

Psychology and Non-Photorealistic Rendering: The Beginning of a Beautiful Relationship

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Abstract

This paper proposes the necessity of developing a theory of psychology within non-photorealistic rendering (NPR). Despite the inherent flexibility of NPR within a variety of visual media, the psychological functionality of NPR remains largely unexplored. As such, we consider aspects of NPR in terms of general, biological, social, and environmental psychology paradigms using results from recent studies, while briefly discussing options for further research and subsequent applications.

1 Introduction

As the modern world develops and utilizes IT applications for work, communication, advertising, and play at an exponential rate, the subsequent demand for psychological research into human-computer interactions has emerged. Because IT interactions are particularly visual, much of virtual reality (VR) incorporates psychological paradigms of visualization (Bente *et al.* 2002) in addition to other technical developments and applications (Bullinger & Ziegler 1999; Forsythe *et al.* 1998). Despite comparable technical research (Strothotte & Schlechtweg 2002) within non-photorealistic rendering (NPR), there exists a relatively small body of psychological knowledge regarding its effect on the user (e.g. Schumann *et al.* 1996; Gooch 2002; see also May 2000).

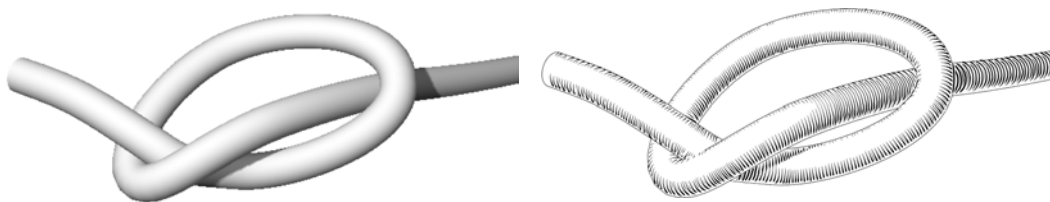


Figure 1: A PR image of a tube (left) and an NPR version of the same tube (right).

Currently VR systems survive on principles of photorealism (PR): a field essentially concerned with rendering images as ‘realistically’ as possible via the integration of physics and rendering algorithms. In contrast, NPR algorithms survive on a comparatively looser philosophy: ranging from artistic preference to the applied functionality of a given image. Consider for example the PR image in Figure 1 (left) and the NPR version of the same object on the right. While the PR

image is defined by the singular principle of appearing as realistic or ‘life-like’ as technologically possible, the NPR image uses only one of a virtually infinite variety of NPR styles. The visual flexibility of NPR holds inherent, though still undefined, potential to influence viewer responses in a variety of manners. Specifically, the coupling of NPR and psychological tests may reveal response variables encompassing aspects of emotion, attention, and memory. The challenge now is to generate such tests that accurately measure user responses and variability to controlled NPR images and environments via relevant psychological paradigms.

Detailed knowledge of the functional relations between users and features of NPR will contribute to a more precise understanding of the cognitive, emotional and behavioral impacts of NPR, both unto the utility of NPR itself as well as for a number of psychological paradigms. Subsequent results could then facilitate the development of *functional* rendering techniques within visual user interfaces applicable to both research and industry demands. Specific directions for research in this area can be generally refined into the following issues:

- What existing psychological paradigms and subsequent theories can be utilized to drive further research and understanding of NPR at a functional and theoretical level?
- What specific properties of NPR are relevant to current psychological paradigms, and how can they be used to support future psychological research and subsequent theory?

We concentrate on four areas accordingly: general psychology, social psychology, biological psychology, and environmental psychology in terms of research we conducted as it applies to both NPR and psychology.

2 General Psychology in NPR

General Psychology is mainly concerned with behavior and cognition, and in terms of NPR, offers several relevant theories surrounding visual processing. Specific to our research of NPR, we discuss *figure-ground-segregation*: when lines, surfaces, and colors facilitate object identification relative to other objects within the visual field.

2.1 Figure-Ground-Segregation for NPR Guided Selection

The greater the visual information in a given image or scene, as in PR environments, the greater the probability for figure-ground segregation errors. Therefore, homogeneously structured simple surfaces are easier to detect and identify as belonging to the same object (Hoffman 1998), and therefore, rendering objects using defined ‘figure’ or ‘ground’ styles, enables the viewer to more rapidly and accurately assess the status of objects within a complex scene. Indeed, our results indicate that NPR styles can strongly facilitate figure-ground segregation processes. In a recent study Halper (Halper *et al.* 2003) asked subjects to “click on three objects” from a set of 20 objects. About half of the objects displayed were rendered in cartoon-style (strong silhouettes and two-tone shading), and the other half were rendered with the same oil-paint style used for the background (see Figure 2). Subjects were randomly assigned to one of two test conditions (A or B—as in Figure 2) to control for biasing based on object preference. Overall, subjects tended to select two or more cartoon-style objects, indicating that rendering style was a greater factor in selection choice than actual object attributes.



Figure 2: A magnified view from the Halper et al.'s interactive rendering task (2003). The left (test A) and right image (test B) use two different rendering styles (cartoon-style and oil paint) to 'define' objects as 'active' versus those perceived as part of the background or 'inactive.' Subjects shown the left image tend to select the active truck while subjects shown the right image tend to select the active duck.

2.2 Future Directions for NPR and General Psychology

Other general psychological theories such as prior knowledge, associative conditioning, and the geon theory are also relevant to NPR and future psychological research. For instance, *prior knowledge* can reinforce behavior in the guided selection of objects discussed above, such that repeated experiments coupled with consistent object interactions would likely strengthen the influence of rendering style until subjects cease to interact with background objects altogether. This could then be applied to interactive graphics, with the potential to simplify and guide user choice. *Associative conditioning* occurs when two or more elements or objects become associated because of an observed relationship (visuo-spatial, temporal, auditory etc.) between their assessed elements. Indeed, graded levels of active and inactive rendering styles associated with the functionality of objects may influence subject responses accordingly. Associations may also be formulated based on other NPR elements within the image. Lastly, the *geon theory* states that humans perceive objects using 'geons,' or compositions of the most elementary geometrical shapes. The simpler an object is, the fewer geons must be processed before achieving object identification. Thus NPR images could support image identification when using simpler rendering algorithms relative to the number of geons necessary for image identification within PR.

3 Social Psychology

Social psychology studies interactions, communication, and information exchange and is thus relevant to NPR in a number of areas. Our research focuses on aspects of social perception and judgment.

3.1 Using NPR to Influence Social Perception and Judgment

Social perception and *social judgment* utilize learned values and behaviors to respond to socially ambiguous situations, wherein interpretation of other people and their expressions—verbal and non-verbal—are necessary (Bente & Krämer 2002; Dörner & Schaub 2002). Simple optical elements may be used to evaluate a person or situation using stereotypic character attributions when too little explicit information is available. Within our own labs, assessments of safety and danger were influenced via line-style: subjects shown Figures 3 and 4 and subsequent variations tended

to perceive the normal lines as safe (whether shown on the house or the tree), and the jagged lines on the door as dangerous. Moreover, images of a geometrically identical character using only variations in line strength successfully conveyed character strength and weakness, wherein subjects tended to assess the characters rendered with thicker, more solid lines as strong, and the sketchy, thin-lined characters as weak.

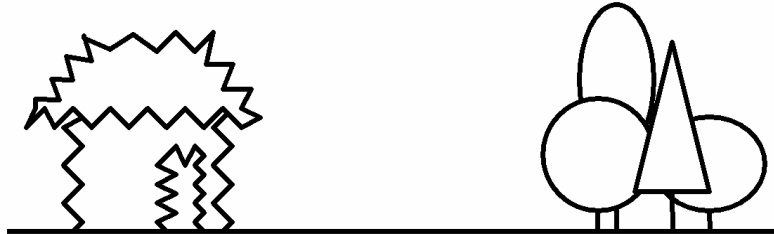


Figure 3: When asked to select the safest location, subjects choose the trees over the house rendered using threat-connnotative lines. In contrast, subjects presented the same house rendered using straight lines tend to regard the house as safer (Halper et al. 2003).

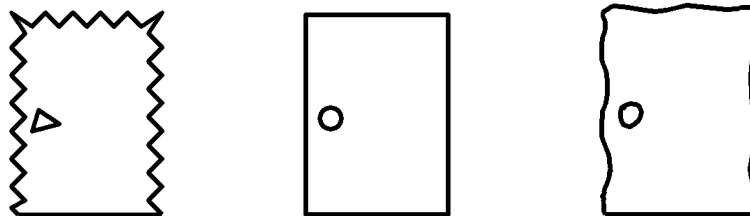


Figure 4: In identifying the door that contains danger, most subjects choose the door on the left with threat-connnotative line styles. (Halper et al. 2003).

3.2 Future Directions for Social Psychology and NPR

In terms of the research discussed above, more complex images, subtler test questions, and extended understanding of social judgments could provide definitive insights into how NPR can be used to guide and influence users and their perceptions of images and environments in general. Furthermore, NPR may also influence *aggressive* and *altruistic* behaviors. For example, NPR and social psychology would benefit from tests measuring the behavioral consequences of negative reciprocity (Felson & Tedeschi 1993; Mummendey *et al.* 1984; Patchen 1993) and whether they vary depending on how a character is rendered (strong, dangerous, etc.). These results might also extend Zimbardo's (1969) early studies on de-individuation, wherein aggressive, reckless, and chaotic behaviors increased in subjects when their identities were masked. Indeed, game environments might reveal much potential in these areas as online players frequently conceal or change their identities. It is possible that via rendering attributes, which convey more information about the player's behavior, certain negative behaviors would then decrease as a result of a sort of 'unmasking' that takes place when the player is no longer able to completely conceal negative aspects of their behavior. Lastly, game designers could systematically vary characters and scene presentation for their own utility within the game, or create 'game' programs employed towards both psychological and gaming goals to better understand the psychosocial impacts of the increasing online game world.

The *minimal group paradigm* is concerned with minimizing errors of perception within inter-group relationships (Diehl 1990) by reducing the arbitrary influences that encourage false group identification (e.g. “All people wearing glasses are smart”). Within NPR, stimuli could be reduced to a minimum of necessary elements, thus decreasing the potential for arbitrary group attributions and identifications while furthering insights into social psychology. Lastly, effects of rendering parameters, such as color, may vary between cultures, whereas other aspects of rendering, such as the threat-connnotative line styles (see Figures 3 and 4) are culture-independent. An analysis of how NPR can be used to convey messages across and within demographic groups could optimize user interfaces as well as help establish techniques for universal communication.

4 Environmental Psychology

Environmental psychology is essentially concerned with human-environment relationships. Of specific interest to NPR is the growing prevalence of human-media environment interactions, wherein environments can be systematically modeled and modified to measure user responses.

4.1 Participation and Interaction in Environments

NPR has long proven useful in the fields of architecture and urban planning: presentation techniques initiated by the Berkeley Environmental Simulation Laboratory (Appleyard & Craik 1978) have been designed to improve user needs when viewing planning alternatives. Additionally, communication between experts and laymen has also developed due to improvements in CAD, visualization, and simulation (Linneweber 1993). In terms of laymen—citizens, investors, and future users, participatory designs must facilitate interactions as well as basic design understanding. Schumann *et al.* (1996) demonstrated that NPR sketch-rendered design qualitatively improves the dialogue between architects and clients, in contrast with dialogues elicited from PR images. Psychologically, sketch-rendered designs maintain different affordances (Gibson 1977; Munz 1989), wherein sketched images appear preliminary, unfinished, and therefore open to change. Thus, the client is more likely to consider and suggest changes to the design.

NPR can also be employed to *guide* behavior. Halper *et al.* (2003) demonstrates that increased levels of detail (LOD) can effectively influence both navigation and exploration behaviors, wherein subjects asked to choose a path to explore or reach a goal in the distance (Figure 5), tend to select the path with the higher levels of detail. Potentially, subjects view increased LOD as more interesting for exploration, relative to lower LOD.



Figure 5: *Implicit cues for exploration (left) and navigation (right). Users tend to choose the detailed paths (Halper et al. 2003).*

4.2 Future Research in NPR and Environmental Psychology

For interactive planning designs, tools may be developed that portray existing buildings as PR while using sketch rendering for structures under consideration. Indeed, this might be applied in a number of areas requiring feedback, wherein incomplete or unreliable information uses varying degrees of sketch rendering mapped to varying levels of certainty. For example, it may be possible to encourage student participation via sketch rendered text and images within a lecture.

Further studies of exploration and navigation can be guided by NPR in conjunction with psychological theories: Familiarity with a specific area may be cued by decreasing LOD, while unknown areas maintain increased LOD to support spatial exploration behavior. For instance, the home range concept (van Vliet 1983) demonstrates that human exploration patterns tend to resemble an ever-expanding circle, wherein space immediately next to the familiar locations is first explored until it becomes familiar before moving outward and so on. Combining experiments that encourage exploration based on visual stimuli could aid level-design to encourage viewers to explore particular areas. Unexplored areas in maps can be ‘sketched’, so that once explored they become more refined and ‘finished.’ A more precise evaluation of the interplay between LOD and sketched representations is necessary to understand how they might be used in combination.

5 Biological Psychology

Biological psychology is concerned with the relationships between behavior, cognition and concurrent brain processes, a number of which are relevant to NPR, including feature binding, attention, and memory. *Feature binding* combines different visual elements (e.g. shape, size, and movement) to create a cohesive image(s) for identification and categorization (“that is a dog and he looks dangerous”). *Attention* occurs when sensory systems (visual, auditory etc.) focus on certain stimuli, and can be automatically triggered (Wright 1998) if certain criteria (e.g. relative size, shape, and newness) are fulfilled, thereby focusing attention on a given stimulus over other stimuli. Lastly, *memory* can influence attention and binding processes—effectively “tuning” individual binding processes to alter individual attention processes. Images already represented in memory usually require less attention because identification occurs rapidly, whereas new objects require increased attention before identification and categorization occurs. Moreover, the memory

quality can influence attention, such that a negatively remembered object may increase attention over a new object.

5.1 NPR in the Brain

Relevant to the NPR research in Section 2, visual data can be “grouped” to deal with feature binding problems that may occur when the visual scene is too complex or “overloaded”. Grouping images simplifies the scene, thus supporting feature binding in complex scenes via Gestalt rules of similarity. That is, if the different parts of an object(s) share the same qualities—in this instance, rendering style, it is easier for our brain to bind these parts together as a whole object or field of related objects. Thus, the toys rendered in the same style and separate from the background are perceived as belonging to the foreground, whereas objects rendered in the same style as the background are perceived as belonging to the background. Moreover, processes necessary to figure-ground segregation discussed in Section 2 require increased levels of attention, such that those objects perceived as foreground necessarily receive more attention than those perceived as background.



Figure 6: Realistic (top) and simplified (bottom) toy animals receive equal attention from 11-month infants.

Memory plays a central role in how images are visually perceived. Within our electroencephalogram (EEG) labs, we were able to measure increased brain activity when subjects were exposed to new images (Herrmann & Bosch 2001), thus indicating increased levels of binding and attention in order to categorize and respond to new images. Interestingly, memory is not dependent on how realistic an image appears and has been demonstrated in infants as young as 11 months. When an object is new or implausible, infants tend to attend to them longer than to previously seen objects, while the duration of object fixation (or attention) was independent of how realistic or simplified the objects appeared (cf. Figure 6) (Pauen 2003). This suggests that NPR can effectively render objects and images in non-realistic styles without influencing primary feature binding processes necessary for basic object identification, while maintaining the potential to vary aspects of the identified objects in manners not possible within PR.

5.2 Future Research in Biological Psychology and NPR

There is much potential for future research in biological psychology. Specific to our labs, we intend to combine EEG measures with assessments of safety based on rendering styles. It is possible that attention-related increases in brain activity will be observed for those objects rendered

as dangerous. Within this paper, assessments of safety and danger have been considered in the context of social judgments, while Provin's radar research (1957) demonstrated that identification of triangles as foes and circles as friendly are pre-conscious processes. Consequently, such assessments of friend and foe could prove effective in facilitating character attribution via rapid character assessment within a game. Further research is necessary to elicit the extent to which triangulation of lines influences both pre-conscious and conscious assessments of danger and how these could respectively vary in terms of brain activity. Furthermore, it is possible that neuropsychological research might uncover specific patterns of activity within visualization techniques using NPR variances in rendering in all the tests mentioned here. For example, interactive decisions regarding path exploration and navigation might reveal varying activation patterns dependent on such things as task, images, and the presence or lack of detail.

Additionally, we plan to use an eye-tracking device to record eye movement from subjects exposed to mixed and independent PR and NPR images. Our hypothesis is that non-photorealistic and photorealistic images will result in different observation times and eye movement patterns.

6 Conclusion

Currently, we are developing a software tool, OpenNPAR (see www.opennpar.org), which allows lay people, as well as programmers, to create new visual effects without technical knowledge of how the effects are generated. OpenNPAR is comprised of modules that can be fitted arbitrarily into a rendering pipeline, which then compute, based on known psychological effects of NPR, the presentation style most likely to achieve the desired effect, while mimicking a designer's creative process with a novel interaction method. Clearly, OpenNPAR stands in stark contrast to other rendering systems, which first demand the technical expertise to directly specify parameters in order to achieve the desired effects. Thus, all users—be they psychologists or computer scientists—can create effects to their own ends. Using this tool, psychologists are able to optimize experimental conditions for NPR. Moreover, OpenNPAR can produce traditional NPR aesthetic qualities in conjunction with psychologically-g geared effects, as seen in medical teaching and reference texts (e.g. Schlechtweg & Strothotte 1999), as well as technical documentation.

In this paper we have (1) reported on recent results, which demonstrate that NPR can evoke reactions for which there are psychological explanations, and (2) outlined future directions for interdisciplinary research between psychology and NPR that will prove mutually beneficial, while providing tools in support of this marriage. Existing psychological paradigms can drive NPR, just as NPR can support future psychological experiments and research. The effectiveness of a particular NPR style can be evaluated via psychological measures ranging from statistical analysis of user selection to analysis of brain activity. As a result, known influences of NPR can be applied in virtual scenarios to optimize applications and testing conditions for psychological experiments. Although we are still far from a full theoretical account of the relationship between NPR and psychology, our recent research results are clearly suggestive of this interdisciplinary potential.

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