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PRESIDENTIAL ADDRESS

Cognitive technologies for gist processing

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Cognitive technologies extend our cognitive abilities, yet they are currently deficient in many respects. According to fuzzy-trace theory, people are gist processors with a fuzzy-processing preference, and information is mentally represented along a fuzzy-to-verbatim continuum. An understanding of gist processing could form the basis of a new generation of more effective cognitive technologies. This suggests, first, the need for new tools to help Web page creators optimize gist representations of text. Such a system could provide feedback about the visitor's gist and make recommendations about rewriting. It also suggests the need for new tools to help authors create more effective means of presenting quantitative data in visual form. The advocated approach capitalizes on the collective knowledge of communities of practice on the Web. Finally, it suggests the need for new tools for collecting input from users. The facial composite system EvoFIT is cited as an example.

The State of the Society

The 35th meeting of what is now the Society for Computers in Psychology or SCiP provides us with a good opportunity to take stock, to assess ourselves as an organization. One index or indicator of our vitality is the record of accomplishment of SCiP presidents past, present, and future.

Let us start with peer-refereed journal articles. Since the year 2000, SCiP's past president Robert Proctor has published 58 peer-reviewed journal articles, including last year's presidential address, "Methodology Is More Than Research Design and Technology" (Proctor, 2005). SCiP's president-elect is Ulf Reips, the first European to assume the presidency of the society. Ulf will take office at the close of our business meeting later today. Since 2000, Ulf Reips has published 20 peer-reviewed journal articles. As for our current president, Chris Wolfe, since the year 2000, I have managed to *read* 5 peer-reviewed journal articles.

Citations are a common yet crude index to the impact of one's work. According to my count from the Social Science Citation Index, past president Robert Proctor has 1,993 citations of his published research articles. According to my count again from the SSCI, president-elect Ulf Reips has 160 citations of his published research articles. As for current president Chris Wolfe, I have 23 *parking* citations.

Of course grants are increasingly important in our work. Since the year 2000, Robert Proctor has been the principal investigator, co-principal investigator, or investigator on four externally funded research projects. These include "A Comprehensive Policy-Driven Framework for Online Privacy Protection: Integrating IT, Human, Legal and Economic Perspectives," funded by the NSF Cyber-Trust Program. Since 2000, president-elect Ulf Reips has been the primary investigator, co-primary investigator, or investigator on eight externally funded research projects. These include "New Technologies and Data Collection in Social Sciences," funded by the European Science Foundation. Considering grants since 2000 for current SCiP President Chris Wolfe, my wife made me see a movie starring *Hugh Grant*. This analysis of the accomplishments of SCiP Presidents past, present, and future leads us to one inescapable conclusion. Whatever the trials and tribulations SCiP may face today, the organization has a glorious past, and a bright and promising future.

Introduction

Actually, my record as a researcher is not quite that bad, and I am particularly proud of my research collaborations with some of the finest people in the field. A common thread connecting much of my research is that I have been influenced by Charles Brainerd and Valerie Reyna's fuzzy-trace theory. My title for the present paper is "Cognitive Technologies for Gist Processing." The word *gist* comes from fuzzy-trace theory, and I use it as in "getting the gist of it," to mean "getting at the basic meaning."

Here I am guided by three premises. First, although they are wonderful in many ways, contemporary cognitive technologies are fundamentally deficient in many important respects. Second, people are, in part, gist processors who tend to extract the essential meaning from stimuli and act on the basis of these gist representations. Third, an understanding of gist processing could form the basis of a new generation of more powerful and effective cognitive technologies.

This is a somewhat revised version of the SCiP 2005 Presidential Address. Correspondence should be addressed to C. R. Wolfe, School of Interdisciplinary Studies, Miami University, Oxford, OH 45056 (e-mail: wolfecr@muohio.edu).

What do I mean by cognitive technologies? With this phrase, I refer to technologies that appreciably extend our cognitive abilities, particularly in the domains of learning, comprehension, memory, reasoning, and problem solving. Cognitive technologies are tools to assist human cognition, regardless of whether or not the underlying technology uses artificial intelligence or any other specific approach. Here I will envision three new cognitive technologies. First, I propose new tools to help the creators of Web pages optimize reader's gist representations of text presented on the World-Wide Web. Second, I propose new tools to help authors create more effective means of presenting quantitative and scientific concepts in visual form. Finally, I describe tools for collecting inputs from users that capitalize on scientific concepts of gist processing. Much of what I describe is "vaporware"—software that remains in a Platonic heaven of ideas. These technologies may seem flights of fancy, yet they are not only desirable but imminently achievable.

The State of the Web

Cognitive technologies today provide us with a vast array of available information, and publishing mountains of text on the Web is easy. We also have simple and powerful tools for visualizing data. Two distinct groups, programmers and graphic designers, are often responsible for leading larger teams that develop commercial Web sites. As information architect Christina Wodtke has said,

> The project comes to the engineers, and they start writing code. The project comes to the designer, and they open Photoshop. What engineers create is pretty on the inside: Engineers often prefer to spend their time with the code that makes the program run, rather than on the interface. What designers create is pretty on the outside: Designers sometimes get caught up in communicating the emotion . . . forgetting about interactivity. (Wodtke, 2003, pp. 58–59)

An important contribution of psychology to the Web has been a focus on issues of usability. Jacob Nielson and the psychologist Donald Norman (1992) have made fortunes by pointing out follies in the design of everyday things and providing rules to enhance the usability of Web sites. Unfortunately, to find lots of examples of usability design flaws, one need look no further than the World-Wide Web. Consider, for example, responses to the events of September 11, 2001 in the days immediately following the attacks. Amazon.com responded with a prominently displayed "upsell module" for the American Red Cross Disaster Relief Fund. Yahoo.com prominently displayed links to the Red Cross, New York Fire Fighter's fund, and other charities. MSN.com, the collaboration between Microsoft and NBC, also got into the act. However, a visitor on September 17, 2001 who wanted to help would have been hard pressed to figure out what to do. He or she would have had to click on a link labeled "Stand Together" with the American Flag to receive the module "Disaster Response: How You Can Help."

My point is not that usability is unimportant. To the contrary, examples such as this clearly demonstrate that the work of Norman, Nielson, and others is needed to make the Web and other cognitive technologies more usable. My point is, rather, that when psychologists focus exclusively on usability, we set the bar too low. Usability should be the very least that we expect from our cognitive technologies, not the standard by which they should be judged. Psychology has much to contribute to the next generation of cognitive technologies, and an understanding of gist processing should be part of that contribution.

From Information Processing to Gist Processing: Fuzzy-Trace Theory

Fuzzy-trace theory is the brainchild of Valerie Reyna and Chuck Brainerd. They deserve full credit for all of the findings and insights derived from the theory. On the other hand, I take full responsibility for any miscommunication, misunderstanding, or misapplication of fuzzy-trace theory and its evidentiary base. This theory, which has been developing over the course of 15 years, enjoys strong empirical support (Reyna & Brainerd, 1995). It represents a shift from viewing human cognition in terms of information processing to viewing it in terms of gist processing (Brainerd & Reyna, 1990). I would argue that information is represented along a continuum from fuzzy to verbatim, and that people exhibit a fuzzy-processing preference. Rather than a sign of sloppiness, gist processing is best viewed as an indication of cognitive sophistication. Yet it does sometimes lead to systematic deviations from optimal performance.

Fuzzy trace is one of several "dual-process" theories of memory and cognition, including the theories developed by Atkinson and Juola (1974), Mandler (1980), Jacoby (1991), and others. A treatment of the distinctions among these theories is beyond the scope of this paper. One way to think about dual process theories is to start with the assertion that adaptive redundancies are bred into the cognitive architecture through evolution. Human beings have more than one way to represent incoming information and more than one way to apply these representations. A key tenet of fuzzy-trace theory is gist extraction: During the encoding of information, global gist-like patterns, impressions, and essential meanings are encoded along with verbatim information. The result is a multifaceted fuzzy-to-verbatim representation. Individual knowledge items are represented along a continuum such that vague, fuzzy traces coexist with more precise verbatim representations.

People prefer to act on gist-like representations of problems rather than exact representations of the givens—even when verbatim responses are accessible to memory. As Reyna, Brainerd, and Connolly noted in a 1990 paper, "The natural habit of thought is to manipulate the barest sense of ideas, a fluid and uncertain process, rather than to march rigidly from given facts to inescapable conclusions." Thus, just "because subjects can discriminate differing quantities, and can act on those discriminations, it does not follow that problems are invariably solved by processing information at the highest possible resolution" (Reyna et al., 1990). Indeed fuzzy-trace theory predicts that people will prefer to reason on the basis of representations at the fuzzy end of the continuum.

The fuzzy-trace principle of output interference states that the act of generating responses interferes with reasoning by creating system-wide noise that degrades performance (Brainerd & Reyna, 1989; Reyna & Brainerd, 1989). In a 1995 paper (Wolfe, 1995), I described output interference as analogous to the difficulty of learning to juggle. Juggling is difficult, because the act of throwing one ball interferes with the act of catching another. One learns to juggle not by adding more hands (i.e., resources) but by learning to coordinate catching and throwing (i.e., coordinating outputs). Output interference suggests significant debilitating consequences for processing irrelevant information, or even too much relevant information. Fuzzy-trace theory predicts that people will seek relatively little information, even if that information is readily available and the cost of information access is negligible.

Fuzzy-trace theory is not unique in noting the central importance of the way in which information is presented to cognitive representation and subsequent cognitive acts such as reasoning and problem solving. As a graduate student at Pittsburgh, I was fortunate to be able to walk across the street to Carnegie Mellon and take Herbert Simon's course on problem solving. Simon once remarked that his first attempts to fund research on isomorphs of the Tower of Hanoi problem were rejected by an anonymous reviewer because it was trivial and obvious that people would behave in the same way on different isomorphs of the same problem. Of course, today most cognitive psychologists would disagree.

The Web is an ephemeral medium. We use phrases such as "browsing" and "surfing" to characterize our interactions with the Web, rather than "studying" or "examining." The Web affords skimming and favors graphics and pithy text. According to research conducted by Jacob Nielson (1999), only 16% of users actually do a word-for-word reading of the text on Web pages. Although it is technologically simple to put book length texts on the Web, such documents violate our assumptions. For the vast majority of users, it is "unnatural" to read all of the text on a typical Web page. At the level of text processing, the Web places high demands on the reader's ability to make connections between new and existing knowledge. Britt and Gabrys (2001) argue that the Web is a more difficult reading environment. The Web strips out textual devices that typically build coherence in linear texts such as textbooks.

Digital Gist Extraction From Text

Although gist processing is natural to human beings, it has proved to be more difficult for computers. Recently, however, digital or automatic gist extraction algorithms have been developed and refined to the point of commercial viability. Two examples of such technology are Oracle Text and the search engine Google. With Oracle Text, theme information is derived from a knowledge base, created by Oracle, "which is a hierarchical listing of categories and concepts. The supplied knowledge base is a general view of the world" (Oracle Text Application Developer's Guide, 2005). Themes present a profile of the main subjects or topics of a document. Oracle Text uses standard SQL to index, search, and analyze text and documents stored in the Oracle database, in files, and on the Web (Oracle.com, 2005) to create gist.

Oracle Text provides two kinds of gist from text: generic and point of view. The generic gist consists of the sentences or paragraphs that best represent the overall subject matter of the document. The point-of-view gist provides a short summary for a single, specific theme (Roti, 2005). Oracle Text themes can be used to "tell me the 10 themes about this page." Oracle Text gist can be used to reduce a 100-page document into a few paragraphs. It also has a rule-driven document classification system (Oracle Text Application Developer's Guide, 2005).

Google also provides gist, in the form of text accompanying the link to a page excerpted from a Web site. Consider the results page for the search term *zymurgy* (the last word in some abbreviated dictionaries, meaning "beer making"). Here the choice of text is driven by the search term, but note that it is not necessary for the search term to actually occur in the chosen text. In this case, the first returned text includes home brewers, home brewing, and beer, but not *zymurgy*. In the second reference, the gist is taken from more than one sentence with the word *zymurgy*, separated by a series of dots. This can be considered analogous to the point of view gist, with the search terms representing the point of view.

These technological developments appear promising. Of course, there is no reason to think that people extract gist in the same way as these programs do. To date, there is little evidence that human and digital gist extraction would return the same results. However, there are good reasons to believe that these gist extraction technologies could be improved through comparison with cognitive psychology experiments involving people.

Digital Gist Extraction for Web Authors

One way to assess the relationship between the gist extracted by these digital gist extractors and human beings is simply to ask people to read over the materials and rate the output of the programs. However, a better approach is to ask research participants to extract the key concepts themselves. Anne Britt and Gareth Gabrys (2004) have developed a drag-and-drop technique that seems well suited for this purpose. Figure 1 presents a screen shot from their program the Sourcer's Apprentice, demonstrating this drag-and-drop technique. Users can highlight different sections of text and drop them into different containers or bins.

More recently, Britt and Gabrys have expanded the technique to use on the Web. It would be interesting to give people instructions to highlight the passages representing the main ideas or gist of the entire Web page and compare the results with those obtained from an automatic gist extractor. Such data could be used to improve the automatic gist extractors, and to shed light on the process of human gist extraction. If not today, then soon, automatic gist extractors will give us a rough idea of what we would expect human readers to take away from Web sites as their gist representations. The insights provided by

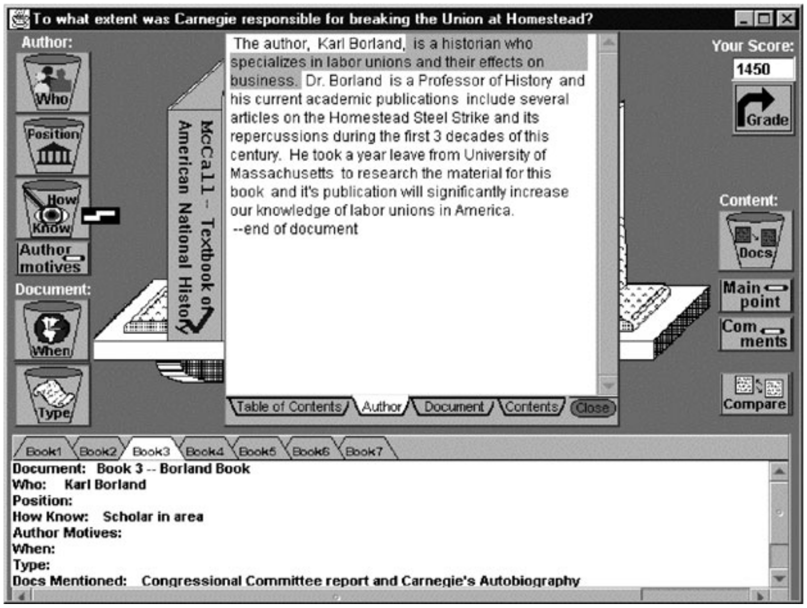

Figure 1. Screen shot from the Sourcer's Apprentice.

these gist extractors could be extremely valuable to Web site developers.

To extend the notion further, with the use of eye-tracking hardware and software, we are beginning to develop a rich understanding of which parts of a Web site people are likely to look at first, and which they are likely to ignore. Researchers such as Christopher Myers (Myers & Schoelles, 2005), who presented his research at SCiP last year, have done eye-tracking experiments with Web pages as stimuli. It would be possible to run automatic gist extractions of two types, first on entire documents, and second, on the portions most likely to be read. Together, these would give developers insight into what future visitors would actually take away from their interactions with the Web site.

This brings us to another idea: building gist extractors directly into Web authoring software such as Dreamweaver to give authors a sense of the likely gist representations formed by their eventual users. Such systems could provide two kinds of gist, gist of the entire Web site and gist of the portions of the site most likely to be viewed. These could also be generic or point of view gist representations. Authors could then compare these gist representations and target outcomes.

It is possible to imagine an interface such as that used by Intuit's TurboTax that uses gist representations as the basis of an interview with the author about what kind of gist he or she would like visitors to acquire by visiting the site. Such a system could provide feedback about what the writer wants the visitor's gist to look like and could make recommendations about rewriting for both the whole site and the parts most likely to be read by most visitors. If we take seriously the notions of gist extraction and fuzzy-processing preference, then tools such as this could provide important insights into how to structure text to optimize gist and subsequent gist-based reasoning.

Cognitive Technologies for Visually Presenting Quantitative Concepts

Let us now turn from text to image, with the goal of sketching, in broad terms, tools to help authors create more effective visual representations of quantitative and scientific concepts. Consider a standard bar graph showing that sales in millions were 30 then, and 60 now. Unfortunately, standard bar graphs are not very sexy. For this reason, there is a tendency to "spice things up" using what I will call, for rhetorical purposes, the *USA Today* approach to graphics (see Figure 2).

Here the height of each "bar" reaches 30 and 60 as one would expect in a standard bar graph. However, according to Edward Tufte (1983), people respond to the area of the figure, not the height of the figure. In making judgments of relative size, figures of twice the area are judged to be larger by a factor of about 0.8. This can be a serious problem, particularly given that gist is preferred even if people can remember verbatim that sales in millions were 30 then and 60 now.

To understand how graphics such as this can distort our representation, we need methods to assess gist representation independently from verbatim representation. Here is a brief example to illustrate. In a series of experiments on analogical transfer and geologic time (Wolfe, Reyna, & Brainerd, 2005), participants were given a chronology of events in natural history. Some were asked to study the materials. These participants generally engaged in rote memorization. Other participants were asked to develop their own analogies for the age of the earth. They placed each of the events onto a new scale, such as the number

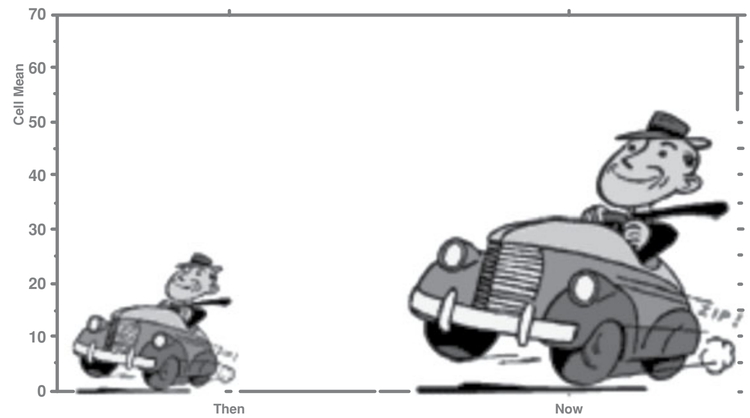

Figure 2. A hypothetical *USA Today* style graph.

of steps from their dorm rooms to the laboratory. When asked to recall the specific verbatim list in a surprise recall task, those in the rote memorization group recalled a mean of 9.4 of 14 items correctly; those in the analogy group, only 2.6 items. However, gist representations were also measured with a variety of tasks. Participants were asked to place items in their correct positions on a time line from creation of the earth to today. Another task asked them to pick which of several pie graphs best represented the correct proportion of the earth's history that had passed since the event in question. Participants were also invited to estimate the percentage of earth history that had occurred since the event. On all of these tasks measuring gist, the analogy groups performed significantly better. Similar methods could be used to assess the consequences of using *USA Today* and standard graphs.

Below I will suggest that the next generation of cognitive technologies should provide automated assistance in developing useful visual representations. For the time being, it is sufficient to say that psychological experiments with visual representations should guide that assistance. It is clear that people need help in visualizing quantitative information. Unfortunately, as those who teach statistics and research methods can attest, understanding concepts such as nominal, ordinal, interval, and ratio scale can be difficult even for smart people. It would be useful to have assistance from applications that make graphs, such as Microsoft Excel.

Rather than try to codify a set of arbitrary principles, it may make sense for such a system to make recommendations and suggestions on the basis of actual practice. Search engines such as Google recommend Web pages on the basis of algorithms that weigh the number and quality of links, as well as page content and other variables. Essentially, this highly successful approach capitalizes on the collective knowledge of the community of Web users. These can be thought of as social technologies as well as cognitive technologies, because they tap into communities of practice. The situation is somewhat analogous to the betting line on horse races or football games. Handicappers set the early line, but the betting public determines the final line with their betting behavior. Bookies make money not by taking chances on the games or races, but by getting the losers to pay off the winners and pocketing the 10% "juice." Our interest here is in the degree to which the final lines are accurate, and the answer is, to a considerable degree. Like markets and betting lines, social technologies can be used to harness the collective wisdom.

It would be possible to set up a similar system for presenting quantitative information in graphic form. Such a system would deploy spiders that crawl the Web, cataloguing graphs. The system would store which kinds of variables were presented in what formats. Such a system could use latent semantic analysis (Landauer & Dumais, 1997) or HAL (Lund & Burgess, 1996) to index words in proximity to the graphs, providing context for specific graphing decisions and conventions. To avoid perpetuating common errors, such a system could disproportionately weigh sources listed in Web of Science, Google Scholar, or any other reputable catalogue of scholarship. It would be possible to have applications such as Microsoft Excel and Word upload documents not found on the Web to a database for the same kind of treatment. The output of such a system could take the form of a prioritized results page, providing suggestions or recommendations that would show visual examples with corresponding text, asking "is this an example of what you are trying to do?" I would find help of this kind much preferable to the so-called "wizards" provided with some commercial software. Such a system could also be extended to other, more sophisticated forms of scientific visualization.

Choosing Faces: Inputs From Gist Processors

The first two cognitive technologies for gist processing that I have proposed are designed to improve computer outputs, the data we receive from the computer. These technologies are specifically related to text on the World-Wide Web and the visual display of quantitative information. The last cognitive technology that I wish to discuss concerns inputs to the system, the ways in which we send data to the computer. The issue, given that people are, to a large extent, gist processors, is this: How can we better match the inputs to cognitive technologies to operations that are natural to gist-processing human beings?

Historically, computers have been quite intolerant of deviations from precise, verbatim specifications for input from the user. If one types a comma instead of a period in the URL of a Web page, one will find that today's technology is still heavily biased toward verbatim inputs. Recently, some cognitive technologies have improved in this respect. Spell checkers in word processing applications, for example, can routinely correct common spelling mistakes automatically. The Britt and Gabrys (2004) drag-and-drop technique is another good example of an input technology better suited to gist-processing human beings.

Consider the case of software designed to help a witness to a crime develop a picture of the suspect that can be used by the police. The traditional low-tech approach is to have a trained sketch artist interview the witness and produce drawings. By working up successive versions of the drawing through several iterations of discussion, erasing and revising, sketch artists sometimes come up with useful drawings. For the last several years, police have also been able to work with digital mug books of suspect photos and software to accomplish similar ends. Current identification systems generally require witnesses to describe an assailant's face and select individual facial features or ask a witness to select from a menu of facial features such as a big nose or fat lips.

Systems such as these are subject to pervasive and systematic biases. In *The Science of False Memory*, Brainerd and Reyna (2005) note that, even under favorable circumstances, many subjects falsely identify innocent suspects. One problem with mug books is that witnesses are looking at pictures of people whom the police believe to be suspects. Moreover, prior exposure to mug shots of innocent suspects increases the chances of later false identification. The gist representation of a face is generally a gestalt, an undivided whole that makes choosing features from a menu subject to distortion.

An alternative approach is used with EvoFIT, created by Charlie Frowd, Peter Hancock and their colleagues at Stirling University in Scotland (here I need to thank Charlie Frowd for his thoughtful and generous correspondence). Unlike in current systems, faces in EvoFIT are modeled in their entirety and not separated into component parts. A facial composite is created by first displaying to the witness 18 faces containing random eyes, noses, mouths, etc. (see Figure 3). The witness selects a few of the faces that are most similar to the target. The selected faces are then mixed or "bred" together to produce a new set of 18 faces that more closely resemble the target. The witness then selects a few of these faces to be bred together again. The process of selection and breeding continues until an acceptable likeness is reached (Frowd et al., 2005).

Empirical investigations with this technology show steady improvement from one version to the next (Frowd, 2006; Frowd et al., 2005). Frowd et al. (2006) had participant witnesses inspect a photograph of a celebrity for 1 min and then 2 days later construct a composite. Composites from EvoFIT were named almost three times better than those of a program in popular use.

EvoFIT uses over 80 vectors for each face, which correspond to facial features, shapes, or textures. EvoFIT's genetic algorithm begins with a set of random solutions to a problem. The best solutions are selected and then bred together, and the process is repeated until a good solution is found. It goes without saying that the success or failure of EvoFIT depends critically on the quality of the underlying algorithm that breeds the faces to create a new generation. My cursory review of the evidence leads me to believe that this approach is very promising.

My interest here lies in the approach to collecting data. Having witnesses select among a series of randomly gen-

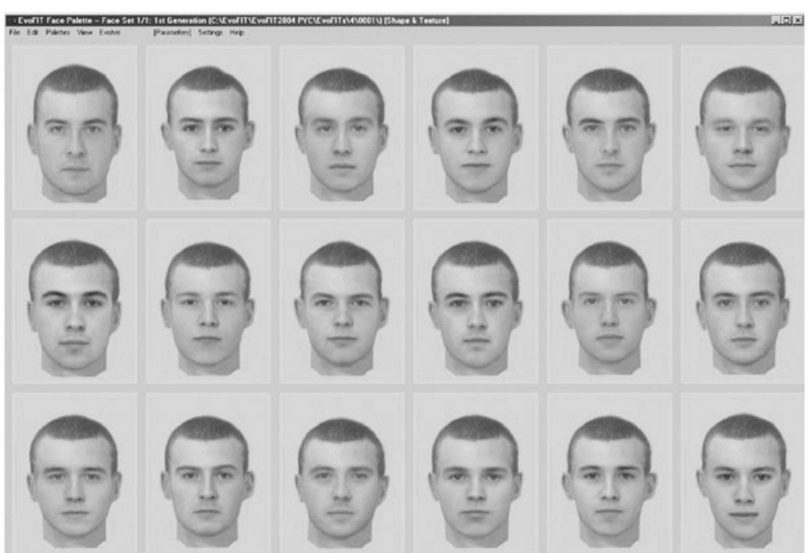

Figure 3. The EvoFIT interface (courtesy of Charlie Frowd).

erated faces seems well suited to the realities of gist processing and a hedge against some—though not all—of the pitfalls of bias and false memory. A system such as this refines the image from generation to generation without the witness being necessarily conscious of the factors affecting his or her judgments. Too often today's cognitive technologies demand that we adapt ourselves to arbitrary and narrowly defined input patterns rather than match what is easy and natural for the user. The EvoFIT interface is intriguing because it has the potential to surpass the biases of face-to-face experience. A police lineup asks us to identify which of several suspects is the culprit, and the demand characteristics of the situation are ripe for false alarms. Picking six of the most similar computer-generated faces, by way of contrast, imposes no such demands. The witness may not even be aware of which aspects of the faces he or she is responding to.

Summary and Conclusions

Here I have argued that contemporary cognitive technologies are still deficient in many respects, that people are gist processors with a fuzzy-processing preference, and that an understanding of gist processing could form the basis of a new generation of more effective cognitive technologies. I have suggested the need for new tools to help the creators of Web pages optimize gist representations of text. I have also outlined a possible direction for new tools to help present quantitative concepts in visual form. Finally, I have briefly reviewed examples of new tools for collecting input from users that capitalize on gist processing. As for actually creating these "vaporware" tools, well, that is up to us. The members of SCiP have a record of accomplishment, and like SCiP itself, cognitive technologies have a bright and promising future.

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