Understanding Online Cognitive Script Formation Based on Electroencephalography (EEG): A Pilot Study

Sylvain Sénécal
HEC Montréal
Montréal, H3T 2B1, Canada
ss@hec.ca

Pierre-Majorique Léger
HEC Montréal
Montréal, H3T 2B1, Canada
pml@hec.ca

Marc Fredette
HEC Montréal
Montréal, H3T 2B1, Canada
marc.fredette@hec.ca

Francois Courtemanche
HEC Montréal
Montréal, H3T 2B1, Canada
francois.courtemanche@hec.ca

René Riedl
University of Linz
rene.riedl@jku.at

CHI'12, May 5–10, 2012, Austin, Texas, USA.

Abstract
A cognitive script is a predetermined sequence of actions that define a well-known situation. The objective of this research is to contribute to the nascent research on online cognitive scripts, which are activated in a computer mediated environment. Specifically, this research investigates when consumers do move from a cognitive script formation phase to a script activation phase while using a retail website. Six subjects performed ten visits to a website and electroencephalography (EEG) measurements were taken simultaneously. Based on this data, a cognitive workload index was calculated and compared across visits. Results suggest that there was a significant change in subjects' cognitive workload between the first two visits and the remaining visits, suggesting that cognitive scripts were formed during the first two visits and then activated during the remaining visits. Theoretical and managerial implications are discussed.

Author Keywords
Cognitive scripts, Online shopping, EEG, NeuroIS.

ACM Classification Keywords
K.4.4 Electronic Commerce

General Terms

Human Factors; Design; Measurement; Management

Introduction

Recent work by [20] suggests that consumers activate cognitive scripts when shopping online. Furthermore, using psychometric and neurophysiological measures, they suggest that *intra*script consumers (i.e., those asked to perform the same task on the same website over multiple visits) appear to use more automatic processing, whereas *inter*script consumers (i.e., those asked to perform the same task on different websites) use more controlled processing.

As suggested by [20], once a script is formed using a single website, consumers may find this website easier to use than others, thus increasing consumers' switching costs because both human physiology and behavior often tend to follow a principle of least effort (e.g., [10, 22]). However, one important question was not investigated in prior work: *Can we identify the number of visits needed to form a script on a given website?*

From a human-computer interaction perspective, answering this question would help understand when most of the learning occurs when using a commercial website repeatedly. From a marketing standpoint, this question is also of great interest because it could help managers design marketing activities to influence new visitors to revisit their website a certain number of times in order to make them develop their cognitive script based on their website, which would lead to lock in advantages [12] since consumers would find it easier to use [20].

Related work

Cognitive scripts are one type of broad classification of memory referred to as schemata, which are defined as stored cognitive structures of knowledge about specific objects or topics and are represented by nodes in semantic memory [5]**.** A cognitive script can be defined as "predetermined, stereotyped sequence of actions that define a well-known situation" ([18], p. 41). Its main function is to facilitate cognitive processing, thereby allowing people to understand and behave appropriately in a given situation [1]**.** [15] suggest that individuals' scripts can be different. For instance, experts are suggested to form more elaborate, distinctive, contingent, and hypothetical scripts than novices [13, 16]. [8] suggest that cognitive scripts are appealing to conduct consumer research since they can help explain how individuals interpret and behave in commercial settings, such as commercial websites.

[2] suggests that the human brain is proactive, "it is continuously generating predictions that approximate the relevant future based on memories of past experiences and associative activation" ([2], p. 328). When encountering a situation, the brain tries to match the input information (e.g., music website) with a similar representation existing in memory (i.e., script) and generates a prediction of what to expect next [1, 2]. Hence, it is suggested that scripts could be at the basis of human brain activity: "Information encoded in our memory guides and sometimes dictates our future behavior. One can look at our experience as stored in memory as scripts" ([2], p. 1239).

Research in psychology, behavioral economics, and neuroscience (e.g., [6, 17]) suggests a dual-process model underlying human decision making: A more

controlled system (conscious, serial, effortful, and slow) and a more automatic system (unconscious, parallel, effortless, and fast). As novices evolve to become experts (thus evolving from a controlled to an automatic system), structural changes in specific brain regions take place [11]. In addition, it is suggested that the transition from a more controlled to a more automatic processing is associated with lower cognitive workload; the latter refers to "any demands on working memory storage and processing of information" ([19], p. 471).

In their work [20] suggest that consumers do form and activate cognitive scripts while using commercial websites. However, an unanswered important question concerns the number of visits needed for a novice user to move from controlled processing to more automatic processing, thus moving from the script formation phase to the script activation phase.

Methodology

During the experiment, a group of 11 subjects were asked to perform 10 online music shopping trips on the same website. Specifically, they were asked to buy a song every time they visited the assigned website. A prepaid credit card was provided to the participant to complete actual online purchases. To avoid any fatigue related biases, the experiment sessions were limited to one hour. No time limitations were given to participants for each purchase and they were not aware of the length of the experiment.

Electroencephalography (EEG) data was acquired using the B-Alert® X10 device from Advance Brain Monitoring (ABM, 2010). The data was acquired from 9 sensors pre-determined by the manufacturer (F3, F4, FZ, C3, C4, Cz, P3, P4 and POz). The B-Alert device calculates an EEG cognitive index developed by [4]. At every second, the measurement instruments estimated the probability that the subject was in each of the following four cognitive states (four-class quadratic discriminant functional analysis using absolute and relative power spectra from channels FZPOz and CzPOz): sleep onset, distraction, low engagement, and high engagement. The data for five subjects was not recorded properly by the B-Alert system. Hence, the analysis reported in the following was performed on data from the remaining six subjects.

Building upon the work of [9], a cognitive workload (CW) odds was calculated using the probability estimated every second during the first 15 seconds of interaction with each website using Equation 1. A greater CW indicates more controlled processing.

Equation 1:

$$\text{Cognitive Workload Odds} = \frac{P(\text{High or Low Engagement})}{P(\text{Distraction or Sleep})}$$

Results

The CW was calculated for each of the 900 data points (15 seconds x 10 visits x 6 subjects). A multivariate regression model was used on the logarithm of the CW odds where fixed effects were added to account for intra-subject variability.

In order to locate at which visit there was a change from script formation (i.e., controlled processing) to script activation (i.e., automatic processing), we

searched the earliest visit satisfying the following two conditions, namely 1) the CW for this visit is significantly smaller than the first one and 2) no significant difference exists between this visit and all the remaining ones (i.e., indication that a cognitive script previously formed was activated).

With the website used in the experiment, the first visit satisfying this condition was the third one. Table 1 presents the results.

Parameter	Est.	SE	P-value
Intercept	4.20	0.400	<.0001
Visit #2	-1.34	0.869	0.1231
Visits #3-#10	-2.42	0.642	0.0002

Table 1. Analysis of maximum likelihood parameter estimates (visit #1 is the reference)

Moreover, based on the Bayesian Information Criterion (BIC), this model is more appropriate than a model using an individual effect for each visit (BIC=6009.31 with an effect for each visit and BIC=6001.31 for a model assuming a common effect for visit #3 to visit #10). This means that we are not losing any information by assuming that the (log) CW between the 3rd and 10th visit are identical. Before that, the CW is smaller in the 2nd visit than the 1st one (B=-1.34) but this difference is not significant (p=0.1231). Starting from the 3rd visit, the CW is significantly smaller than the 1st visit (B=-2.42 p=0.0002). Therefore, it can be assumed that a cognitive script was formed during the first two visits and activated in the remaining visits.

The first 15 seconds of online shopping were also analyzed in order to get insights into the difference between online shopping using controlled processing and automatic processing at a dynamical level. Figure 2 shows the slopes of the cognitive workload odds for the first two visits (script formation) visits 3 to 10 (script activation).

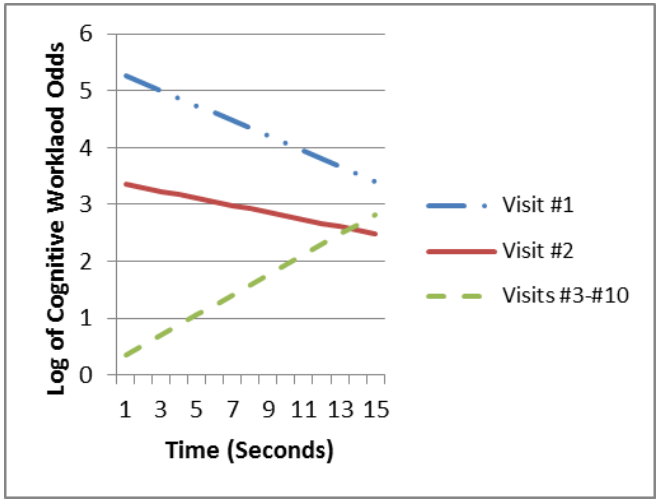

Figure 1. CW odds over the first 15 seconds per visit

A greater CW indicates more controlled processing (see Equation 1). It seems that when subjects interact with a website for the first two visits, cognitive workload is high and it decreases thereafter. Starting from the third visit, cognitive workload is low at first and increases after a few seconds. This low y-intercept and positive slope are both significantly different than those estimated for the first visit (respective p-values are 0.0003 and 0.0363). This result is in line with the previous one and validates the hypothesis that subjects start using a formed cognitive script at their 3rd visit.

According to the Cognitive Load Theory [21, 7], schema acquisition occurs in working memory and requires a large amount of cognitive resources. Once automated, schemata are stored in long-term memory, they can be accessed at low cost during task resolution [14]. The process of schema acquisition function in a recursive manner is, at each phase of learning, small and newly acquired schemata are integrated in larger and more efficient ones. In fact, as shown in Figure 1, a large amount of cognitive workload is needed at the beginning of visit 1, as no schema can be recalled and scripts have to be developed in working memory. The script formation process continues during visit 2, but at a lower CW cost. During visits 3 to 10, a little CW is needed to organize shopping behavior after webpage loading since the required scripts are recalled from long-term memory instead of being processed in working memory.

Conclusion and discussion

Our findings suggest that consumers repeatedly performing a transactional task on a commercial website move from an online cognitive script formation phase to a script activation phase. Hence, in the context of this experiment, results suggest that it took two visits to a commercial website to move consumers from controlled processing to more automatic processing. Future research is obviously needed to replicate this result.

These findings have important theoretical and managerial implications. First, they extend prior research on online cognitive scripts [20] by indicating how long it takes consumers to form an online cognitive script on a commercial website. For managers, these findings suggest that they have to find ways to convince new visitors to quickly revisit their website after their initial visit/transaction (e.g., discount on 2nd order, loyalty programs). These actions would lead to a script formation that is based on their website instead of their competitors'. It would contribute to lock in consumers by increasing their switching costs and making their website perceived as easier to use [12, 20]. Thus, considering that easier-to-use websites imply less cognitive effort for users to accomplish their specific goals (e.g., searching for information or buying a product), probability for repeated interactions with a specific website increases.

Since research on online cognitive scripts is in a nascent stage, several future research avenues are worth pursuing. For example, research needs to be performed to test if the two visit script formation duration is applicable to other online contexts (e.g., other industries, non-commercial websites, social networks, mobile apps). In addition, it would be of interest to investigate what consumers are actually doing and looking at on the website during the first seconds of their visits. Specifically, it would be interesting to compare their behaviors between script formation and activation phases. So, the complementary use of eye-tracking could significantly advance the understanding of online cognitive script formation

References

[1] Abelson, R.P. Psychological Status of the Script Concept. *American Psychologist* 36, 7 (1981), 715-29.

[2] Bar, M. The Proactive Brain: Memory for Predictions. *The Philosophical Transactions of the Royal Society* 364 (2009), 1235-1243.

[3] Bar, M. and Neta, M. The Proactive Brain: Using Rudimentary Information to Make Predictive Judgments. *Journal of Consumer Behaviour* 7, 4/5 (2008), 319-330.

[4] Berka, C., Levendowski, D.J., Lumicao, M.N., Yau, A., Davis, G., Zivkovic, V.T., Olmstead, R.E., Tremoulet, P.D. and Craven, P.L. EEG Correlates of Task Engagement and Mental Workload in Vigilance, Learning, and Memory Tasks. *Aviation, Space, and Environmental Medicine* 78, 5 (2007), 231-244.

[5] Brown, T.J. Schemata in Consumer Research: A Connectionist Approach. In *Advances in Consumer Research*, Association for Consumer Research 19 (1992), 787-794.

[6] Camerer, C., Loewenstein, G. and Prelec, D. Neuroeconomics: How Neuroscience Can Inform Economics. *Journal of Economic Literature* 43, 1 (2005), 9–64.

[7] Clark, R.C., Nguyen, F. and Sweller, J. *Efficiency in Learning: Evidence-Based Guidelines to Manage Cognitive Load*. Pfeiffer, San Francisco, CA, USA, 2006.

[8] Erasmus, A.C., Boshoff, E. and Rousseau, G.G. The Potential of Using Script Theory in Consumer Behaviour Research. *Journal of Family Ecology and Consumer Sciences* 30 (2002), 1-9.

[9] Freeman G.F., Mikulka, P.J., Prinzel, L.J. and Scerbo, M.W. Evaluation of an Adaptive Automation System Using Three EEG Indices with a Visual Tracking Task. *Biological Psychology* 50, 1 (1999), 61-76.

[10] Haier, R.J., Siegel, B.V., MacLachlan, A. and Soderling, E. Regional Glucose Metabolic Changes After Learning a Complex Visuospatial/Motor Task: A Positron Emission Tomographic Study. *Brain Research* 570 (1992), 134–143.

[11] Hill, N.M. and Schneider, W. Brain Changes in the Development of Expertise: Neuroanatomical and Neurophysiological Evidence about Skill-based Adaptations, in *Cambridge Handbook of Expertise and Expert Performance*, Cambridge University Press, New York, NY (2006), 653-682.

[12] Johnson, E.J., Bellman, S. and Lohse G.L. Cognitive Lock-In and the Power Law of Practice. *Journal of Marketing* 67, 2 (2003), 62-78.

[13] Leong, S.M., Busch, P.S. and Roedder-John, D. Knowledge Bases and Salesperson Effectiveness: A Script Theoretic Analysis. *Journal of Marketing Research* 26 (1989), 164-178.

[14] Logan, G.D. An Instance Theory of Attention and Memory. *Psychological Review* 109 (2002), 376–400.

[15] Lord, R.G. and Kernan, M.C. Scripts as Determinants of Purposeful Behavior in Organizations. *Academy of Management Review* 12, 2 (1987), 265-277.

[16] Martin, I. Expert-Novice Differences in Complaint Scripts. In *Advances in Consumer Research*, Association for Consumer Research 18 (1991), 225-231.

[17] Satpute, A.B. and Lieberman, M. D. Integrating automatic and controlled processing into neurocognitive models of social cognition. *Brain Research* 1079 (2006), 86-97.

[18] Schank, R.C. and Abelson, R.P. *Scripts, Plans, Goals and Understanding*, Lawrence Erlbaum Associates, Hillsdale, New Jersey, USA, 1977.

[19] Schnotz, W. and and Kürschner, C. A Reconsideration of Cognitive Load Theory, *Education Psychology Review* 4, 19 (2007), 469–508.

[20] Sénécal, S., Léger, P-M., Fredette, M. and Riedl, R. Consumers' Online Cognitive Scripts: A Neurophysiological Approach. In Proc. *International Conference on Information Systems 2012*, Association for Information Systems (2002).

[21] Sweller, J., van Merrienboer, J. and Paas, F. Cognitive architecture and instructional design. *Educational Psychology Review* 10 (1998), 251-296.

[22] Zipf, G.K. *Human behavior and the principle of least effort*. Addison-Wesley Press, Oxford, England, 1949.