PERCEIVED QUALITY OF COMPUTER-SIMULATED ENVIRONMENTS

Rohrmann, B., Palmer, S., & Bishop, I.

Dept. of Psychology, Univ. of Melbourne,
Parkville Vic 3052, AUSTRALIA
E-Mail: rohrmann@unimelb.edu.au

Strategic Data
P.O.Box 4262 at Melb.Univ. P.O., Vic 3052, AUSTRALIA
E-Mail: Simon.Palmer@StrategicData.com.au

Centre for Geographic Information Systems and Modelling, Univ. of Melbourne, Parkville, Vic 3052, AUSTRALIA
E-Mail: i.bishop@eng.unimelb.edu.au

published 2000 in:
Moore, G., Hunt, J., Trevillon, L. (Eds.), Environment-Behavior Research on the Pacific Rim: Proceedings PaPER'98 (pp. 341-352). Sydney: Faculty of Architecture, University of Sydney

ABSTRACT

This research deals with computer-generated simulations of urban or natural environments; these are increasingly utilized in planning and design as well as in perception research. While the respective computer tools have become highly sophisticated, the quality and utility of such presentation technologies still need validation. This issue was addressed in a series of lab and field studies. In study <1>, variations of a simulation of a suburban environment were presented to respondents (N=120) to investigate the effects of lighting (day-sun/ day-fog/ night), shadows(yes/no) and sound (on/off) on perceived simulation quality. In study <2>, 50 subjects were presented with a computer simulation and a video-recording of the same environment. In study <3>, the focus is on a comparison between judgments about the actual environment (collected during a site visit) and its computer-simulation, for both day and night conditions (N=80). In all studies, comprehensive questionnaires measuring cognitive and affective aspects by quantitative and qualitative means were employed. These include: assessments of realism, content recall, comprehension/legibility, appreciation of the environment, and preferences for presentation modes. Main results so far are that simulations are perceived as valid and acceptable but not fully matching the perceptions induced by the respective reality nor the realism of video recordings; that appraisals differ significantly according to lighting and time-of-day conditions; and that availability of sound enhances the perceived quality of presentations. The findings elucidate which factors are crucial for improving simulations and clarify the validity of computer simulations for assessing environments. Altogether the study confirms the potential of presenting environments via computer graphics, and it appears well justified to expand the utilization of this approach to pertinent problems in architecture, urban or landscape design and decision-making by planning authorities.

Keywords: Computer simulation; Environmental perception; Simulation validity

1 RESEARCH ISSUE

1.1 The relevance of computer-simulations

The simulation of buildings, landscapes and other environmental structures using computer graphics is one of several means to visually represent environments, may they be existing or future ones. This technology has become a widely applied and considerably refined one (Marans & Stokols 1993). The capacity to generate highly realistic simulations has prospered with increasing computer power and sophistication in rendering algorithms. Consequently, computer simulations of environments (subsequently abbreviated as *CSE*) are now indispensable tools for many professionals such as architects, landscape planners, environmental researchers and so on. Two main functions are: communication of design and planning impacts (e.g., Bishop & Hull 1994, Liggett & Jepson 1995, Sheppard 1989) and research into human perception of environments (e.g., Bishop & Rohrmann 1995, 1997, Orland 1993).

How does CSE compare with other means for depicting envirromments, such as drawings, photographs, physical models, film and video? The available presentation modes differ considerably in their focus and attributes, e.g., whether they capture three-dimensionality, movement and non-visual features; see *table 1* for a summary.

Table 1:
MODES OF PRESENTING ENVIRONMENTS

Features:	Projection: *2dim/axonometric/3dim*			Animation: *partial/full*		Object: *plan/model/reality*			Non-visual senses: *audio/smell*	
o Drawings	+	+	-	-	-	+	:	:	-	-
o Photographs	+	-	-	-	-	:	:	+	-	-
o Physical Models	-	-	+	-	-	+		+	-	-
o Film/Video	-	-	+	-	+	:	+	+	+	-
o Computer graphics	+	+	+	+	-	+	+	:	+	-

+ standard feature **-** *not occurring or unfeasible : possible but rare*

No mode can completely match the perceptions created by the actual environment . The crucial question is therefore, how valid is a representation? Is it realistic enough to induce responses which are sufficiently similar to the evaluation of the real environment?

The more CSEs are utilized, the more important a critical assessment of its validity becomes. While there is considerable knowledge regarding conventional means of presentation (such as drawings and photographs; see e.g. Bateson & Hui 1992, Vining & Orland 1989), the CSE approach is far less researched. There are hardly any comparisons with video presentations or appraisals based on actual site visits. A review of the few empirical evaluation studies (e.g., Bergen at al. 1995, Bishop & Hull 1991, Decker 1994) indicates that the greater the degree of realism in the simulation, the more effective it becomes. However, the relevance of specific features (such as colours, light and shadows) is not yet well understood. One noteworthy advantage of the use of computer graphics in this context is that controlled experiments can be conducted in which the researcher can easily define and design the visual stimulus in order to clarify the impact of particular CSE attributes.

1.2 **Aims of the research**

In order to further clarify the validity of computer simulation of environments, the following research questions were investigated:

- Are computer simulations accepted as valid representations of environments?
- What influence does the presentation style have (animation, shadows, sound)?
- Is there a difference in validity between day and night situations?
- Does appreciation of an environment interact with the appraisal of its simulation?

Both natural and built features of environments were to be considered.

2 PROJECT DESIGN

2.1 **Type of studies**

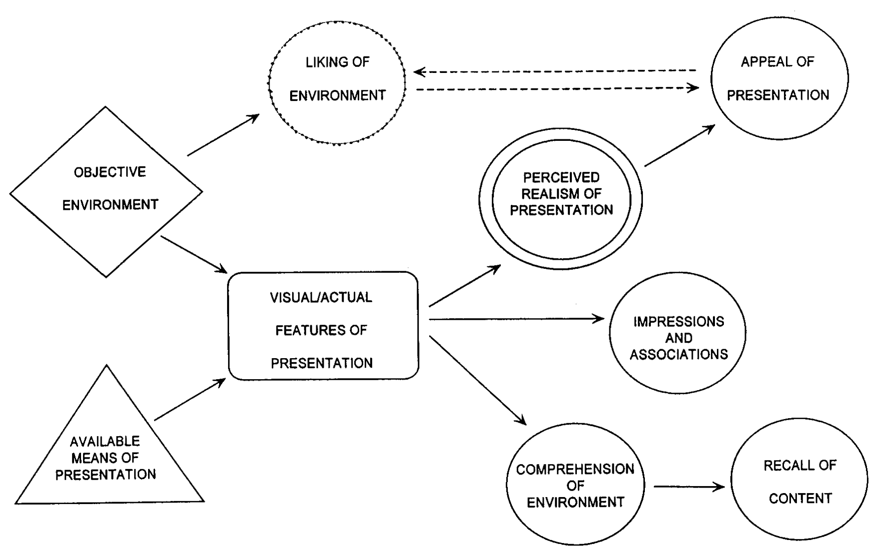
A project composed of three different sub-studies was conducted at Melbourne University. To address the outlined validity issues, both lab and field studies were conceptualized. Three approaches were chosen for presenting a CSE to respondents and measuring their cognitive and affective appraisals:

- presenting several variations of a simulation of a particular environment (study <1>, Bishop & Rohrmann 1997, Rohrmann & Bishop in press)
- presentation of a computer simulation and a video-recording of that environment <study <2>, Palmer 1998)
- comparing appraisals of a CSE with judgments about the actual environment (collected during a site visit) (study <3> (under way; Rohrmann & Bishop in prep.)

2.2 **Conceptual framework**

The principal assumption underlying this evalution research is that an environmental simulation should evoke a similar set of responses as would a direct experience of the same environment if presentation validity is to be claimed. This should encompass both the cognitive and affective facets of responses. Accordingly, a variety of assessment aspects was chosen, including appraisals of relevant environmental attributes, perceived simulation quality , comprehension and retention. The assumed structure among these variables is depicted in *fig. 1.* (in this graph, the constructs shown in circles refer to judgments by respondents). The overall appeal of a CSE is seen as influenced by the perceived realism of the presentation and contingent on the appreciation of that environment. Further impacts of the chosen presentation means relate to the impressions and associations induced (affective response) and the comprehensibility (cognitive impact) which influences how well the environment can be remembered and described (recall). This framework determined the content of the response measurements (described in 2.4 below).

Fig. 1:
CONCEPTUAL FRAMEWORK FOR CSE ASSESSMENTS



2.3 **Experimental material**

For this study, a computer-simulation of an outdoor environment was developed, showing a walk through a suburban area of about 1 sq-km, the Civic Center in Camberwell, Melbourne. It consists of different types of buildings; lawns, trees and other vegetation; streets (including a tramline) and pathways.

Fig. 2 gives an impression of the area. The CSE is based on a comprehensive data base of geometry and textures and was created using several graphics and visualizer software packages (Bishop & Rohrmann 1995). It includes moving objects (e.g. passing trams) but no humans except for the shadow of a person walking through the area. This CSE was produced in five versions, differing in time-of-day, light/weather, and shadows; a sound recording matching the walk is available as well.

Fig. 2:
PARTIAL VIEW OF THE ENVIRONMENT UNDER STUDY

Picture (1) based on video recording, (2) based on computer simulation

2.4 **Response questionnaire**

In order to measure the perceived quality of a CSE, first a comprehensive variable list and then a set of questions and scales was developed. The resulting standardized questionnaire booklet includes scale-based and open-ended questions regarding the presentation quality and realism, appraisals of the environment (including an attribute profile to capture impressions and associations, from Russel & Lanius 1984), recall tasks and various demographic items. For a full list of all variables see *table 2*. This list also contains the stimulus features [block S] considered in the experimental designs of the three sub-studies and variables which were controlled in order to check for moderator effects [block M].

Table 2:
CONCEPTS & VARIABLES - Studies <1>, <2>, <3>

[S] ***Stimulus features***	
S1	Light: day/sun, foggy weather, dark/night
S2	Shadows (yes/no) <fog condition has no shadows>
S3	Sound (yes/no)
S4	Time of day: day, night
[A] ***Appraisal of the content***	
A1	Salient features of the area <*qual.*>
A2	Salient features of the simulation <*qual.*>
A3	Appreciation of the environment <*rating; scale: 1..7*>
A4-A11	Affective qualities: arousal/disliking/inertia/order/pleasure/ threat/similar/ natural <8 aspects, based on 3 attributes each; *scale: 1..7*>
[R] ***Retention***	
R1-R9	Recall of specific features (re weather, buildings, vegetation, lighting, shadows, sound etc)
R10	Recollection correctness <index, *0..8*>
[C] ***Comprehension***	
C1	Legibility and understanding of the setting <*rating; scale: 1..7*>
C2	Correctness of respondent's drawing of the area
C3	Accuracy of perceived north-south orientation (*i.e., deviation in degrees)*
[E] ***Evaluation of realism***	
E1	Perceived realism of CSE - overall rating <*scale: 1..7*>
E2	Rating of presentation validity <*scale: 1..7*>
E3-E7	Realism of specific features (e.g., shadows, lighting, buildings, vegetation, pace <*scale: 1..7*>
E8	Realism quality <index>
E9	Reasons for CSE evaluation <*qual.*>
[D] ***Demographics***	
D1-D5	Age, sex, education, place of residence, ethnicity
[M] ***Moderator variables***	
M1	Order of presentations
M2-M3	Degree of computer usage and familiarity with graphic simulations

2.5 **Study design and data collection**

The experimental design (mixed between/within groups plan) is summarized in table 3.

Table 3:
EXPERIMENTAL DESIGNS FOR STUDIES 1, 2, 3

***Study <1>**: ALLOCATION OF 10 SIMULATION VERSIONS TO 6 GROUPS (A-F)*

light ->	day-sun				nighttime				day-foggy weather	
shadow ->	shadow		no-sh		shadow		no-sh		(no-shadow)	
session ->	*I*	*II*	*I*	*II*	*I*	*II*	*I*	*II*	*I*	*II*
sound:										
no-sound CSE	A1	B2	C1		D1		E1		F1	
CSE with sound	B1	A2		C2		D2		E2		F2

***Study <2>**: COMPARISON VIDEO AND COMPUTER SIMULATION (Groups, A & B)*

Presentation of:	Video	Computer simulation
Session order:		
Video first	A1	A2
Simulation first	B2	B1

***Study <3>-**: CSE AND REALITY AS CONDITIONS FOR 4 GROUPS (A to D)*

Presentation mode ->	Site visit		Computer simulation	
Time of day ->	day	night	day	night
Session order:				
Reality first	A1	C1	A2	C2
CSE first	B2	D2	B1	D1

In study <1>, each of the groups <A> to <F> had to assess two CSE's presented on portable video-projectors (session I and II). For the condition "day/sun + shadows" a plan balancing "sound/no-sound" and "order" was realized; for the other conditions, the no-sound CSE was always presented first.

In study <2>, respondents assessed both the CSE and a video recording of the same environments; for groups <A> and <B>, the order was different.

In study <3>, not only simulations but also the real environment presented in the CSE's was assessed by the participants during a site visit (which included a walk through the area). Different respondents were exposed to the day and the night condition (groups <A> +<B>, and <C>+<D>, respectively), with order also varied.

2.6 **Propositions**

For each study, pertinent hypotheses can be derived from prior simulation research and concepts from environmental psychology. The principal propositions to be analyzed in this project were:

- Computer simulations are seen as reasonable representations of environments;
- Including light features and shadows improves comprehension and perceived realism;
- Provision of sound enhances the acceptance of CSE's;
- CSE's for day/sunshine are rated more favorably than night; least favorable ratings are given for the fog condition;
- Simulations induce similar impressions of the environment's attributes (affective quality) as the

reality, but recall, legibility of the setting and geographic understanding (cognitive impacts) are less good/rich for CSE's,

- The appreciation of an environment is influenced by simulation quality.

3 RESULTS

3.1 Data sets: overview

For each of the experimental conditions/groups defined in table 3 a data set according to table 2 resulted. Alltogether N=150 people participated in study <1>, N=50 in study <2> and N=80 in study <3>. The sample for <1> was recruited from parents' groups in schools (predominantly urban, female, middle-aged and well-educated people); studies <2> and <3> were conducted with psychology students.

A full description of samples and data is beyond this article; thus the presentation will focus on the main propositions outlined above.

3.2 General appraisal of simulation quality

Responses to different types of CSE's, as presented in study <1>, are shown in *table 4,* which lists selected overall means (column ALL) and results per condition.

Firstly, the area presented in the CSE's is seen as moderately attractive (cf. variable A3; scale: 1..7). with good but not high legibility (C1). So, how is the computer simulation of this environment judged? As block [E] in table 4 demonstrates, the overall evaluations of perceived realism (E1, index E8; scale: 1..7) are in the positive range. Building realism gets the highest, person shadow the lowest rating. When asked for their reasons (E9), the respondents mention positive and negative points equally often; shortcomings in the animation, artificiality, absence of relevant features and lack of sound (if not provided) are the most frequent reasons for critical appraisals. While a valid graphic representation of trees is a rather difficult problem, (and in the author's view not yet satisfactory in the present CSE), the respondents did not comment much on this shortcoming.

Table 4:
MEAN DIFFERENCES BETWEEN CONDITIONS (CSE TYPES) - *Study <1>*

		time of day & weather			*sound*		*shadow*		
		day/sun	night	fog	yes	no	yes	no	ALL
[A]	*APPRAISAL OF THE CONTENT*								
A3	Liking of the environment	4.0	4.1	3.3	4.2	3.8	4.1	4.0	4.0
[R]	*RETENTION*								
R8	Recollection index	4.0	3.5	3.9	3.7	3.7	4.1	3.4	3.7
[C]	*COMPREHENSION*								
C1	Legibility of the setting	5.3	5.0	4.6	5.6	5.3	5.5	4.9	5.1
[E]	*EVALUATION OF REALISM*								
E1	Perceived CSE realism overall	4.6	4.4	4.3	4.5	4.3	4.5	4.5	4.4
E4	Realism of lighting	4.7	4.5	3.3	4.7	4.5	4.7	4.6	4.4
E5	Realism of buildings	5.1	4.9	4.6	4.9	5.0	5.1	4.9	4.9
E6	Realism of vegetation	4.7	4.6	4.2	4.7	4.8	4.9	4.5	4.6

p.t.o.
{Table 4 continued}

E9	Reasons* for CSE evaluations (%)								
	Animation/motion (deficient)	15	10	15	16	13	16	9	13
	Artificiality/sterility	12	13	11	5	10	9	16	11
	Shadows (missing/invalid)	3	0	9	3	3	2	4	3
	Objects (shortcomings)	8	7	9	8	8	8	11	8
	Sound <*if provided*> (invalid)	2	5	9	3	35	4	4	12
	Ommission of relevant content	15	6	5	13	35	19	20	10
	General negative comments	34	22	32	24	43	28	29	28
	General positive comments	38	39	19	47	27	39	28	34
	* Multiple replies possible								
E8	Realism index	4.8	4.6	3.7	5.0	4.8	4.9	4.6	4.6

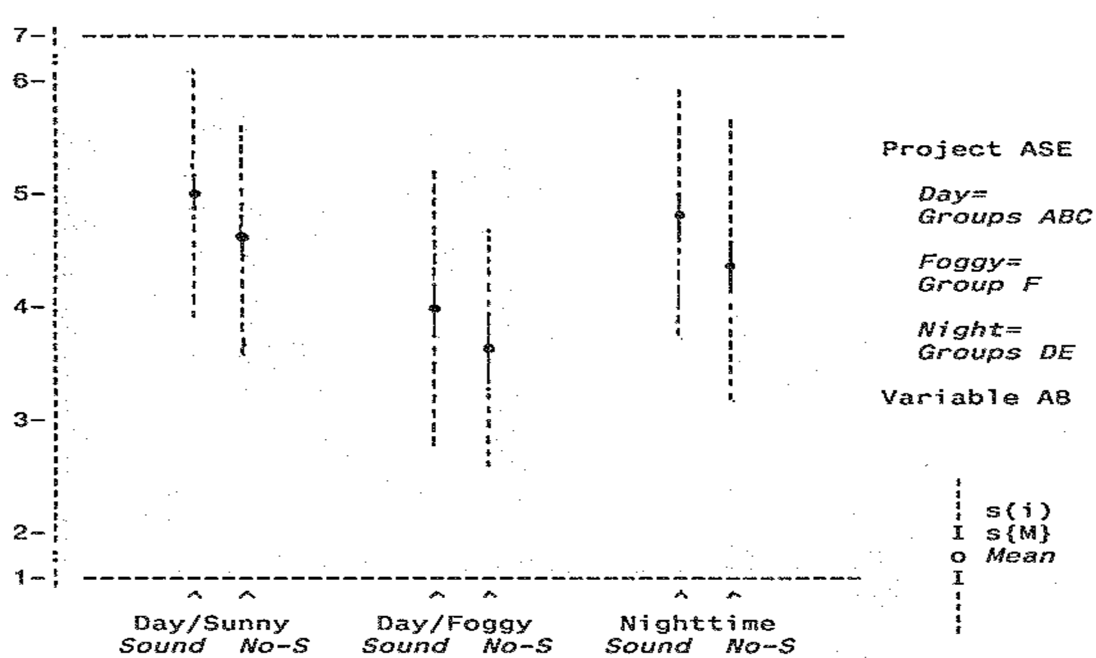
3.3 **Effects of presentation features**

As hypothesized, there are some substantial disparities between the appraisal of CSE's differing in time-of-day, weather, use of shadows and provision of sound

Regarding the three *time-of-day and weather* conditions, the perceived realism (E1, E8) is highest for day/sun and lowest for foggy. *Fig. 3* gives a graphical illustration (s[i] refers to the standard deviation of the raw scores, s[M] to the standard error of the mean). The same rank order appears for the legibility of the setting (C1).

Regarding s*hadows,* the provision of a personal shadow has only slight effects on perceived realism (E9) and legibility (C1); note though that object shadows were present in all versions of the CSE.

Fig. 3
PERCEIVED REALISM (INDEX 1..7) FOR DIFFERENT CSE CONDITIONS



Regarding s*ound,* provision of sound enhances the acceptance of the simulation while lack of sound is frequently mentioned as a deficiency (cf. E8, E9, A2). Sound also slightly increases the perceived familiarity, naturalness and liking of the area.

The main variables were also analyzed in terms of their ability to predict the overall realism evaluation (E1), using single and multiple correlations (data not included here). These analyses showed that building realism (E5) tends to be the strongest factor for day conditions, lighting realism (E4) for the night situation;neither legibility nor recall nor the respondents' familiarity with computer work and computer games correlate significantly with perceived simulation realism.

3.4 **Comparisons CSE/Reality**

As the ‘real’ environment depicted in the CSE could be presented in two ways, via a video and as an actual site visit, the quality of the simulation could be assessed against two types of reference criteria.

Selected results from study <2> are presented in *table* 5 (note that 0-10 scales were used here). From these data it is obvious that

- the perceived quality of the CSE presentation (cf. realism ratings in block [E]) is clearly lower, both overall (variable E1) and for visual attributes such as lighting, colour, relief and boundaries of objects;
- comprehension (measured via the accuracy of the participant’s north/south orientation) and recollection are lower for the CSE;
- the video presentation induces a slightly higher appreciation of the environment.

(The video presentation itself is rated as presenting the environment very well.)

Table 5:
MEANS FOR FACETS AND ATTRIBUTES BY REPRESENTATION MODE- *Study <2>*

		Simulation	Video
[R]	***Retention***		
R10	Recollection score	7.8	8.5
[A]	***Appraisal of the content***		
A3	Appreciation of the environment	5.7	6.3
[C]	***Comprehension***		
C3	Accuracy of perceived north-south orientation	77.1	38.3
[E]	***Evaluation of realism***		
E1	Perceived realism overall	4.6	9.2
E4	Realism of lighting	6.5	7.1
E11	Realism of colour	7.0	7.9
E7	Realism of sound	4.8	5.6
E20	Realism of frame stability	6.5	3.1
E21	Realism of animation speed	5.0	4.9
E22	Realism of the relief of the objects	5.5	7.1
E23	Realism of boundaries	5.2	8.1

all scales are 0…10, except C3

Finally, appraisals of CSE versions and of the real environment were compared in both a day and a night setting; a small selection of results are presented in *table 6.*

Regarding simulation quality, study <3> demonstrates:

- Perceived realism (variables E1 to E8) is in the positive range (except for vegatation) and actually similar to study <1> were no comparison with reality was offered;

- retention of environmental features and comprehension (measured via the area sketch produced by the participants) are slightly lower for the CSE's;
- for most aspects, participants found the night CSE more satisfying than the day one.

Table 6:
MEAN RESPONSES TO CSE PRESENTATION AND REALITY - *Study <3>*

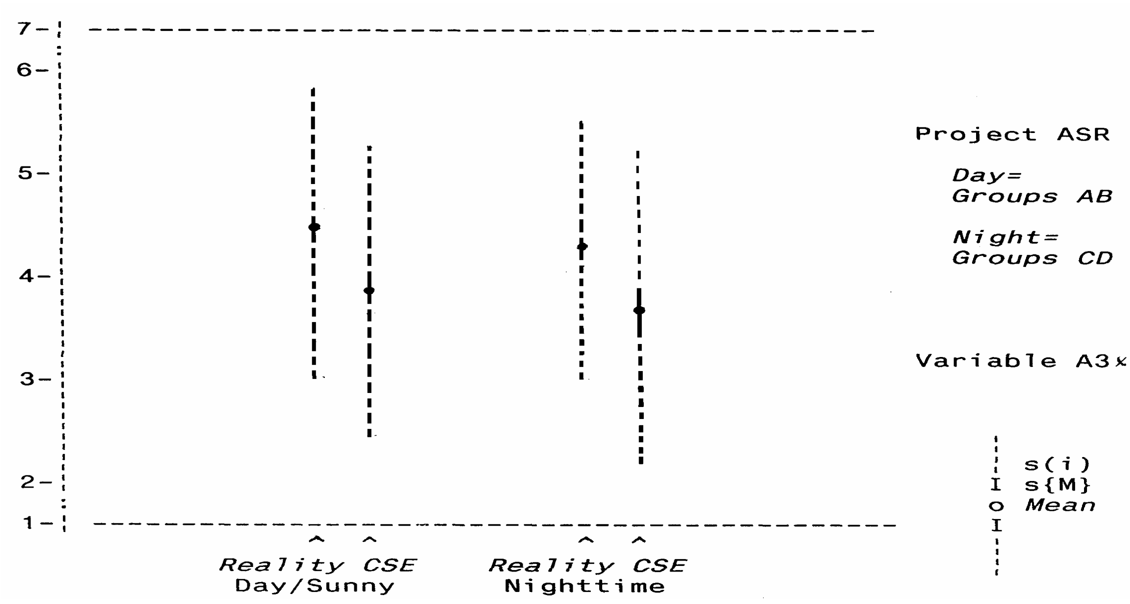
Assessment of:	*Reality*		*CSE*	
Time of day:	*day*	*night*	*day*	*night*
[A] *APPRAISAL OF THE CONTENT*				
A1 Salient feature of area <qual.; in %>				
Vegetation	64	55	73	58
Buildings	19	30	12	13
Pathways (roads/paths/stairs)	19	8	15	13
Vehicles (cars, tram)	5	3	17	25
Lighting	0	15	7	20
A3 Appreciation of the environment	4.8	4.4	3.8	3.7
[R] *RETENTION*				
R8 Recollection index	1.4	1.4	1.1	1.1
[C] *COMPREHENSION*				
C1 Legibility of the setting			5.3	5.6
C2 Correctness of respondent's drawing	2.7	2.8	1.9	2.0
[E] *EVALUATION OF REALISM*				
E1 Perceived CSE realism overall			4.1	4.4
E4 Realism of lighting			4.0	4.6
E5 Realism of buildings			4.4	4.6
E6 Realism of vegetation			3.6	3.9
E8 Realism index			4.2	4.6

Regarding the perception of the environment, the data suggest:

- vegatation is the most salient feature in both presentation modes (more so for the day situation);
- presentation via simulation slightly reduces the appreciation of the environment for both day and night conditions. As *figure 4* demonstrations, the variance of these judgments is rather large.

Fig. 4

LIKING OF THE AREA (SCALE 1..7) FOR CSE & REALITY CONDITIONS



The attribute profiles (A3) for the three conditions, shown in *figures 5 and 6*, are quite similar, except for "natural" and "pleasing" in the 'day' condition. The impressions differ considerably more for the 'night' conditions: when presented via simulation, the environment is perceived as less "familiar" and "natural" while ratings for "inertia", "threat" and "disliking" are slightly higher.

In sum, in comparison to the reality CSE's tend to induce less favourable appraisals, and ratings of realism are only moderately positive.

Fig. 5

ATTRIBUTE PROFILES FOR COMPUTER SIMULATION AND REALITY: *=DAY=*

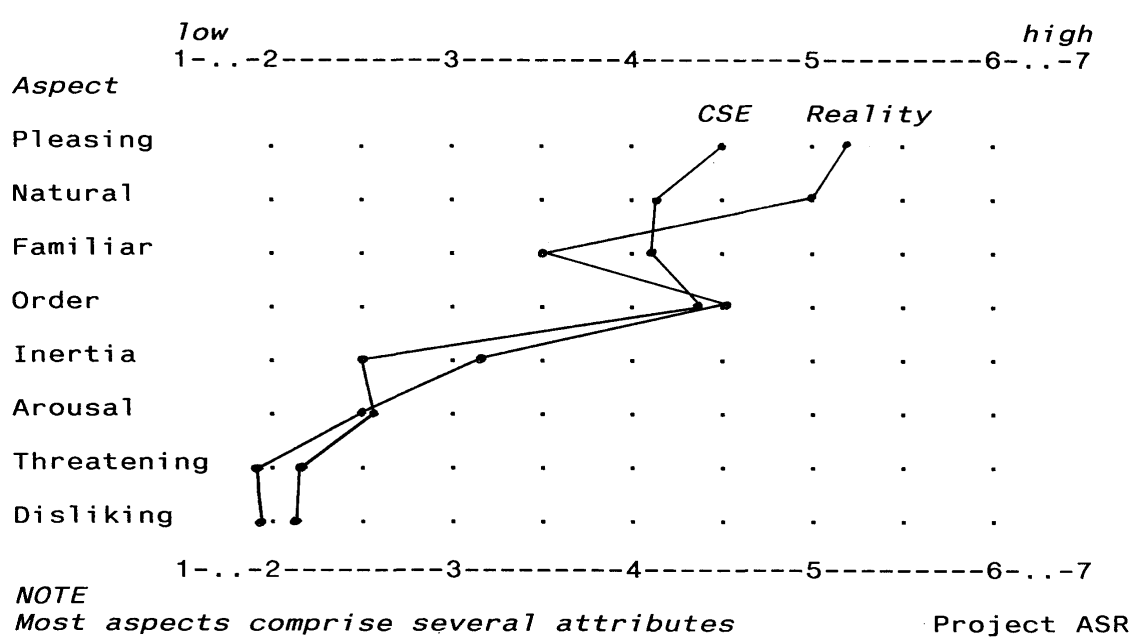
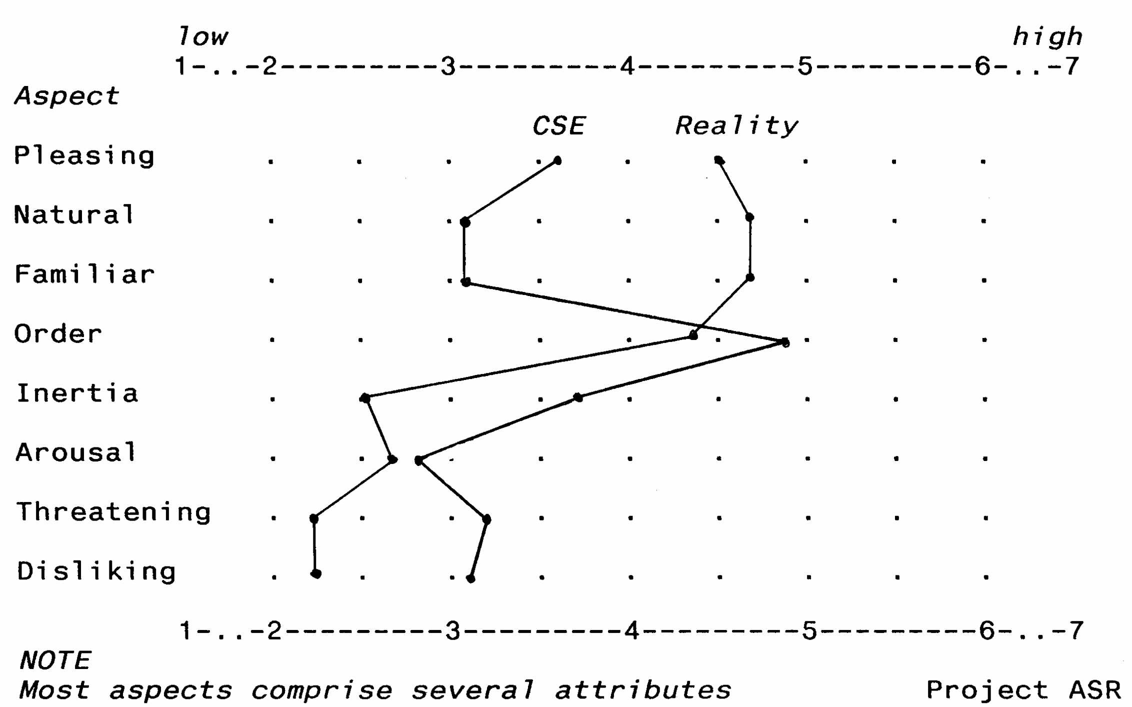


Fig. 6

ATTRIBUTE PROFILES FOR COMPUTER SIMULATION AND REALITY: =*NIGHT*=



3.5 **Experimental order effects**

As all respondents were exposed to two presentations (cf. the designs in figure 3 above), order effects on the respective judgments had to be checked in all three studies. There is not enough space to go into any detail, and the results are quite complex. Generally the data suggest that perceived realism (E1),as well as the liking of the environment (A3) decrease slightly from session 1 to 2; that the ‘sound-first’ conditions increases attention for details and omissions; and that realism judgments for CSE’s (E1, E8) tend to be more positive if the reality (or the video taken there) was presented first.

As expected, significant order occur effects if respondents are asked for repeated judgments; thus this problem needs to be controlled carefully.

3.6 **Content preferences as moderator influence**

It is widely assumed that the quality of a representation will influence how favorable a building or environment is judged (architects and landscape designers obviously try to utilize this mechanism). Does such effect show up in this study? The data actually show a correlation between perceived simulation quality (variable E1) and appreciation of the area (A3), namely r=0.44/0.49/0.42 in studies <1>, <2> and <3>; for the "disliking" attribute of the impression profile (A5) the correlation is r=-0.54/-0.26 <studies 1 and 3>.

However, it may be that the influence is the other way round, i.e., people who like an environment might evaluate the simulation quality more leniently. As respondents found it difficult to separate the two aspects conceptually, and as the experimental set-up of the present study does not allow to test the effect unequivocally, this causality issue remains to be clarified.

4 CONCLUSIONS AND OUTLOOK

4.1 Validity and utility of computer simulations

The critical question underlying this research is: Are computer simulations of built or natural environments a valid representation of the respective environment? And consequently, is their use in applied work as a substitute for reality justified? The results gained so far indicate that CSE's are acceptable to most people as understandable and sufficiently informative ‘portrait’ of an area and its main characteristics, even though they are quite aware of limitations if compared to the information provided by a video or an actual site visit. Quality and completeness clearly matters, as added information such as shadows improved evaluations and comments on shortcomings focused on missing or insufficient features. On the other hand, that various aspects of the simulation were less differentiated and rich in detail than the reality (e.g., colours, texture of buildings and plants, borders) was less criticized than expected. Furthermore, providing sound is important in enhancing perceived realism (and also fosters attention & recognition).

The night version used in studies <1> and <3> - although quite different in its appearance - was considered as valid as the daytime/sun CSE. This is encouraging as the night situation is relevant in many contexts. Clearly, if pertinent, both a day *and* a night presentation should be provided when an environment is to be simulated for assessment purposes.

In *methodological* terms, it seems that the quality evaluation of simulations is confounded with the perceived appeal of the presented environment; thus both aspects need to be measured and to be untangled in pertinent analyses. Also, order effects threaten the validity of results and need to be controlled carefully.

4.2 Research needs

The three studies reported here provide valuable findings and also point at necessary improvements of computer/video presentation techniques. However, substantial further research is needed to get a full understanding of the validity of CSE's. Firstly, more comparisons with appraisals of *reality* (based on videos or better site visits) seem essential. Secondly, further studies should incorporate CSE's of several different environments (including 'pure' natural and built ones), apply a wider range of visual/graphic means (regarding colour, texture, animation and so on) and offer interaction modes for viewers in order to analyze which findings can be *generalized.* Thirdly, applications to 'real-life' problems - such as an information program for residents or an environmental planning decision of a council (cf. Lawrence 1993) - should be designed and investigated. Such research would help to decide where further sophistication of the CSE technology is most crucial.

Finally, it should become 'standard procedure' to include validity assessments with pertinent samples of users whenever new means of computer-simulation are invented and applied (Bishop & Rohrmann 1995, Haase & Dohrmann 1996, Globus & Azelton 1995) - *empirical* validation is indispensable!

4.3 Outlook

Altogether the project confirms the potential of presenting environments via computer graphics, and it appears well justified to expand the utilization of the CSE approach - particularly in situations when a building, urban area or landscape cannot be visited or is to have its features changed. The use of effective environmental simulation systems in both research and applied work can lead to better understanding of human-environment interactions; better communication between architects, landscape architects, planners and the public; and better decisions by urban design and urban planning authorities. Finally, the more interactive the presentation techniques become, the better the chances will be to fully exploit the potential of this technology.

5 REFERENCES

Bateson, J. E., & Hui, M. K. (1992). The ecological validity of photographic slides and videotapes in simulating the service setting. *Journal of Consumer Education, 19*, 271-281.

Bergen, S. D., Ulbricht, C. A., Fridley, J. L., & Ganter, M. A. (1995). The validity of computer-generated graphic images of forest landscape. *Journal of Environmental Psychology*, *15*, 135-146.

Bishop, I., & Hull, R. (1991). Integrating technologies for visual resource management. *Journal of Environmental Management, 32*, 295-312.

Bishop, I. D., & Rohrmann, B. (1995). Visualisation tools: Their role in understanding human resonses to the urban environment. In Wyatt, R. & Hossein, H. (Eds.) *4th International Conference on Computers in Urban Planning* (pp 313-322), University of Melbourne.

Bishop, I. D., & Rohrmann, B. (1997). The validity of computer simulations of urban environments for planning and design. In Skala, V. (Ed.), *5th International Conference on Computer Graphics and Visualization*, Pilsen/Czech Republic.

Bishop, I.D., & Rohrmann, B. (in review). Subjective responses to simulated and real environments: A comparison. *Environment & Bahavior.*

Clipson, C. (1993). Simulation for planning and design: A review of strategy and technique. In Marans, R. W., & Stokols, D. (Eds.), *Environmental simulation research and policy issues* (pp. 23-60). New York: Plenum .

Decker, J. (1994). The validation of computer simulations for design guideline dispute resolution. *Environment and Behavior*, *26*, 421-443.

Globus, A., & Uselton, S. (1995). Evaluation of visualization software. *Computer Graphics*, *29*, 41-44.

Haase, H., & Dohrmann, C. (1996). Doing it right: Psychological tests to ensure the quality of scientific visualization. In G'Obel, M., David, J., Slavik, P., & van Wijk, J.J. (Eds.), *Virtual environments and scientific visualization '96* (pp. 243-256): Springer Verlag.

Hull, RT.B., Stewart, W.P. (1992). Validity of photo-based scenic beauty judgments. Journal of Environmental Psychology, 12, 101-114.

Lawrence, R. J. (1993). Simulation and citizen participation: Theory, research, and practice. In Marans, R. W., & Stokols, D. (Eds.), *Environmental simulation research and policy issues* (pp. 133-162). New York: Plenum Press.

Liggett, R. S., & Jepson, W. (1995). Use of real time visual simulation technology for urban planning/design decision making, *4th International conference on computers in urban planning and urban management* . Melbourne: University of Melbourne.

Marans, R. W., & Stokols, D. (1993). *Environmental simulation: Research and policy issues*. New York: Plenum Press.

Orland, B. (1993). Synthetic landscapes: Review of video-imaging applications in environmental perception research, planning, and design. In Marans, R. W., & Stokols, D. (Eds.), *Environmental simulation research and policy issues* (pp. 213-250). New York: Plenum Press.

Palmer, S. (1998) Subjective appraisal of computer simulations of environments.Thesis, University of Melbourne, Dept. of Psychology.

Rohrmann, B., & Bishop, I. B. (in review) Subjective responses to computer simulations of urban environments. *Journal of Environmental Psychology.*

Russell, J. A., & Lanius, U. F. (1984) Affective appraisal of environments. *Journal of Environmental Psychology, 4*, 119-135

Sheppard, S. R. J. (1989). *Visual simulation: A user's guide for architects, engineers and planners*. New York: Van Norstrad Reinhold.

Vining, J., & Orland, B. (1989). The video advantage: A comparison of two environmental representation techniques. *Journal of Environmental Management*, *29*, 275-283.

*****