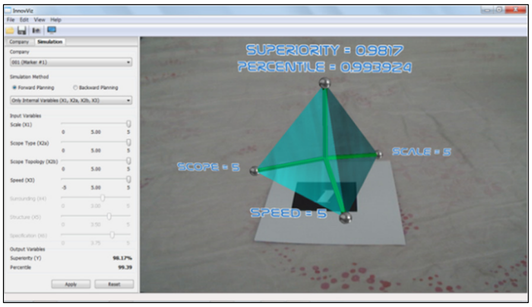
Business users embrace greater numbers of visuals as communication tools in decision making. InnovViz 2.0 is a software program being developed to simulate firm performance and innovation with neural network technology and visualizing firm performance and innovation with mixed reality [Helweg-Larsen, and Helweg-Larsen, 2007; Jeong, 2011; Tufte, 2001]. Version 1.0 of the InnovViz features only hard-coded visualization of up to 10 companies at a time through MR technology [Savetpanuvong et al., 2011]. InnovViz version 2.0 features a full-version of Windows based software with neural network model integration and spreadsheet data file interface.

Visuals presented in the InnovViz consist of Cube, Tetrahedron and Saturn. *Cube* or Industry Cube (IC), primarily designed for external analysis or macro analysis, is represented with three axes of 5×5×5 resembling five-point Likert scale of business surrounding, industry structure and customer specifications. Firms, which are software and IT service entrepreneurs in this study, are symbolized by spheres floating within the cube located at the intersection of different coordinates identified by the CEOs' view of external factors. *Tetrahedron*, a short name for Innovation Strategy Tetrahedron (IST), is a visual analogized hydrocarbon chemical structure, Methane (CH_4) [Savetpanuvong and Tanlamai, 2008]. IST illustrates the bonding of external (strategy-related) variables and internal (innovation-related) variables. Tetrahedron visualizes the relationship between Surrounding (business environment), Structure (industry five/six forces), Specification (customer expectation) and Superiority (profitability) for external analysis. It also visualizes the relationship between Scale (innovation capital), Scope (innovation portfolio with mixed types and topologies), Speed (innovation timing of entry) and Superiority for internal analysis. *Saturn* or Innovation Saturn with Double Rings (ISDR) embodies single sphere dynamically rotating with innovation speed and is surrounded by inner and outer rings of innovation scope. The inner ringexhibits innovation topologies whereas outer ringdemonstrates the innovation type [Savetpanuvong et al., 2010; Savetpanuvong et al., 2011].

The NN-based simulation features embrace two modes : forward and backward simulations. Forward simulation allows business users to create what-if scenarios from resources towards goals. On the contrary, business users can set goals first and then resource requirements will be suggested by a backward simulation engine. User interface (UI) of the simulation is designed with slide bars for adjusting input and label reporting the outputs from NN simulation engine. <Figure 3> and <Figure 4> illustrate MR visuals and real-time NN-based simulation interface respectively.



⟨Figure 3⟩ Three Key Visuals in InnovViz : Cube, Tetrahedron, and Saturn [Savetpanuvong et al., 2009]



⟨Figure 4⟩ Real-Time neural Network-Based Simulation Interface

5. Technology Adoption

The UTAUT (Unified Theory of Acceptance and Use of Technology) was developed and used by Venkatesh et al. [Tufte, 2001] to study-various behavioral aspects of information systems for eight projects. The model integrates 8 key theories about technology adoption such as Theory of Reasoned Action (TRA), Theory of Planned Behavior (TPB), Technology Acceptance Model (TAM), and Innovation Diffusion Theory (IDT). The first three constructs of the UTAUT model, Performance Expectancy (PE), Effort Expectancy (EE) and Social influence (SI), are hypothesized to affect Behavioral Intention (BI).

〈Table 1〉 Path Coefficients of Previous UTAUT Studies

Authors	PE	EE	SI	FC	GEN	AGE	EXP	VOL
Venkatesh et al. [2003]	**.46~.59**	.08-.20	.07~.11	.01~.03	.01~.04	.01~.09	N/A	.01~.04
Anderson et al. [2006]	.41~.47	.02~.21	.02~.05	.05	~.23	~.01	.18	**.48**
Aounet al. [2010]	.30	.19	.08	**.39**	N/A	N/A	N/A	N/A
El-Gayar and Moran [2007]	**.33**	.25	.32	.29	N/A	N/A	N/A	N/A
Im et al. [2010]	.31	.42	.19	**.79**	N/A	N/A	N/A	N/A
Kijsanayotin et al. [2009]	**.43**	.20	.17	.24	N/A	N/A	.33	.10
Kleef et al. [2010]	**.36~.45**	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Zhou et al. [2010]	**.37**	.06	.22	.24	N/A	N/A	N/A	N/A

The fourth construct, Facilitating Conditions (FC), is found to have an impact on Use Behavior (UB). The moderating variables are Gender (GEN), Age (AGE), Experience (EXP), and Voluntary to Use (VOL) [Venkatesh et al., 2003].

Performance Expectancy refers to the degree to which an individual believes that using the system will help him or her increase job performance. *Effort Expectancy* is defined as the degree of ease associated with the use of system. *Social Influence* denotes the degree to which an individual perceives that important others believe he or she should use the new system. *Facilitating Condition* sindicate the degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the system [Venkatesh et al., 2003; Anderson et al., 2006; Aoun et al., 2010].

Previous UTAUT and technology-adoption related studies used various statistical methods in analyzing the results including multiple linear regression [Gupta et al., 2008], cluster analysis [Benslimane et al., 2004], covariance-based structural equation modeling (SEM) [Im et al., 2011; Xu et al., 2009] and SEM with partial least squares (PLS) technique [Anderson et al., 2006; Aoun, 2010; El-Gayar and Moran, Gsell, 2007; Gsell, 2009; Kijsanayotin et al., 2009; Udeh, 2008; Xu et al., 2009; Zhou, 2010]. Depending on the number of samples, the nature of data distribution and correlations, analysis techniques varies from setting to setting. <Table 1> summarizes the path coefficients found in example studies using the UTAUT framework with the highlight on the maximum coefficient value in each study. It appears PE was found to have the highest coefficients in most of the studies.

6. Cognition and Perception of Mixed Reality Visuals

With their spatial and interaction benefits from 3D generated models, MR visuals provide less abstract and more natural objects as compared to virtual reality objects. Thus, MR objects can improve the perception and cognition level by intrinsically providing a more meaningful form of graphic so as to communicate complex concepts [Dunston et al., 2002]. Complex concepts tend to require intensive information processing as well as intensive mental processing of task activities. By using MR technology, the visual representations with natural interaction are likely to improve productivity in decision making [Dunston and Wang, 2011]. Besides examining the overall acceptance of the system, the present research aims to study cognition and perception of potential users on various MR visuals in the InnovViz system. In cognitive system engineering where the human is treated as part of the system, or so-called *joint cognitive systems*, it is expected that the human who has more experience such as an ICT expert or an ICT-CEO will have better perception and cognition than those at junior management level or master students in strategy and innovation planning in ICT business [Nilsson and Johansson, 2006].

7. Research Method

The objectives of the study are twofold. 1) To examine the technology adoption of InnovViz MR and NN using the UTAUT model. 2) To investigate whether the three newly developed visuals are usable for showing data and company assessment. This section will describe the study constructs and hypotheses for both objectives.

7.1 Study Constructs for Technology Adoption

In this study we follow the UTAUT developed by Venkatesh et al. in 2003 except that specific perception about usefulness in showing data and assessment (UFS, UFA), the experience (EXP) and demographics – University (UNIV) were added to the model. Please note that Use Behavior (UB) construct in the original model was removed because InnovViz 2.0has not been commercialized as yet. <Figure 5> illustrates the study framework for technology adoption.

Hypotheses and sub-hypotheses from the UTAUT-based study framework areas follows :

H1 : Performance expectancy (PE) of participants will have a positive effect on behavioral intention (BI) to use the InnovViz.

H2 : Effort expectancy (EE) of participants will have a positive effect on behavioral intention (BI) to use the InnovViz.

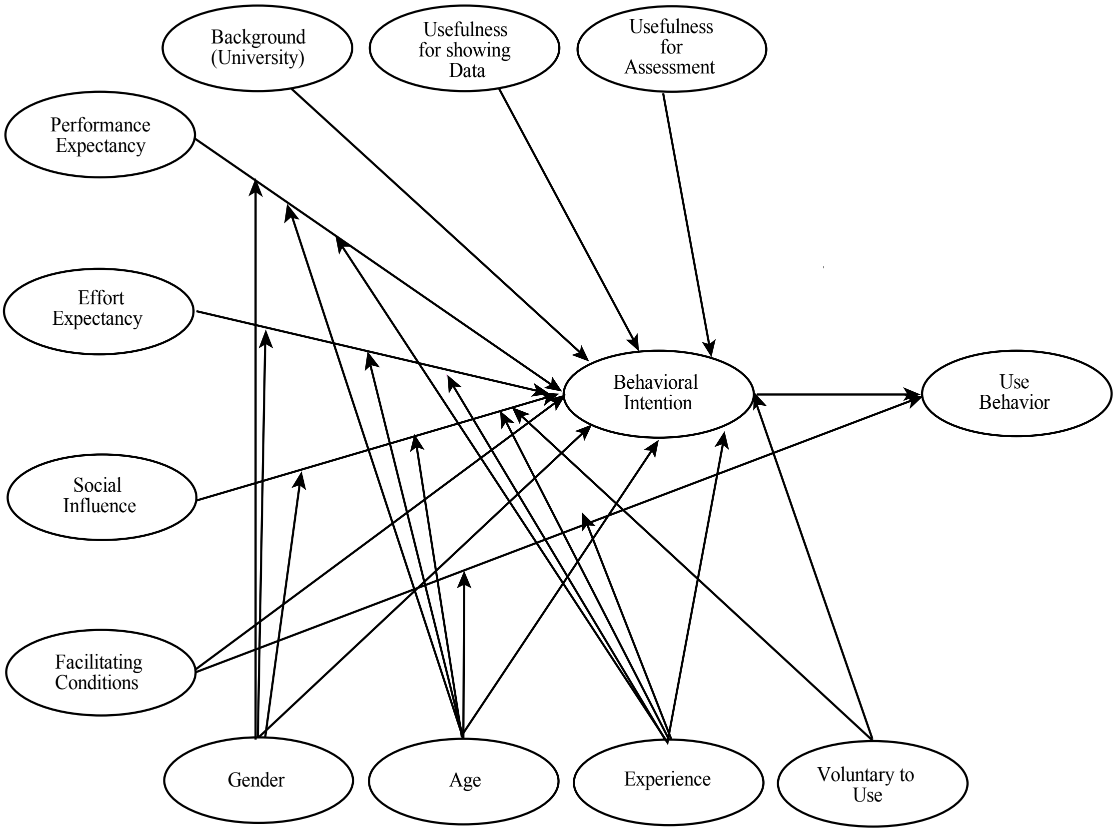
H3 : Social Influence (SI) of other participants will have a positive effect on behavioral intention (BI) to use the InnovViz.

H4 : Facilitating Conditions (FC) of participants will have a positive effect on behavioral intention (BI) to use the InnovViz.

H5 : Voluntariness to use (VOL) of participants will have a positive effect on behavioral intention (BI) to use the InnovViz.

H6a : Perceived usefulness for showing data (UFS) of participants will have a positive effect on behavioral intention (BI) to use the InnovViz.

H6b : Perceived usefulness for assessment (UFA) of InnovViz participants will have a positive effect on behavioral in-



〈Figure 5〉 The UTAUT-based Study Framework

tention (BI) to use InnovViz.

H7a : Higher years of experience (EXP) in business and technology of participants will have positive effect on behavioral intention (BI) to use the InnovViz.

H7b : Higher age(AGE) of participants will have a positive effect on behavioral intention (BI) to use the InnovViz.

H7c : Participants with different genders (GEN) will have different effects on behavioral intention (BI) to the use of InnovViz.

H7d : Participants from different backgrounds, or in this case university (UNIV), will have different effects on behavioral intention (BI) to the use of InnovViz.

7.2 Study Constructs for Information Processing and Cognition

"Learning in visualization use is learning about the dataset being visualized" as summarized by Chang et al. [2010], the present study is grounded in learner's self-reported assessment relating to the following constructs :

1. Cognitive processing measures (the amount of time spent and the complexity of in-

formation).

2. Perception measures of the interface system (ease of use, usefulness for showing data, and usefulness for assessment).
3. Knowledge drawn from the data representation measures (congruence between participant's rating versus expert's rating with the commonvisuals and common experimental data set).

If all other things are equal, between experts and master student participants, the information and cognitive loads from using a mixed reality interface system will be lower, system perception in terms of ease of use and usefulness will be higher, and knowledge drawn will be more consistent [Tanlamai et al., 2010]. Thus, hypotheses are posited as follows :

H8a : There is no difference between the cognition and perception of ICT experts seeing the InnovViz and master students with technical background.

H8b : There is no difference between the cognition and perception of ICT experts seeing the InnovViz and master students with business background.

7.3 Experiment Protocol

Each participant was first trained on the use of MR and NN technology within the InnovViz 2.0 for 20minutes. Tworeal entrepreneurial firm datasets (Company 003 and 004) were used to guide the participant aboutways of presenting, interpreting and simulating data. The participants wereinformed that they would be asked to assess a company's innovation, strategy and performance afterwards. Following the training, the master student participants were asked to use data from two different firms (Company 001 and 002) to assess their individual company status. Due to limited time, experts were asked to use data from a single firm (Company 001. The ratings from both groups were compared and the absolute different scores were treated as congruence measures.

In the present study, paper-based markers were developed as MR interfacesby authorsfrom the same sets of data [Larngear Technology, www.larngeartech.com.]. As shown in <Figure 6>, subjects were able to rotate the markers so as to view the graphs from every anglein a computing laboratory environment [Tanlamai et al., 2010].

〈Figure 6〉 Experiment Set up

7.4 Experimental Subjects

In order to compare the user's learning experience of innovation and strategy, we used real data for company 001 to compute the congruence ratings between experts and students and between students from two different backgrounds.

Experts consisted of top management from 4 leading ICT entrepreneurs who have very good understanding of the nature of ICT business in Thailand. Participants were master students in young executive programs with only a few years of experiences. They are from 2 leading universities, KMUTT and CU for short. KMUTT students are those in the Master of Science program who have a technology and innovation background and are from the graduate school of management and innovation. CU students are from the young executive MBA program with the majority focusing on the field of finance and accountancy. Each participant received a free lunch and a small souvenir for his or her participation. All experimental sessions were conducted in a computer laboratory (<Figure 6>).

7.5 Data Collection Instrument

The data was collected by a closed-end questionnaire, consisting of 5 sections as follows : 1) the assessment of the innovation and performance of Company 001 and Company 002; 2)cognition and perceived usefulness of the three InnovViz visuals : Cube, Tetrahedron and Saturn; 3) questions pertaining to the UTAUT constructs; 4) demographics and experience; 5) questions on the Voluntary to Useconstruct. Most items in the UTAUT-based model use a 7-point Likert scale, except for the 5 point scale being employed for the Voluntary to Useconstruct in the closing section.

8. Analyses and Results

This sectionconsists of 1) Descriptive statistics of young executive master students and experts. 2) Analyses and results of technology adoption and 3) Analyses and results of cognition and perception. Descriptive statistics and mean differences were analyzed and extracted from SPSS v17.0. The analysis of UTAUT was carried out by the partial least squares (PLS) method in path modeling. The reason why this technique was used was because, compared to MLR and covariance-based SEM, it was based on variance methods with fewerminimum requirements of normal distribution assumption, measurement scales and sample size. PLS consists of 2 equations : 1) the inner model and 2) the outer model. The inner model represents paths among constructs. The outer model refers to the relationship between indicators and constructs [Chin, 1998; El-Gayar and Moran, 2007; Gsell, 2009; Henseler et al., 2009; Hulland, 1999; Kijsanayotin et al., 2009; Ringle et al., 2007; Zhou et al., 2010]. In addition, bootstrapping is considered to complement nonparametric analysis because it can provide a t-statistic test and significant level. SmartPLS 2.0 M3 was used to conduct the mentioned analysis [Henseler et al., 2009; Ringle et al., 2007].

8.1 Participant Characteristics

Questionnaires were distributed during sessions of experiments to 161 young executive masterdegree program students. 96.89% (156 participant subjects) were complete and usable.

The experiments were conducted with students from two leading universities in Thailand. There were 115 (73.7%) first year students in the Young Executive MBA program, business participants here after, and 41 (26.3%) second year students in the Master of Science in Technology and Innovation program. Subject profiles included 88 (56.4%) males and 68 (43.6%) females. The majority of participants were young with 122 (78.2%) participants aged 21~30 years old. 144 (92.31%) of them had up to 5 years of strategic planning experience. Only 5 (3.21%) had more than five years of experience in innovation planning and more than ten years of ICT experience. Very few participants (1.3%) understood mixed reality or augmented reality technology. Also, none of the participants was familiar with neural network technology. Thus, the subject contents of the InnovViz were quite new to the student participants in this study. <Table 2> illustrates the participants' profile.

〈Table 2〉 Profileof Participants

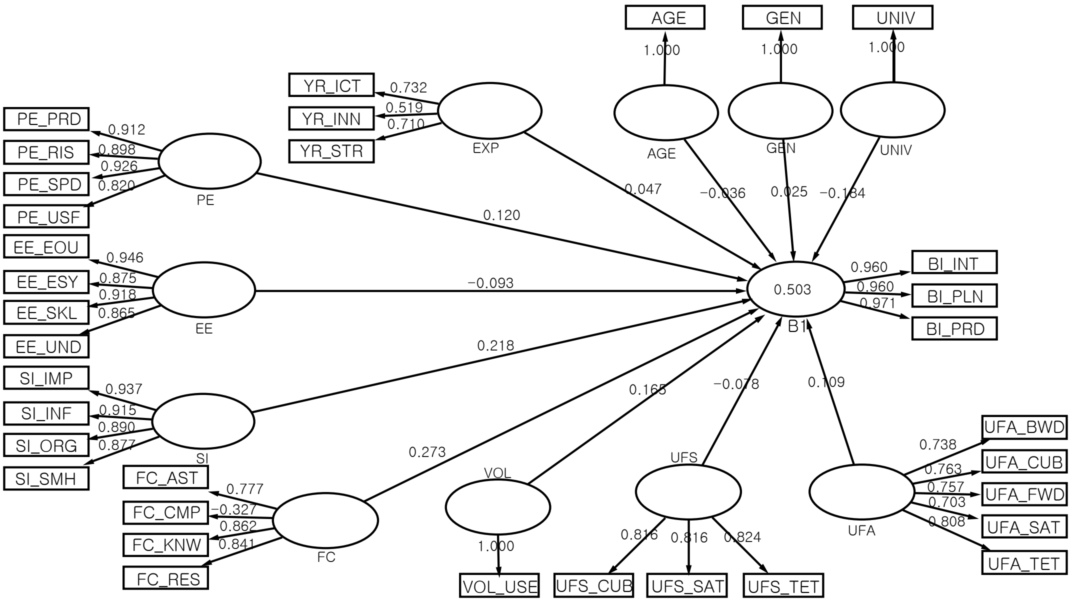
Attributes	Frequency
University	Technical : 41 (26.28%) Business : 115 (73.71%)
Gender	M : 88 (56.41%) F : 68 (43.59%)
Age	21~30 : 122 (78.21%) 31~40 : 31 (19.87%) 41~60 : 3 (1.92%)
Experience in Strategic Planning	0~4.9 : 144 (92.31%) 5~9.9 : 9 (5.77%) > = 10 : 1 (1.92%)
Experience in Innovation Planning	0~4.9 : 151 (96.79%) 5~9.9 : 4 (2.57%) > = 10 : 1 (0.64%)
Experience in ICT Business	0~4.9 : 131 (83.97%) 5~9.9 : 20 (12.82%) 10~15.9 : 4 (2.57%) > 20 : 1 (0.64%)
Know Mixed Reality Technology	Yes : 2 (1.28%) No : 154 (98.72%)
Know Neural Network Technology	Yes : 0 (0.00%) No : 156 (100.00%)

8.2 Expert Characteristics

Four experts from ICT software and service entrepreneurial firms were solicited to join the usability test of InnovViz 2.0. Two were CEOs from leading multi-touch application and online reservation system companies. The other two were senior business development managers from e-commerce education and e-commerce hosting businesses. All experts had an ICT background in programming or information management but none reported that they understood deeply in NN technology and only one knew MR technology. <Table 3> shows the experts' profiles.

〈Table 3〉 Experts' Profile

Attributes	Frequency
Title	CEO : 2 (50.00%) Bus. Dev. Mgr. : 2 (50.00%)
Gender	M : 2 (50.00%) F : 2 (50.00%)
Age	21~30 : 1 (25.00%) > 30 : 3 (75.00%)
Experience in Strategic Planning	0~4.9 : 1 (25.00%) > = 5 : 3 (75.00%)
Experience in Innovation Planning	0~4.9 : 2 (50.00%) 5~9.9 : 1 (25.00%) > = 10 : 1 (25.00%)
Experience in ICT Business	0~4.9 : 1 (25.00%) 5~9.9 : 1 (25.00%) > = 10 : 2 (50.00%)
Know Mixed Reality Technology	Yes : 1 (25.00%) No : 3 (75.0%)
Know Neural Network Technology	Yes : 0 (0.0%) No : 4 (100.0%)



〈Figure 7〉 PLS Results

8.3 Results of Technology Adoption

The results of technology adoption with modified UTAUT were analyzed for all participant datasets. <Figure 7> shows the diagram of path modeling, extracted from the result screen of SmartPLS 2.0 M3 with PLS algorithm. The model has anR^2 equal to 50.38%, which is considered to be moderate explanatory power. Please note that two popular models, MLR and SEM, were evaluated prior to the running of the PLS model. The two former models failed to have adequate explanatory power. MLR with all variables entered to predict the average Behavioral Intention (BI) had an adjusted-R^2 equal to 49.60% and a GFI equal to 0.67 (unacceptable threshold) when the SEM was used.

Convergent validity of each construct in the PLS model was tested with the statistic known as Composite Reliability (CR) [Fornell and Larcker, 1981; Henseler et al., 2009; Hulland, 1999]. CR, which is a preferred measure of internal consistency over Cronbach's alpha in this context, was suggested to be more than 0.70 [Hulland, 1999]. Another measure for validity is Average Variance Explained (AVE). It refers to average variance shared between the construct and its measures. It recommended that AVE should exceed 0.50 [Chin, 1998]. All constructs seemed to have good validity except experience

〈Table 4〉 Composite Reliability (CR) and Average Variance Explained (AVE)

Construct	CR, AVE	Construct	CR, AVE
PE	0.94, 0.79	UFA	0.87, 0.57
EE	0.94, 0.81	EXP	0.69, 0.44
SI	0.95, 0.82	AGE	1.00, 1.00
FC	0.72, 0.54	GEN	1.00, 1.00
VOL	1.00, 1.00	UNIV	1.00, 1.00
UFS	0.86, 0.67	BI	0.98, 0.93

〈Table 5〉 Loadings from the PLS Analysis Model

Construct		Description	Loadings	t
PE	Performance Expectancy			
	PE_PRD	Increase productivity	0.91	43.10*
	PE_RIS	Chances of getting raise	0.90	37.50*
	PE_SPD	Accomplish tasks more quickly	0.93	58.52*
	PE_USF	Useful in my job	0.82	14.60*
EE	Effort Expectancy			
	EE_EOU	Easy to use	0.95	91.18*
	EE_ESY	Easy for me	0.88	27.49*
	EE_SKL	Easy to become skillful	0.92	41.25*
	EE_UND Easy to understand		0.87	33.36*
SI	Social Influence			
	SI_IMP	Important Others	0.94	53.72*
	SI_INF	Influencers	0.92	40.41*
	SI_ORG	Organization Support	0.89	37.39*
	SI_SMH	Senior Management	0.88	32.77*
FC	Facilitating Conditions			
	FC_AST	Have assistance when facing difficulties	0.78	14.22*
	FC_CMP	System Incompatibility	-0.33	2.01*
	FC_KNW	Have knowledge	0.86	22.26*
	FC_RES	Have resources	0.84	21.19*
VOL	Voluntary to Use			
	VOL_USE	Voluntary to Use	1.00	N/A*
UFS	Useful Format for Showing Data			
	UFS_CUB	Cube useful for showing data	0.82	14.24*
	UFS_SAT	Saturn useful for showing data	0.82	18.67*
	UFS_TET	Tetrahedron useful for showing data	0.82	16.50*
UFA	Useful Format for Assessment			
	UFA_BWD	Backward simulation useful for assessment	0.74	10.47*
	UFA_CUB	Cube useful for assessment	0.76	11.86*
	UFA_FWD	Forward simulation useful for assessment	0.76	9.37*
	UFA_SAT	Saturn useful for assessment	0.70	8.30*
	UFA_TET	Tetrahedron useful for assessment	0.81	19.30*
EXP	Experience			
	YR_ICT	Years in ICT business	0.73	1.11
	YR_INN	Years in Innovation Planning	0.52	1.26
	YR_STR	Years in Strategic Planning	0.71	1.17
AGE	Age			
	AGE	Age	1.00	N/A*
GEN	Gender			
	GEN	Gender (Female = 0, Male = 1)	1.00	N/A*
UNIV	University			
	UNIV	Background of University (KMUTT = 0, CU = 1)	1.00	N/A*
BI	Behavioral Intention			
	BI_INT	Intend to use in 6 months	0.96	88.99*
	BI_PLN	Plan to use in 6 months	0.96	69.59*
	BI_PRD	Predict to use in 6 months	0.97	94.79*

Note) *** $p <= .001$, ** $p <= .01$, * $p < .05$.

(EXP). The experience construct consists of items that did not correlate to each other. Students who had high experience in ICT may be less exposed to strategy or innovation planning or vice versa. <Table 4> shows the CR and AVE of all constructs.

Outer loadings are presented in <Table 5>. All constructs are properly loaded by their indicator variables with value above recommended 0.70 except for the loading of Years in Innovation Planning (YR_INN) variable to Experience (EXP) construct. Therefore, EXP is neither considered reliable nor has significant loading to its indicator variables in this study.

Path model coefficients and hypotheses are summarized in <Table 6>. The following constructs have a positive effect on Behavioral Intention (BI), in descending order : Facilitating Conditions (FC), Social Influence (SI), Voluntary to Use (VOL), Performance Expectancy (PE), Useful Format for Assessment (UFA), Experience (EXP), and Gender (GEN). Also in descending order, the following constructs have a negative impact on Behavioral intention : University (UNIV), Effort Expectancy (EE), Useful Format for Showing Data (UFS) and Age (AGE). At 0.05 level of significant, only FC and VOL had positive impacts on BI.

〈Table 6〉 Hypotheses Summary

Hypothesis	Coefficient (Standard)	t	Support
H1 : PE → BI	0.12	0.87	No
H2 : EE → BI	-0.09	0.62	No
H3 : SI → BI	0.22	1.49	No
H4 : FC → BI	0.27	1.96*	Yes
H5 : VOL → BI	0.17	2.02*	Yes
H6a : UFS → BI	-0.08	0.52	No
H6b : UFA → BI	0.11	0.78	No
H7a : EXP → BI	0.05	0.42	No
H7b : AGE → BI	-0.04	0.41	No
H7c : GEN → BI	0.03	0.31	No
H7d : UNIV → BI	-0.18	1.89	No

Note) *** $p <= .001$, ** $p <= .01$, * $p < .05$.

While Venkatesh et al., suggested that FC had a direct influence on Use Behavior but not on the Behavioral Intention, results from the present study showed that FC and VOL play a significant role in the adoption of InnovViz 2.0. Almost all participants in the study were first-time users of MR. Thus, the link between FC and BI might be caused by the novelty effect of encountering new technology. Likewise, the three visuals introduced in the InnovViz-Cube, Tetrahedron, and Saturn-were seen as new and novel to the participants as well. A few participants pointed out that if they were more knowledgeable and had more training time, they would understand the holistic idea of the systemsand be able to assess a firm's performance better. Regarding Voluntary to Use, for those who have "free will", their perception toward the InnovViz was to commit to its future use because they were willing to try and learn new technology [Venkatesh et al., 2003].

With respect to the rest of the constructs, though not statistically significant, their coefficients and factor loadings can contribute to the future commercialized plan of the InnovViz. Constructs with the positive coefficients including SI, PE, UFA, and GEN will be analyzed further. As mentioned earlier, EXP has been ignored because of its low reliability level and small loadings. From the social influence viewpoint, the InnovViz should be targetedatinfluential users or key persons in the innovation and strategy planning areas, especially senior management. Nevertheless, gender difference seemed to affect technology adoption. Similar to the 2003 findings of Venkatesh et al. [2003], male participants were more comfortable with new technology than their female counterparts.

In order to address performance expectancy, the InnovViz ought to offer speed and productivity improvement to its users. As shown in <Table 6>, the relationship between behavioral intention and usefulness for showing data is not as high as that with usefulness for assessment. Participants perceived that Tetrahedron, forward simulation and Cube were the most advantageous features whereas backward simulation and Saturn wereless useful.

The AGE, UFS, EE, and UNIVconstructs were found to have negative coefficients with nostatistical significance. Younger participants tended to adopt new technology more easily. This is consistent with Venkatesh et al. [2003] and Anderson et al. [2006], Venkatesh et al. [2003]. The usefulness of showing data was not recognized as the key factor for technology adoption. Most students found InnovViz to be neither easy to use nor easy to become skillful at but the application could be adopted by a novice user if facilitating conditions are provided. This finding is contrary to previous studies but not to the surprise of the authors. This is because InnovViz has not been used commercially and training resources have not been made available for skill building as yet.

Participants from different universities differed in their adoption. Those with a strong technical background rated higher in InnovViz's adoption than participants with a business background. The former were in the second year of their master degree program in management science and had taken courses in strategic management and innovation management whereas the latter were in a typical MBA program with a financial and accounting concentration.

8.4 Results of Cognition and Perception

In this section, the analyses and results will be reported in four parts : 1) The assessment of Company 001 data by experts versus technically savvy participants. 2) The assessment of Company 001 data by experts versus business-driven participants. 3) The assessment of Company 002 by technical versus business participants. 4) A comparison of Cognition and Perception ratings between experts versus technical participants and between experts and business participants.

In performing the tasks, data from two companies, 001 and 002, was used. The experts were asked to assess only the data from Company 001 where a sparticipants at both universities were asked to assess the data from both companies. There were 9 questionnaire items being used. The first two items were for the company assessment of Innovation (1) and Strategy (2). The other seven items were used in the InnovViz NN model namely Superiority (3), Scale (4), Scope (5), Speed (6), Surrounding (7), Structure (8), and Specification (9).

The differences in means were tested between experts and technical participants in the assessment of Company 001. Results show that, at the significant level of 0.05, technical participants had a congruent opinion with experts for all aspects including "Innovation", "Strategy" and all other items except "Speed" and "Surrounding." Allexperts agreed that Company 001 had very good speed 6.00 (0.00) but technical participants assessed it to have only moderate speed 3.95 (1.44).

As shown in <Table 7>, there were more congruencies in the ratings between (A) experts and technical participants than (B) experts and business participants. Two out of nine items differed with statistical significance for the former and all except one item for the latter. This was expected since the technical participants had taken courses that covered innovation and strategy topics. Technical participants were more knowledgeable in the topics of the experiment than business participants. Interestingly, the only item that appeared to capture the different ratings by all three groups of experimental subjects was "Speed" and that was true for both company's data sets.

The different ratings between experts and business participants might be attributable to their lack of exposure to innovation and strategic management concepts. These business participants were first year MBA students who had only gone through basic business function courses. The participants indicated that they did not know the terminology used in innovation and strategy discipline.

Assessment ratings using Company 002 data were also compared between technical and business participants. The results showed 6 out of

〈Table 7〉 Mean Differences of the Assessment Ratings

Assessed Variables	Company 001					Company 002
	Experts (N1 = 4)	Technical Participants (N2 = 41)	Business Participants (N3 = 115)	(A) Expert-Technical t (N1, N2)	(B) Expert-Business t (N1, N3)	Technical-Business Participants (N1 = 41, N2 = 115)
Innovation	5.50	6.07	4.31	t =-1.32 (0.20)	t = 3.63 (0.02)*	3.14-3.30, t =-0.53 (0.60)
Strategy	5.25	5.78	4.70	t =-1.26 (0.214)	t = 1.02 (0.31)	3.48-3.29, t = 0.76 (0.45)
Superiority	5.75	5.76	4.00	t =-0.01 (0.99)	t = 5.93 (0.00)***	2.46-1.58, t = 3.84 (0.00)***
Scale	5.50	5.44	3.52	t = 0.08 (0.93)	t = 2.64 (0.01)**	2.63-1.83, t = 2.96 (0.00)***
Scope	5.75	5.46	4.54	t = 0.51 (0.61)	t = 2.47 (0.02)*	3.51-3.44, t = 0.40 (0.69)
Speed	6.00	3.95	4.50	t = 9.06 (0.00)***	t =15.09 (0.00)***	5.98-5.53, t = 2.18 (0.03)*
Surrounding	6.50	5.27	4.35	t = 2.47 (0.02)**	t = 4.99 (0.00)***	3.56-3.69, t =-0.68 (0.50)
Structure	6.00	5.56	5.02	t = 0.94 (0.35)	t = 2.28 (0.02)*	3.66-3.79, t =-0.58 (0.57)
Specification	6.25	5.46	4.70	t = 1.28 (0.21)	t = 2.40 (0.02)*	4.39-4.93, t =-1.93 (0.06)

Note) *** p < = .001, * *p < = .01, * p < .05.

9 items had equal means, consisting of Innovation, Strategy, Scope, Surrounding, Structure and Specification. The ratings for Superiority, Scale and Speed were not equal; technical participants ranked these three variables higher than their business counterparts. This might be attributable to the lack of industry benchmark information. Company 002 significantly underperformed Company 001 in terms of intangible assets and profitability. The Superiority score of Company 002 was at the 15.53^{th} percentile with a Scale of approximately 0.88 and a 2% Return on Sales (ROS). Company 001, on the other hand, was at a percentile of 69.90^{th} in Superiority with a Scale of 3.60 and a 25% ROS. Nevertheless, Company 002 was recognized as a speedy player in ICT innovation. Its Speed was rated at 4.40 from a possible 5.00as compared to 3.60 out of 5.00 by Company 001. Since no industry average was used as a frame of reference, this was the only comparison that could be done was from the assessment data of these two companies.

Turning from assessment to cognition and perception data, the results are shown in <Table 8>. The ratings between the two groups of participants, technical versus business, were obviously different. Again, cognition and perception ratings from technical participants were more congruent with those from experts, except

〈Table 8〉 Mean Differences of Cognition and Perception Ratings

Cognition	Expert-Technical	Expert-Business	Technical-Business
Information Complexity	4.00-4.07(t =-0.10)	4.00-2.63(t = 2.38*)	4.07-2.63(t = 6.63***)
Amount of Time Spent	4.50-4.78(t =-0.40)	4.50-3.02(t = 2.17*)	4.78-3.02(t = 7.31***)
Perception			
Ease of Use	6.00-2.78(t = 13.97***)	6.00-4.60(t = 9.91***)	2.78-4.60(t =-6.65***)
Frustrating to Use	5.25-5.09(t = 0.23)	5.25-3.23(t = 2.52*)	5.09-3.23(t = 7.49***)
Complicate to Use	5.00-5.32(t =-0.52)	5.00-2.76(t = 3.01**)	5.32-2.76(t = 9.99***)
Useful format for showing data (Cube)	6.00-6.00(t = 0.00)	6.00-4.83(t = 1.79)	6.00-4.83(t = 6.35***)
Useful format for showing data (Tetrahedron)	6.50-6.07(t = 0.92)	6.50-4.90(t = 2.15*)	6.07-4.90(t = 5.95***)
Useful format for showing data (Saturn)	4.50-6.07(t =-1.18)	4.50-3.87(t = 0.79)	6.07-3.87(t = 9.94***)
Useful format for assessment (Cube)	5.75-5.88(t =-0.29)	5.75-4.69(t = 3.74*)	5.88-4.69(t = 6.20***)
Useful format for assessment (Tetrahedron)	5.50-6.09(t =-1.35)	5.50-4.83(t = 0.94)	6.09-4.83(t = 6.86***)
Useful format for assessment (Saturn)	5.00-5.87(t =-0.81)	5.00-4.01(t = 1.27)	5.87-4.01(t = 8.97***)
Useful format for assessment (Forward Simulation)	6.25-6.10(t = 0.37)	6.25-5.49(t = 1.21)	6.10-5.49(t = 3.65***)
Useful format for assessment (Backward Simulation)	6.50-6.02(t = 1.09)	6.50-5.42(t = 1.71)	6.02-5.42(t = 3.426***)

*** p < = .001, ** p < = .01, * p <.05.

for "Ease of Use" where experts gave a rating of 6.00 and technical students 2.78, resulting in a. 001 level of significance. Business participants appeared to have a hard time with InnovViz. They rated the system to be less friendly to use as compared to the experts and the technical participants. In fact, the difference between the two groups of participants was astounding. Business participants found InnovViz to be complex and difficult to use.

Among different visuals being introduced in InnovViz, the Tetrahedron was perceived by experts as the most useful format for showing data, followed by Cube and Saturn. Nonetheless, Cube was perceived as the most useful format for assessment, followed by Tetrahedron and Saturn. Although Tetrahedron, Cube and Saturn are three-dimensional visuals that can reduce the cognitive load of decision makers, each visual seems to provide its own unique detailed information. Tetrahedron shows numbers without scale. Cube gives scale information of external factors and performance and size of firms without numbers. Saturn, however, providesa dynamic way of representing Scope and Speed information with neither scale nor numbers.

Both experts and students perceived simulation features to be useful. Experts perceived backward simulation as more useful than forward simulation while student participants perceived forward simulation as more useful than backward simulation.

As shown in <Table 8>, experts' self-ratings on cognition and perception itemswerehigher than technical participants and much higher than those rated by business participants. The results support the hypothesis that the greater the knowledge and experience of participants, the better the rating of cognition and perception of InnovViz given by the participants. In this particular case experts were the most experienced participants, followed by technical participants (second year) and finally business participants (first year).

The hypotheses H8a and H8b posited that there is no difference in the cognition and perception of experts about InnovViz as compared to both technical and business participants. The results show that H8a was supported but H8b was mixed since the experts' ratings were different (at .05 level of significant) from business participants in both cognition measures and six from twelve items of perception measures.

In the last section of the questionnaire, partic-

〈Table 9〉 Student's Voluntary to use and Behavioral Intention

Assessed Variables Levene TestF (sig)	Expert-Technical	Expert-Business
	Mean (SD)	Mean (SD)
Voluntary to Use F = 0.42(0.52)	4.50(0.58) - 4.39(0.74) t = 0.288 (0.78) df = 43	4.50(0.58) - 3.22(1.02) $t = 2.48(0.01)^{**}$ df = 117
Behavioral Intention F = 0.28(0.60)	4.25 (2.31) - 4.34 (1.45) t = -0.115 (0.91) df = 43	4.25 (2.31) - 2.45(1.30) $t = 2.65(0.01)^{**}$ df = 117

Note) $^{***}p <= .001$, $^{**} p <= .01$, $^{*} p < .05$.

ipants were asked about their Voluntary to Use. The result is shown in <Table 9> along with Behavioral Intention (BI). Technical participants responded in a similar way to experts that had volunteered to use and intended to use InnovViz with relatively high value. In contrast, business participants reacted in a different manner; they were less voluntary and had less intention of using InnovViz.

9. Discussion and Conclusion

This study aims to test technology adoption with the UTAUT model and cognition and perception of InnovViz with experts and student participants. Surprisingly, Facilitating Conditions (FC), the only construct from four key constructs in the UTAUT model, was found to be significant. Voluntary to Use from the original model which indicated the effect on Use Behavior, however, in the present study was found to have an effect on Behavioral Intention (BI).The results are similar to those found in the Anderson et al., 2006 study. FC had the highest impact on BI, though not as measurably significant as in the case of Tablet PC adoption in a faculty setting [Anderson et al., 2006]. Aoun et al., 2010 discovered that FC had an equally high influence as BI on Use behavior under an accounting information system (AIS) usage [Aoun et al., 2010]. Hart and Henriques et al. 2006 also found that FC influenced usage of a decision support system (DSS), however, their study was based primarily on TAM and a few detailed measures within the FC construct [Hart and Henrique, 2006]. Novel users who were willing to use the software expected that they should be provided with facilitating conditions including knowledge, resources, assistance and compatibility respectively.

Path coefficients of Performance Expectancy (PE) and Social Influence (SI) were found to be positive, which is consistent with previous studies as shown in <Table 1>. Kleef et al. [2010] studied the AR business model and found that in AR application, performance expectancy influenced positively behavioral intention but constructs were rearranged from the original UTAUT and the number of subjects was too small (N = 49).

From the loadings shown in <Table 5>, InnovViz would accelerate user speed to accomplish their tasks and increase their productivity. In addition, important others and key influencers in business or technology areas should become lead users of the InnovViz. Age and gender were found to be consistent with previous studiesandyounger generation participants were more salient than older ones and male participants were given social roles to be task-oriented and to handle all technically complex tasks [Tufte, 2001]. The negative path coefficient of Effort Expectancy and the significantly positive coefficient of the Voluntary to Use shown in the results implies that although the InnovViz is pretty difficult to a certain extent in the beginning, users find the system to be challenging and quite attractive to use. These naïve users might draw on it in the future when they have moved along their learning curve at a faster pace. Unlike TAM's Ease-of-Use construct, this finding was somewhat contradictory - intending to use despite its difficulty during the first trail.

Regarding subject contents, experts and technical student participants embraced MR and NN technology within InnovViz 2.0 more than business users did. Notwithstanding, from the authors' introduction to the InnovViz, this system was originally targeted for "business" managers to analyze and plan innovation and strategy within an organization. With complex data and a relatively difficult to use system, business users were hindered from voluntariness and intention to use. This problem, however, should be solved by future system development and diffusion strategy that will ensure a smooth transition from innovators to early majorities of the target segments.

Concerning the perception of the three new visuals being introduced to users, Useful format for showing data (UFS) was found to have a negative impact on BI while Useful format for assessment was found to have a positive impact. This implies that InnovViz will be seen as useful, if and only if, there are features for company assessment that helpin strategic decision making. Referring to the level of usefulness for assessment as shown in <Table 8>, experts seemed to appreciate the more holistic view of information garnered from Cube. Technical students and business students preferred Tetrahedron. Saturn was least appreciated by all participants. The reason might be that Saturn did not provide scale or number on its rotating graphics. While cube is agraphic with scale, tetrahedron is a graphic with number but without scale. In future product developments, all visuals will provide graphics with number and scale to improve usefulness in assessment especially during the comparison of company strategy and innovation. The astounding dynamics during the rotation of Saturn can easily attractusers to only a certain level if the processing power of graphical display is not adequate.

Forward simulation was perceived by student participants that it was useful for assessment, however experts reported differently. Backward simulation was important because, in practice, managers set the goals or performance targets of an organization before performing resource allocation. Forward planning was considered among practitioners as simulating incremental changes in the resources that would affect performance.

Results from the adoption, cognition and perception should be cautiously interpreted. Students with voluntary to use may not be the ones who can make the decision to purchase InnovViz when it starts to be commercialized. In addition, the system should continue to reduceits difficulty to use since Effort Expectancy was found to be negative to Behavioral Intention.

Nevertheless, experts embraced InnovViz 2.0entirely. Therefore, if one were to do an adoption test using the Innovation Diffusion Theory, experts and business users should then be treated as innovators or lead users/influencers while technical users might be the early adopters of the system.

Findings from the study significantly shed light on how radical technology such as mixed reality integration with a neural network can be included in business applications. Facilitating conditions, voluntariness to use, perceived usefulness in assessment of visuals and simulations and an adequate level of technical skills to handle system complexity were found to influence the adoption of InnovViz 2.0.

9.1 Limitation and Future Research

Though we leapfrogged the development of strategic information system by integrating NN simulation and interactive presentation layer with MR technology, MR can be inflexible because it requires a camera or webcam to read the data. The size of markers and the distance between the webcam and where the markers will be handled by a user also affects the projection angle and the quality of the 3D objects [Savetpanuvong et al., 2011].

Future research should address three issues : 1) Design of experiment and facility, 2) Experimental subjects and 3) Product development.

Regarding the design of experiment, future research should be designed to test two different modes of strategy and innovation planning tasks and measure user productivity by including 1) traditional planning with a spreadsheet table and 3D-on-2D visual created by spreadsheet program and 2) innovative planning with InnovViz 2.0. Facilitating conditions should be improved to ensure that lab facilities have adequate processing power for rendering 3D graphics from InnovViz. Aquick start guide of system, Q&A during the training and more technical support staff, and additional time should be provided for business users to digest complex information and familiarize themselves with the system. Given that these facilitating conditions are satisfied, the authors expect that other UTAUT constructs including Performance Expectancy, Effort Expectancy and Social Influence might play a more important role in technology adoption. In case InnovViz is distributed as an evaluation license for a trial period, another element of UTAUT dependency construct data, Use Behavior, should be collected. Novelty effect from time constraints with the present experiment mightbe removed. Alternatively the perceived innovativeness construct can be tracked for both pre-test and post-test items. On the topic of experimental subjects, items enquiring about knowledge and background information, such as the subject's position in organization, industry sector, nature of their planning work and so on, should be more detailed, especially for those who indicate their voluntary to use. In addition, extended testing of InnovViz with other student groups who might have higher management positions, such as the executive MBA students, should be investigated as well.

Future product development should correct the design pitfalls in terms of the inconsistency of design of the 3D visualsin the InnovViz (Cube, Tetrahedron, and Saturn). Based on Tanlamai and Soongsawang's study in 2011, Graph with Number (GWN) comforted business analysts in making decisions [53]. Thus, effective InnovViz's visuals should be designed with the theme of 3D graphics with both number and scale so as to be useful in assessing either a single company's performance or a comparison of performances from two or more companies. Any new visuals should be carefully designed and tested for their perceived usefulness in assessment if they are to incorporate dynamicity. The current version of InnovViz has addressed compatibility and ease of use by incorporating interfaces with a spreadsheet program. In future releases, the system will be developed so that it can integrate with other office automation software, de facto financial reporting tools, business intelligence and the internet without compromising the performance of the system.

Even though representation of the abstract concepts in innovation and strategy in a real 3D object have been found astonishing to users, the interpretation of visuals and numbers into meaningful business terminologies are recommended by experts in any future product roadmap. How Scale, Scope, and Speed are visualized in the Tetrahedron visual can easily be translated back to business terms, however, the development budget for those visuals can be quite high. Whilst future research should prepare to answer the following questions to a business user : 1) What amount of innovation capital investment does Scale with 3.00 refer to? 2) What combination of innovation portfolio does Scope with 3.5 denote? and 3) What if we increase Speed from 4.0 to 4.5, how much budget will we need? Also, to address usefulness for assessment, industry average information should be provided as additional reference visuals.

Long-term future research should incorporate the study of other competitive industrial sectors, such as retail, finance, and fast-moving consumer goods [Tanlamai et al., 2010]. It is also possible to explore a different type of unit of analysis, i.e. from the competitiveness level of company to company into nation to nation competitiveness level by focusing on the same ICT software and service industry but in other global settings such as Bangalore or Silicon Valley.

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