Naive Realism:
Misplaced Faith in Realistic Displays

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A theory of why users and display designers prefer highly realistic, supposedly intuitive displays despite their poor performance.

HUMAN FACTORS/ERGONOMICS (HF/E) is concerned with complex systems of users and technologies. For those systems to function effectively, the design of the technology must draw on underlying basic science. For example, the presentation of visual information should be informed by basic vision science, work space layout should be informed by anthropometry and physiology, and so on.

In this article, we highlight an alarming disconnect between basic and applied science in the principles that explicitly, and through widespread folk belief, are driving the design of many visual displays. We review the evidence for a theory we call *naive realism* to account for this disconnect, discuss its origins and why it persists, and conclude with a discussion of design approaches to counteract it.

Trends in Visualization

For a wide variety of tasks, the primary technological artifact that users employ is a visual display. And for many task domains, such as civil emergency, air traffic, and military operations, users need to monitor, interact with, and make decisions about geospatial data. The question is, how should these geospatial visual displays be designed to make them effective and intuitive?

The few display principles HF/E can offer to designers to help them approach visualizing these data suggest that designers should strive for realism. Stanley Roscoe's complementary principles of *pictorial realism* and the *moving part* emphasize that displays should maintain spatial and temporal continuity, respectively, with their real-world analogues (Roscoe, 1968). Pictorial realism is reflected in the design of a variety of displays, such as in the growing array of three-dimensional (3-D) perspective views of geospatial data. The principle of the moving part is reflected in the design, for example, of direct manipulation interfaces (Hutchins, Hollan, & Norman, 1985), in which objects move realistically, contingent on user input, such as when one drags objects with a mouse. The moving part is also implicitly reflected in a whole class of situation displays that update in real time (temporally realistic). A simple example of temporal realism is showing the current values of gauges rather than graphing their histories.

The HF/E design principles emphasizing realism are reinforced by designers' intuition that realistic depictions must "minimize interpretive effort" (Dennehy, Nesbitt, & Sumey, 1994) by approximating what it is like to see the depicted scenes (see Figure 1 on the next page). Potential users are equally enthusiastic when shown these prototypes, frequently praising them for their ability to provide a sense of being there and "seeing" the situation as it really is.

FEATURE AT A GLANCE: How should display designers visualize geospatial environments for users engaged in tasks such as civil emergency operations or air traffic control? One visualization principle emphasizes striving toward realism, on the belief that realistic depictions result in near-effortless comprehension. We think this faith in realism is misplaced and term this misplaced faith *naive realism*. Naive realism stems from misconceptions that scene perception is simple, accurate, and rich when it is actually remarkably complex, error-prone, and sparse. Naive realism results in the development of realistic displays that, though preferred and considered intuitive, give users flawed, imprecise representations that lead to poor performance.

KEYWORDS: displays, design principles, perception, folk beliefs, 3-D displays, change detection

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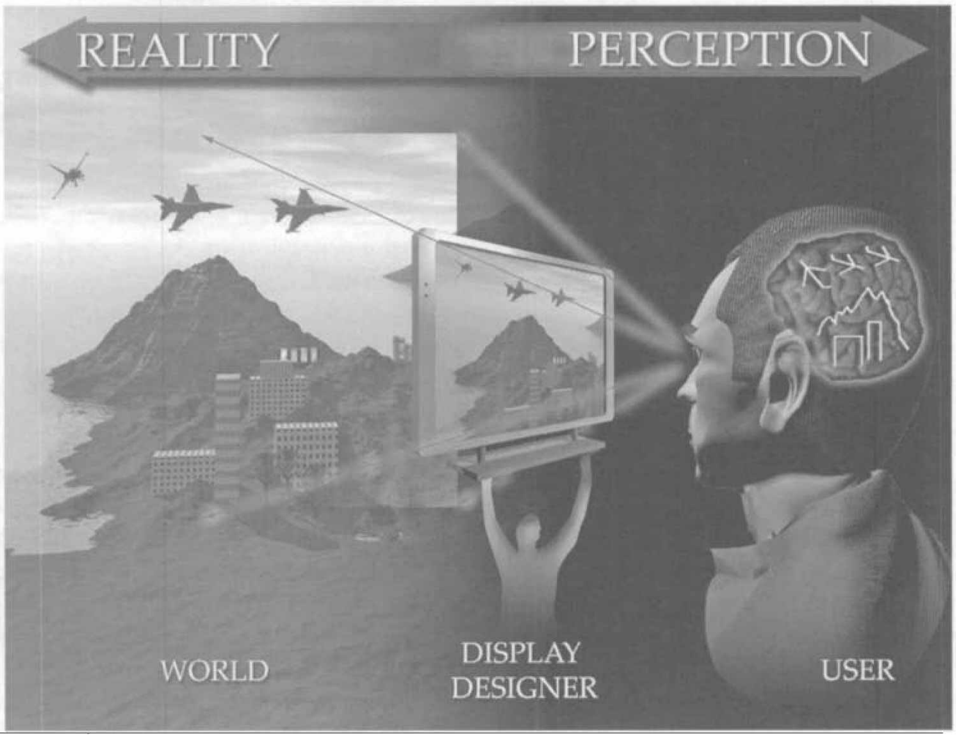

Figure 1. With naive realism, users and designers intuitively believe that existing HF/E display principles encourage – and technology increasingly supports – highly realistic displays. All harbor misplaced faith in human perceptual systems to extract information from natural scenes, leading to displays that, though favored, underperform.

Further, the rapid pace of technological innovation in the speed and sophistication of 3-D renderings increasingly supports this photorealism. Thus, a positive feedback loop for ever-greater realism has developed from a troika of mutually supporting forces: user's and designer's intuitions about the nature of visual perception, technological innovations, and HF/E design principles such as pictorial realism and direct manipulation.

Unfortunately, all is not well with this picture. The preference for realism is not matched by superior task performance. In fact, an intriguing pattern has emerged from our exploration into the human factors of visualizing tactical information in a series of studies conducted for the U.S. Navy. Time and again, we found that users naively predict superior performance for, and strongly prefer, displays that mimic and maintain the integrity of realistic scenes over nonrealistic ones, in spite of demonstrably worse performance. We believe this paradoxical behavior is caused by *naive realism,* which we define as the misplaced faith in people's ability to extract information from realistic displays. We introduce this concept and its origins and illustrate it with examples from our studies on the representation of space, objects, and time on tactical geospatial displays.

Origins and Implications of Naive Realism

Naive realism has its origins in everyday visual experience (see the table below). When we open our eyes, our visual system delivers a rich, seamless, 3-D perceptual world. We observe everything within view – it feels complete. We see the world objectively as it really is – it feels accurate. And it feels easy – it is available instantly and effortlessly. These feelings about visual experience are backed by a folk theory that visual perception works through a simple and straightforward process of taking in the world through the eyes and then reproducing the scene on an "inner screen" in the mind (Frisby, 1980; Pylyshyn, 2003).

Three Misconceptions Feeding Naive Realism and Design Approaches to Combat Each

Misconceptions of Seeing	Design Approaches
Easy – inner screen fallacy	Caricature reality
Accurate – illusion of objectivity	Gracefully inform of likely error
Complete – illusion of visual bandwidth	Quietly supplement what is missed

This folk theory, combined with the intuitions about visual perception, lead to a misplaced faith in realistic displays. Designers believe they have only to present a rich and realistic depiction of the scene – an outer screen – and the user's natural perceptual apparatus will quickly and effortlessly convert it into an accurate and complete interpretation, to play out on the inner screen.

Naive realism may help explain the paradox that eyewitness testimony is often afforded a disproportionate weight against stronger forms of evidence.

Basic perceptual science, however, informs us that this folk theory is wrong and based on several misconceptions. As others have wryly put it, "the mother of all illusions is the illusion of objectivity" (MacLeod & Willen, 1995). Back stage, through processes not consciously accessible, fully a third of our brain labors to keep up the "objective illusion show" that is visual perception. And what a rickety production that show turns out to be (Cavanagh, 1995)! Despite feeling rich and seamless, the visual scene is actually sparse and sewn together. Little of the scene is actually sampled or computed beyond what is needed in order to serve immediate task demands, and the rest is filled in (Ballard, Hayhoe, Pook, & Rao, 1998). Rather than complete and accurate, perception is so hard (Marr, 1982) that the brain has to rely on a large number of simplifying assumptions. These assumptions distort interpretation and result in imperfect, just-in-time, just-good-enough approximations of reality.

Perceptual science therefore exposes the flaws in the folk logic of naive realism. It makes it clear that naively realistic displays give users interpretations that are no better than natural vision, which is itself flawed and imprecise. All this despite the fact that the display is beguilingly intuitive.

Visual perception is hard. As instructors of psychology perception classes can attest, their primary task is to disabuse students of their firmly held, naive misconception that perception somehow functions simply as an inner screen. This misconception is held even by some experts. Zenon Pylyshyn, for example, argued that the inner screen theory is giving rise to false expectations among some brain imaging scientists of what they expect to find as the neural substrate of mental imagery (Pylyshyn, 2003). And in a now-famous incident in 1967, Marvin Minsky, an MIT professor of the then-nascent discipline of artificial intelligence, considered visual perception to be so simple (compared with other so-called higher mental processes such as problem solving) that he assigned an undergraduate student a summer project of programming a computer to parse a visual scene (to "see"). The student failed. Now, 40 years later, the entire field of computer vision is still widely considered to be in its infancy. If images truly were as easy to interpret as they were to make, then the field of computer vision would be as successful and as celebrated as the field of computer graphics.

Visual perception is flawed. Perception is flawed out of necessity. Although optics (making images of the world) is a relatively straightforward proposition, perception (interpreting the 3-D world that gave rise to those images, or *inverse optics*) is fraught with intractable problems. The brain employs a range of simplifying assumptions to make tractable the otherwise tricky and underconstrained process of image interpretation. For example, when interpreting a scene, the brain must disentangle the shape of a surface from the location of a light source falling on that surface, even though both are conflated in the intensity profile falling on the retina, leading to multiple possible interpretations. Is a gradient from light to dark caused by a bump that is illuminated from above or by a divot that is illuminated from below? To solve this problem, the brain simply assumes that the light source is above (Ramachandran, 1988); see Figure 2.

Similarly, perspective views result from projecting three spatial dimensions into two-dimensional (2-D) images. This projection results in massive ambiguity (Sedgwick, 1986). An infinite number of different 3-D scenes could give rise to the same 2-D image. Recovering the specific 3-D layout that gave rise to the perspective view requires assumptions analogous to disentangling the light source from the shape of an object.

In our work, we found that realistic 3-D perspective views are surprisingly poor for making precise relative position and distance judgments (St. John, Cowen, Smallman, & Oonk, 2001). Underlying this poor performance were pervasive errors in the interpretation of perspective. These errors resulted from another simplifying assumption that our studies revealed: Geometrically, depths into a perspective view of a scene compress much faster with distance than do widths. Psychologically, the brain simply assumes that depths compress at the same, slower rate as do widths. This simplifying assumption enables distance estimates in 3-D scenes to be made by *cross-scaling*

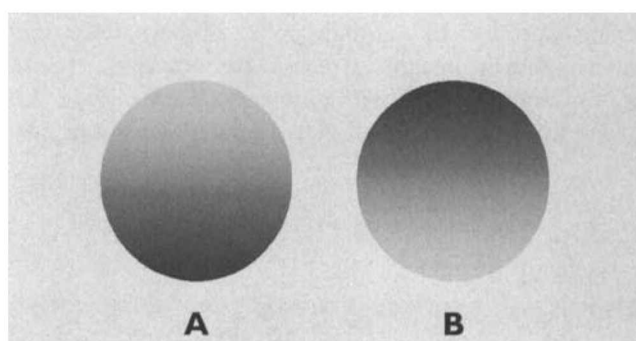

Figure 2. Simplifying assumption that the light source is above. Shape A appears as a bump and Shape B appears as a divot. Rotate the figure, and the divots and bumps reverse to preserve the light source from above

from width estimates to depth estimates (Smallman, St. John, & Cowen, 2002).

Though a reasonable approximation for nearby distances, cross-scaling results in progressively underestimated distances and thus in large errors, particularly at the back of 3-D scenes (see Figure 3). This cross-scaling error is surprisingly common; for example, it was evident in 71% of the line drawings of a large sample of psychology students (Smallman, Manes, & Cowen, 2003) and has even shown up in an expert author's diagrams in his textbook on perception!

It is probably no accident that the phrase "real-time 3D!" adorns so much software marketing material.

The illusion of objectivity is that the ubiquity of these errors goes unobserved, thereby fostering and maintaining naive realism. The brain is a master at concealing its tricks, and only occasionally does one get to glimpse the real Wizard of Oz behind the curtain. For example, the natural response is to laugh off and dismiss as an "illusion" the surprising morphing of divots into bumps when we see demonstrations such as that in Figure 2 – a demonstration of the light source assumption. In other cases, the tricks are kept literally out of reach. The absolute errors in perceived distance resulting from the cross-scaling perspective misconception begin to reveal themselves only at distances greater than arm's length (outside of "action space"; see Cutting, 2003) and hence remain inconspicuous as we go about our busy lives (see Figure 4). Within action space, space perception is accurate, metric, and reinforced by continual motor feedback. The danger with realistic 3-D displays is that they depict distances in ranges outside action space, where space perception is distorted, nonmetric, and approximate and where no feedback is available.

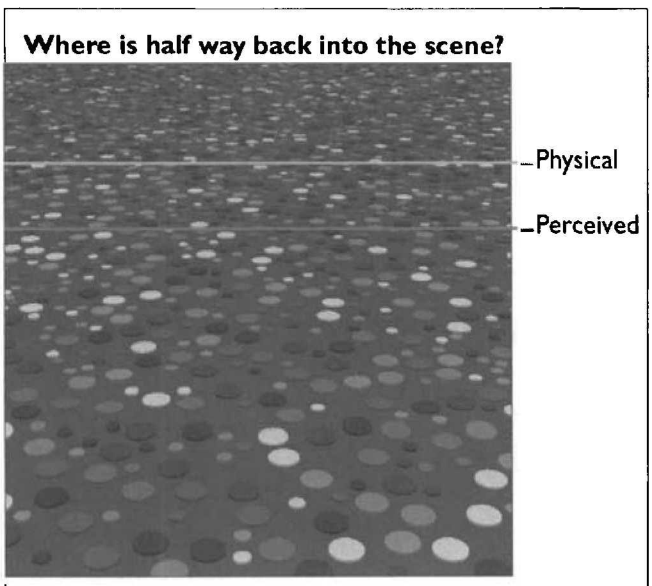

Figure 3. Systematic distance errors in realistic 3-D scenes. The physical half-way back point in a 3-D scene (top horizontal line) is farther back than the perceived half-way back point predicted from the cross-scaling misconception model (bottom horizontal line). See Smallman et al. (2002).

Naive realism applies to the representation of both objects and space. Showing objects realistically in perspective deleteriously affects their identification as well as their perceived locations. For example, military tactical displays are populated with a variety of friendly and enemy forces, neutral and commercial objects, and natural and cultural features. In our Navy work, we were struck by how often we would hear users comment enthusiastically on the depictions of miniature, realistically rendered icons of ships and aircraft in 3-D views (Smallman, St. John, Oonk, & Cowen, 2000) compared with conventional 2-D displays that show assets as abstract military symbols (see Figure 5). However, in a battery of performance tests including naming, memorization, and visual search, we consistently found that although users rated 3-D icons as preferable and believed they were likely to aid performance, comparable military symbols produced consistently superior identification performance (Smallman, Oonk, St. John, & Cowen, 2001; Smallman et al., 2000; Smallman, St. John, Oonk, & Cowen, 2001a). Once again, the beguiling realism of 3-D realistic displays serves to undermine their utility for many tasks.

There were at least three reasons for the poor performance of icons. First, a realistic iconic code retains a visual

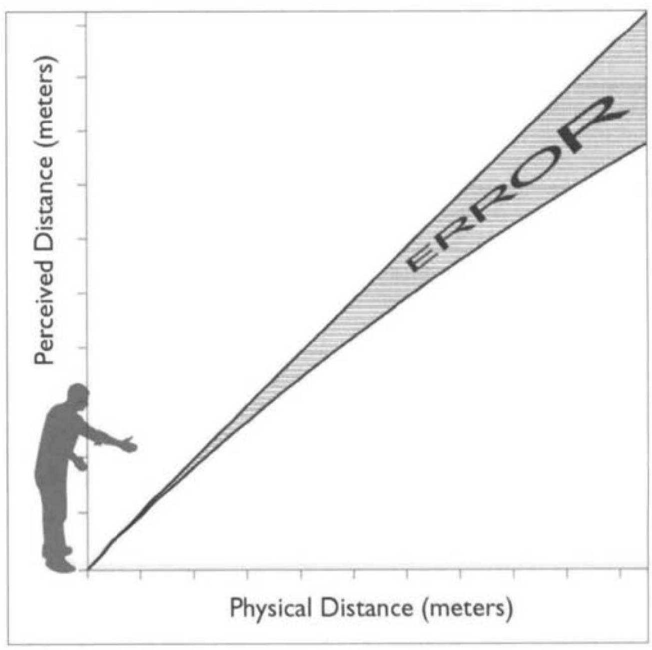

Figure 4. Staying in the dark. In this graph of perceived distance (y axis) against physical distance (x axis), accurate perception would be the upper diagonal line. But people experience the lower curve, a progressive underestimation of distance. Distance error, the region swept out between the two lines, grows with distance but is not apparent within reaching distance, leaving users in the dark.

similarity between the depicted object and its referent. When a set of depicted objects are inherently similar (e.g., many aircraft look somewhat alike, as do many ships), users have difficulty discriminating their icons and misidentify them. Military 2-D symbols, on the other hand, are designed to be mutually discriminable.

Second, a realistic iconic code overloads the spatial dimension of a display by forcing it to realistically code too many different attributes, leading to ambiguity. For example, a 3-D view confounds the pitch of an aircraft with its heading. Judged by their identical course leader lines (the black lines showing in which direction each aircraft is heading), both of the aircraft icons in Figure 5 are flying in the same direction. However, one is actually flying level going southeast and the other is descending going east.

Third, perspective views show both symbolic and spatial information and conflate the two (Ellis, 1993). Imagine an icon viewed from straight on, or an icon miniaturized to convey great distance. Increasing realism actually decreases interpretability by forcing the brain to go through a tortuous, error-prone process of deconflating the two aspects. Time pressure or a requirement for precision only exacerbates the problem. Users' preference for icons suggests either that they believe they can compensate for these problems or that they are oblivious to them.

Visual perception is spartan. Perception is also surprisingly spartan in terms of how little of a visual scene is continually sampled rather than mentally assumed and constructed. A wealth of change blindness and related cognitive studies suggests that little is actually sensed of a scene beyond a sample of fixations. The brain fills in or constructs the vast remainder while giving the viewer the sense of having an accurate representation of the entire scene (O'Regan, 1992). In a powerful demonstration, an experimenter asked a passing pedestrian for directions. During the pedestrian's response, two men passed between the conversants carrying a large door. After the men passed, the experimenter came back into view, and apparently nothing had changed. However, unbeknown to a majority of the pedestrians, the experimenter had been replaced with an entirely different person (Simons & Levin, 1998)! More mundanely, we have all had the experience of searching for an object that is eventually discovered to be "hiding" in plain sight.

That the sparseness of perception could be so extensive and yet remain inconspicuous does seem hard to swallow. However, throughout history, that sparseness has been exploited by various professions. For example, magicians and card sharks live off the permeability of visual attention. Film editors have discovered that they can get away with dramatic lapses in continuity by simply cutting to a new point of view. Only recently has cognitive science begun to systematically study these phenomena. Participants in these studies are so convinced of the seamless nature of their visual experience that they dramatically overestimate their change detection ability and are stunned by their inability to do the experimental tasks. This overestimation was recently referred to as the *illusion of visual bandwidth* (Varakin, Levin, & Fidler, 2004).

Although the 3-D research has revealed the limits of spatial realism, research on the sparseness of perception has important implications for the limits of temporal realism. In another project, we investigated users' ability to maintain and recover situation awareness in complex display-monitoring tasks and the discrepancy between the nature of the tools they desire and those they need. That users need support was recently highlighted in a study of naval air warfare displays in which participants were occasionally interrupted. When they returned from the interruption, they often failed to notice changes that had occurred during their absence (DiVita, Obermayer, Nugent, & Linville, 2004).

In our own studies, we confirmed that users were unlikely to detect changes that had occurred during interruptions, and we also showed that change detection can be near chance for changes that occur even while the user is actively engaged in monitoring a busy situation (Smallman & St. John, 2003). Furthermore, users were overconfident in their ability to spot changes, and they underestimated the potential help provided by a tool that automatically detected and arranged

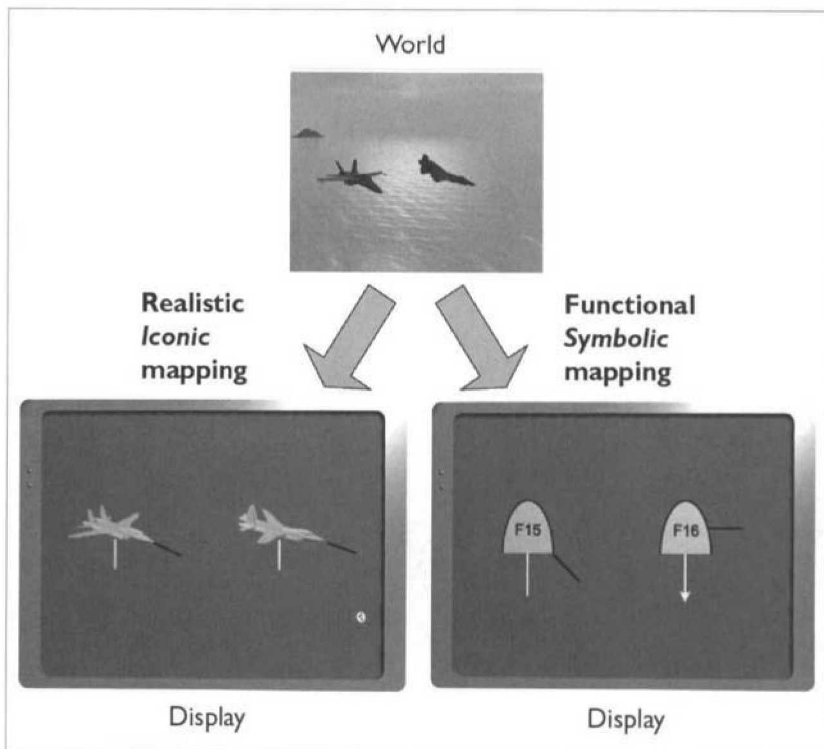

Figure 5. Which aircraft is descending? Which is headed east? Which is an F-15? The answers are all easier with the functional symbols (right), but users still prefer the realistic icons (left).

important changes into a consistently accessible table. This Change-History-EXplicit tool (CHEX), however, improved response times as much as 80%, and the rate of misses dropped to zero.

Recently, we compared CHEX with another support tool, one that lies in accord with naive realism (St. John, Smallman, & Manes, in press): an instant replay tool that allowed users to replay periods of the situation at high speed. Instant replay is natural and realistic in that it maintains the temporal integrity of the actual sequence of events. Although predicted as useful by many participants and human factors colleagues alike, replay was actually less useful than having no support tool at all, and it was far worse than CHEX, with its less realistic but explicit representation of change information.

Naive Realism in Other Domains

Naive realism accounts for a trend seen in a wide range of human-computer interaction domains beyond the representations of space and time on geospatial situation displays. In telecommunications, for example, Hollan and Stornetta (1992) issued an early rebuke to designers for what they saw as "imitating the medium rather than facilitating the message." In the development of new collaborative groupware spaces, there is a tendency among designers to mimic realistic discourse by rendering humans and workspaces realistically in near-real-time 3-D virtual environments (e.g., Benford, Greenhalgh, Rodden, & Pycock, 2001). In fact, it is probably no accident that the phrase "real-time 3D!" adorns so much software marketing material – it is aimed squarely at our naive realism.

Naively realistic expectations are so ingrained that they have led to superfluous research in order to maximize realism, even though low-fidelity tools can offer superior functionality. Designers intuit, for example, that the realism afforded by animating training sequences must result in superior performance. However, a growing literature shows that animation sequences do little to support user comprehension of events over time compared with static snapshots (e.g., Hegarty, Kriz, & Cate, 2003; see Tversky, Morrison, & Betrancourt, 2002, for a review). Yet intuitions persist that animation's temporal realism must ultimately show its efficacy, and so the literature on developing and evaluating animations grows.

Meanwhile, naively realistic expectations have led to neglect in other fields where high-fidelity displays are thought to provide adequate support even though they actually do not. Our own situation awareness recovery work highlighted the fact that research was seldom deemed necessary to improve on situation displays in order to support change detection. The realistic temporal unfolding of events in time is not sufficient to support effective monitoring and change detection. Users underestimated the utility of an unrealistic support tool (CHEX) that extracted changes for them (Smallman & St. John, 2003) and overestimated the utility of a realistic support tool (instant replay; see St. John et al., in press). Through their repeated use of replay, users actually missed new changes in the display and consequently performed worse than if they had had no support tool at all.

Naive realism is founded on a renewed appreciation of the implications of folk fallacies about how perception affects user preferences and usability assessments. It exemplifies one of potentially many implications for human factors/ergonomics that may emerge from tracking the growing field of metacognition, the (mis)understanding of one's cognitive and other abilities (e.g., Levin, 2003). As such, naive realism throws new light on the old conundrum of why user preference and performance can decorrelate (Andre & Wickens, 1995).

There are a number of reasons for this decorrelation. Payne (1995) documented an example in which participants used inappropriately piecemeal heuristics to evaluate stimulus-response compatibility mappings in stove layout designs they had to rate. Here, users falsely believed that nothing was more intuitive or effective than a rich visual experience. In both cases, they failed to apprehend the significance of the factors that actually influence performance.

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Naive realism is not the only reason users desire realism, nor is it the only factor governing the expression of realism in display design. For example, users may desire that displays be as realistic as possible to guard against display designers' abstracting away information users believe is needed to do their tasks. As we have shown, though, realism can obscure as easily as it can illuminate. And there is an extensive literature on the fidelity required of training simulators that does not hinge on folk fallacies about perception's efficacy. The detailed qualities of the experience can, in some cases, be an important component of the task itself. For example, firefighters must learn to deal with smoke, heat, and noise. Gray (2002) provided a good discussion of tailoring the level of fidelity to the research question.

Naive realism also may help explain the paradox observed in jury decision making that eyewitness testimony is often afforded a disproportionate weight against other, undeniably stronger forms of evidence, such as forensic DNA (Wells & Loftus, 2002). Jurors place excessive faith in perceptual systems to extract information and then in memory systems to later recall it. As discussed, perception doesn't function as the recording of a videotape, and memory doesn't function as the replay of a videotape, even though that is often people's intuition (Schachter, 1966).

Naive realism also highlights the limits of existing HF/E display principles. Roscoe's principles were developed to support post-World War II aviation design at a time when existing displays were obscure and not user-friendly. At the time of their inception, these principles were undeniably helpful. Now, driven by constant improvements in computer speed and technology, these principles are being taken to extremes and slavishly followed in a way that Roscoe never intended (see Roscoe, 2004). In a sense, designers are working toward the vision Ivan Sutherland articulated 40 years ago of the "ultimate display" (Sutherland, 1965): a computer display transformed into a seamless lens on the world, or different configurations of it. This ultimate display was always a vision for the virtual reality community to work toward, but it is implicitly becoming the gold standard for all geospatial display design.

Good display design is more than slavishly adhering to realism. "Design is choice" (Tufte, 1983). Design must be informed both by the information requirements of the tasks for which the displays are used and by knowledge of how the mechanisms of visual perception are likely to transform and represent what is shown. Specifically, displays should highlight task-relevant information, and this process of highlighting inevitably entails paring down reality. This process of abstraction immediately creates a conflict with the naive realism display philosophy. Taking naive realism to heart, designers may now feel that they are on the horns of a dilemma, needing to balance user preferences against the realities of perceptual science. But becoming aware of the basis for users' desires should prove helpful in wrestling with this problem.

Design Implications

In this respect, naive realism offers a new and cautionary perspective on the recent and growing interest in hedonism and on the interplay of pleasure and usability in human-computer interaction design (Jordan, 2000; Norman, 2004). We are not advocating a curmudgeonly return to sparse, unattractive displays, however – only that we shouldn't let in the bath water with the baby. To further this aim, we suggest three design approaches to combat naive realism (see the table on page 7), though there will undoubtedly be others.

The first approach, which combats the complexity of perception, is to simplify and caricature reality. Caricaturing removes unnecessary ephemera that obscure identification while maintaining a feeling of familiarity. Caricatures can also maintain pictorial realism and moving-part realism for just the features of displays that are relevant to the task. This strategy results in a more sophisticated application of Roscoe's principles. Caricatured icons have proven extremely successful for maximizing both performance and preference in our own symbology work (Smallman, St. John, Oonk, & Cowen, 2001b).

The second approach, which combats the sparseness of perception, is to quietly supplement perception to make up for what we believe is missed because of its permeability. The CHEX change history tool (Smallman & St. John, 2003; St. John et al., 2005), for example, provides a linked table of changes to a situation that is continually available to supplement a user's permeable attentional system, yet it is unobtrusive and minimally distracting from ongoing tasks. Unobtrusiveness is a key to this approach, as it is to the other approaches. Gridlines in 3-D views, on the other hand, may be a useful supplement for depth perception, but they can easily become obtrusive and cluttering, especially toward the back of the display, where they are most valuable.

The third approach, which combats the imprecision of perception, gently points out the errors that users are likely to make with realistic depictions. Every automobile passenger is familiar with the monolithic warning on the side mirror that reads "Objects in mirror are closer than they appear." This rather baffling sentence warns of potential perceptual error but offers no indication of the likely extent of error or of any redress for it. We are currently evaluating a graphical concept for informing users of the size of their potential distance misperceptions with 3-D perspective views that simultaneously affords a way to navigate effortlessly to other views that have less potential for perceptual error.

Users and designers are locked in an unhealthy conspiracy, of which neither party is guilty or conscious, to create increasingly realistic, real-time displays that beguile but underperform. We hope that the present paper shines a light on this process and introduces a dialogue for redressing this important human factors/ergonomics problem.

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