Cognitive engineering, cognitive augmentation, and information display

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Abstract — From a perspective of cognitive engineering, this paper presents eight principles of good display design based on human cognition: (1) displays that divide attention will increase the cognitive load on working memory; (2) displays that continuously present the same information may compensate for the decay of short-term memory; (3) displays that assist the viewer in mentally chunking information will decrease the cognitive load on working memory; (4) displays that present icons or images to direct attention to important visual stimuli will likely minimize inattentional blindness; (5) displays that help minimize attentional distractions and help focus attention on a given task will minimize the burden on working memory; (6) displays that present cues composed of strong singletons will capture and engage exogenous attention; (7) displays that help the viewer make a mental connection between an analogue and a target will assist in the induction of analogical reasoning; (8) displays that present over time multiple exposures consisting of statistical regularities may promote implicit learning and expertise development. Thus, information displays of the future can systematically engage high-level human cognitive processes for purposes of improving human performance on a variety of tasks found in education, the military, and many other applications.

Keywords — *Cognitive engineering, cognitive augmentation, human cognition.*

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1 Introduction

This article presents a set of principles for the design of information displays that is based on human cognition, which is different from what has been offered in the past. Over the past several decades, there have been many advances in the field of information display in terms of hardware, electronics, and optics. These advances have permitted many different types of information to be presented to people's visual system (as well as other sensory systems) with many different techniques, with high speed and high fidelity.

A reasonable assumption, not explicitly stated but nonetheless potent in its influence on display design, has been that visual displays engage, obviously, the visual system. What has not been fully appreciated is that information processing in the brain does not stop at the visual system, but instead continues into higher levels of cognition. But this statement is, in the author's view, still not correct. Rather, an argument can be made that perception is actually an *embedded substrate* of cognition and that all perception occurs within the context of higher-level cognition. The reason for this is that the visual system specifically, and the brain more generally, have evolved largely to extract meaning from stimulation in the world. Thus, arguably, it is important to realize that the process of perceiving artificially generated stimuli also occurs within a context built for the extraction of meaning.

The following section discusses the empirical literature supporting this idea – that humans possess a strong tendency to extract meaning from visual stimulation. But before moving on to that section, the reader is encouraged to take a moment to reflect on the following thought experiment: imagine an individual turning around and – with great surprise – immediately seeing an attacker standing very close to him or her and holding and pointing a knife! How long do you think it would take for that person to realize that his or her life was threatened? According to Thorpe *et al.*,[1] as well as other papers cited below, that individual would probably register the existence of the threat within about 150 msec of visual-processing time, which is a little shorter than the duration of a single visual fixation. Of course, that individual would also perceive the color of the attackers's shirt, the size of the attacker, *etc.* But the important point is that that person would very likely *register* in his or her brain, in a holistic and meaningful way, the existence of the threat in a very brief period of time. The perception of color and size would occur within a context of meaning.

The implication of the above is that people who design visual displays have the opportunity to engage the viewers' cognitive systems in ways that have been under appreciated. In other words, the richness and complexity of human cognition have yet to be *systematically* exploited when information displays are designed. One reason for this is that much of the efforts at visual display design have been geared toward the entertainment industry. But what if efforts became systematically directed at understanding how certain display features can selectively engage certain human cognitive processes, such as enhancing the capacity of working memory or promoting the development of analogical reasoning? In a sense, visual displays could be designed for *augmenting* human cognition. Such displays could play a role in education, in the military, and in many applications

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where human performance – not entertainment – is important. It is reasonable to predict that visual display design in the future, as well as displays designed for other sensory systems, will in large measure be focused on *cognitive augmentation.* Because this endeavor would entail the establishment of a tight interface between the fields of cognitive psychology and display engineering, one can refer to this area as *cognitive engineering.* While there undoubtedly are a number of efforts currently being undertaken in this direction in the field, there is so much more that could be done.

The purpose of the present paper is provide a new approach and guiding principles to the design of information displays. This new approach focuses on the role of human cognition in the practice of designing information displays. This paper also presents articles in the human-cognition field that provide an entry point into that literature. Below are presented a number of topics in human cognition, and from those topics are derived eight principles of good display design based on a consideration of human cognition. The eight principles presented below are preliminary in nature and thus they represent good starting points for future empirical experimentation. Similar arguments have been made by Patterson and Holland (2010).[a]

The next section is a brief review of the literature on how well humans extract meaning from visual displays. That section is followed by a brief overview of relevant human-cognitive processes. The final section presents some concluding remarks.

2 Extraction of meaning from visual displays

Michotte,[2] see also Ref. 3, demonstrated that the relative timing and spatial arrangement between moving elements can induce individuals to mentally project meaning into simple events depicted on a visual display. For example, in a typical demonstration of this kind, a red disk was made to move rightward, from the left-hand side of a display, and into the center where a stationary blue disk was positioned. At exactly the time when the red disk appeared to make contact with the blue disk, the red disk ceased its movement (and came to rest in the center of the display) and the blue disk suddenly began to move rightward to the right-hand side of the display. Even though the actual stimuli were nothing more than two colored disks presented on a visual display, most observers would say that the red disk “caused” the blue disk to move. On the other hand, if the blue disk began its movement before the red disk reached the center, so that both disks were moving rightward at the same time, some observers would say that the red disk was “chasing” the blue disk. Generally, changing the relative timing, distance, and size of the disks would induce different attributions of causation. These demonstrations, and many others like them, reveal that humans have a propensity to extract meaning from visual stimulation.

This conclusion is underscored by a number of studies that have shown that visual identification and visual search are enhanced by the presence of a visual context relative to isolated stimuli, especially visual contexts that have meaning. For example, Biederman[4] and Biederman, Glass, and Stacy[5] have shown that the speed or accuracy of identifying a single, cued object was greater when the object was presented within a coherent real-world scene than when the object was presented in a jumbled scene, which indicated that an object's meaningful context affected perceptual recognition. Moreover, Biederman[6] found that violations of semantic relations of an object in a scene were as readily detected as physical violations, and that extensive semantic processing of a scene was readily achieved from a single fixation. Weisstein and Harris[7] found that individuals could identify a briefly flashed line segment more accurately when it was part of a unified drawing than when the line was in a less-coherent configuration; and Weisstein *et al.*[8] found that flashed line segments were easier to perceive in three-dimensional patterns. Finally, Enns and Rensink[9] reported that visual search is significantly influenced by the properties of three-dimensional scenes, such as their three dimensionality.

That the meaning of stimulation can be easily extracted from visual stimulation was revealed by Grill-Spector and Kanwisher,[10] who employed a combined detection and recognition task and reported that as soon as observers detected the presence of an object, they already knew its category. Similarly, Oliva and Torralba[11] reported that the semantic information of a scene could be extracted from a mere 200-msec exposure. This idea of meaning extraction is consistent with the well-known propensity of humans to remember the meaning and interpretation of pictures but forget much of their physical details.[12,13]

Thus, humans seem to possess a natural tendency to extract meaning from visual stimulation, which suggests that high-level cognitive processes are amenable to exploitation via information displays if one has knowledge of the relevant cognitive processes. We now turn to those processes.

3 Cognitive processes

The cognitive processes reviewed in this section can be conceptualized as comprising part of a dual-process model for reasoning and decision making, as reviewed by Patterson *et al.*[14] That source should be consulted for a more thorough discussion of that model. In the present paper, a set of cognitive processes is represented as a functional flow diagram, shown in Fig. 1. The figure depicts two basic processes of interest: working memory, which involves multiple subcomponents and is one component of what is termed the analytical reasoning; and decision-making system and pattern recognition, which is a component of what is called the intuitive or implicit decision-making system.[14] These processes may be of particular interest to display designers, as discussed below.

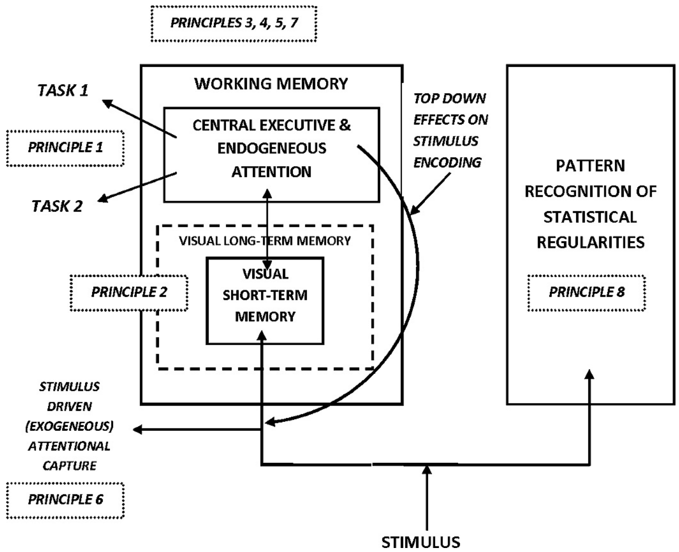

FIGURE 1 — Functional flow diagram of several components of human cognition. In working memory, the central executive activates neural representations from long-term memory that are called short-term memory, maintains and updates goals, plans, and selects responses. The central executive allocates attention for performing multiple tasks. Attentional capture (exogenous attention) is triggered by stimulation and controls access to working memory. Pattern recognition of statistical regularities occurs in a different cognitive system. See text for details.

3.1 Working memory

Working memory[15–19] refers to the temporary store or activation of information that provides an individual with the ability to perform dynamic complex mental operations, such as planning for the future. A core component of working memory is the central executive, which controls the activation of relevant memory representations, goal states, responding, and the mental chunking of information (Fig. 1). A key component of the central executive of working memory is *endogenous attention,* which refers to voluntary attention. The limit of endogenous attention is about four items or chunks.[20] The central executive controls the switching of attention and the coordination of simultaneously performed multiple tasks.

3.2 Pattern recognition

Pattern recognition (Fig. 1) refers to the recognition of patterns formed from statistical regularities encountered in the environment (or on artificial displays). Pattern recognition is based on *implicit learning,* which refers to learning without intention and without being able to verbalize easily what has been learned.[39,40] Pattern recognition underlies the ability to make intuitive decisions[14] as well as the development of expertise.[41]

We now turn to eight principles of good display design based on the brief discussion of human cognition given above.

4 Eight principles of good display design

Principle #1: *Displays that divide attention will increase cognitive load on working memory and potentially degrade performance on a given cognitive task.* The central executive controls the switching of attention and the coordination of simultaneously performed multiple tasks (see Fig. 1). Thus, performance on attention-demanding tasks, such as those involving divided attention, or tasks with distraction, would be expected to be relatively lower than performance on non-attention-demanding tasks.[21,22]

Principle #2: *Displays that continuously present and refresh the same information can compensate for the decay of short-term memory and possibly aid performance on a given cognitive task.* The central executive, through endogenous attention, is involved in the control of the short-term activation of information in different modalities, such as visual short-term memory,[15,17] as shown in Fig. 1. This short-term memory is time limited, with decay occurring within 10–20 sec (but rehearsal can reactivate the memory). Short-term memory can become activated either through the operation of endogenous attention or an external triggering stimulus (Fig. 1).

Principle #3: *Displays that present information as retrieval cues for long-term memory and assist the viewer in mentally chunking information via its meaning will decrease cognitive load on working memory and possibly enhance performance on a given cognitive task.* The central executive of working memory controls the chunking of information. *Chunking* is a mental strategy for increasing the amount of information that can be encoded (which refers to the initial conversion of the visual images into a mental symbolic representation), processed or remembered by recoding items of low information content into a smaller number of items with high information content.[23]

In the process of chunking, features or cues contained in the pattern of stimulation trigger the activation of long-term-memory representations. Alternatively, the goals or expectations held by the viewer may activate long-term-memory representations.[21] Due to their activation, these long-term-memory representations then become part of working memory. The knowledge contained in the activated memory representations organizes the way in which the incoming information is encoded (Fig. 1). Thus, displays that present information which serves as a retrieval cue for activating certain long-term-memory representations can control how the incoming information gets encoded. Chunking will usually be based on the meaning of the stimulation, thus chunking is specific to a given content domain. A recent estimate of the capacity of working memory is about four chunks.[20]

With respect to chunking and meaning, master-level chess players were able to reconstruct the position of chess pieces placed on a chess board with a legal configuration almost perfectly after a 5-sec viewing,[24] performance that was based on the chess masters' ability to perceive structure among the chess pieces (*e.g.*, arrangements of pieces based on attack, defense, *etc.*) and encode them in mental chunks.[25] Interestingly, the master chess players were no better than weaker players in reconstructing randomly placed pieces because there was no meaningful basis on which to chunk the pieces.

Principle #4: *Displays that present images in order to direct attention to important visual stimuli will help minimize the potential for inattentional blindness.* Recall that one key component of working memory is endogenous attention. Endogenous attention can control, at an early stage of processing, which stimuli get encoded for subsequent processing, a so-called "top-down" effect (Fig. 1). This would be important when there is a potential for an overwhelming amount of sensory information to be present.[16] Failure to direct attention to an important stimulus because attention and expectation are directed elsewhere can lead to the situation where the stimulus is not perceived at all, which is called "inattentional blindness."[26–28] The potential exists for inattentional blindness when many elements are presented to which attention could be directed. Endogenous attention also selects which information gets actively maintained in working memory, and which responses get selected when interacting with the environment.

Principle #5: *Displays that help minimize attentional distractions or help focus attention on a given task, or take the burden away from working memory by having some kind of external memory system for irrelevant information, may enhance performance on a given cognitive task.* Information that gains access to working memory must then be maintained in an active state for the duration it is relevant to a given task, which is one function of endogenous attention, or it will decay. For example, an individual's ability to respond consistently with one's goals can occur only when the goal to perform that response is maintained in an active state in working memory.[29] One way in which information can be maintained in memory is through rehearsal, which involves covert shifts of endogenous attention toward the information to be remembered.[16] Environmental distractions or other conditions that foster goal neglect[29] have the potential to degrade performance.

Principle #6: *Displays that present cues composed of strong singletons that direct attention to important information will capitalize upon exogenous attention and may enhance performance on a given cognitive task. Exogenous attention* refers to the deployment of attention based on the presence of a triggering stimulus somewhere in the visual field, usually in the periphery. Exogenous attention is also called "attentional capture" (Fig. 1). Egeth and Yantis[30] refer to exogenous attention as passive and stimulus driven, as opposed to endogenous attention which is active and goal directed. With exogenous attention, certain visual attributes that distinguish a stimulus from its background (*e.g.*, color), which are called "singletons," can serve as the triggering stimulus and thus capture attention, especially abrupt visual onsets.

Principle #7: *Displays that present information as retrieval cues for long-term memory and help the viewer make a mental connection between an analogue and a target may assist in the induction of analogical reasoning and the transfer of inferences to a given target problem to be solved.* There are many ways in which high-level reasoning and thinking could be influenced by information displays; too many, in fact, for them to be discussed in this short paper. To give an example of how reasoning and thinking could be impacted by information displays, *analogical reasoning* will be briefly considered. Reasoning by analogy involves making inferences from the similarity of relationships of elements across two or more domains[31–34] in order to transfer inferences between or among domains. Analogical reasoning is one of the more fundamental thinking skills possessed by humans.[35]

Many individuals can use analogies for reasoning provided that the connection between the analogue and the target is made explicit. For example, in a study on analogical reasoning, Gick and Holyoak[36,37] presented to individuals a target problem that involved the hypothetical administration of doses of radiation to a patient who had stomach cancer. Because the needed dose to kill the tumor would kill healthy cells in the body as well, the solution was to direct the radiation from different sources around the body – a "convergence solution." The hypothetical analogue to this target problem was how to overrun a fortress that had four roads leading into it with an attacking army. Because the roads were mined in such a way that a large group of individuals would detonate the mines, the solution was to split up the army into small groups, each of which attacked the fortress from one of the roads – another "convergence solution."

Gick and Holyoak found that only 30% of individuals were able to generate the convergence solution for the radiation problem after receiving the convergence solution to the fortress story with no hint to apply it. However, Pedone *et al.*[38] found that significant improvement was obtained in the generation of the solution to the target problem (radiation problem) from the solution to the analogue (fortress story) when an animation display was used to convey moving lines converging onto a target. The animation display served as a retrieval cue for the solution to the analogue that was represented in long-term memory, which could then be applied to the target problem.

Principle #8: *Displays that present over time multiple exposures with statistical regularities may promote implicit learning and pattern-recognition-based decision making, and possibly contribute to the development of expertise in certain domains.* One form of implicit learning entails the process of learning statistical regularities without intention and without being able to verbalize easily what has been learned.[39,40] It is a ubiquitous, robust process that likely provides a foundation for our ability to make *intuitive* decisions based on situational pattern recognition[14] (Fig. 1), which we do on a frequent basis every day of our lives.

Moreover, implicit learning likely occurs in parallel with the learning of more complex forms of knowledge, such as when individuals attempt to acquire a high level of expertise in a given content domain.[41]

Implicit learning and pattern-recognition-based (intuitive) decision making, as well as perhaps expertise and skill development in a number of domains, could be developed via multiple training sessions, which create the necessary multiple exposures to the relevant information.[14] Thus, visual displays that present multiple exposures of statistically related patterns over time offer the possibility of helping to create implicit learning as a foundation for pattern-recognition-based (intuitive) decision making, as well as contributing to the development of expertise (Fig. 1).

5 Evolution of display design

These eight principles of good display design, based on human cognition, can be viewed within an (technology) evolutionary context. Presently, displays are constructed in ways that allow pixel-level information to be rendered with high fidelity or signal strength. Recent algorithms, such as adaptive contrast algorithms, attempt to enhance the contrast of object boundaries. At the next level, displays might be designed that present information for the purpose of controlling human attention, learning, and memory, as suggested in the present paper. In a sense, the issue is one that concerns the evolution of future *smart displays*. This evolution will require close interaction between display designers, and subject-matter experts so that appropriate content can be displayed that selectively controls cognitive functioning.

6 Concluding remarks

In this paper, eight principles of good display design were derived from knowledge of human cognition: (1) displays that distract or divide attention will likely degrade performance due to increased cognitive load on working memory; (2) displays that continuously present the same information may increase performance due to compensation for the decay of short-term memory; (3) displays that assist the viewer in mentally chunking information will likely enhance performance due to decreased cognitive load on working memory; (4) displays that present icons or images to direct attention to important visual stimuli will likely increase performance and help minimize inattentional blindness; (5) displays that help minimize attentional distractions and help focus attention on a given task will enhance performance by minimizing the burden on working memory; (6) displays that present cues composed of strong singletons which capture attention and direct it to important information will likely increase performance by engaging exogenous attention; (7) displays that help the viewer make a mental connection between an analogue and a target will help problem solving by assisting in the induction of analogical reasoning; (8) displays that present over time multiple exposures consisting of statistical regularities may promote implicit learning, pattern-recognition-based decision making, and the development of expertise.

Knowledge about cognitive processes such as working memory, attention, short-term memory, chunking, analogical reasoning, and implicit learning should be exploited in the design of information displays of the future. These displays will likely go beyond the creation of entertainment and engage high-level human-cognitive processes for purposes of improving human performance on a variety of tasks found in education, the military, and many other applications.

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References

a R. Patterson and J. Roland, "Cognitive engineering and information displays," in *Handbook of Visual Display Technology,* J. Chen, W. Cranton, and M. Fihn, eds. (Springer, Berlin, Germany, 2010), Chapter 10.6.3, pp. 2260–2269..

1 S. Thorpe *et al.,* "Speed of processing in the human visual system," *Nature* **381**, 520–522 (1996).

2 A. Michotte, *The Perception of Causality* (Methuen, Andover, MA, 1962).

3 F. Heider and M. Simmel, "An experimental study of apparent behaviour," *Am. J. Psychol.* **13** (1944).

4 I. Biederman, "Perceiving real-world scenes," *Science* **177**, 77–80 (1972).

5 I. Biederman *et al.,* "Searching for objects in real-world scenes," *J. Exptl. Psychol.* **97**, 22–27 (1973).

6 I. Biederman, "On the semantics of a glance at a scene," *Perceptual Organization,* M. Kubovy and J. R. Pomerantz, eds. (Erlbaum, Hillsdale, NJ, 1981), pp. 213–253.

7 N. Weisstein and C. S. Harris, "Visual detection of line segments: An object-superiority effect," *Science* **186**, 752–755 (1974).

8 N. Weisstein *et al.,* "Depth, connectedness, and structural relevance in the object-superiority effect: Line segments are harder to see in flatter patterns" (1982).

9 J. T. Enns and R. A. Rensink, "Influence of scene-based properties on visual search," *Science* **247**, 721–723 (1990).

10 K. Grill-Spector and N. Kanwisher, "Visual recognition: As soon as you know it is there, you know what it is," *Psychol. Sci.* **16**, 152–160 (2005).

11 A. Oliva and A. Torralba, "Building the gist of a scene: The role of global image features in recognition," *Progress in Brain Resarch: Visual Perception* **155**, 23–36 (2006).

12 J. M. Mandler and G. H. Ritchey, "Long-term memory for pictures," *J. Exptl. Psychol.: Human Learning and Memory* **3**, 386–396 (1977).

13 M. A. Gernsbacher, "Surface information loss in comprehension," *Cognitive Psychol.* **17**, 324–363 (1985).

14 R. Patterson *et al.,* "Training robust decision making in immersive environments," *J. Cognitive Eng. Decision Making* **3**, 331–361 (2009).

15 A. D. Baddeley and G. J. Hitch, "Working memory," *The Psychology of Learning and Motivation: Advances in Research and Theory,* Vol. 8, G. H. Bower, ed. (Academic Press, New York, 1974), pp. 47–89.

16 E. Awh *et al.,* "Interactions between attention and working memory," *Neuroscience* **139**, 201–208 (2006).

17 A. D. Baddeley, *Working Memory* (Oxford University Press, New York, 1986).

18 A. D. Baddeley, "Working memory: Looking back and looking forward," *Nature Rev. Neuroscience* **4**, 829–839 (2003).

19 A. D. Baddeley and R. H. Logie, "Working memory: The multi-component model," *Models of Working Memory: Mechanisms of Active Maintenance and Executive Control,* A. Miyake and P. Shah, eds. (Cambridge University Press, New York, 1999), pp. 28–61.

20 N. Cowan, "The magical number 4 in short-term memory: A reconsideration of mental storage capacity," *Behavioral Brain Sci.* **24**, 87–185 (2000).

21 N. Cowan, *Attention and Memory: An Integrated Framework* (Oxford University Press, New York, 1995).
22 R. W. Engle *et al.*, "Individual differences in working memory capacity and what they tell us about controlled attention, general fluid intelligence, and functions of the prefrontal cortex," *Models of Working Memory: Mechanisms of Active Maintenance and Executive Control,* A. Miyake and P. Shah, eds. (Cambridge University Press, NY, 1999), pp. 102–134.
23 G. A. Miller, "The magical number seven, plus or minus two: Some limits on our capacity for processing information," *Psychol. Rev.* **63**, 81–97 (1956).
24 A. D. de Groot, *Thought and Choice in Chess* (Mouton The Hague, 1965).
25 W. G. Chase and H. A. Simon, "Perception in chess," *Cognitive Psychol.* **4**, 55–81 (1973).
26 U. Neisser and R. Becklen, "Selective looking: Attending to visually specified events," *Cognitive Psychol.*, **7**, 480–494 (1975).
27 A. Mack and I. Rock, *Inattentional Blindness* (MIT Press, Cambridge, MA, 1998).
28 D. J. Simons, "Attentional capture and inattentional blindness," *Trends Cognitive Sci.* **4**, 147–155 (2000).
29 M. J. Kane and R. W. Engle, "Working-memory capacity and the control of attention: The contributions of goal neglect, response competition, and task set to Stroop interference," *J. Exp. Psychol.: General* **132**, 47–70 (2003).
30 H. E. Egeth and S. Yantis, "Visual attention: Control, representation, and time course," *Ann. Rev. Psychol.* **48**, 269–297 (1997).
31 J. H. Holland *et al., Induction: Processes of Inference, Learning, and Discovery* (MIT Press, Cambridge, MA, 1986).
32 K. J. Holyoak *et al.*, "Introduction: The place of analogy in cognition," *The Analogical Mind: Perspectives from Cognitive Science,* D. Gentner *et al.,* eds. (MIT Press, Cambridge, MA, 2001), pp. 1–20.
33 A. Juthe, "Argument by analogy," *Argumentation* **19**, 1–27 (2005).
34 A. B. Markman and C. P. Moreau, "Analogy and analogical comparison in choice," *The Analogical Mind: Perspectives from Cognitive Science,* D. Gentner *et al.,* eds. (MIT Press, Cambridge, MA, 2001), pp. 363–400.
35 G. Klein, "Applications of analogical reasoning," *Metaphor Symbolic Activity* **2**, 201–218 (1987).
36 M. L. Gick and K. J. Holyoak, "Analogical problem solving," *Cognitive Psychol.* **12**, 306–355 (1980).
37 M. L. Gick and K. J. Holyoak, "Schema induction and analogical reasoning," *Cognitive Psychol.* **15**, 1–38 (1983).
38 R. Pedone *et al.*, "The use of diagrams in analogical problem solving," *Memory Cognition* **29**, 214–221 (2001).
39 A. Cleeremans *et al.*, "Implicit learning: News from the front," *Trends Cognitive Sci.* **2**, 406–416 (1998).
40 P. Perruchet and S. Pacton, "Implicit learning and statistical learning: One phenomenon, two approaches," *Trends Cognitive Sci.* **10**, 233–238 (2006).
41 R. Patterson *et al.,* "Implicit learning, expertise development, and naturalistic decision making," *J. Cognitive Eng. Decision Making* **4**, 289–303 (2010).