An Experimental Study of Simulated Web-Based Threats and Their Impact on Knowledge Communication Effectiveness

—NED KOCK, RUTH CHATELAIN-JARDÓN, AND JESUS CARMONA

Abstract—*It is evolutionarily adaptive for humans to have enhanced memories of events surrounding surprise situations, because in our ancestral past surprise situations were often associated with survival threats. Vividly remembering memories immediately before and after a snake attack, for example, allowed our hominid ancestors to be better prepared to avoid and deal with future attacks, which in turn enhanced their chances of survival. This study shows that such enhanced memorization capacity likely endowed on us by evolution can be exploited for knowledge communication through computer interfaces. A knowledge communication experiment was conducted in which subjects were asked to review web-based learning modules about International Commercial Terms (Incoterms), and then take a test on what they had learned. Data from six learning modules in two experimental conditions were contrasted. In the treatment condition, a web-based screen with a snake picture in attack position, displayed together with a hissing background noise, was used to create a simulated threat that surprised the subjects. In the control condition the simulated threat was absent. As expected, based on the evolutionary psychological view that surprise can enhance learning, the subjects in the treatment condition (i.e., with the snake screen) did approximately 28% better than those in the control condition (i.e., without the snake screen) at learning about Incoterms. This improvement occurred only for the two web-based modules immediately before and after the snake screen. Those two modules comprise what is referred to in this study as the surprise zone. There were no significant differences in learning performance between the two experimental conditions for modules outside the surprise zone.*

Index Terms—*Computer-mediated communication, electronic communication, evolutionary psychology, experimental research, knowledge communication, simulated threats, web-based learning.*

The field of evolutionary psychology is concerned with psychological traits that have evolved over time by our ancestors and that are **adaptive** from a Darwinian, or evolutionary, perspective [1]–[4]. Evolutionarily adaptive psychological traits refer to brain mechanisms that conferred on some of our hominid ancestors certain advantages in terms of survival and mating. Because they conferred advantages, the genes that coded for those traits have been **selected**. That is, those genes have been passed on to successive generations of individuals, and over time spread throughout the human species.

One evolutionarily adaptive psychological trait is enhanced memorization of events and context surrounding surprise situations [5], particularly situations where surprise is elicited by a survival threat. Having brain mechanisms that enhanced memories in the vicinity of a surprise event associated with some sort of survival threat would have allowed our hominid ancestors to avoid or better deal with the source of the surprise in future events. If the source of surprise was a snake attack, for example, having enhanced memories about certain elements involved in the attack would enable a hominid ancestor to better handle such an attack in the future. Those elements remembered include the ecological niche in which the attack took place, and the behavior of the snake during and after the attack.

Brain mechanisms evolved to deal with problems in our evolutionary past are still part of our brain today. In many cases, those brain mechanisms may not have the same survival advantage that they had in the environment of our evolutionary adaptation. Most of us live in urban areas where the threats that existed in that environment are largely absent. Also, new threats exist for which evolution has not prepared us. Nevertheless, those Stone Age brain mechanisms are part of our brain design and can be exploited for performance improvement in modern-day tasks.

Here we report on a study that shows that the enhanced memorization capacity endowed on us by evolution can be exploited for knowledge communication through computer interfaces. A knowledge communication experiment was conducted in which subjects were asked to review web-based learning modules, and then take a test on what they had learned. Data from six learning modules in two experimental conditions were contrasted. In the treatment condition a web-based screen with a snake picture in attack position, displayed together with a hissing background

Manuscript received July 29, 2006; revised April 2, 2007.
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IEEE 10.1109/TPC.2008.2000345

noise, was used to create a simulated threat that surprised the subjects. In the control condition the simulated threat was absent. The results of the study support the evolutionary psychological view that surprise elicited by a web-based simulated threat enhances learning.

The importance of this study comes from the possible use of its findings in situations where the memorization of certain pieces of knowledge is particularly critical. Those pieces of knowledge may be part of a larger body of knowledge, where not all of the other pieces are as critical. For example, machine operators being trained using web-based interfaces can be induced to develop vivid memories of key steps in risky operational procedures (where there may be a risk of injury, for example). They can also be induced to vividly memorize key procedures to avoid accidents, such as pressing a "stop" button with a specific shape and location on a control panel. This study suggests that those enhanced memorization results can be achieved through the selective incorporation of simulated threats on the web-based interfaces used for training.

RESEARCH BACKGROUND AND HYPOTHESES

SURPRISE can be defined as a state of mind in which there is a significant discrepancy between an actual occurrence in a certain context, and what an individual was expecting to occur in that same context [6]. Usually surprise leads to key physiological reactions. Some of those reactions are a heart beat increase and changes in respiration patterns.

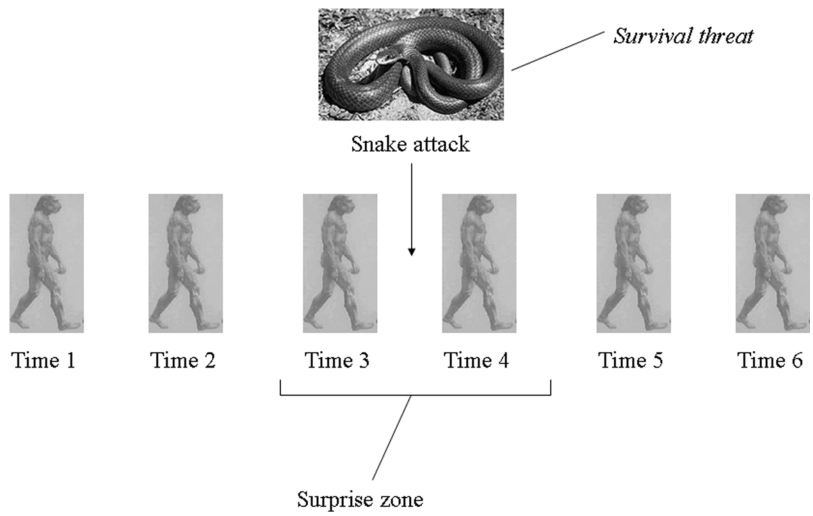
In addition to observable physiological reactions, surprise has also been found to have cognitive effects. Surprise seems to enhance memory recall related to information that is acquired within a time interval that could be called the SURPRISE ZONE; that is, a period of time immediately preceding and following the surprise event. Social researchers have called this phenomenon "flashbulb" memorization [7], [8].

The Surprise Zone: Surprise as an Evolutionary Response Surprise responses, whether they are physiological or cognitive, seem to be involuntary, automatic, and instinctive. As such, those responses are likely guided by biological mechanisms that have an evolutionary basis [4]. For this to happen, though, those responses need to be ADAPTIVE from a survival and/or mating perspective. In other words, they must have been evolved to enhance our ancestors' chances of surviving and/or mating.

It is reasonable to conclude based on findings from the field of biological anthropology (see, e.g., [9]) that surprise in our ancestral past was often associated with danger (e.g., an attack by a venomous snake). Even though today surprise is elicited by a number of events that are not necessarily associated with threats, it is reasonable to assume that its evolutionary roots are associated with threats. Physiological reactions such as an increase in heart beat could precede physical reactions such as reflex retreat and running, whose survival advantages would be self-evident. But what would have been the survival advantage of enhanced memorization within the surprise zone?

The answer to the above question is deceptively simple, and relates to a likely increase in survivability in our ancestral past enabled by increased memory recall of events and details occurring within the surprise zone. Simply put, enhanced cognition within the surprise zone enabled our hominid ancestors to identify and avoid those circumstances that surrounded the surprise event. For example, let us consider the case of a hominid ancestor walking through a certain path in a savannah during time intervals one, two, three, four, five, and six. Those time intervals could last a few minutes each (see Fig. 1). Let us also assume that between time intervals three and four, the hominid ancestor was attacked by a venomous snake, and survived that attack. Snakes, like most animals, live in ecological niches with key defining characteristics. Therefore, if the hominid ancestor's brain was wired in such a way as to remember particularly well those characteristics, then that would enhance his or her chances of survival.

The recurrent occurrence of situations such as the one depicted in Fig. 1 with many individuals of a species, and over long periods of time (e.g., hundreds of thousands of years), would place certain evolutionary pressures on the species as a whole [2]. One of such pressures, in the case of hominids (and also their primate ancestors), would be that of favoring the survival of individuals equipped with brain mechanisms that would enhance cognition within the surprise zone. That pressure would be exerted until all individuals of subsequent generations, and "branched" out species up to the human species, possessed those brain mechanisms. If that was the case, this should be observable in the cognitive responses of modern humans within the proximity of a surprise event; that is, within the modern-day version of the surprise zone.



Notes:
Hominid picture source: www.wilderdom.com
Snake picture source: www.herpnet.com

Fig. 1. A hominid walk over time and the surprise zone.

The Evolutionary Psychological Basis of Surprise Responses One subfield within the field of psychology, namely the evolutionary psychology subfield, provides a strong basis for the assumption that enhanced memorization will take place in the surprise zone. Cosmides and Tooby are largely regarded as the founders of the subfield of evolutionary psychology [10]. Those authors, and other prominent researchers in that subfield, view the human brain as a collection of modules designed to address survival and mating challenges faced in our evolutionary past [11]–[13].

In typical Darwinian fashion [14], [15], the genes that code for brain modules that enhance an individual's chances of survival or mating are hypothesized to be passed on to the next first generation [10]. As those genes confer survival or mating advantages, they are again passed on to the second generation, with a higher frequency than in the first generation. Over many generations, this process leads to the **fixation** of the related genetic traits in the species as a whole, in a process mathematically described by Fisher [16].

The above process seems to be true for a number of brain adaptations, from the enhanced memorization within the surprise zone, which is proposed here, to less intuitive adaptations. There are several examples of less intuitive adaptations that have led to much research, resulting in large bodies of evidence confirming the existence of those adaptations. There is evidence that our brain is designed to identify health indicators such as body and face symmetry, which are highly correlated to universal perceptions of beauty [11], [12]. There is also evidence that our brain is designed to identify kinship indicators (e.g., what we refer to today as race), which allowed our ancestors to better identify those individuals with whom they shared a large proportion of genes [5], [17], [18].

From an evolutionary psychological perspective, the evolution of brain mechanisms to enhance memorization of threat-related information within the surprise zone would unfold as follows. Random genetic mutations would endow one or more individuals in a generation of hominids with enhanced memorization within the surprise zone. Those individuals would then have a slightly better survival rate than individuals without that mutation, since the latter would be more likely to die in similar threatening situations in the future.

Here, the assumption is that a proportion of the threatening events would lead to death, but not all of them, otherwise the mutation would not have any effect on survival. That is, if all individuals subjected to a particular survival threat (e.g., a snake attack) died as a result of the threat then there would be no evolutionary pressure favoring enhanced memorization associated with surprise caused by that particular threat.

The genes responsible for the enhanced memorization within the surprise zone mutation would then be passed on to the next generation,

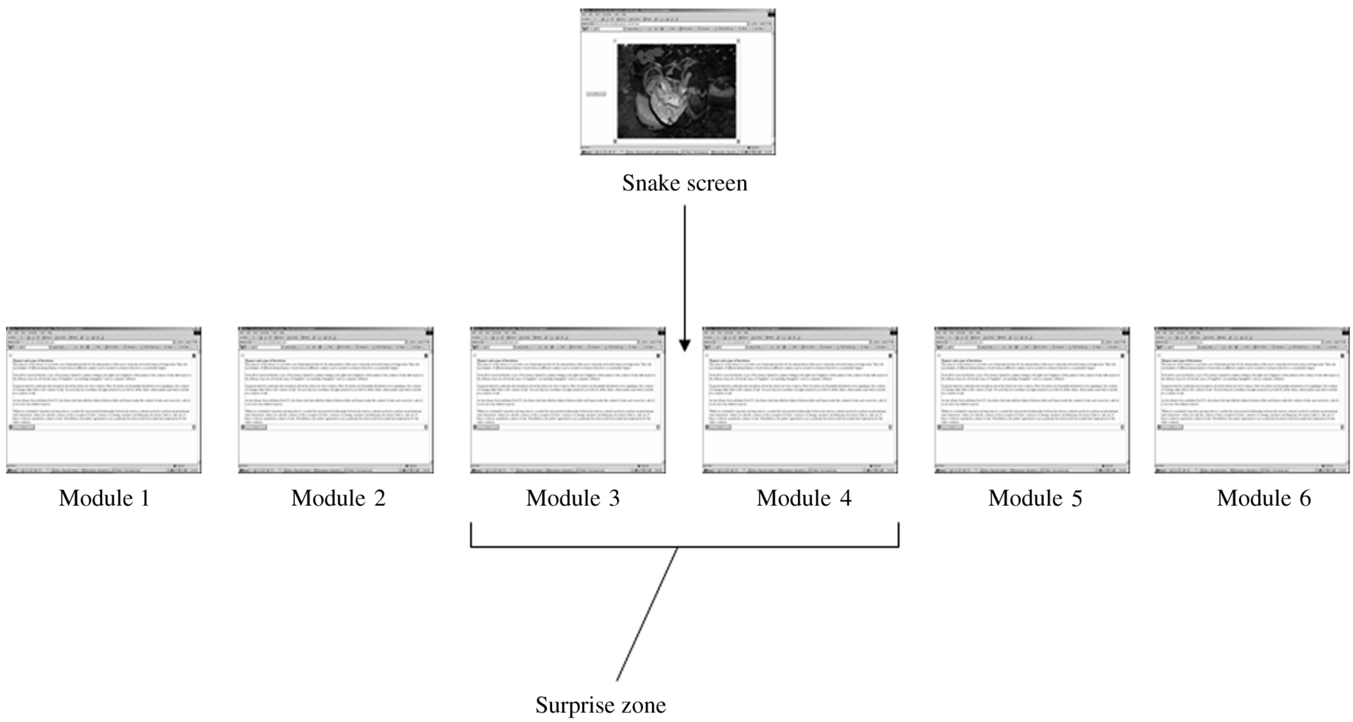


Fig. 2. Web-based modules and the surprise zone.

with a higher frequency than in the first generation (this higher frequency in subsequent generations is due to the greater survival rate of the individuals possessing those genes). Over many generations, the genes responsible for the enhanced memorization mutation would become present in the entire population. It is reasonable to assume that modern humans descend from ancestors that were part of the population that inherited those genes; analogous assumptions underlie much of the research in evolutionary psychology [2], [14]. Based on this reasoning, it makes sense to assume that the enhanced memorization mutation should be observable in the responses within the surprise zone of modern humans.

Inducing Surprise Through Web-Based Simulated Threats An involuntary and instinctive response to surprise, such as that of increased cognitive capacity in the presence of what is perceived as a threat, should be relatively easy to exploit with the use of simulated threats. One possible implementation would be a web-based knowledge communication task made up of several web-based learning modules. Fig. 2 shows a diagrammatic representation of one such task, comprising modules one, two, three, four, five, and six.

The simulated threat in Fig. 2 is represented as a snake in attack position. It is likely that snake representations are particularly good candidates for simulated threats from a primate evolution, and thus a hominid evolution, perspective. There is a long documented history of coevolution of snakes and primates in general, where snakes had been the main predators of primates [19], [20]. Strong evidence exists suggesting that instinctive surprise responses and related brain mechanisms in several primate groups have been in large part developed as a result of that coevolution [20], [21].

In between modules three and four a web-based screen is inserted showing a snake in attack position, together with a snake attack hissing noise in the background. With that, modules three and four make up the surprise zone in this task. As such, the level of knowledge communication effectiveness for those modules should be enhanced, compared with the other modules. Of course, this will only occur if indeed cognitive abilities are enhanced as predicted based on the evolutionary psychological perspective taken in this study.

HYPOTHESES

The above discussion can be summarized through a small set of hypotheses in connection with a web-based knowledge communication task. In the task in question a simulated threat is expected to enhance cognition, and thus knowledge communication effectiveness. The hypotheses are stated below. They refer to knowledge communication effectiveness before, in, and after the surprise zone. Also, the hypotheses assume a test context in which control and treatment experimental conditions are used. In the control condition, the simulated threat is absent. In the treatment condition, the simulated threat is included as a web-based screen showing a snake in an attack position, together with a snake attack hissing noise in the background.

> **H1**: Knowledge communication effectiveness for web-based modules located before the surprise zone will not differ significantly in the treatment (threat) and the control (no threat) conditions.
> **H2**: Knowledge communication effectiveness for web-based modules located in the surprise zone will be significantly higher in the treatment (threat) than the control (no threat) condition.
> **H3**: Knowledge communication effectiveness for web-based modules located after the surprise zone will not differ significantly in the treatment (threat) and the control (no threat) conditions.

Some researchers may be tempted to test the theoretical model underlying the hypotheses above through an experiment with only one experimental condition, namely the treatment condition. This temptation may come from the fact that the end goal of the test is to compare the knowledge effectiveness of modules before, in, and after the surprise zone; and these modules are all present in the treatment condition. However, it is important to use a control condition (with no threat) together with a treatment condition to test the knowledge communication effectiveness effect of a web-based simulated threat. Learning modules and related questions must be designed to test the knowledge effectiveness of each module. The reason why a control condition is needed in addition to a treatment condition is that one cannot assume with absolute certainty that different learning modules and related questions have the same degree of difficulty. That is, with only the treatment condition, it is difficult to assign apparent variations in knowledge effectiveness to the presence of a simulated threat. Those variations may be due to the different degrees of difficulty associated with different modules or related questions.

Also important is to try to assess the impact of control variables on knowledge communication effectiveness, so that one can rule out other possible effects that are unrelated to the presence of a simulated threat. Good candidates for control variables are demographical and perceptual variables. Demographical variables often included as control variables in experimental research are gender and age. In experiments employing student subjects, another commonly used demographical control variable is the subjects' scholastic "status" (e.g., freshman, sophomore, junior, etc.).

Examples of perceptual variables that are relevant in the context of the theoretical model being tested here are motivation, fear, and distraction. MOTIVATION refers to the degree of motivation of a subject to perform well in the knowledge communication effectiveness experiment. FEAR refers to the degree to which a subject is actually scared by the simulated threat used in the experiment. Finally, DISTRACTION refers to the degree to which the simulated threat causes a subject to be distracted.

Fig. 3 contains a diagram depicting the effects stated in the hypotheses and the effects related to the control variables. The hypotheses are shown on the left part of the diagram as full arrows representing causal links between pairs of variables. The links are between the variables labeled Threat stimuli (snake screen) presence and Knowledge communication effectiveness before (H1), in (H2), and after (H3) the surprise zone. Those links are expected to be either neutral (H1 and H3) or positive (H2).

The control variables' effects are depicted on the right part of the diagram in Fig. 3. They are shown in a different way than the hypotheses' effects because some of their details are not known at this point. The dotted arrows suggest the exploratory nature of the assessment of the links between each of the control variables and knowledge effectiveness before, in, and after the surprise zone. That is, those arrows symbolize the uncertainty of both the existence and sign (i.e., positive or negative) of those effects.

RESEARCH METHOD

A web-based knowledge communication experiment was conducted so that data from two experimental conditions could be contrasted. Those conditions were a treatment and a control condition. A total of 186 student subjects from a mid-sized public university in the southern US participated in the experiment. The subjects' ages ranged from 18 to 48, with a mean age of 24. Approximately 47% of the subjects were males. In terms of their university status, the subjects were distributed as

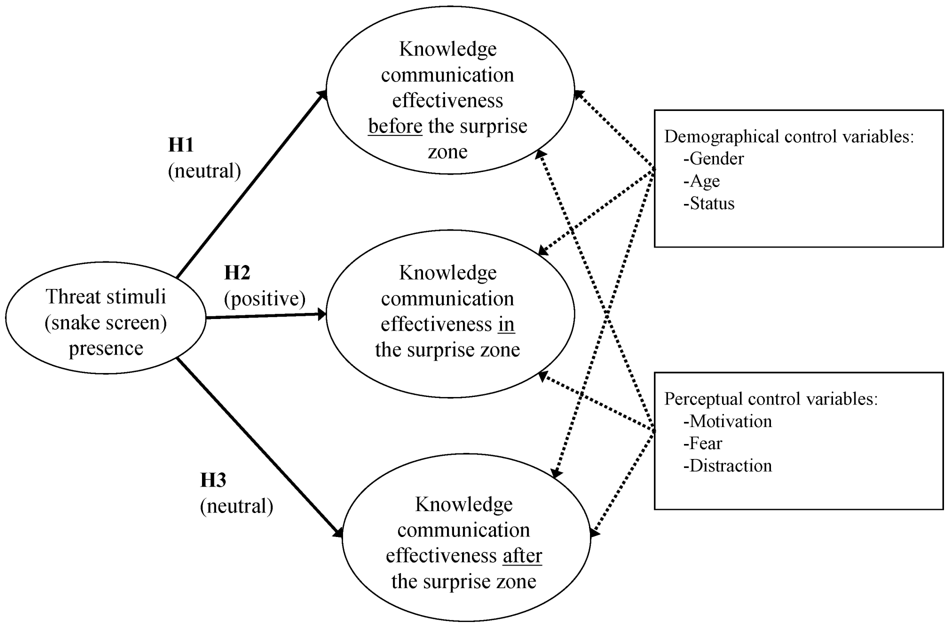


Fig. 3. Diagrammatic representation of the hypotheses.

follows: sophomore (6.45%), junior (43.55%), senior (41.94%), and graduate (8.06%).

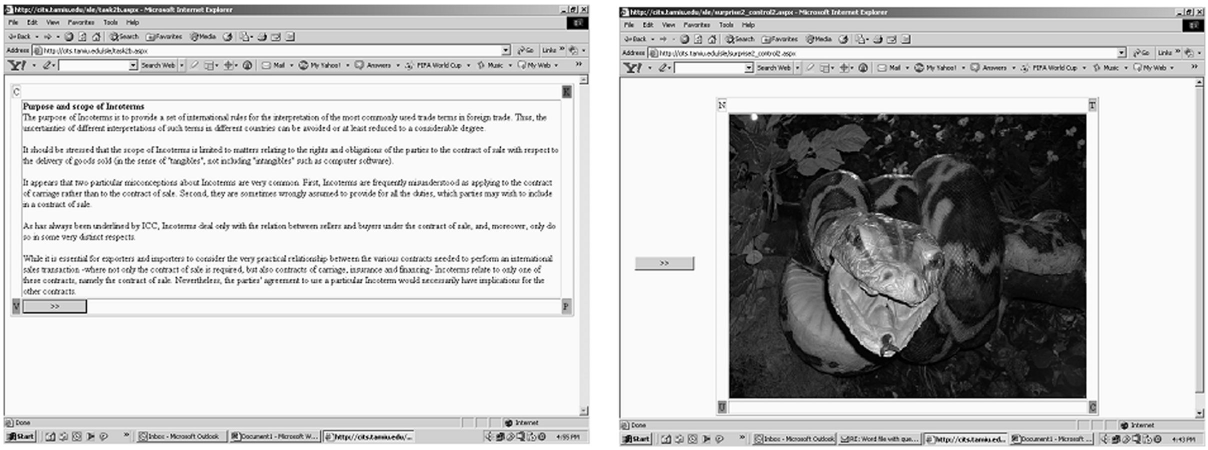
All subjects were business students. In both conditions the subjects were asked to review web-based learning modules about INCOTERMS, which is an abbreviation for International Commercial Terms. Those terms form a body of standard terminology published by the International Chamber of Commerce, which is widely used in international trade contracts. The subjects were not familiar with Incoterms prior to their participation in the experiment.

In the treatment condition, a web-based screen with a snake picture in attack position was used to create a simulated threat that would surprise the subjects (see Figs. 4 and 5). That screen was shown for 10 seconds together with noise in the background—the hissing noise normally made by a snake when it is about to attack. The simulated threat was absent in the control condition. Approximately half of the subjects were randomly assigned to each condition.

Subjects reviewed modules one, two, and three, after which they saw the snake screen (in the treatment condition only), and then reviewed modules four, five, and six. The experiment was timed in the sense that each module was reviewed by the subjects during a set time interval, which was the same for all subjects. Each module contained approximately 265 words and was reviewed by the subjects for 2.35 minutes. These numbers (i.e., 265 words and 2.35 minutes) have been found in past research on organizational communication to be close to the "optimal" communication unit size [22]–[24]. This is the reason why they were used here.

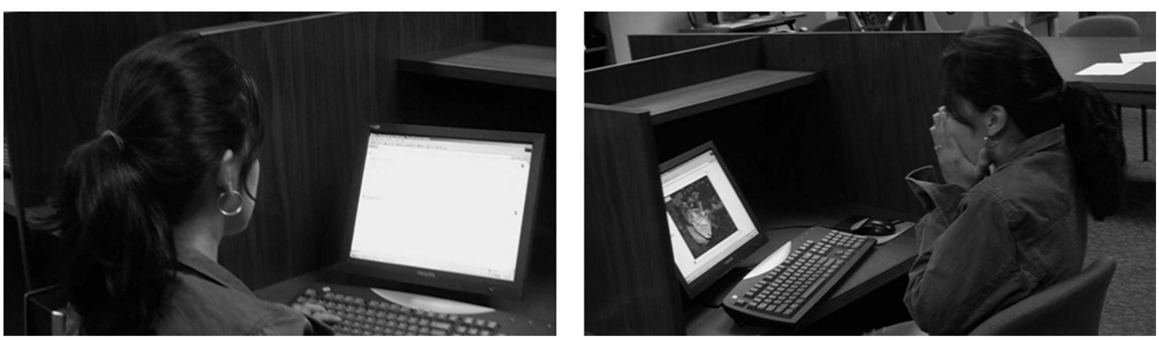
After reviewing the learning modules, the subjects were asked to complete a questionnaire and take a test covering the Incoterms that they reviewed. The test was aimed at assessing the knowledge communication effectiveness for each module. It contained three multiple-choice questions per module. That is, for each of the six learning modules on Incoterms, there were three questions prepared to quantify the knowledge communication effectiveness associated with the module. Each question had four choices, of which only one was correct.

The questionnaire contained demographics questions, as well as questions on perceptions by the subjects regarding their motivation to do well in the experiment, perceived fear elicited by the simulated threat in the treatment condition, and perceived degree of distraction elicited by the simulated threat in the treatment condition. These perceptions were assessed through latent variables reflectively measured through multiple indicators. (See the Appendix for a list of indicators used for each latent variable.)



Notes:
Left: example of Web-based learning module screen on Incoterms
Right: Web-based simulated threat screen; snake in attack position plus hissing noise

Fig. 4. Web-based screens showing a learning module and the snake in attack position.



Notes:
Left: Subject viewing Web-based learning module screen on Incoterms
Right: Subject viewing Web-based simulated threat screen; snake in attack position plus hissing noise

Fig. 5. Subject viewing web-based screens showing a learning module and the snake in attack position.

Data validation analyses for the reflective latent variables involved the calculation of indicator-to-construct loadings and cross-loadings in a nonconfirmatory factor analysis, as well as indicator-to-construct loadings and respective chance probabilities through a confirmatory factor analysis. Reliability coefficients and average variances extracted (AVEs) were also calculated and used for data validation purposes.

Structural modeling analyses were conducted using the partial least squares (PLS) method [25], [26] to test the hypotheses. There are several reasons why structural modeling was used here instead of simpler methods, such as analysis of variance (ANOVA). The two main reasons are: (a) control variables were included in the analysis; and (b) several of those control variables were latent variables.

PLS is a variance-based structural modeling method that has two advantages over covariance-based structural modeling methods such as those implemented through the software package LISREL [27]. One of those advantages is that PLS does not require that all the variables included in the model be normally distributed [26]. The other advantage is that PLS allows for the use of latent variables measured in a formative way [25].

Three formative latent variables were included in this study's structural model to measure knowledge communication effectiveness performance in the pairs of web-based modules located before, in, and after the surprise zone. Such use of formative latent variables is required since one cannot reasonably expect the subjects' learning performances to be the same across different modules, regardless of the presence or absence of the simulated threat. That is, one cannot reasonably expect that the scores on questions related to different modules will load on a single factor (see, e.g., [28] and [29]), because different questions may present different degrees of difficulty. Also, it could not be ensured in this study that all of the variables used in the analysis were normally distributed. Therefore, PLS became the natural method of choice for this study's structural modeling analysis.

VALIDATION OF THE PERCEPTUAL VARIABLES MEASUREMENT MODEL

The reflective measurement model used for the perceptual control variables must be tested for validity and reliability, since measurements of perceptions are particularly prone to errors. Those errors are primarily due to the design of statements associated with each latent variable. Key problems in that design need to be checked for the following: (a) the statements may not be understood in the same way by different individuals, (b) the statements may not actually measure the latent variables that they are designed to measure, and (c) statements designed to measure one latent variable may also measure one or more other latent variables.

The degree to which these problems exist in the data is assessed through reliability, convergent validity, and discriminant validity tests. Such tests build on the design of multiple statements for each of the variables (called latent variables) and the calculation of several coefficients, including the following: indicator-to-construct loadings (through factor analysis), coefficients of reliability (e.g., Cronbach's alpha), average variances extracted for each latent variable, and correlations between latent variables. Those coefficients are then compared with each other or with thresholds obtained from the quantitative methods research literature.

Passing these comparison tests is an indication that validity and reliability problems are below a threshold of concern. It also suggests that the subjects in the study answered the statements in a careful (as opposed to mindless) way. The latter is an important consideration in experiments employing students, as often the results of such experiments are challenged based on validity considerations. For example, data analysis results cannot be trusted if students answer statements randomly to complete an experiment as quickly as possible. If that were the case, however, one obvious outcome would be that the subjects' response to statements would not load on the latent variables that the statements were designed to measure. That is, the validity and reliability tests conducted here allow us to conclude that the bias effect of distraction by the subjects on the results was not significant.

Loadings obtained from a nonconfirmatory factor analysis are shown in Table I in the columns labeled Motivation, Fear, and Distraction. The extraction method used to calculate these loadings was principal components analysis, and the rotation method was varimax [30], [31]. The loadings associated with the indicators (i.e., statement measures) that were designed to load on their respective latent variables are shown in shaded cells. The columns labeled Alpha and CR show Cronbach's alpha coefficients and coefficients of reliability, respectively, calculated for each of the latent constructs. COEFFICIENTS OF RELIABILITY (i.e., CRs) are similar to Cronbach's alphas, with the difference that they are calculated by taking into consideration the different weights associated with each indicator.

Whenever the "right" indicator-to-construct loadings associated with latent variables are 0.5 or higher, the convergent validity of a measurement model is considered to be acceptable [32]. The "right" indicator-to-construct loadings are those that refer to statements that were designed to measure particular latent variables. They are shown in shaded cells in Table I. For this study, those loadings are all equal to or above 0.802, which suggests that the measurement model employed has acceptable convergent validity. Additionally, a confirmatory factor analysis [31] was conducted. The results of this confirmatory factor analysis suggest that all of those loadings are statistically significant at the 0.01 level.

The reliability of a latent variable-based measurement model can be assessed through Cronbach's alpha and composite reliability coefficients. Reliability is generally considered to be acceptable if those coefficients, calculated for each latent variable, are 0.7 or above [33], [34]. As can be seen in Table I, all of the Cronbach's alpha and composite reliability coefficients obtained for this study were equal to or above 0.903, which allows one to conclude that the measurement model used presents a more than acceptable level of reliability.

TABLE I
INDICATOR-TO-CONSTRUCT LOADINGS AND RELIABILITY COEFFICIENTS

	Motivation	Fear	Distraction	Alpha[a]	CR[b]
Motiv1	.905	-.117	-.013	.903	.933
Motiv2	.907	.011	.007		
Motiv3	.860	-.167	-.014		
Motiv4	.853	.131	.049		
Fear1	-.057	.922	.231	.979	.985
Fear2	-.019	.959	.231		
Fear3	-.021	.945	.243		
Fear4	-.060	.927	.262		
Distr1	.007	.235	.802	.930	.950
Distr2	.010	.187	.932		
Distr3	.067	.252	.904		
Distr4	-.045	.222	.886		

[a] Chronbach's alpha reliability coefficient
[b] composite reliability coefficient

TABLE II
LATENT VARIABLE CORRELATIONS AND AVEs

	Motivation	Fear	Distraction
Motivation	(.777)		
Fear	-.073	(.942)	
Distraction	.015	.479*	(.827)

$*$ = correlation significant at the .01 level
AVEs are shown on diagonal

Table II shows correlation coefficients calculated for each pair of latent variables. The coefficient followed by $*$ was found to be significant at the 0.01 level in a two-tailed test. The average variances extracted for each of the latent variables are also shown in Table II, on the diagonal and within parentheses.

The discriminant validity of a measurement model containing latent variables is generally considered to be acceptable if the square root of the average variance extracted (AVE) for each latent variable is higher than any of the correlations involving the latent variable in question [33]. A more conservative discriminant validity assessment can also be used, and was used here, which involves comparing the average variances extracted (as opposed to their square roots) with the correlations between latent variables. An inspection of Table II suggests that all AVEs are higher than the correlations below them, in the same column, and to their left, in the same row. This allows for the conclusion that the measurement model presents an acceptable level of discriminant validity.

DATA ANALYSIS RESULTS

Fig. 6 contains a diagram with the results of the structural modeling analysis aimed at testing the hypotheses. The effects of the control variables were also tested, together with the hypotheses, and the respective results are also shown in Fig. 6. The β coefficients associated with statistically significant links are shown near the arrows. Those β coefficients refer to effects that were strong enough to be considered unlikely to be due to chance. The letters NS (which stand for "not significant") are shown near some arrows in place of the β coefficients, meaning that the respective β coefficients were not statistically significant. Either the symbol $*$ or $**$ follows each of the significant β coefficients. The symbol $*$ indicates an effect that is significant at the 0.05 level; the symbol $**$ refers to an effect significant at the 0.01 level.

As can be inferred from Fig. 6, the knowledge communication effectiveness for the web-based modules located before and after the surprise zone did not differ significantly in the treatment (threat) and the control (no threat) conditions. Conversely, the knowledge communication effectiveness for modules located in the surprise zone was significantly higher in the treatment than the control condition ($\beta = 0.201$, $P < 0.05$).

Among the demographical and perceptual control variables, only one had a significant effect on knowledge communication effectiveness before, in, or after the surprise zone. That was the perceptual control variable that gauged the perceived fear elicited by the simulated threat in the treatment condition. The variable was measured as a latent reflective variable with multiple indicators, and it was found to have a significant negative effect only on the knowledge communication effectiveness after the surprise zone ($\beta = -0.244$, $P < 0.01$).

Fig. 7 shows the variation in knowledge communication effectiveness in each of the learning modules for both the treatment and control conditions. Also indicated in Fig. 7 is the chance baseline; that is, the KNOWLEDGE COMMUNICATION EFFECTIVENESS SCORES (i.e., scores on the items for Incoterms) that the subjects would have obtained if they had either answered the test questions

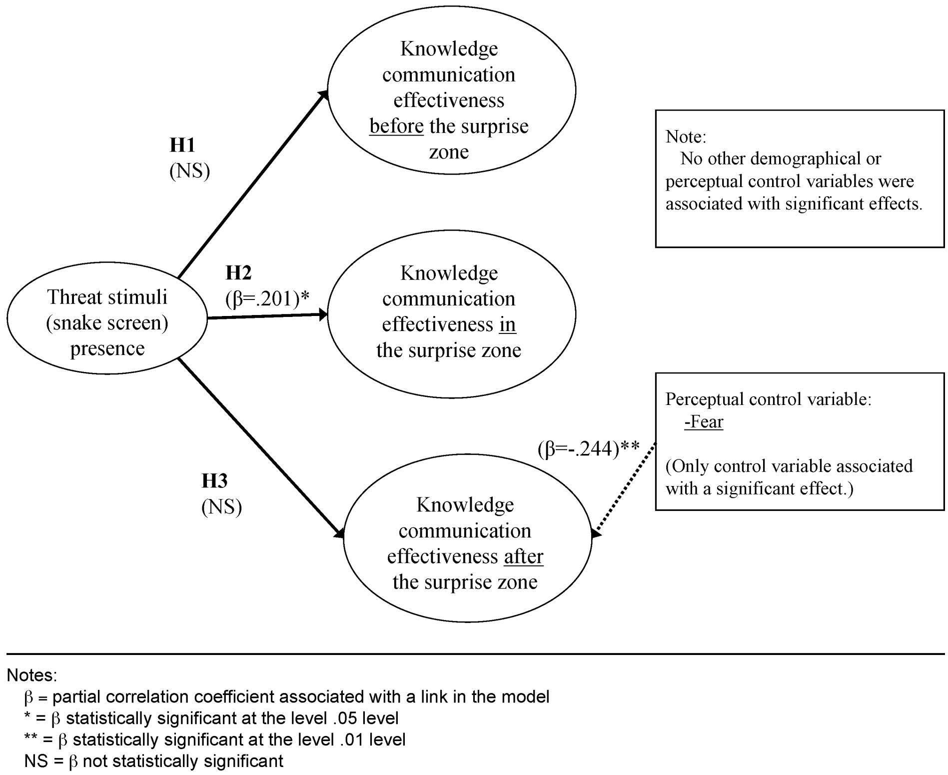


Fig. 6. Diagrammatic representation of the data analysis results.

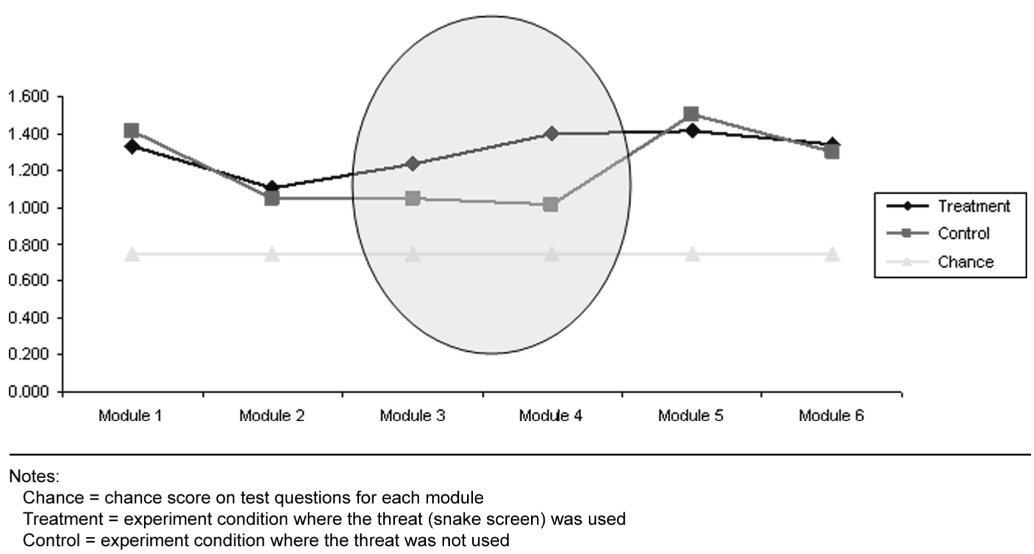
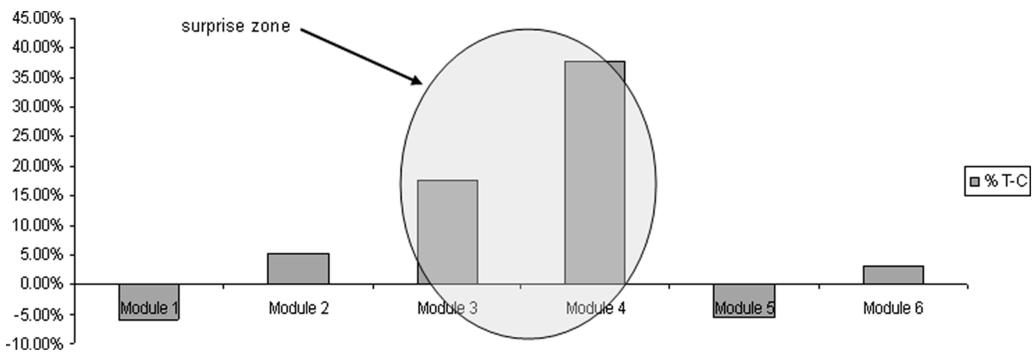


Fig. 7. Means of scores on test questions for each module.

mindlessly, or learned nothing about Incoterms during the web-based learning task.

As it can be seen from Fig. 7, the subjects did significantly better than chance in their learning of the Incoterms in both the treatment and control conditions. Also, the knowledge communication effectiveness scores for the two conditions were very close for the modules before and after the surprise zone, but significantly different in the modules within the surprise zone. Fig. 8 shows the differences (in percentage points) in scores obtained in each module for both treatment and control conditions, which makes it easier to see the relative magnitude of those differences.



Notes:
% T-C = percentage difference between scores in the treatment and control conditions
Treatment = experiment condition where the threat (snake screen) was used
Control = experimental condition where the threat was not used

Fig. 8. Percentage difference between means of scores on test questions for each module.

Fig. 8 suggests that the percentage differences in knowledge communication effectiveness scores for the treatment and control conditions were about 5% or less before and after the surprise zone. At the beginning of the surprise zone, in Module 3, that difference grows to nearly 18%. At the end of the surprise zone, in Module 4, that difference reaches approximately 38%.

DISCUSSION

All of the three hypotheses were supported by the data analysis results (Table III). Knowledge communication effectiveness appears to have been significantly improved in the surprise zone for subjects that were exposed to the web-based simulated threat (i.e., snake screen with hissing noise in the background). Those subjects did approximately 28% better in the surprise zone at learning about Incoterms than the subjects who were not exposed to the web-based simulated threat.

Ruling Out Alternative Enhanced Memorization Explanations Past research on human cognitive mechanisms has yielded evidence that is well aligned with the results of this study, but that nevertheless could be seen as offering alternative explanations for the results presented here. That research establishes that surprise has been found to have a strong effect on memory retention and accuracy. This phenomenon has been dubbed flashbulb memorization [7], [8].

It has been theorized that flashbulb memories are associated with emotional events, and linked to what has been termed the BINDING HYPOTHESIS.

TABLE III
SUMMARY OF HYPOTHESIS-TESTING RESULTS

Hypothesis	Supported
H1: Knowledge communication effectiveness for Web-based modules located before the surprise zone will not differ significantly in the treatment (threat) and the control (no threat) conditions.	Yes
H2: Knowledge communication effectiveness for Web-based modules located in the surprise zone will be significantly higher in the treatment (threat) than the control (no threat) condition.	Yes
H3: Knowledge communication effectiveness for Web-based modules located after the surprise zone will not differ significantly in the treatment (threat) and the control (no threat) conditions.	Yes

The essence of that hypothesis is that "emotional reactions trigger binding mechanisms that link an emotional event to salient contextual features such as event location" [35, p. 25]. One could argue that this is an alternative explanation to the results of this study.

It is likely that the simulated threat used in this study elicited an emotional response. However, the problem with the argument that the results of this study can be explained through the binding hypothesis is that the root causes of the binding hypothesis have not yet been clearly established [36]–[38]. The results of this study support the binding hypothesis, and the theoretical development preceding the presentation of those results provides a root cause for it. That root cause is a brain designed by natural selection to enhance memorization of contextual information surrounding surprising events. The reason for this particular design, it is argued here, is that a large proportion of surprise events experienced in our evolutionary past were likely associated with survival threats.

This study also sheds light on the validity of an alternative explanation to the flashbulb memorization effect, sometimes referred to as the “rehearsal” explanation. Otani et al. have argued that the memories surrounding a surprise event are enhanced through rehearsal, rather than at the time of encoding of the memories [39]. Additionally, Otani et al. argue that memories are enhanced over long periods of time, such as weeks or months, of mentally rehearsing a surprise event [39]. Their theorization leaves little room to the interpretation that mental rehearsals of one hour or less would be effective in the creation of enhanced memories. Moreover, it is unclear from that theorization exactly what would induce individuals to engage in more mental rehearsal of certain details than others (i.e., the contextual details surrounding a surprise event).

This recent explanation proposed by Otani et al. has been presented as a key challenge to the more traditional cognitive view of flashbulb memorization, which is that enhanced memorization happens at the time of the cognitive processing of the information surrounding a surprise event [39]. The results of this study allow for the rejection of rehearsal explanation. This is because the subjects of this study had not had enough time for mental rehearsal before they were asked to answer questions about what they had learned about Incoterms in the experimental task.

Memorization Differences Before and After the Surprise Zone The 28% improvement mentioned earlier, in connection with the subjects’ learning about Incoterms, was not evenly distributed in the surprise zone modules. In the first of the two modules that comprised the surprise zone in this study’s experimental task, the subjects in the treatment condition (simulated threat) did approximately 18% better at learning about Incoterms than the subjects in the control condition (no threat). In the second of the two modules that comprised the surprise zone, the subjects in the treatment condition (simulated threat) did approximately 38% better at learning about Incoterms than the subjects in the control condition (no threat). No significant differences in knowledge communication effectiveness were found for the modules before or after the surprise zone.

Two possible explanations can be found for the above difference. One explanation, and perhaps the most intuitive one, is that cognition is enhanced to a larger degree after a surprise event than before. The surprise event in this case is the appearance of the web-based snake screen during 10 seconds, right in the middle of what is referred to in this study as the surprise zone. The other explanation is that the module durations before and after the surprise event do not accurately capture the actual cognitive enhancement timeframes caused by the surprise.

To illustrate the second explanation above, one could make the following argument. If the study looked at what happens with cognition, say, one minute prior to the simulated threat (instead of 2.35 minutes, as was done here), then perhaps the results would have been different. One possible difference would have been a cognitive enhancement effect of the same magnitude before as that found after the surprise event. If this explanation is correct, it is likely that the enhanced cognition timeframes immediately before and after the surprise event are different. The enhanced cognition time interval before the surprise event may be shorter than that after the surprise event.

More empirical research is needed to ascertain which of the two explanations above is most likely to explain phenomena such as that unveiled by this study. One possible variation that could be employed in future research is the use of shorter time intervals of each of the modules, perhaps one third of the time duration used in this study. Those web-based modules would be around 47 seconds in duration, and have approximately 88 words if only text was used.

Interestingly, the higher degree of knowledge communication effectiveness enhancement after the web-based simulated threat is at odds with the only control variable effect observed. That was the inverse and significant link between the control variable, fear, and knowledge communication effectiveness **after** the surprise zone. This effect can be interpreted as an impairment of learning through fear after the simulated threat. Yet, this effect does not seem to have affected learning within the surprise zone in the module immediately after the simulated threat. That is, the perceived impairment is somewhat delayed. Also, the impairment may be only a perceived effect, and not an actual one. The differences in learning scores between experimental conditions after the surprise zone are insignificant and similar in magnitude to those before the surprise zone.

The perceived effect of fear makes sense from an evolutionary psychological perspective. Our hominid ancestors would derive an advantage from enhanced memorization of events immediately after the occurrence of a survival threat, but at some point they would have to make use of some of their cognitive resources to find a solution to the problem facing them. That solution might involve fleeing the situation, fighting the threat, and/or finding their way back to their social groups so that their wounds could be treated. At that point, which can be seen as occurring after the surprise zone, it might have been more adaptive for our brain to focus some of its resources on those actions. This may be at the source of the perception that fear impairs cognition after the surprise zone. The fact that this is a perceived but not an actual effect suggests that the cognitive resources used do not take much away from other cognitive functions.

CONCLUSION

This study is one of the first to employ evolutionary psychological ideas to explain electronic communication phenomena. Notable examples of studies in related areas are those addressing electronic consumer behavior [40], [41], virtual team leadership [42], electronic user interface design [43], and information search and use behavior [44].

More importantly, the study presented here is arguably the first on the effects of simulated web-based threats on knowledge communication effectiveness, building on an evolutionary psychological perspective. As such, it adds to the current and relatively small body of literature addressing electronic communication phenomena from a Darwinian perspective (see, e.g., [45]), and provides the impetus for continued research linking evolved human instincts and their effects on behavior as we use electronic technologies to communicate with each other.

While adding to the current state-of-the-art knowledge on evolutionary psychological influences on behavior toward technology, this study presents limitations that must be addressed in future research. Two limitations of this study are particularly noteworthy. First, a replication of this study should include one more condition, in addition to the two conditions used here, where the third condition would include a stimulus of no evolutionary significance. This would lend more credence to the evolutionary psychological theorization underlying this study. Second, this study should be replicated in another country, ideally one in which at least one or more cultural dimensions (see, e.g., [46]) are significantly different from the corresponding cultural dimensions of the US. This would also lend more credence to the evolutionary psychological theorization presented here, if the results were very similar for the two countries.

Furthermore, this study lends support to the notion that surprise enhances cognition, even though its focus is narrower; that is, simulated threats are not the only types of surprise stimuli that could be used in computer interfaces. An extensive review of the relevant literature suggests that this study is the first to demonstrate that surprise in the form of a web-based simulated threat can be used in a controlled way to enhance knowledge communication effectiveness through a web-based human–computer interface. This finding can be successfully used in situations where certain pieces of knowledge, which are part of a larger body of knowledge, need to be conveyed in a way that is enhanced relative to other pieces of knowledge.

For example, airline pilots undergoing online training on aspects of the operation of an airplane may be induced to better memorize certain pieces of knowledge that are critical to the operation of the airplane in an emergency. That can be done through the design of web-based modules that incorporate surprise zones, such as in this study. The results of this study suggest that the pilots' learning effectiveness in connection with other modules outside the surprise zones would not be negatively affected (even though the pilots may perceive otherwise). These types of applications may allow us to use knowledge about survival threats in our ancestral past to save lives today.

APPENDIX

PERCEPTUAL VARIABLES AND INDICATORS

A Likert-type scale (1 = Very strongly disagree to 7 = Very strongly agree) was used for each of the latent variable measurement indicators listed below. The statements that refer to each latent variable were designed to reflect each variable. The questionnaire that contained the statements below also contained demographics questions (e.g., age, gender, etc.).

Motivation

Motiv1: I am motivated to do well in this experiment.
Motiv2: Doing well in this experiment is important for me.
Motiv3: I intend to do my best to do well in this experiment.
Motiv4: Performing well in this experiment is one of my goals.

Fear

Fear1: I was scared by the stimuli (snake).
Fear2: The snake that appeared on the screen made me scared.
Fear3: The stimuli (snake) made me scared.
Fear4: I felt fear when I saw the snake on the screen.

Distraction

Distr1: I was distracted by the stimuli.
Distr2: I lost concentration because of the stimuli.
Distr3: The snake made me lose focus.
Distr4: It was difficult to focus after the snake on the screen.

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