Conjoint analysis and virtual reality : a review

Conjoint Analysis and Virtual Reality – a Review

Jan Dijkstra
Harry J.P. Timmermans
Eindhoven University of Technology
Department of Architecture, Building and Planning
Eindhoven
The Netherlands

ABSTRACT

This paper describes a review of an ongoing research project which aims to develop a conjoint analysis and virtual reality (CA&VR) system as part of a design information system in virtual reality. The research project aims to develop a design system that can be used for interactive design and evaluation of design alternatives. A virtual environment model and dynamic virtual objects representing the different design aspects of interest can present a design. The different design aspects are called attributes. Each attribute level is a different state of the concerned virtual object. In the case of a virtual walk through a building design, the system can be viewed as a visual simulation of the environment. The CA&VR system has the potential advantage that individuals' preferences can be measured in designed hypothetical choice situations. As part of the ongoing research project, principles underlying the CA&VR system will be illustrated by simple examples. The status of this research project, both in retrospect and in prospect will be described.

1 INTRODUCTION

Conjoint analysis or experimental choice analysis represents a widely applied methodology for measuring and analyzing consumer preferences. Conjoint analysis is a generic term coined by Green and Srinivasan (1978) to refer to a number of paradigms in psychology, economics and marketing that are concerned with the quantitative description of consumer preferences or value trade-offs (Timmermans, 1984; Louviere, 1988). Conjoint analysis sometimes also referred to as stated preference modeling involves the use of designed hypothetical choice situations to measure individuals' preferences and predict their choice in new situations (Oppewal, 1995). Conjoint experiments involve the design and analysis of hypothetical decision tasks. Multiple hypothetical alternatives (product profiles) are generated according to the principles underlying the design of statistical experiments and presented to subjects, who are requested to express their degree of preference for these profiles. Most applications of conjoint analysis involved a verbal description of product profiles, although some studies have used a pictorial presentation. Virtual reality systems offer the potential of moving the response format beyond these traditional response modes.

This paper describes the status of an ongoing research project, which aims to develop such a conjoint analysis and virtual reality (CA&VR) system. Such a system is of particular interest when subjects have to experience the context of choice and/or the attributes describing the choice alternatives. You can take this argument one step further and to explore the possibilities of using such a system as a decision-making tool.

This paper is organized as follows. First, we will discuss the research project intentions. The definition of the problem and the research objectives will be considered. Then, in section 3, we will give a retrospect of our research efforts. We will look back at simple illustrations of conjoint experiments and decision-making to illustrate the potential of a CA&VR-system. In section 4, we will consider the prospect of our research. We will discuss future directions, the refinement of the CA&VR-system and additional methodology for advanced problems. We will finish with a brief discussion.

2 RESEARCH PROJECT INTENTIONS

This research project is part of the VR-DIS research platform on the development of a design information system in virtual reality. VR-DIS (Virtual Reality – Design Information Systems/Distributed Interactive Simulations) aims to develop a design system that can be used for interactive design and evaluation using a VR interface. The objective of our research project is to investigate and develop possibilities of a VR-DIS system in those cases where choice behavior and decision-making processes of consumers are important.

Most studies of conjoint analysis have involved a verbal presentation format, although some studies used a pictorial presentation format. There is a potential lack of realism with such traditional presentation formats, possibly this influencing the choice behavior of interest. The problem definition can be formulated as follows: is it possible to use a presentation format based on virtual reality in conjoint analysis? Therefore, the ultimate goal of this research project is the development of a research tool based on conjoint analysis as part of a VR system. This system should support the interaction of a subject with a profile alternative, which brings the subject in a 'state of mind' that better resembles the actual decision-making more closely.

Buildings and especially public spaces are not designed for a single user, but are more typically designed with various users in mind. The task of the designer is to create spaces that meet particular criteria. To the extent that the performance of the building or public space is dependent upon how users react in that particular environment, the a priori evaluation of design alternatives depends on how successful one is in predicting user behavior and user satisfaction in that particular environment. We suppose that a CA&VR-system has the potential advantage that user behavior can be observed for various design alternatives, before the building or public space is actually build. Product profiles are generated in a virtual environment and subjects are requested to choose in that virtual environment the profile they prefer. In subsequent stages of the research project, we will examine in depth the different parts of the CA&VR-system. Also we will investigate whether the analysis of the conjoint data should be part of such a system or that the presented data should be analyzed with conjoint analysis software. In this context, the question whether additional methodology needs to be developed is desirable.

3 RETROSPECT

In this section, we review our research project findings over the last two years. Before discussing some research intentions, some basics of conjoint analysis and virtual environment will be explained first to better understand over accomplishments.

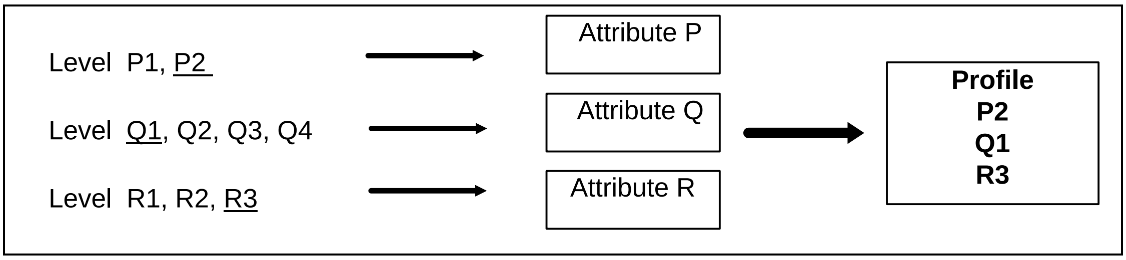
3.1 **Conjoint measurement and virtual environment**

Conjoint analysis is a family of related techniques for measuring user preferences or choice behavior. It helps to understand why consumers prefer or choose certain products or services, perhaps in new conditions.

3.1.1 *Traditional conjoint analysis*

The application of conjoint analysis techniques implies the study of the joint effects of multiple product attributes on product preferences or product choice. In a conjoint study, a researcher (i) select the attributes (characteristics) that are assumed to influence the choice behavior of interest, (ii) classifies these attributes into numerical or categorical levels, and (iii) combines these attribute levels into profiles according to some statistical design. Thus, the researched products are described in terms of profiles. Each profile is a combination of attribute levels for the selected attributes.

Figure 1: **Relationship among a profile, attributes and levels**



Conjoint analysis has two major objectives: (i) to determine the contribution of predictor variables (attribute levels) to consumer overall preferences, and (ii) to establish a valid model of consumer judgements useful in predicting consumer acceptance of any combination of attributes, even those not originally evaluated by consumers (Hair *et al*, 1995). In order to achieve these objectives, coefficients called utilities (or part-worths) are estimated for the various attribute levels making upon the alternatives of interest by decomposing the measured overall preferences for product profiles into these part-worth utilities according to some a priori defined combination rule which specifies how subjects are assumed to integrate those separate part-worth utilities to arrive at an overall preference or choice. The profile utility is an overall utility or 'worth' of a profile calculated by combining all utilities of attribute levels defined in that profile, according to the assumed combination rule. Fig.2 gives the example of an additional rule.

Figure 2: **Preference measurement in conjoint analysis**

$$U_j = \sum_{i=1}^{N} x_i$$

, U_j = overall utility of the profile alternative j

x_i = 'part worth' of the I-th level of the x-th attribute

N = number of attributes

3.1.2 *Experimental designs*

To allow an unbiased estimator of the assumed combination rule, the attribute levels need to be varied according to some experimental design that satisfies the necessary and sufficient conditions to estimate the rule of interest. Thus, consequently, profile construction in conjoint analysis involves determining which attributes to present to subjects, and how to present these attributes. In a conjoint experiment, first the key dimensions (attributes) of products or services are defined. Next, the levels of each attribute are specified. The chosen attributes and their levels should be realistic and relevant to the problem. Also, the ultimate definition of attributes and their levels will be influenced by the possibilities of constructing a suitable experimental design. That is, the design should satisfy the necessary and sufficient conditions, required to estimate the assumed preference or choice model that describes the way in which subjects are assumed to arrive at some choice or preference. Traditionally, in axiomatic conjoint measurement, the focus is on testing the structure of preference functions, that i.e., whether preference functions are additive, multiplicative or combined additive-multiplicative. More recently, preference functions are estimated from experimental design data using an appropriate multivariate statistical technique. Conjoint experiments thus require subjects to express their preference for various experimentally designed hypothetical alternatives in terms of their most relevant attributes. Two or more fixed levels are defined for each attribute and these are combined to create different profiles. Subjects are invited to express their preference for the experimentally varied profiles by rating or ranking these in terms of overall preferences. Alternatively, subjects may be asked to choose the profile they like best. Preference functions are estimated from this data. Obviously, the number of possible combinations increases exponentially with an increasing numbers of attributes and/or levels. Fortunately, the data collection can be greatly reduced by using fractional factorial design techniques (Montgomery, 1991). In analysis-of-variance terms, this often means that only main effects are estimated. Therefore, an experimental design is defined by an optimal subset of profiles of a fractional factorial design, which can be presented to a subject without negatively influencing responses in terms of boredom or fatigue.

A subject's preferences are decomposed into part-worth utilities, which represent the contribution to the individual's overall preference or utility of the attribute levels that were used to generate the profiles. If one wishes to construct a choice model, the attribute profiles have to be placed into choice sets. Subjects are then asked to choose one alternative from each choice set, or alternatively, to allocate some fixed budget among the choice alternatives.

In experimental designs, attributes are termed 'factors'. The goal is to structure the data collection process in such a way that the identification possibilities for the utility function are maximized. In a full profile approach, a distinction is made between a full factorial design and a fractional factorial design. A Full Factorial (FF) design contains descriptions of all possible combinations of attribute levels. It enables one to independently estimate all main effects and all interaction effects of each attribute. On the other hand, a fractional factorial design contains a fraction of a FF design. It assumes that certain interaction effects among the attributes are not statistically significant.

3.1.3 *Virtual environments*

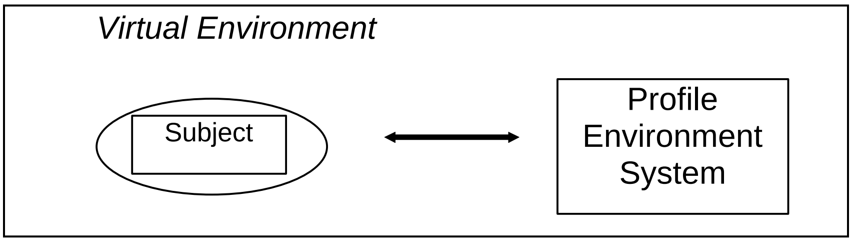
In architectural and real estate simulations, it is interesting to get as realistic as possible impressions of a designed model by means of virtual reality. The user has an active involvement in VR and is not a passive observer. The user becomes an essential participant in the virtual environment with unlimited freedom to explore, control and change it. The only limits are those set by the designers of the virtual environment. VR techniques can be used to create an interface that allows modeling in an intuitive way. Through the imitation of behavioral aspects of the real world, the interface gets predictable and recognizable characteristics. In fact, simulation based design technologies within VR technology enhances the capabilities of the design to the manufacturing process. The product can be visualized, design changes can be made, and new concepts, without the traditional expense of prototyping, can be tested. Advances in VR techniques enable users to be immersed in new environments and experience new products or services. This aspect is of interest to get a better insight into user behavior and support product testing in its most general meaning.

3.2 **The CA&VR-system concept**

Most studies of conjoint analysis involve verbal descriptions of product profiles, although some studies have used a pictorial presentation of product profiles. Klabbers *et al* (1996) propose a multimedia engine for stated choice and preference experiments, which enables researchers to use varying presentation formats thereby measuring the influence of the presentation format. In our research project, profiles presented by a virtual reality presentation format, are for conjoint measurement. In a CA&VR-system we have in mind an integration of conjoint measurement and virtual environment. A concept of a CA&VR-system is developed in Dijkstra, Roelen and

Timmermans (1996). In this concept, virtual reality depicts product profiles in a three-dimensional environment and allows subjects to interact with these product profiles. A profile consists of a virtual environment model and dynamic virtual objects representing the attributes with respective levels. Each attribute level is a different state of the concerned virtual object. Both the virtual environment and objects model can be designed by 3-D graphical and virtual reality software.

Figure 3: **Interception between subject and a generated product profile**



This concept of a CA&VR-system is motivated by the possibility to create 3D representations of environments, varied according to the principles of experimental designs, thereby reliving the controlled observations of user reactions to design alternatives. By recording these observations in a particular way, various statistical and other methodologies can be applied to evaluate design alternatives or predict user reactions to possible future situations.

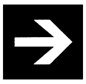
3.3 **Illustrations of conjoint measurements**

In this section we will look back at some simple illustrations of conjoint measurement that we developed over the last two years. Initially, to show the potential of the CA&VR-system concept these simple illustrations have been made within the context of wayfinding. First, we will discuss some aspects of wayfinding.

3.3.1 *Wayfinding concepts*

Most settings are laid out in a plan people can relate to and which allows them to determine their location within the setting, determine their destination within that setting, and form a plan of action that will take them from their present location to their desired destination. The representation people have of their surrounding environment is a psychological concept that underlies the notion of spatial orientation. This is called a cognitive map, which is an overall mental image of the spaces and the layout of a setting. Wayfinding concerns the spatial organization of the setting, the circulation system and architectural as well as graphic communication. It can be described as all perceptual, cognitive, and decision-making processes necessary to find one’s way, that is as a mental and physical act of reaching destinations (Arthur and Passini, 1992). The process of reaching a destination is best defined as spatial problem solving, comprising the interrelated processes of decision-making (make a plan of action) and decision execution (transform the plan of action into appropriate behavior). Besides the spatial problem solving aspect, there is also the architectural and graphic communication aspect of wayfinding. The spatial organization of a setting and the circulation system determine the nature of wayfinding problems. Environmental communication provides the information necessary to solve wayfinding problems. In terms of wayfinding communication, designers have to respond to three major questions: what information should be presented, where and in what form (Passini, 1996). Therefore, the design part provides information, identified by three aspects:

content of information



location of information

form of information

People tend to feel disoriented when they cannot situate themselves within a spatial representation and when, at the same time, they do not have or cannot develop a plan to reach their destination. The decision to find one’s way can only be made by receiving adequate information through perception, cognition and exploration. Developing signs can solve wayfinding difficulties. In virtual wayfinding, the visual environment will be simulated and people are located at a virtual setting in this environment. They find their way from the present location to a desired destination by making a walk-through in the virtual environment. During virtual wayfinding, people will select that information which is relevant to their task. Information, based on the three aspects of information mentioned before, will be presented as different virtual design objects in the virtual environment.

3.3.2 *The wayfinding experimental design*

Graphic communication may at least partially compensate for possible flaws in architectural design. In Dijkstra *et al* (1996) and Dijkstra *et al* (1997b), an illustration of wayfinding was given with the focus on this aspect which often is of crucial importance in facility management. Thus, in the experimental design, only the design part of wayfinding, especially the graphic communication as part of the environmental communication will be considered. Graphic communication includes signs, maps, directories and good sign-posting, etc. In graphic communication, functional information type will be emphasized. That is, functional information type is considered in relation to those things that people need in information settings: (i) information about the settings, the way it is organized (information to make decisions), (ii) information directing them to their location (information to execute decisions) and (iii) information identifying the destination on their arrival (information to conclude the decision-making/execution process). These types of information comprise attributes in the CA&VR-system. Each of these attributes has two levels. Together, the number of attributes and their associated levels comprise the design specifications.

The experiment will also measure the travel-time from the entrance to destination.

To appreciate the potential contribution of the CA&VR-system, we let subjects experience two possible guidance alternatives and ask them to express the one they prefer. Obviously, this is the simplest application that stays closest to the traditional use of conjoint choice and preference models. However, we could also think of an experimental task in which subjects are invited to find a destination. In that case, we could measure whether they found the target destination and if so, how long it took to reach the destination.

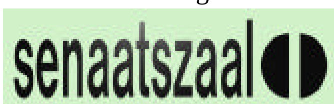
Figure 4: **Experimental design specifications**

Attribute	Level	Description
◊ Orientation	⇒ Floor plan ⇒ Directory	Ability to perceive an over-view of a given environment
◊ Directional signage	⇒ Text besides arrow sign ⇒ Text inside arrow form	Guides people along a desig-nated route to a destination
◊ Identification	⇒ Name ⇒ Sign with name	Information provided at the destination

For instance:

Identification: Name

Identification: Sign with name



3.3.3 *The application of conjoint measurement as a dynamic decision making tool*

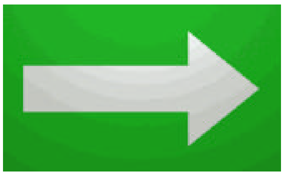
In the previous illustration, one is primarily interested in understanding the contribution of attributes of the guidance system on users' preferences. However, if may well be that the researcher's or designer's interest goes beyond this problem. For example, the question of interest might be whether subjects were successful in finding an exit, or in the time it took them to find an exit. In these situations, the dependent variable of the model shifts from a ranking, rating or choice to a dichotomous yes/no variable or a time variable respectively.

Figure 5: **Design specifications of the illustration**

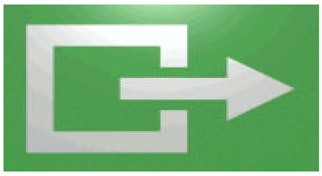
Attribute	Level	Description
◊ Directional Exit-sign Location	⇒ Fixed at wall, column ⇒ Fixed at ceiling	Guides people along exit-route to exit
◊ Directional Exit-sign Type	⇒ Exit sign I ⇒ Exit sign II	Guides people along exit-route to exit
◊ Exit Identification	⇒ Exit Font I ⇒ Exit Font II	Information provided at exit

For instance:

Exit sign Type I



Exit sign Type II



The given illustration of virtual wayfinding is really a dynamic decision making process. Decisions will be made real-time and also the time dimension had been considered. Indications like signs presented as different virtual objects could be tested for their suitability. After a fire alarm and during a smoke production, an individual should find his way to the exit within a certain period. Thus, the time-pressure aspect had been involved. Maybe, we could get answers on the questions how subjects deal with dynamic tasks and about how adaptive their behavior is. The perception of virtual objects in the virtual environment gives the necessary feedback. The illustration of virtual wayfinding is a matter of functional simulation. As a consequence, a decision about the actual signage can be proposed. It is possible that a potential difference between this actual signage and the preferred signage is the consequence.

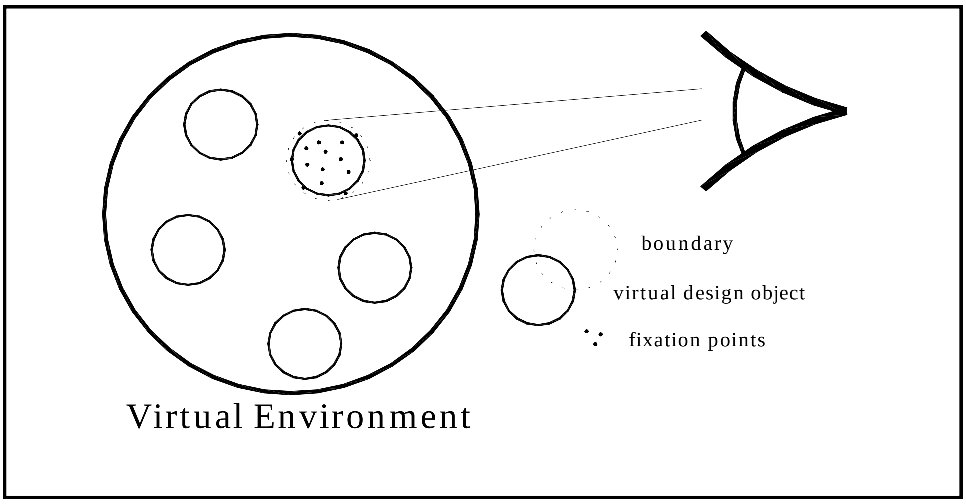
3.3.4 *Eye tracking as a user behavior registration tool*

User behavior may be recorded in different ways. In Dijkstra *et al* (1998) the focus is on perceptual aspects of user behavior. How to record user perceptions of virtual environments, especially with respect to specific design concepts which are of interest to the designer/researcher. In this illustration the concept of a CA&VR-system is extended to an evaluation tool based on user perceptions, obtained by eye tracking techniques.

By eye tracking techniques, it is possible to monitor the orientation of eyes, and thus the direction of gaze. The ability to track the direction of gaze enhances the communication between the subject and the computer. The amount of potential information transfer can be increased by using the information about what the subject is looking at, and even designing objects especially intended for the user to look at. By monitoring the subject, the computer can react to all kind of gestures. To what extent

users are interested in specific design concepts can be based on measurement of visual attention by eye movements. The perception of a scene in a virtual environment involves a pattern of fixations, where the eye is held fairly still, and saccades, where the eye moves to foveae a new part of the scene. Eye movements can be measured by eye tracking techniques. In our research we are particularly interested into user behavior concerning charming design concepts and/or effectiveness of design concepts. Eye movement measurement allow one to determine which areas of the scene in the virtual environment act as visual attention fields on which the eye focuses and with longer duration of fixation.
We think about the head-mounted eye tracking system as the most convenient system because the user travels through the virtual environment with fewer restrictions.

Figure 6: **Visual attention field**



With regard to conjoint analysis, we have seen that conjoint analysis involves the use of designed hypothetical choice situations to measure individual preferences and predict their choice in new situations. Conjoint experiments involve the design and analysis of hypothetical decision tasks. Alternatives will be described by product profiles and the researcher, in contrast to observed behavior in real choice situations has specified product profiles. Although conjoint analysis has been applied typically for measuring preferences and choices, the underlying principles can also be used for measuring perceptions. Experimental designs can still be used to vary design parameters or solutions of interest. Rather than measuring preferences or choices, the interest in this case shifts to user perceptions.

In this way, the application of a CA&VR-system is not restricted to problems of preference and choice but can also be applied to perceptual issues. With respect to the case of virtual wayfinding, we consider the functional design aspect of wayfinding with emphasizes graphic components. This means we look at information that gives users an overview of where they are, and where the destination is. In this illustration the attribute ‘orientation’ involves the ability to perceive an overview of a given environment, which has two proposed levels: ‘floor plan’ and ‘directory’. Also other graphic components can be considered. A given situation of the graphic component attributes represents a product profile. In this case of virtual wayfinding, indications like signs presented as different virtual design objects could be tested for their suitability. The perception of virtual design objects in the virtual environment gives the necessary feedback. With a head-mounted eye tracking system, this feedback will be given by measuring the duration of fixation on the visual attention fields of virtual design objects. As a perceptual task becomes more difficult, by definition, time to perceive objects increases. In a perceptual task that involves scanning virtual design objects, this change is correlated with a change in one or more eye movement parameters. The parameters of eye movement involved in the perception of virtual design objects are duration and the location of eye fixations. Fixation time on attributes can be assumed to reflect the effectiveness of the concerned attributes. Randomization in experimental design helps to reduce undesirable effects of a subject’s expectations and strategies.

4 PROSPECT

In the previous section, we have demonstrated the potential of a CA&VR-system as a research tool for conjoint analysis, not only for traditional conjoint analysis, but also as an evaluation tool for decision-making processes and user perceptions. The promising results we obtained for testing a prototype, warrants the actual testing and applying of the system to particular empirical problems, involving actual data collection.

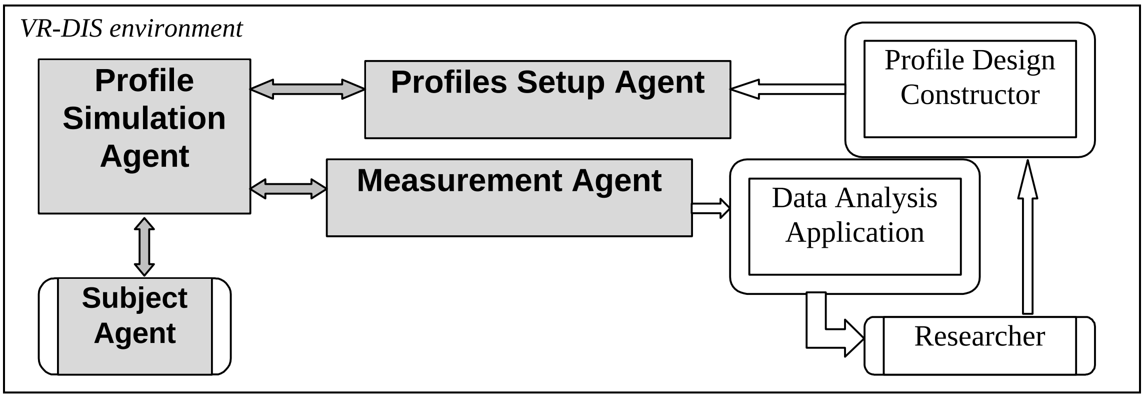
It is our intention to start this process in the near future. First, however, some problem-specific issues need to be explored in more detail. In particular, the framework of the CA&VR-system needs to be refined, attention should be paid to possible pitfalls and the reliability and validity of the proposed concept should be examined.

In this section, we will discuss some of the issues that need to be further developed. In particular, an outline of the CA&VR-system concept, some issues in modeling virtual environments and methodology as a reflection for future research.

4.1 **The CA&VR-system**

In Huhns *et al* (1998), agents are defined as active, persistent (software) components that perceive, reason, act, and communicate. Partly, the CA&VR-system can be considered as a multi-agent system. That is, a computational system composed of several agents capable of mutual and environmental interaction. This means, the CA&VR-system consists of system components and a number of agents with communication channels between them, designed as a collection of interacting (autonomous) agents, each having their own capacities and goals that are situated to a common environment. In our research, this common environment is the VR-DIS environment.

Figure 7: **The rudimentary CA&VR-system concept**



Explanation:

- *Subject Agent* : The person who navigates through the profile virtual environment. Perceptions can be measured and actions can be taken. The goal is fulfilling a task in the profile virtual environment and afterwards a preference measurement of this profile or a choice between profiles.
- *Profile Simulation Agent* : Simulation of a virtual environment of a selected profile alternative. When a subject takes part of the static profile environment, virtual objects describing the profile attribute levels will be loaded. Interaction with the 'measurement agent' takes place to record user behavior.
- *Profiles Setup Agent* : Selection of a profile alternative, or profile alternatives in choice set of profiles (profile selector). Besides the profile selector, the profile database is part of this agent. The profile database consists of the profiles-setup, that means the product profile descriptions (attributes and their levels) and accompanying product profile presentations (virtual design objects).
- *Measurement Agent* : Measurement of response data and recording of user behavior and measurement of response data.

Figure 8: **Agent page description**

Agent		**Percepts**	**Actions**	**Goals**
Subject		Perceptions	Decisions	Fulfilling a task
Profile Simulation		Perceptions, answers	Questions, registrations	Virtual interaction, preference measurements
Profiles Setup		Messages	Selections	Presentation of a profile alternative
Measurement		Messages	Measurements, registrations	Conjoint measurement, registration user behavior

- *Profile Design Constructor* : Generates the profile-design, both the profile attributes and attribute levels (profile designer), and the profile virtual objects (objects modeler). The static profile environment(s) will be generated, too. The profile-setup and their representation is supplies the input for the profile database.
- *Data Analysis Application* : Analysis of the performances of the measurements. Decision-making about design concepts.
- *Researcher (and designer)* : Supply of design concepts. Evaluation of the measurements.

In the near future, it is our intention to examine in depth the several agents and system components.

4.2 **Choice models**

Choice models are suitable for the use of experimental designs to construct hypothetical products or services, and observe subjects' choices. The researcher has control over the attributes and their correlation. The basic principle is:

- Ask subjects to choose from Profile A and Profile B.
- Choice of A vs. B indicates preference of the preferred Profile attribute levels.
- Systematically varying attribute levels allows building models of such trade-offs.

Subjects are assumed to attach an overall value to a choice alternative. Originally, choice sets will be formed and subjects decide which profile alternative from the choice set is chosen. In a virtual reality based conjoint measurement experiment, it is not appropriate to choose from more than one choice set without negatively influencing responses in terms of boredom or fatigue. For subjects, only a small number of reduced choice sets could be dealt with. If we want to perform an experiment on this manner, many mores subjects are needed. Adaptations of accepted utility functions need to be developed.

Instead of choice measurement after navigating through several profile alternatives, we will also consider a preference measurement of profile alternatives.

4.3 **Virtual environments**

A virtual environment is very convenient to explore virtual objects. By clicking a virtual objet, a specific attribute level will be displayed. A virtual object will present each attribute and each virtual object has a number of appearances. Each appearance is a level of the attribute. By exploring the attributes in this way, the subjects' preferred profile could be generated. Due to the conjoint measurement in a virtual environment, it is also feasible to record subjects' walk through a virtual environment. Data about actions, decisions, judgments, perception and time-span can be collected and evaluated. Obviously, a virtual environment is a particular environment for applying conjoint measurement experiments. The conjoint measurement can be affected by:

- Experience. That is, experience about virtual reality, experience about the model, and experience about virtual reality techniques. It is important that the virtual environment is familiar to subjects participating in the conjoint measurement experiment.
- Effects of attributes that are of interest may be confounded with the effects of other factors in the virtual environment.
- Also the order of displayed attributes as virtual objects can act on the measurement.

4.4 **Methodology**

Conjoint analysis originally was developed to measure users' utilities for multiattribute choice alternatives. The design of experiments should allow one to reflect the assumed preference function or choice model. Consequently, to measure preferences or utilities, subjects are requested to rank or rate the experimentally varied attribute profiles on some preference scale. The observed values can then be decomposed into the utility contributions of the attribute levels. Similarity, if the focus is on testing an assumed choice model, then the profiles are placed into choice sets and subjects are requested to choose from each choice set the alternative they like best.

These response formats can also be applied to attribute profiles, which are appropriate for a virtual reality presentation. For instance, these response formats can be applied for the problem of wayfinding if one is primarily interested in understanding the contribution of attributes of the guidance system. The illustration of the wayfinding experimental design is an example of this approach. This is the simplest application that stays closest to the traditional use of conjoint choice and preference models. However, if may well be that the researcher's or designer's interest goes beyond this problem. We could think of an experimental task in which subjects were successful in finding a target destination, or in the time it took them to find the destination. An example of the latter approach is the illustration of the application of conjoint measurement as a dynamic decision making tool. In these situations, the dependant variable of the model shifts from a ranking, rating or choice to a dichotomous yes/no variable or a time variable respectively. The multivariate statistical analyses that are commonly applied in conjoint analysis are no longer appropriate for these situations and new appropriate methodology needs to be developed.

If the focus of interest concerns the question whether users are successful in finding the destination, then the binary logit model is a candidate for analysis. It allows one to estimate the contribution of attribute level on the probability that users find a destination. Hence, the result of the analysis may be used to identify the most critical attributes. Alternatively, if the focus of interest concerns the issue of how long it takes to find a target destination, the dependant variable of the model consists of positive numbers only. Poisson regression analysis is an appropriate multivariate analysis tool to analyze such data. In that case, the coefficients of the regression equation indicate the effect of the attribute levels on the time it takes to find the destination.

In the illustration of eye tracking as a user behavior registration tool in virtual environments, we have seen the measurement of fixation time at visual attention fields of virtual design objects. That means an extension to the conventional basis of conjoint analysis for perceptual tasks.

In our project, alternative and appropriate methodology to conjoint analysis will be part of the investigation.

5 DISCUSSION

In this paper we have advocated the development of a system based on conjoint analysis and virtual reality techniques. Such a system should allow a better representation of attributes, thereby hopefully also increasing the reliability of the measurement.

We have looked back on simple illustrations of wayfinding to show the potential of the CA&VR-system concept. It suggests virtual reality systems allow the creation of interactive environments, can be used to observe user reactions and decision making in not yet existing environments, and offers the potential of simulation, taking conjoint analysis into a completely new direction.

We have argued that the methodology for conventional conjoint analysis is well developed, but for some more advanced problems, additional methodology needs to be developed.

Finally, the proposed system offers the potential of an a priori evaluation of building performance. The ultimate test of the relevancy of such a system, however, depends on empirical testing. We hope to report on the progress of our research in the near future.

6 REFERENCES

Arthur, P. and R. Passini (1992) *Wayfinding, People, Signs and Architecture*. McGraw-Hill Ryerson, Toronto.

Dijkstra, J., W.A.H. Roelen and H.J.P. Timmermans (1996) Conjoint measurement in virtual environments: a framework, *in* H.J.P. Timmermans (ed.), *3rd Design and Decision Support Systems in Architecture and Urban Planning Conference, Vol. I: Architecture Proceedings*, pp. 59-71.

Dijkstra, J. and H.J.P. Timmermans (1997a) Exploring the possibilities of conjoint measurement as a decision-making tool for virtual wayfinding environments, *in* Y.T. Liu *et al* (eds.), *Proceedings of The Second Conference on Computer Aided Architectural Design Research in Asia*, pp. 61-71.

Dijkstra, J. and H.J.P. Timmermans (1997b) The application of conjoint measurement as a dynamic decision making tool in a virtual reality environment, *in* R. Junge (ed.), *Proceedings of The 7th International Conference on Computer Aided Architectural Design Futures*, pp. 757-770.

Dijkstra, J., H.J.P. Timmermans and W.A.H.Roelen (1998) Eye tracking as a user behavior registration tool in virtual environments, *in* T. Sasada *et al* (eds.), *Proceedings of The Third Conference on Computer Aided Architectural Design Research in Asia*, pp. 57-66.

Green, P.E. and Srinivasan, V. (1978) Conjoint analysis in consumer research: issues and outlook, *Journal of Consumer Research*, **5**, pp. 103-123.

Hair, J.F., R.E. Anderson, R.L. Tatham and W.C. Black (1995) Conjoint analysis, in *Multivariate data Analysis*, Prentice Hall, Englewood Cliffs NJ, pp. 556-599.

Huhns, M.N. and M.P. Singh (1998) Agent and multiagent systems: themes, approaches, and challenges, *in* M.N. Huhns and M.P. Singh (eds.), *Readings in Agents*, Morgan Kaufmann Publ., 1998, pp. 1-23.

Klabbers, M.D., H. Oppewal and H.J.P. Timmermans (1996) ESCAPE: (multimedia) engine for stated choice and preference experiments, Working paper *3rd Design and Decision Support Systems in Architecture and Urban Planning Conference.*

Louviere, J.J. (1988) *Analyzing Decision Making: Metric Conjoint Analysis*, Sage University paper Series on Quantitative Applications in the Social Sciences, series no.07-067, Sage Publications, Beverly Hills.

Montgomery, D.C. (1991) *Design and Analysis of Experiments*, John Wiley, Chichester.

Oppewal, H. (1995) *Conjoint Experiments and Retail Planning: Modelling Consumer Choice of Shopping Centre and Reatailer Reactive Behaviour*, Ph.D thesis, Bouwstenen 32, Eindhoven University of Technology.

Passini, R (1996) Wayfinding design: logic, application and some thoughts on universality, *Design Studies*, **17**, pp. 319-331.

Timmermans, H.J.P. (1984) Decompositional multiattribute preference models in spatial choice analysis: a review of some recent developments, *Progress in Human Geography*, **8**, pp. 189-221.