Incorporating Simulated Animal Attacks in Human Technology Interaction Interfaces:

The Predictive Power of Biosemiotics and Evolutionary Psychology

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ABSTRACT

Enhanced cognition within the temporal vicinity of animal attacks arguably allowed our hominid ancestors to better build and associate memories related to the animals and their typical habitat markers, which in turn increased their survival chances. This may be at the source of an unusual phenomenon with limited but interesting practical uses in the design of human-technology interaction interfaces for learning tasks; the phenomenon involves modern humans' short-term memories being instantaneously turned into long-term memories through surprise in the form of simulated animal attacks. This study explores this phenomenon in the context of a computer-supported learning task, by testing the prediction that a simulated snake attack will lead to cognition enhancement within its temporal vicinity. In an experiment, those participants who were surprised by a Web-based snake screen did significantly better in the test questions for Web-based learning modules that were temporally adjacent to the snake screen.

Keywords: *biosemiotics; cognition; evolutionary psychology; incoterms; Web-based learning*

INTRODUCTION

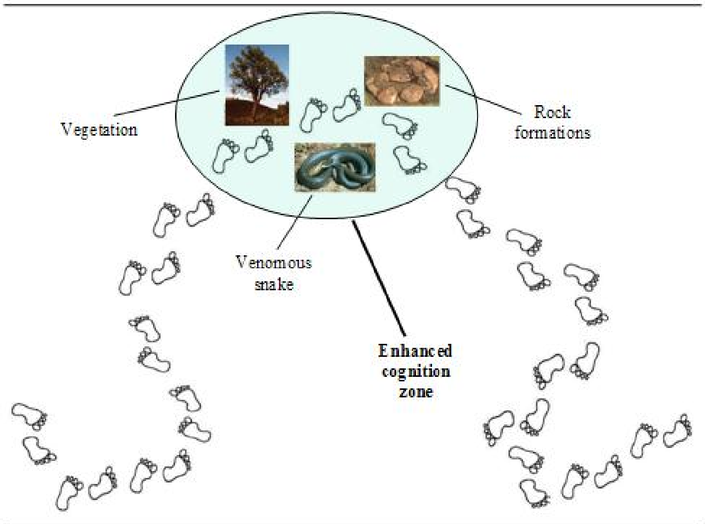
Human-technology interaction can arguably be understood based on a biosemiotics and evolutionary psychological perspective (Barbieri, 2006; Cosmides & Tooby, 1992; Kravchenko, 2006). Certain adaptive mental mechanisms that were evolved to improve reproductive success in our ancestral past may have spread throughout most of the species (Buss, 1999; Cosmides & Tooby, 1992; Plotkin, 1998), and thus would be at the source of observable patterns in human-technology behavior today. Understanding the role of these mental mechanisms today would not only lead to interesting predictions regarding the interaction of humans and technology, but also a better understanding of the human mind (Pinker, 1997; Trivers, 2002; Wilson, 2000). Moreover, technology designers could greatly benefit from this understanding as it would enable them to develop technologies that would be more effective in supporting certain tasks and have greater commercial success. Technology features whose design is motivated by an understanding of evolved brain mechanisms are likely to have universal appeal among users.

The potential of ideas underlying the new fields of biosemiotics and evolutionary psychology to explain human-technology interaction behavior, however, has been largely unexplored among technology design researchers. With a few notable exceptions (Hubona & Shirah, 2006; Kock, 2004; Kurzban & Weeden, 2005), the situation is generally the same among researchers in many related fields, such as human evolution and evolutionary psychology. The study presented here aims at bridging this research gap by showing that a biosemiotical and evolutionary psychological perspective of human-technology interaction has the potential to lead to counterintuitive predictions that are fairly well-aligned with empirical results.

This study is the first to look into how simulated animal attacks can be incorporated into computer-based interfaces in order to enhance those interfaces' knowledge communication effectiveness. Underlying the study is the theoretical assumption that animal attacks are surprise events that enhance cognition, particularly memorization of contextual information that would allow an individual to recognize the attacker's habitat upon entering it in the future (Nairne, Thompson, & Pandeirada, 2007). The co-evolution of snakes and our primate and hominid ancestors (Boaz & Almquist, 2001; Isbell, 2006) likely make reactions to real or simulated snake attacks particularly strong today. Thus, a computer-simulated snake attack is a particularly well suited surprise event for the purposes of this study.

Investigations of snake attacks and encounters with humans (Hung, 2004; Shine & Koenig, 2001) allow for the development of a generic and typical scenario involving an unintentional hominid-snake encounter. A schematic representation of a hominid walk where an attack by a venomous snake takes place is shown in Figure 1. It illustrates the point that enhanced cognition in animal attack situations likely contributes to increasing reproductive success. One key assumption here is that the hominid whose footprints are shown in the schematic representation survives the attack after being treated for his or her wounds. Nevertheless, many such attacks in the environment of our evolutionary

Figure 1. A hominid walk and the enhanced cognition zone



adaptation were likely fatal, as they are today in nonurban environments, and involved individuals who had not reached reproductive maturity (Hung, 2004). These characteristics allow us to conclude that a great deal of evolutionary pressure has been placed in favor of the selection of mental attributes that helped our ancestors effectively avoid fatal attacks. The area near the attack in the schematic representation contains animal habitat markers, such as specific rock formations and vegetation.

Figure 1 shows within a shaded oval what is referred to in this study as an enhanced cognition zone (see Appendix A for a list of key terms and definitions used in this article). That zone is the temporal area where cognition is likely to be enhanced to generate more vivid and long-lasting mental associations between habitat markers and the attack itself. Given the nature of snake attacks (Hung, 2004), and animal attacks in general (Manipady, Menezes, & Bastia, 2006; Sriaroon, Sriaroon, Davirata-nasilpa, Khawplod, & Wilde, 2006), this temporal area is hypothesized to start a few minutes before an animal attack and end a few minutes after the attack. Having particularly vivid memories of habit markers associated with animal attacks is assumed here to have increased the reproductive success of our hominid ancestors.

The rationale for the belief that enhanced cognition associated with attacks by animals, such as venomous snakes, has contributed to increasing the reproductive success of our ancestors is relatively simple. Strong memories of the habitat markers have arguably allowed our hominid ancestors to be more alert when entering the habitats of dangerous animals, or avoid those habitats, thus reducing the probability of death in future attacks.

While the above discussion refers primarily to our hominid ancestors, the related enhanced cognition effect probably has a more remote origin. For example, it is likely that our prehominid primate ancestors also had to develop similar mental mechanisms to better deal with attacks by various animals. Snakes in particular must have played a key role in that respect. There is a long documented history of co-evolution of snakes and primates in general, where snakes had been the main predators of primates (Barton, 1999; Isbell, 2006). Primate researchers have suggested that instinctive surprise responses and related brain mechanisms in various primate groups have been developed as a result of that co-evolution (Crockford & Boesch, 2003; Isbell, 2006).

BACKGROUND AND HYPOTHESES

Past research has provided ample evidence that surprise events in general enhance cognition (Brown & Kulik, 1977; Edery-Halpern & Nachson, 2004). Nevertheless, the root causes of the phenomenon have been hotly debated (Greenberg, 2005; Otani et al., 2005). A brain scan study reported by Michelon, Snyder, Buckner, McAvoy, and Zacks (2003) suggests that surprise events are processed by the brain differently than events that do not lead to surprise. Schutzwohl and Reisenzein (1999) studied the responses of children and adults to surprise events, and concluded that those responses are age invariant and have a Darwinian evolutionary origin. It seems that surprise events, particularly those that are unpleasant, trigger enhanced memory encoding mechanisms that have arguably been evolutionarily adaptive (Schützwohl & Borgstedt, 2005). Enhanced memorization of salient contextual features such as event location has been frequently reported in the literature on the effects of surprise on cognition (MacKay & Ahmetzanov, 2005; Schutzwohl, 1998).

One difficulty associated with research on surprise effects on cognition is that not all startling events elicit the same degree of surprise from different individuals. For example, Berntsen and Thomsen (2005) studied 140 Danes' contextual memories associated with the news of the Danish occupation and liberation in the 1940s. Their study found that participants who reported having ties to the Danish resistance movement had more vivid, detailed, and accurate contextual memories than those participants without ties to the movement.

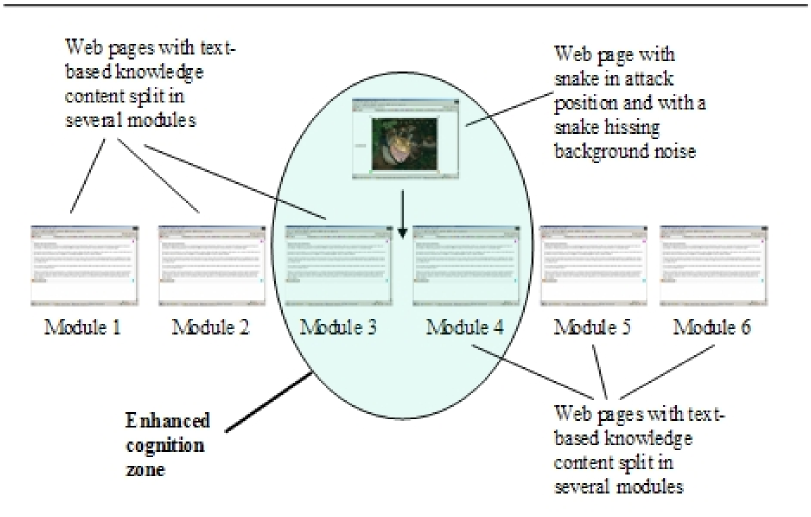
The study by Berntsen and Thomsen (2005) underlies the need for research on surprise and cognition that focuses on events that are less likely to be influenced by the participants' cultural background. Arguably, events that are similar to those faced by our hominid ancestors, such as animal attacks, are less likely to elicit different degrees of surprise among different individuals than events that are very unlike those faced by our ancestors.

If the enhanced cognition effect in animal attack situations has a genetic basis, one would expect to observe it in modern humans facing animals attacks. This opens the door for the conclusion that computer-simulated snake attacks could be used to enhance cognition in a utilitarian way, with the goal of enhancing learning associated with certain topics. Nevertheless, because computer-simulated animal attacks are different from actual attacks, it is reasonable to expect them to have an effect of lower magnitude than actual attacks.

Figure 2 shows how a computer-simulated snake attack could be implemented in the context of a Web-based learning task. (This would certainly require informed consent from the participating individuals and, in the case of a research study, Institutional Review Board approval.) The learning task in question is assumed to be made up of six learning modules, where text-based knowledge is provided in Web pages, one Web page corresponding to each learning module. In between modules 3 and 4, a Web page with a snake in attack position is shown to surprise the individuals viewing the learning modules.

Based on the above discussion, one would expect the enhanced cognition zone to comprise modules 3 and 4, because those modules appear immediately before and after the surprise event elicited by the snake screen. That is, due to the enhanced cognition effect, one

Figure 2. Web-based modules and the enhanced cognition zone



would expect the knowledge associated with modules 3 and 4 to be acquired more effectively than for modules 1, 2, 5, and 6. The hypothesized enhanced cognition effect essentially entails the short-term memories acquired for modules 3 and 4 being instantaneously turned into long-term memories (Brown & Kulik, 1977; Schacter, 2001; Schutzwohl, 1998).

Testing the above predictions in the context of a Web-based learning task cannot easily be accomplished if only one condition is used, namely a condition in which the snake screen is included in between modules 3 and 4. The reason is that it is very difficult to design learning modules with the same degree of difficulty. If modules have different degrees of difficulty, and performance is measured through test scores on questions associated with each of the modules, then differences in the difficulty levels across modules may account for a larger percentage of the variance in test scores than the surprise stimulus.

One way to avoid the above problem is to have two conditions, one treatment and one control condition. The two conditions would only differ in that one, the treatment condition, would have the snake screen and the other would not. Variations in knowledge acquisition effectiveness elicited by the snake screen could then be measured based on differences between the two conditions in test scores. Any variations in module learning difficulty would cancel each other out when performance was compared between conditions. Hypotheses H1 and H2 below provide a formalization of the prediction that knowledge communication effectiveness in the enhanced cognition zone would be increased in the treatment condition.

H1: The test scores in the treatment condition will be higher than those in the control condition for the module immediately before the snake screen.

H2: The test scores in the treatment condition will be higher than those in the control condition for the module immediately after the snake screen.

One more issue that needs to be explicitly addressed is whether enhanced cognition immediately after the snake screen is likely to be of the same magnitude as immediately before the snake screen. Different experiences may lead to variations in how effectively knowledge is acquired and vividly recalled (Werkle-Bergner, Muller, Li, & Lindenberger, 2006). Memory recall is also affected by the sensorial nature of the knowledge acquisition experience (Winkler & Cowan, 2005). Nevertheless, an individual's memories of a topic that he or she studied generally tend to fade over time (Schacter, 2001; Waddell, 2002; Werkle-Bergner et al., 2006).

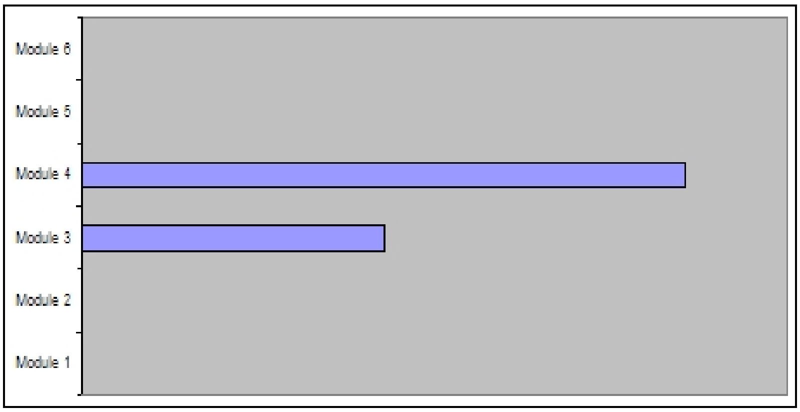
Because the knowledge in Module 3 is acquired before the surprise event, our brain is not yet as alert to the need for enhanced cognition as it is for Module 4. That is, while our brain needs to work on memories that are already fading for Module 3, it has advance notice in connection with Module 4. Therefore, one would expect a greater effectiveness in knowledge acquisition for Module 4 than for Module 3. This expectation is formalized through hypothesis H3 below.

H3: The test scores difference between the treatment and control conditions will be greater for the module immediately after than for the module before the snake screen.

Figure 3 depicts the predictions formalized through hypotheses H1 to H3. It shows a graph with the expected average differences between test scores for each module in the treatment and control conditions. Modules 1, 2, 5 and 6 are outside the enhanced cognition zone, so differences in connection with those modules are expected to be insignificant and are thus represented as zero. Differences for modules 3 and 4 are expected to be significant, hence the two bars protruding out to the right. The difference between modules 3 and 4 is also expected to be significant, which is why the bar for Module 4 is represented as approximately twice the size of the bar for Module 3.

The graph representation in Figure 3 is schematic. Neither the precise sizes of the bars nor the exact magnitudes of the underlying effects are tied to any specific hypotheses. The bars and their relative sizes are used for illustration purposes only. That is, it is not being hypothesized here that the test scores for Module 4 will be on average two times greater than the test scores for Module 3. It is only hypothesized that the test scores for Module 4 will be on average significantly greater than those for Module 3.

Figure 3. Expected differences between treatment and control test scores



RESEARCH METHODS

A Web-based learning experiment was conducted with 186 student participants. Students were promised extra credit for their participation, where the amount of extra credit would be proportional to their performance in the experimental task. Data in connection with each participant's review of 6 text-based modules was analyzed, with the goal of comparing the participants' performance in the treatment and control conditions. The modules were shown to the participants as Web pages. All participants were business students distributed as follows in terms of their university status: sophomore (6.45%), junior (43.55%), senior (41.94%), and graduate (8.06%). The ages of the participants ranged from 18 to 48, with a mean age of 24. Approximately 53% of the participants were females.

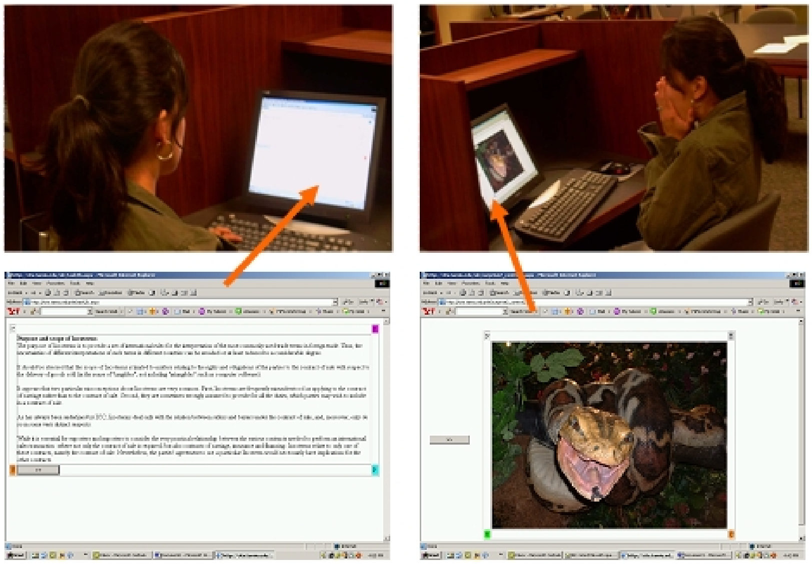
Each of the 6 modules contained text-based knowledge on Incoterms. The term "Incoterms" is an abbreviation for "International Commercial Terms." They are a body of standard terminology used in international trade contracts. Incoterms are published by the International Chamber of Commerce, an international organization dedicated to the promotion of global trade and global economic growth. Incoterms was a new topic for all of the participants; that is, students reported having no knowledge about Incoterms prior to their participation in this study.

A Web-based screen with the picture of a snake in attack position was used to surprise the participants in the treatment condition (see Figure 4). That screen was absent in the control condition. The snake screen was shown to participants for 10 seconds in between modules 3 and 4 in the treatment condition. The hissing noise normally made by an attacking snake accompanied the display of the snake screen. Approximately half of the participants were assigned randomly to each of the two conditions. Institutional Review Board approval was obtained, and the study participants signed informed consent forms, prior to the study.

The participants' review of the modules on Incoterms was timed. That is, each participant reviewed each module during a set amount of time, after which he or she reviewed the next module, and so on. The time set for review of each module was 2.35 minutes, and was the same for all of the participants. Each module contained approximately 265 words. Three organizational communication studies suggesting optimal communication unit sizes in different media (Kock, 2001; Kock & Davison, 2003; McQueen, Payner, & Kock, 1999) served as the basis for the decision to design modules with these characteristics; that is, with approximately 265 words, and to be viewed for 2.35 minutes.

After their review of the modules the participants took a test covering the knowledge about the Incoterms that they had reviewed. The test contained three multiple-choice questions for each of the modules reviewed by the participants. Each question had four choices, and only one correct answer. Shapiro-

Figure 4. Subject viewing Web-based modules



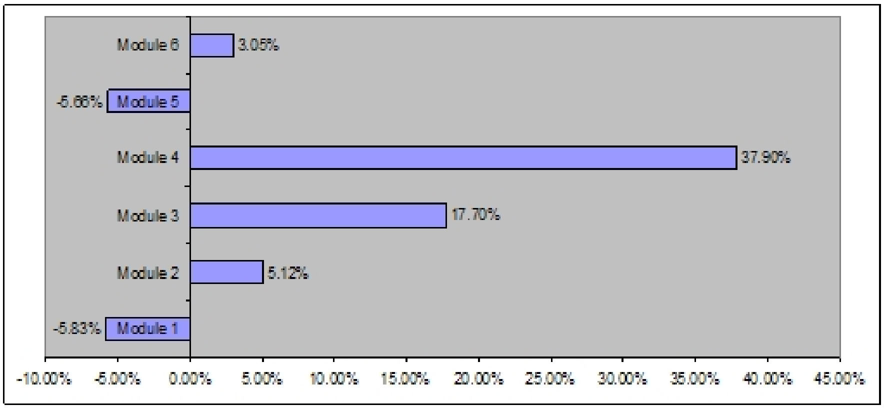
Wilk normality assessments (Shapiro & Wilk, 1965) of the test scores for each of the modules were conducted. The results suggested that no test score distribution was significantly different from the equivalent normal distribution. This in turn led to the conclusion that the test scores could be used as a basis for parametric statistical analysis tests such as ANOVA and generalized linear modeling tests (Hair, Anderson, & Tatham, 1987; Rosenthal & Rosnow, 1991).

The test scores obtained in the treatment and control conditions were compared through one-way ANOVA tests where the performance on the test scores for each module was compared across the treatment and control conditions. Additionally, interaction effects between the variable condition (i.e., presence or absence of snake screen) and three demographic variables (gender, age and grade point average) were assessed through generalized linear modeling tests.

DATA ANALYSIS RESULTS

Figure 5 shows the percentage differences in average test scores obtained by participants in the treatment and control conditions. Each bar refers to a percentage difference, calculated by subtracting, for each module, the average score obtained in the control condition from the average score obtained in the treatment condition, and dividing the result by the average score

Figure 5. Percentage differences between treatment and control test scores



obtained in the control condition. That is, each bar indicates how much greater, in percentage terms, the average score in the treatment condition was when compared with the average score in the control condition.

As can be seen from Figure 5, the differences between conditions were of less than 6% for the modules outside the enhanced cognition zone, namely the scores for modules 1, 2, 5 and 6. For Module 3, immediately before the snake screen, the average score obtained by participants in the treatment condition was 17.70% greater than the average score in the control condition. For Module 4, that difference in average scores was 37.90%. Table 1 shows the results of a one way ANOVA test comparing those differences. Effect sizes are shown in the column labeled "*d,*" which lists Cohen's "d" standardized effect size statistics associated with each comparison. The last row compares the magnitude of differences between modules 4 and 3.

The results summarized in Table 1 suggest that the differences between scores in the treatment and control conditions were statistically insignificant for modules 1, 2, 5 and 6. The 17.70% difference for Module 3 was found to be significant ($F_{1,184}$=2.71, p=.05, d=.24), providing support for hypothesis H1. The 37.90% difference form Module 4 was also found to be significant ($F_{1,184}$=.9.06, p=.001, d=.43), providing support for hypothesis H2. Finally, the 20.20% difference in the magnitude of the effects in connection with modules 3 and 4 was found to be significant as well ($F_{1,106}$=4.15, p=.04, d=.27), providing support for hypothesis H3.

In addition to the main effects' results summarized above, three main interaction effects were assessed in connection with modules 3 and 4 through generalized linear modeling

Table 1. One way ANOVA results

Module	T-C (%)	*F*	*p*	*d*
1	-5.83	.37	.27	.09
2	5.12	.16	.34	.05
3	17.70	2.71	.05	.24
4	37.90	9.06	.001	.43
5	-5.66	.53	.23	.10
6	3.05	.09	.38	.04
4-3	20.20	4.15	.04	.27

Notes: T-C (%) = percentage difference between treatment and control scores; p = chance probability of F test statistic; d = Cohen's d standardized effect size statistic; Last row compares differences for modules 4 and 3

tests. Those interaction effects refer to the demographic variables gender, age and grade point average. The interaction effects between condition (i.e., presence or absence of snake screen) and gender were statistically insignificant for Module 3 ($F_{1,184}$=1.12, p=.29, η^2=.006) and for Module 4 ($F_{1,184}$=2.42, p=.12, η^2=.01). Also, the interaction effects between condition and age were statistically insignificant for Module 3 ($F_{1,184}$=.96, p=.49, η^2=.08) and for Module 4 ($F_{1,184}$=.67, p=.79, η^2=.06). Finally, the interaction effects between condition and grade point average were statistically insignificant as well for Module 3 ($F_{1,184}$=.55, p=.93, η^2=.07) and for Module 4 ($F_{1,184}$=.60, p=.89, η^2=.08).

DISCUSSION

The study reported here was arguably the first to look into whether a computer-simulated surprise event, in the form of a Web-based snake screen accompanied by a hissing background noise, enhanced the performance of participants in a Web-based online learning task. The study compared data collected from 186 individuals who were randomly assigned to a treatment (surprise) and a control (no surprise) condition. The results of the analysis supported the theoretical prediction that computer-simulated surprise does have a significant and positive effect on cognition. The theoretical prediction had three main facets, formalized through three hypotheses (see Table 2). All hypotheses were supported by the results.

Individuals who were surprised did approximately 18% better in terms of test scores for the Web-based module immediately before the surprise event, and approximately 38% better for the module after the surprise event. A simple analogy may help put these findings into

Table 2. Summary of the results vis-à-vis the hypotheses

Hypothesis	Supported?
H1: The test scores in the treatment condition will be higher than those in the control condition for the module immediately before the snake screen.	Yes
H2: The test scores in the treatment condition will be higher than those in the control condition for the module immediately after the snake screen.	Yes
H3: The test scores difference between the treatment and control conditions will be greater for the module immediately after than for the module before the snake screen.	Yes

perspective. In a small test, this performance enhancement would be enough to account for a difference in grades from "C" to "A" (i.e., from approximately 70 to 90, out of 100), where the individuals that were surprised would get an "A" grade in a test on what they learned and those who were not surprised would get a "C" grade.

The positive effects of surprise on performance for the modules immediately before and after the surprise event occurred regardless of whether the participants were males or females. Or, in other words, both males and females did equally better in terms of test scores for those modules when surprised. The positive performance effects were observed also regardless of the participants' ages (which ranged from 18 to 48), and regardless of whether the participants were under- or over-achievers in their programs of study (measured through the participants' grade point averages). These combined findings provide some support for the notion that surprise-induced enhanced cognition is a rather universal phenomenon. These findings are also fairly consistent with the Darwinian evolutionary basis hypothesized in this study.

Another interesting aspect of the findings is that the performance in the modules outside the enhanced cognition zone was not significantly affected. That is, the variations in performance between those who were surprised and those who were not were statistically insignificant for modules that were not temporally adjacent to the surprise event. This is an interesting finding, because one could expect that surprise would be followed by distraction, and thus decrease in performance, at least for the modules after the module immediately next to the surprise event.

The positive effect in the enhanced cognition zone (modules 3 and 4, in this study), combined with the lack of a negative effect outside that zone (modules 1, 2, 5 and 6), bodes well for possible future applications of the surprise-enhanced learning approach discussed here. Certainly, the scope of the applications is limited by the unpleasant nature of the surprise, and by the fact that it cannot ethically be used without informed consent. Nevertheless, there are many computer-based training situations in which it makes practical sense to enhance the learning of particular topics, as long as that does not detract from the learning associated with other topics.

An area of application would be training in connection with emergencies, where surprise could be used to create long-term and vivid memories of procedures needed to handle emergency situations. Because emergency situations are rare, related training is likely to be sparse, hence the need for special cognitive enhancement during training. For example, commercial and military aircraft pilots are routinely trained on how to operate airplanes through the use of computer simulators. Airplane control interfaces are among the most complex of all human-technology interfaces. Certain parts of those interfaces are associated with critical situations such as an emergency response to a loss of cabin pressure. Having surprise-induced enhance cognition associated with those parts of the interfaces, as well as related sequences of actions to be taken by pilots, may significantly enhance the chances of survival in emergencies.

Online training on issues unrelated to emergencies could also benefit from human-technologies interfaces surprise stimuli. In fact, the underlying theoretical basis and the results of this study suggest that the surprise-enhanced cognition phenomenon can be widely applied in the design of online training, as long as ethical considerations make it advisable to do so. Using surprise stimuli of the type employed in this study without the consent of those who will be surprised will in most cases be considered unethical. Nevertheless, human-technology interfaces can be designed so that their users can opt for using surprise or not, when employing an interface for online learning purposes. Users can also be allowed to choose the type of surprise to which they are willing to be subjected. In these cases, a certain degree of unpredictability, through randomness and variability in the surprise stimuli used, still needs to be incorporated into the human-technology interface design. Without a certain degree of unpredictability, the stimuli in question will cease to be surprising.

CONCLUSION

This study explores an unusual phenomenon with limited but interesting practical uses in the design of human-technology interaction interfaces for learning tasks. The phenomenon, whose underlying basis builds on notions from the fields of biosemiotics and evolutionary psychology, involves modern humans' short-term memories being instantaneously turned into long-term memories through surprise in the form of simulated animal attacks. This study explores this phenomenon in the context of a computer-supported learning task, by testing the prediction that a simulated snake attack will lead to cognition enhancement within its temporal vicinity. In an experiment involving student participants, those participants who were surprised by a Web-based snake screen did significantly better (as much as 38% better) in the test questions for Web-based learning modules that were temporally adjacent to the snake screen than participants who were not surprised.

The potential of ideas from the fields of biosemiotics and evolutionary psychology to explain and predict human-technology interaction behavior has been largely untapped by technology researchers. The field of information systems, of which human-technology interaction is often seen as a subfield, is an example of this oversight. Information systems researchers are chiefly concerned with the impact that computer technologies have on individuals and groups (Galliers, Markus, & Newell, 2006). To date, there are only a handful of published studies in information systems journals that clearly attempted to understand research findings from a biosemiotical or human evolutionary perspective.

Notable examples of studies that used biosemiotics or human evolutionary perspectives to understand information systems phenomena are those by Rajala and Hantula (2000) as well as Smith and Hantula (2003) addressing electronic consumer behavior, by DeRosa et al. (2004) on virtual team leadership, by Hubona and Shirah (2006) on electronic user interface design, and by Spink and Cole (2006) on information search and use behavior. These studies are exceptions, as most information systems studies build on social theories. One influential social theory among information systems researchers has been Anthony Giddens's structuration theory, which served as the basis for DeSanctis and Poole's (1994) widely cited adaptive structuration theory of human-technology interaction. Another influential social theory used by information systems researchers is Jürgen Habermas's critical theory of communication action (Habermas, 1987). Te'eni's (2001) excellent review of theories informing information systems research provides not only a good understanding of the influence of Habermas's ideas in that field, but also a clear picture of how underutilized Darwinian perspectives have been in the field of information systems.

Human-technology interaction is often seen as an important area of research within the broader field of information systems. Empirical research on human-technology interaction has a long history, arguably dating back to the 1960s. That empirical research led to the development of several theoretical frameworks aimed at summarizing and integrating empirical findings. An extensive review of human-technology interaction frameworks conducted by Kock (2004) suggests that the vast majority of theoretical models of human-technology interaction either build on social theories or adopt a technology deterministic perspective. The technology deterministic perspective assumes that users adopt technologies as intended by the designers of the technologies, which is not often the case in practice

(Markus, 2005). Kock's (2004) review identified 11 major human-technology interaction models, none of which built on human evolution notions as a basis for their behavioral predictions.

The study presented here contributes to bridging that theoretical research gap, and will hopefully stimulate more research in the future that will follow the same theoretical orientation. Not only does this study clearly show that biosemiotical and evolutionary psychological perspectives of human-technology interaction can lead to unexpected predictions, but also that such perspectives can lead to predictions that are remarkably well-aligned with empirical results in connection with technology effects on humans.

Beyond its contemporary applications, this study also goes some way toward providing evidence that having enhanced cognition associated with animal attacks likely improved the survival chances of our ancestors. Evidence of uniform behavioral responses to technology by modern humans, where animal attacks are simulated through technology, can help us better understand our past. Understanding our evolutionary past sheds light into the design of those brain mechanisms that have been shaped by evolution and influence our current behavior. In this sense, this study makes an important contribution to the incipient fields of biosemiotics and evolutionary psychology, and hopefully will stimulate further research into the phenomenon of surprise-induced enhanced cognition.

As with any research study, especially one in a new and somewhat unusual topic as this is, the findings and related conclusions must be supported in future research in order to gain increasing credibility. Future research should include variations in research methods and design, one of which could be the addition of conditions where surprise stimuli of different types are used, for example, nonthreatening stimuli. This would allow for a better understanding of the arguably evolutionary nature of the surprise-enhanced cognition phenomenon unveiled through this study.

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APPENDIX A: TERMS AND DEFINITIONS

- **Control condition**: Experimental condition containing no snake screen, used as a contrast to the treatment condition.
- **Enhanced cognition zone**: Temporal area starting a few minutes before a real or simulated animal attack and ending a few minutes after the attack.
- **Animal habitat**: The physical area in which an animal lives, which is characterized by markers such as specific rock formations and vegetation.
- **Incoterms**: Body of standard terminology published by the International Chamber of Commerce and widely used in international trade contracts.
- **Module**: Web-based learning module containing knowledge about Incoterms in textual format.
- **Snake screen**: Web-based screen with a snake picture in attack position shown for 10 seconds together with the hissing noise normally made by a snake when it is about to attack.
- **Test scores**: Average scores on questions related to each of the modules; 3 multiple-choice questions were used to quantify the participants' learning in connection with each module.
- **Treatment condition**: Experimental condition in which a snake screen is shown between modules 3 and 4.

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