The Communication Value of Graphic Visualizations Prepared with Differing Levels of Detail

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1 Introduction

This study investigates viewer attitudes regarding the communication effectiveness of computer graphic visualizations (CGVs) with differing levels of visual detail. The emphasis is on levels of detail generated through the application of geometrical refinement, material appearance and texture, and lighting effects in computer generated 3D models. The viewer response group is intended to approximate that associated with the project review process common to an American public Town Planning Board meeting. The purpose is to determine which levels of illustrative content, in this case created from a digital 3D model, are perceived by lay respondents as containing adequate visual detail to foster an informed opinion regarding the merits of specific design elements for a proposed development project. A secondary purpose is to determine the production efficiency of preparing CGVs of differing visual quality relative to their usefulness in communicating design intent.

Other researchers have investigated topics of graphic communication. DANIEL & MEITNER (2001) found that only very high levels of graphic detail are acceptable when examining aspects of scenic beauty in the landscape. However, these conclusions apply mainly to landscapes with panoramic views and significant levels of natural or rural scenery. In contrast, LANGE (2001) determined that any level of detail could be valid in the right situation, though his work focused on large scale views from a land planning perspective. Studies by BISHOP & ROHRMANN (2001) found that computer generated animation is not a valid substitute for real life experiences, and yet they concluded that the animations have some value as a vicarious experience of the real world for certain scene elements only.

In addition to providing for decision making, designers and their visualizations often have to demonstrate design aspects that can be unpopular to the interested public. The impacts of these possibly contentious elements must be shown in sufficient detail to provide fair representation. Neto stated that “the public were much more open to options normally considered unacceptable when they saw what these options would look like in real life” (NETO 2006, 348).

In order to display a project’s scope, there must be enough detail in an image to show the project’s context in the existing landscape, major amenities and organizational elements, and any areas of conflict. This has been a contentious issue in previous studies, and research has come to conflicting conclusions in measuring abstractness versus realism in levels of detail. Lange found that “even simulations with a lower degree of realism can still contain the most important information needed for a specific purpose” (LANGE 2001, 165) and Hall determined, “The impression of realism does not necessarily require correct imagery in terms of geometric detail as long as the general behavior is reasonable; that high image complexity is primary in creating the perception of realism; that subtle shading and surface detail are key in creating the perception of realism” (HALL 1990, 195). These studies state that any level of detail can be valid in the right situation, but others refute this idea, finding that only the highest possible level of realism is a valid representation of scenic beauty as shown in Daniel and Meitner's 2001 study. During his 2006 Ribeira study, Neto determined that both realistic and abstract representations should be used to communicate designs to both specialists and laypeople.

Other studies single out specific scene elements that must contain a higher degree of realism as in Bishop and Rohrmann's study comparing animation to a real life walkthrough of a site, stating; "most viewers accepted the presentation as reasonably valid" despite rating the "vegetation, [and] colors [as] not fully convincing" (BISHOP & ROHRMANN 2003, 275) Neto supports this idea by claiming that with current computer technology, it is "impossible to simulate our real experience of a space thoroughly" and that we should instead "try to 'catch a likeness' that reveals a key aspect of a prospective design" (NETO 2006, 350) when creating CGVs.

2 Methods

2.1 Computer Generated Visualizations

An imaginary site and project was created to minimize any possible real world bias of survey respondents (NIMBY effects, traffic concerns, etc.). The model was drafted using AutoCAD 2007, then processed in 3D Studio Max 2008 to create the 3D geometry, material textures, and lighting. Three sets of seven images were created from this model, each set representing a unique level of rendered detail. (See Fig. 1)

1. Image Set A – Low Detail (massing) Model – All designed elements are represented by basic geometry with minimal modeled detail. Colors were applied to objects to represent proposed materials without the use of texture mapping. A single direct spotlight provided illumination for the scene while generating shadow mapped shadows. Images were rendered using 3D Studio Max's default scanline renderer.
2. Image Set B – Mid-Detail Model – Design elements are recognizable with basic detail modeled into buildings, curbs, etc. Objects have image based textures applied to represent their proposed materials while vegetation is represented by mid-resolution (150 ppi) image maps placed in a billboard X. A single direct spotlight acted as the sun and cast advanced ray traced shadows, with less intense "fill lights" included to brighten areas of the scene without casting shadows. 3D Studio Max's standard methods of calculating radiosity were used to generate the lighting and shadows.
3. Image Set C – High Detail Model – Design elements are modeled to their actual intent and to the best ability of the author (but were limited by the computer at the time of the study). Objects have image based textures, bump maps, and other custom maps (specular, reflection/refraction, etc.) to best represent real world materiality. 3D Studio Max's sunlight system was used along with the third party V-Ray renderer, with global illumination (GI) enabled to simulate real world lighting and shadows.

Seven vantage points were chosen, representing views commonly used to display a design for presentation to a public review board when seeking project approval. Views were rendered though 3D Studio Max's standard camera, simulating a photograph taken through a 55mm lens, providing an approximate 45° field of view. These viewpoints were shared

Fig. 1: Views at three levels of detail (Image Sets A, B, & C from right to left)

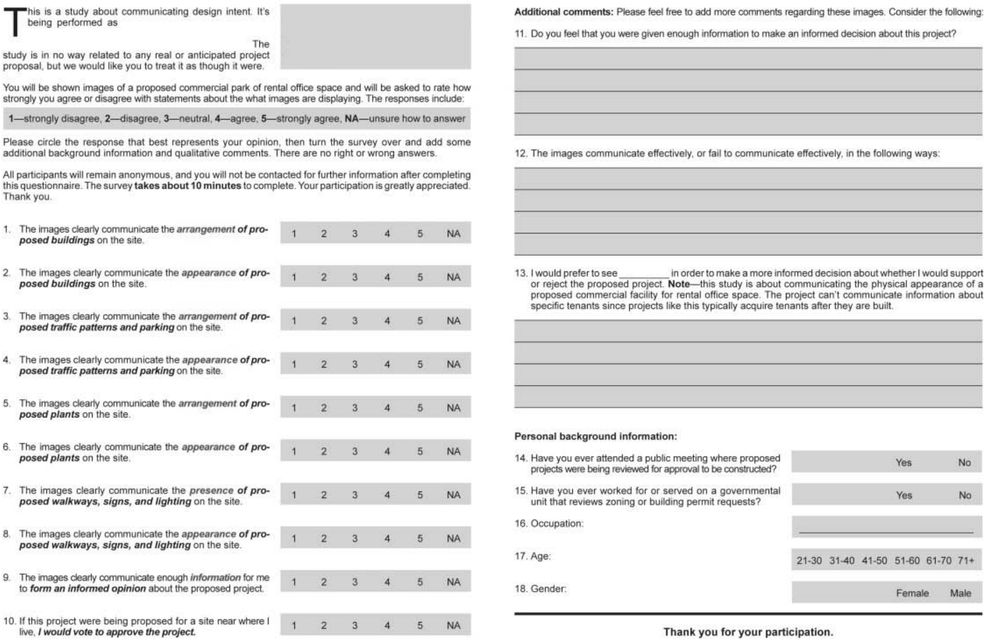
between the three levels of detail when creating the static 2D rendered images to ensure similar experiences between sample groups. The time spent performing each task of the modeling, texturing, lighting, and rendering process was recorded individually for use in a time/value analysis. The rendered CGV's were printed on 8.5"x11" 28lb. bond on a high quality inkjet printer, one image per sheet and were loosely bound in sets with a paper clip.

2.2 The Survey

This study's intent was to survey a sample group thought to represent people likely to be participants in a public town board meeting for project review and approval. Due to scheduling constraints, access to actual town board meetings was not possible, so volunteers were recruited from people using public libraries. Interested passers-by were asked to participate without discrimination in order to collect a random sample. After reading the instructions provided on the survey instrument, participants were randomly assigned a single set of images; either A, B, or C. Respondents were asked to view one set of computer generated visualizations from a single level of detail in order to avoid preference bias between the three levels of detail, as people are likely to choose the highest level of detail; the "prettier picture", when able to compare across detail sets (LANGE 2001, 173).

The survey (see Fig. 2) aimed to measure whether respondents believed that they were able to understand the design intent displayed in the computer generated visualizations and whether they found the images to be an acceptable communication device. It consisted of both qualitative and quantitative questions in order to obtain a measurable scale of acceptance for each level of detail, as well as a set of open ended questions to allow respondents to elaborate on what they believed was most effective or lacking in their set of images. Quantitative responses were measured on a five (5) point Likert scale, with one (1) representing strong disagreement, and five (5), a strong agreement of the question statement. An answer of NA (not applicable) was provided for respondents who felt that they could not respond to a statement based on the materials provided.

Specific elements in the images were called out in pairs of questions on the survey, broken down to the buildings, traffic patterns, vegetation, and wayfinding elements. One question dealt with arrangement of scene elements, and the other with their appearance. Separating the two allowed this study to analyze whether representational detail contributes to, or interferes with image comprehension and decision making.



This is a study about communicating design intent. It's being performed as

The study is in no way related to any real or anticipated project proposal, but we would like you to treat it as though it were.

You will be shown images of a proposed commercial park of rental office space and will be asked to rate how strongly you agree or disagree with statements about the what images are displaying. The responses include:

1—strongly disagree, **2**—disagree, **3**—neutral, **4**—agree, **5**—strongly agree, **NA**—unsure how to answer

Please circle the response that best represents your opinion, then turn the survey over and add some additional background information and qualitative comments. There are no right or wrong answers.

All participants will remain anonymous, and you will not be contacted for further information after completing this questionnaire. The survey **takes about 10 minutes** to complete. Your participation is greatly appreciated. Thank you.

1. The images clearly communicate the ***arrangement of proposed buildings*** on the site.	1	2	3	4	5	NA
2. The images clearly communicate the ***appearance of proposed buildings*** on the site.	1	2	3	4	5	NA
3. The images clearly communicate the ***arrangement of proposed traffic patterns and parking*** on the site.	1	2	3	4	5	NA
4. The images clearly communicate the ***appearance of proposed traffic patterns and parking*** on the site.	1	2	3	4	5	NA
5. The images clearly communicate the ***arrangement of proposed plants*** on the site.	1	2	3	4	5	NA
6. The images clearly communicate the ***appearance of proposed plants*** on the site.	1	2	3	4	5	NA
7. The images clearly communicate the ***presence of proposed walkways, signs, and lighting*** on the site.	1	2	3	4	5	NA
8. The images clearly communicate the ***appearance of proposed walkways, signs, and lighting*** on the site.	1	2	3	4	5	NA
9. The images clearly communicate enough ***information*** for me to ***form an informed opinion*** about the proposed project.	1	2	3	4	5	NA
10. If this project were being proposed for a site near where I live, ***I would vote to approve the project.***	1	2	3	4	5	NA

Additional comments: Please feel free to add more comments regarding these images. Consider the following:

11. Do you feel that you were given enough information to make an informed decision about this project?

12. The images communicate effectively, or fail to communicate effectively, in the following ways:

13. I would prefer to see _________ in order to make a more informed decision about whether I would support or reject the proposed project. **Note**—this study is about communicating the physical appearance of a proposed commercial facility for rental office space. The project can't communicate information about specific tenants since projects like this typically acquire tenants after they are built.

Personal background information:

14. Have you ever attended a public meeting where proposed projects were being reviewed for approval to be constructed?	Yes No
15. Have you ever worked for or served on a governmental unit that reviews zoning or building permit requests?	Yes No
16. Occupation:	
17. Age:	21-30 31-40 41-50 51-60 61-70 71+
18. Gender:	Female Male

Thank you for your participation.

Fig. 2: The studies two page survey form

3 Results and Findings

3.1 Quantitative Results

A three-way analysis of variance (ANOVA) was done over the first eight Likert questions for all three sample groups and a single factor ANOVA was run for questions 9 & 10 (see Fig 2). The analysis indicates there is a significant difference between image sets A-B and A-C, but not between B-C (P-value <.01); with Groups B and C showing nearly identical means (4.09 and 4.07 respectively) and Group A being quite a bit lower at 3.74. This indicates that overall the people in Group A thought the graphics they were viewing were less effective at communicating various aspects of the project being depicted than did those in Groups B and C.

The analysis indicates that there were no significant differences between the sample groups for most questions. However, there were significant differences (P-values < .01) for questions two and nine (see Fig. 2). This indicates that the people in Group A thought the graphics they were viewing were less effective at communicating project content than did those in Groups B and C. One would expect that understanding and communication of design elements would increase as greater levels of detail were shown, but instead the data shows that Image Set B (the mid-detail image set) was preferred by survey respondents.

Responses by gender and surveyed age group did not show a statistically significant difference within or between image sets, though male respondents tended to be slightly less approving of the images overall.

There was no statistically significant difference in viewer responses for the arrangement of scene elements, while the appearance of the buildings in Image Set A received a significantly lower rating from the other levels of detail. While the appearance of the vegetation in the low detail set did not show a statistical difference from the other sets, respondents wanted to see more plant material (based on responses to open ended questions) despite vegetation amounts and locations being identical across all levels of detail. Image Set A also revealed a significant difference in whether people felt that the images contained enough information for them to make an informed decision on the project.

The results show some unexplainable discrepancies. For example, the geometry used for roads and parking, vegetation, walkways, lights, and signs in Image Sets B and C were identical. There was enough modeled detail in the mid-detail set that it was not worth the modeler's time to improve upon them for the high detail set outside of material adjustments. Despite this, Image Set C received noticeably higher marks for traffic patterns, parking, walkways, signs, and lighting, while Image Set B saw a higher mean in reference to the vegetation. Each of these discrepancies occurs in the questions regarding the arrangement of site elements; responses dealing with appearance were rated much closer between Image Sets B and C.

With the exception of vegetation in Image Set B, interpretation of the arrangement of scene elements was rated higher than that of their appearance. This demonstrates that project design information could be gathered independently of the graphic quality of representative elements. Representative detail did have a noticeable effect on whether people were able to make an informed decision on the project or in voting for its approval, as shown in Image Set A's low ratings for questions 9 and 10.

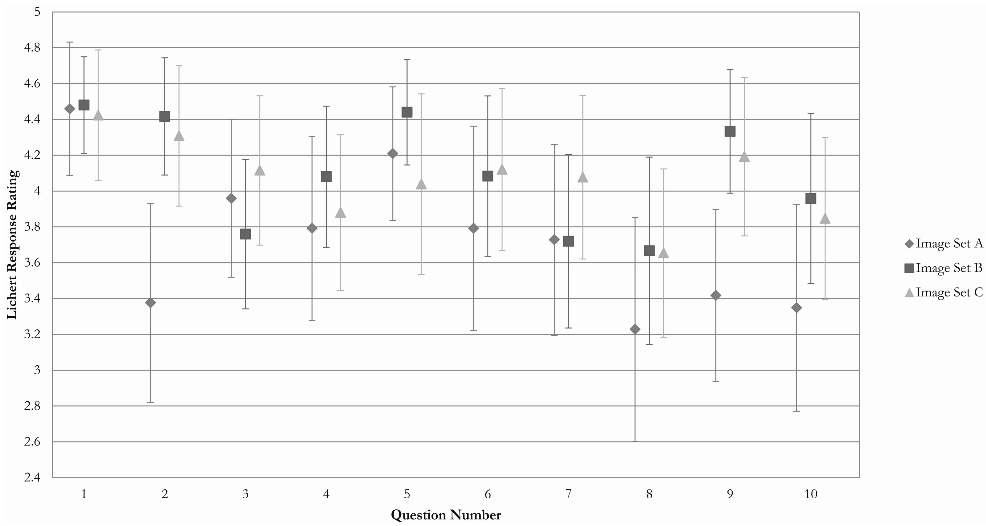


Fig. 3: Mean response per question with 95% confidence intervals

3.2 Qualitative Comments

In creating the 3D models, it was decided to keep off-site elements to a minimum to keep survey respondents focused on the proposed improvements. Adjacent buildings were modeled simply and quickly to provide context, but the ground plane was purposely ignored. However, the most common comment from all groups was that more off-site context would help them in making decisions. If a designer is required to provide more off-site context in the 3D model beyond the conceptual massing level, not only would model creation time increase, but rendering time as well. This could force a reduction in model quality with the increased computer memory load of off-site details, textures, and lighting solutions.

Another often requested element was for supporting analysis diagrams, surveyed traffic, and pedestrian figures. This indicates that respondents were being conscientious about the project evaluation, but the data requested was outside the scope of what this study sought to discover. Despite the instructions included on the survey form stating the imaginary nature of the project and the purposeful lack of proposed tenant information, many respondents wrote that they could not vote for project approval without knowing the types of businesses that would reside in the buildings.

Other comments for the low detail CGVs (Image Set A) asked for more detail, specifically in the buildings, and that there did not seem to be enough plants shown. For the mid-detail images (Image Set B), only one person requested more detail, with most other comments asking for building tenant information and more lighting, both on buildings and in the landscape.

Respondents to Image Set C were able to look beyond what was shown in the model and notice things that were missing, such as ADA ramps, handicap parking spaces, HVAC equipment, vehicular directional arrows, and building lighting. Comments for the other detail sets focused more on the site surroundings or a lack of detail in the modeled elements.

3.3 Time and Value Assessment

Digital Image Creation Time Invested (Hours, minutes, seconds)				
	CAD Setup	**Image Set A**	**Image Set B**	**Image Set C**
CAD Drafting	4:00:00	4:00:00	4:00:00	4:00:00
Line Clean-up	1:15:00	1:15:00	2:00:00	2:30:00
Terrain Modeling		2:30:00	3:30:00	3:30:00
Building Modeling		0:15:00	2:45:00	5:15:00
Landscape Modeling		0:30:00	1:15:00	3:15:00
Entourage Modeling		0:30:00	1:30:00	4:00:00
Materials		0:30:00	1:30:00	1:30:00
Lighting		0:30:00	0:45:00	1:15:00
Post-Processing		0:15:00	0:30:00	1:00:00
Total Time	5:15:00	10:00:00	17:45:00	26:15:00
Rendering Time		0:01:36	0:13:13	76:36:15
Total Per Image Set		10:01:36	17:58:13	102:51:15

Fig. 4: Time invested per element and per level of detail

Initial set-up for the 3D models used Autodesk's AutoCAD 2007 to create the basic 2D line work for the project. This necessitated some clean-up of the lines after importing into 3D Studio Max as some of the smooth curves created in CAD were misinterpreted, changing their radii. This optimization took 5 hours 15 minutes.

The low detail model elements took 4 hours 45 minutes to model and 1 minute 36 seconds to render all seven final images, making a total of 10 hours 1 minute 36 seconds for completion of image set A after adding in the CAD setup time. The largest amount of time went into the terrain, 2 hours 30 minutes, which includes the roads, curbs, sidewalks, and landscaped areas.

Image set B, displaying the mid-detail model added an additional 7 hours 45 minutes to the project time with a total of 17 hours 45 minutes for modeling alone. Instead starting from scratch, the lower detail elements were reused and refined to create the greater level of detail. Here the most time was spent modeling the buildings at 2 hours 45 minutes, though an additional hour was needed to refine the terrain, meaning that if this were the intended level of detail, then the terrain modeling would still require the greatest amount of time.

In creating the rendered CGVs, the mid-detail model used a different method of lighting than the low detail model. Radiosity approximates light reflection and refraction by shooting parallel "light beams" from a light source and calculates the angle of deflection, color pickup, and intensity loss as they hit a modeled element depending on the material applied to its surface. These calculations need only be performed once, and then any number of rendered images can be produced from the model. The radiosity calculations took 27 minutes 50 seconds for image set B, and when combined with the time spent rendering each of the seven views, the total rendering time was 43 minutes 43 seconds.

The high detail model required similar refinement as the mid-detail model did, though again, elements were re-used from the earlier models instead of starting over. Total modeling time for image set C was 26 hours 15 minutes, with the largest investment in time given to the buildings. The terrain modeling was deemed sufficiently detailed enough to re-use the mid-detail elements without need for refinement in geometry, though the materials were changed. The third party plug-in V-Ray was able to use global illumination (GI) to calculate lighting for the scene. GI simulates real world conditions better than radiosity alone, providing smooth lighting gradients and shadows. The increased realism came at a heavy price, with the total rendering time for the seven high detail images at 76 hours 36 minutes 15 seconds. If the computer used for the modeling of this project was a professional machine configured for 3D modeling, then 3D trees and people could have been used, increasing the level of detail at the cost of greatly longer render times. As it was, the computer was unable to handle the processing demands.

This study attempted various methods of creating 3D geometry, along with different lighting setups and material settings. Reviews of models in progress, and problems encountered in model processing, led to changes in direction or further refinement of geometry that added unforeseen time to the modeling process. The time associated with this learning curve was not included in the time invested for the time-value analysis. Because the design and the site were imaginary, the model and the rendered views were able to change as the focus of the project progressed.

An office creating 3D content is likely to have computers built specifically for the task with workflow and graphic style standards that would streamline this type of work. It is also likely that they would have a library of purchased and re-purposed 3D content. If this study had access to an existing source of content, the models for this project could have been created much faster, allowing a designer to focus on increasing project specific detail instead of having to start from scratch for each element. Lighting rigs and materials are likely to have been standardized (and approved), and the ability to re-purpose not only saves time up front, but reduces the need for a large amount of time wasting test renders and changes.

3.4 Results

Though the comments seem to show otherwise, Image Set B received nearly identical marks (a .028 difference between the means) to those of Image Set C when analyzing the Likert responses despite the enormous differential in time invested. It should be noted that Image Set B did seem to communicate better than Image Set C, especially in questions 9 & 10 (see Figures 2 & 3) despite the difference in levels of detail. The mid-detail set (B) of images took less than 18 percent of the time needed to produce compared to the high detail set (C). The comments show that the low detail set was lacking in a number of areas and would likely only be used inside of an office as a massing study model.

The time investment for creating the high detail set of images seems to be cost inefficient given the survey results compared to the mid-detail set, as it required 8 hours 30 minutes more of a designers time, and nearly 73 hours of additional computing time to create the rendered computer generated visualizations. This time could be reduced with faster computers, but that requires a larger investment in hardware and time differences between the two levels of detail would likely remain constant.

The results of this study show that the public would be willing to accept a lower level of detail for some content (traffic patterns and entourage elements in Image Set A), but desire greater levels of detail for others (buildings and lighting in Image Sets B & C); that there is no single consistent level of acceptable detail. This is stated with the understanding that this study's results are based on a single presented design and further study is necessary to support these findings, especially as computers are able to create ever more convincing representations of reality.

If a client or a review board were to request greater detail in a set of images, the comments and data show that a designer's time would be best spent refining architecture, being sure to include more character defining elements like doorknobs, entry signs, building lights, and railings. Following this would be site entourage elements like walkways, lighting, signage, and public utilities.

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