Museums and the Mind:
Applying Cognitive Neuroscience to Free-Choice Learning

Summary: Advances in neuroscience are revealing biological pathways underlying emotion, attention, and memory. How can this research be integrated with educational pedagogy to enhance free-choice learning? Join experts from neuroscience, education, and museums to explore practical ways in which new insights about the brain can be applied to creating museum experiences.

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The role of design has long been recognized for its ability to evoke a particular set of emotions. One of the most famous examples is the Vietnam Memorial, whose design elements combine to create a powerful moment of somber introspection. Why does this experience continue to resonate with so many people long after their visit? In the human brain, a structure called the amygdala responds to the emotional significance of an event. Its activation enhances the formation of long-term memories – in effect, it "decides" which experiences are important enough to remember. While the museum field has perhaps made the intuitive connection between emotional arousal and learning, only recently have efforts been made to collect evidence of this relationship in the practical context of exhibition development and design.

An exhibit that specifically targets a neural pathway of emotion is *Goosebumps! The Science of Fear*, developed and designed by the California Science Center and the Science Museum of Minnesota. The amygdala is involved in processing fear as well as other positive and negative stimuli, and various design elements of *Goosebumps* aim to evoke these arousal responses. In the Challenge Course Hallway, a narrowing corridor with small, harshly lit rooms enhanced the effect of fear-inducing interactives, while a soothing color palette and comfortable furniture in the Coping Lounge created a calm, playful environment.

Evaluation of *Goosebumps* demonstrated that emotional arousal induced in an exhibit setting does result in a significant increase in the quality and quantity of learning. *Goosebumps* visitors were able to describe their science center experience in greater depth and breadth than controls. However, data from learning studies as well as psychological models suggest an inverted U-shaped relationship between levels of arousal and memory or learning (Fig. 1), where an optimal learning experience balances unexpected outcomes with the learner's perceived resources to solve the problem.

While fear responses, such as those evoked in *Goosebumps*, can increase memory for the arousing event, they often narrow the attentional focus on the stimulus at the expense of the broader context. Other emotions, such as interest, confusion, surprise, and awe, trigger a different neural response that motivates learning and exploration through attraction to the unfamiliar. In the brain, dopamine, a neurotransmitter important for signaling reward and novelty, also modulates functions of long-term memory formation. But, measurement of cortical activity demonstrates that, in a novel situation, deeper conceptual processing occurs when the unexpected outcome is perceived as a challenge rather than a threat. Similar to the model of an optimal level of arousal for learning, these data indicate that knowledge seeking is most effective when novelty or complexity is high, but well balanced by resources for comprehension.

The challenge in developing exhibits that create this learning environment lies in the diversity of interests, knowledge, and skills of science center visitors – "one size" does not fit all. We will discuss several potential strategies that can be used to allow visitors to find their individual position on the optimal learning curve. How can we create a flexible balance between novelty/complexity and comprehension for a given interactive experience? Two approaches, among others, include exhibits where visitors can adjust the content and exhibits that adjust themselves to the visitors. An example of the first is the Multi-User Simulation with Handheld Integration developed at the University of Michigan, where visitors adjust the interaction by choosing their role and the strategy they use to play. Technology is key to the second approach, such as flOw, a computer game that automatically adjusts to the player's skill level to keep them engaged.

The concepts of novelty-complexity and comprehensibility are not new to free-choice learning, but the systematic application of this relationship founded in neuroscience has the potential to create a novel framework for exhibit development and design.

Thank you for attending this session and we look forward to hearing your ideas!

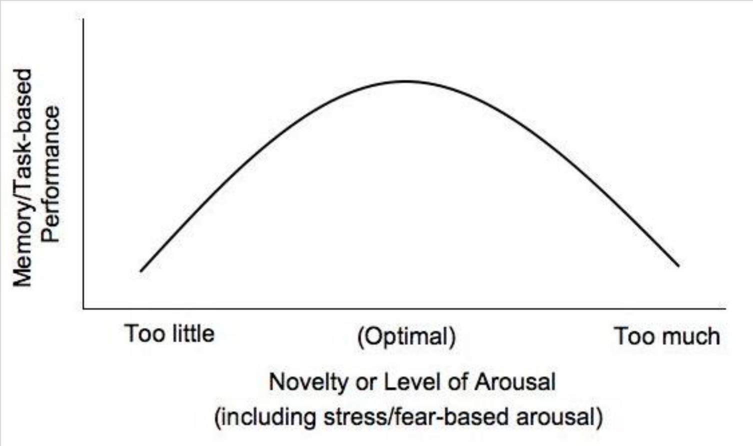

Figure 1. Model of inverted U-shaped relationship of relationship between novelty or level of arousal and memory or task-based performance.

References:

Butterfield, B., & Mangels, J. A. (2003). Neural correlates of error detection and correction in a semantic retrieval task. Cognitive Brain Research, 17, 793-817.

Chen, J. (2006) Flow in games. Unpublished thesis: http://www.jenovachen.com/flowingames/Flow_in_games_final.pdf

Falk, J. H. & Balling, J. D. (1982) The field trip milieu: Learning and behavior as a function of contextual events. Journal of Education Research, 76(1), 22-28.

Hollerman, J. R., & Schultz, W. (1998). Dopamine neurons report an error in the temporal prediction of reward during learning. Nature Neuroscience, 1(4), 304-9.

Kashdan, T. B. (2004). Curiousity. In C. Peterson & M. E. P. Seligman (Eds.), Character strengths and virtues (pp. 125-141). New York: Oxford University Press.

Lyons, L. MUSHI online: http://www-personal.umich.edu/~ltoth/

Lyons, L. (2007) What Research Can Teach Us about Science Learning: A Poster Session, ASTC, Los Angeles, CA, USA, ASTC Conference.

Lyons, L., Lee, J., Quintana, C., and Soloway, E. (2006). MUSHI: A Multi-Device Framework for Collaborative Inquiry Learning, Proceedings of the International Conference of the Learning Sciences (ICLS2006), Bloomington, IN.

Mangels, J. A., Butterfield, B., Lamb, J., Good, C. D., & Dweck, C. S. (2006). Why do beliefs about intelligence influence learning success? A social cognitive neuroscience model. Social Cognitive and Affective Neuroscience (SCAN), 1, 75-86.

Rescorla, R.A. & Wagner, A.R.. (1972). A theory of Pavlovian conditioning: variations in the effectiveness of reinforcement and nonreinforcement in: A.H. Black,W.F. Prokasy (Eds.), Classical Conditioning II: Current Research and Theory, Appleton–Century–Crofts, New York, pp. 64–99.

Silvia, P. G. (2006) Exploring the psychology of interest. New York: Oxford University Press.

Silvia, P. G. (2008). Interest-The Curious Emotion. Current Directions in Psychological Science, 17(1), 57-60.

Stevens, R. Video Traces online: http://faculty.washington.edu/reedstev/vt.html

Stevens, R., & Hall, R. (1997). Seeing tornado: How video traces mediate visitor understandings of (Natural?) Phenomena in a Science Museum. Science Education, 81,735-747.

Stevens, R. & Toro-Martell, S. (2003). Leaving a trace: Supporting museum visitor interaction and interpretation with digital media annotation systems. The Journal of Museum Education, 28(2).

Tomoka, J., Blascovitch, J., Kibler, J., & Ernst, J.M. (1997). Cognitive and physiological antecedents of threat and challenge appraisal. Journal of Personality and Social Psychology, 73(1), 63-72.

Witmann, B. C., Schott, B. H., Guderian, S., Frey, J. U., Heinze, H. J., & Duzel, E. (2005). Reward-related FMRI activation of dopaminergic midbrain is associated with enhanced hippocampus-depedent long-term memory formation, Neuron, 45(3), 459-67.