Title	Creativity and visual one-shot learning
Sub Title	
Author	石川, 哲朗(Ishikawa, Tetsuo) 茂木, 健一郎(Mogi, Kenichiro)
Publisher	Centre for Advanced Research on Logic and Sensibility The Global Centers of Excellence Program, Keio University
Publication year	2011
Jtitle	CARLS series of advanced study of logic and sensibility Vol.4, (2010.) ,p.113- 119
JaLC DOI	
Abstract	
Notes	Part 1: Brain and Evolution
Genre	Research Paper
URL	https://koara.lib.keio.ac.jp/xoonips/modules/xoonips/detail.php?koara_id=KO12002001-20110331-0113

13 Creativity and Visual One-shot Learning

Tetsuo Ishikawa[1,2,3] *and Ken Mogi*[3,4]

[1] Centre for Advanced Research on Logic and Sensibility (CARLS), Keio University
[2] Department of Computational Intelligence and Systems Science, Interdisciplinary Graduate School of Science and Engineering, Tokyo Institute of Technology
[3] Sony Computer Science Laboratories, Inc.
[4] Graduate School of System Design and Management, Keio University

I. Introduction

Many animals, including humans, exhibit creative abilities to solve open-ended problems in an innovative, unexpected, and ingenious manner. German gestalt psychologist Köhler (1917) called it *einsicht* (insight or intuition). Bühler (1907) applied the word *Aha-erlebnis* (Aha! experience) to the subjective and affective experience (Gick & Lockhart, 1995). There are plenty of anecdotes about the historic moment of creativity of the scientific discoveries: the "*Eureka*" moment of Archimedes who saw an overflowing bathtub (Vitruvius, ca. 27 B.C.), Newton's apple (Stukeley, 1752), Kekulé's dream of the Ouroboros (Kekulé, 1890), and so on and so forth (Horvitz, 2002). Keep in mind that all of these ideas are based on visual and graphical images. These kinds of moments are not the privilege of the geniuses: Ordinary people also have such insightful moments in daily life. Since most of the underlying processes that induce the instantaneous insight problem solving are unconscious and intuitive (e.g., sensibility) (Volz & von Cramon, 2006; Gigerenzer, 2007), it is very different from conscious and gradual processes such as deliberate thinking and analytic solution (i.e., logic) (Morewedge & Kahneman, 2010). However, little is understood about cognitive mechanism and neural underpinnings of creativity.

II. Characteristics of Insight Problem Solving

The insight solution in problem solving differs from the non-insight solution in several conspicuous points: (i) solvers experience their solutions as sudden and obviously correct (the Aha!), (ii) prior to producing an insight solution solvers sometimes come to an impasse, no longer progressing towards a solution, and (iii) solvers usually cannot report the processing that enables them to overcome an impasse and reach a solution (Bowden et al., 2005).

Sandkühler and Bhattacharya (2008) similarly summarized the features of insight in four keywords as “suddenness”, “deeper understanding”, “mental impasse”, and “restructuring”. The invention of general relativity and the proof of mathematical problems such as Fermat’s last theorem or Poincaré conjecture, for example, probably met the criteria mentioned above. Thus, those challenges must have involved certain kinds of problem solving by insight. To study insight experimentally, however, much easier problems like sentence comprehension tasks (Auble et al., 1979), anagrams (Bowden, 1997; Aziz-Zadeh et al., 2009), riddles (Luo & Niki, 2003) or compound remote associates (CRA) problems (Jung-Beeman et al., 2004; Sandkühler et al., 2008) are frequently used. Note that these commonly-used insight problems are not visual, but verbal puzzles.

III. Visual One-shot Learning

3.1. Visual Aha! Experience or One-shot Learning

In the field of visual perception, the famous “dalmatian” (Gregory, 1970) and “cow” pictures (Dallenbach, 1951) are difficult for naïve subjects to recognize at first sight. But once subjects realize what is in the figure, a rapid perceptual learning occurs and is completed in a very short time. The dramatic transition from an unconscious impasse to a conscious epiphany during hidden object recognition meets the requirements for insight. Thus, hidden figure perception is an instance of visual Aha! experience. This learning effect is long lasting and also called Eureka effect (Ahissar, 1997) or visual one-shot learning (Mogi et al., 2005, 2006, 2007; Giovannelli et al., 2010). Except for a few heuristics (Mogi et al., 2006), little is understood about how to create “good” hidden figures.

3.2. Neural Correlates of Visual One-shot Learning

In the insightful moment when subjects perceive “Mooney” faces (Mooney, 1957), neural synchronization spreads all over the brain, which lasts for about 100 milliseconds (Rodriguez et al., 1999). In general, when “Mooney” objects and their original grayscale photographs are presented alternately, activities of inferior temporal and parietal regions are enhanced (Dolan et al., 1997), and the early retinotopic cortex, foveal confluence is modulated by top-down interpretation as well as ventral visual stream, lateral occipital complex (Hsieh, et al., 2010). Repetitive transcranial magnetic stimulation (rTMS) over the parietal cortex during the presentation of the undegraded images disrupts identification of the degraded counterparts 30 minutes later (Giovannelli et al., 2010). The activation of left amygdala predicts memory performance one week later in a similar paradigm (Rubin et al., 2006), suggesting the importance of emotional aspects of one-shot learning. Most of these studies dealt with “induced” visual one-shot learning, in which answers were shown during the experiment. Neural substrates of “spontaneous” visual one-shot learning are not well known.

3.3. Evolutional Origin of Visual One-shot Learning

Considerable cognitive efforts are needed to perceive surroundings in scotopic vision, as color information is useless and spatial resolution is much lower than usual. The segregation of figure from ground is ambiguous in these impoverished contexts. Mammals, birds and insects judge shapes of objects by, for example, perceiving illusory contour (Nieder, 2002). Ability to perceive illusory contour in partial occlusion or in dimly lit situation such as under the moonlight is biologically adaptive in the natural surroundings, as it is advantageous to be able to detect mimicry species as quickly as possible to flee from predator or to target prey. Visual system with such an ability is called “anti-camouflaged device” (Ramachandran, 1987). The same holds true for visual one-shot learning: seeing hidden figures such as the grayscale picture of a cow (Dallenbach, 1951) and the tow-tone image of a dalmatian (Gregory, 1970).

VI. Experiment

Here we present a novel procedure to clarify the behavioral characteristics of visual one-shot learning involved in the perception of hidden figures. By morphing "Mooney" objects with the original grayscale images, figures of varied perceptual difficulties were produced (Ishikawa & Mogi, 2010, 2011). Morphing provides a means of dynamically probing into the cognitive processes of one-shot learning, as opposed to the static approach of the conventional hidden figure.

4.1. Methods Summary

Nine healthy volunteers (5 females, 32±6 years old) participated in the experiment. Thirty-two movies were made by morphing from a "Mooney" object to the grayscale original (Fig. 1). The movie sequence consisted of 101 frames (0% – 100% grayscale), with a duration of 20.2 seconds (200

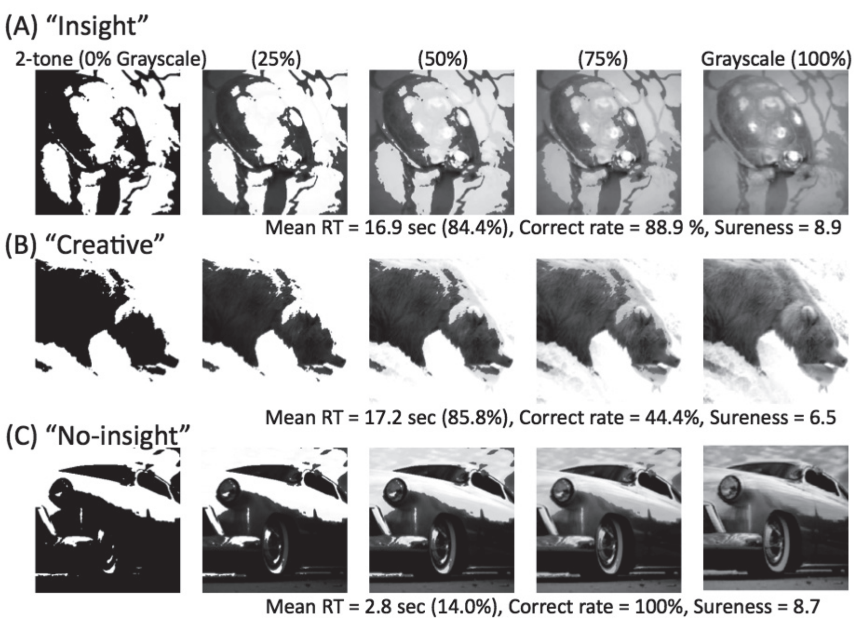

Figure 1. Representative stimuli: (A) "Insight" problem, (B) "Creative" problem (i.e., high false alarm rate), and (C) "No-insight" problem.

msec/%).

Participants were instructed to stop the movie (visual angle: 10° x 10°) by clicking the mouse when they perceived what was in the movie. They verbally reported the name of object and the "sureness" in a 11-point (0 to 10) scale.

4.2. Results and Discussion

Almost all participants reported subjective "Aha!" experience while watching the movie A, while none of them reported a feeling of insight in the movie C. Comparing the movie A to the movie C, correct rate (A: 88.9% vs. C: 100%) and confidence rating (A: 8.9±1.3 vs. C: 8.7±1.4) were both comparable. Therefore, a high degree of certainty is a necessary but not sufficient condition of insight. According to Fig. 2, the rising time of the movie A (84.4±20.2%) was significantly slower than the movie C (14.0±8.7%) (t test: $p < 0.0001$). This gap indicates that it is likely that there has been a mental impasse before the correct perception of the movie A.

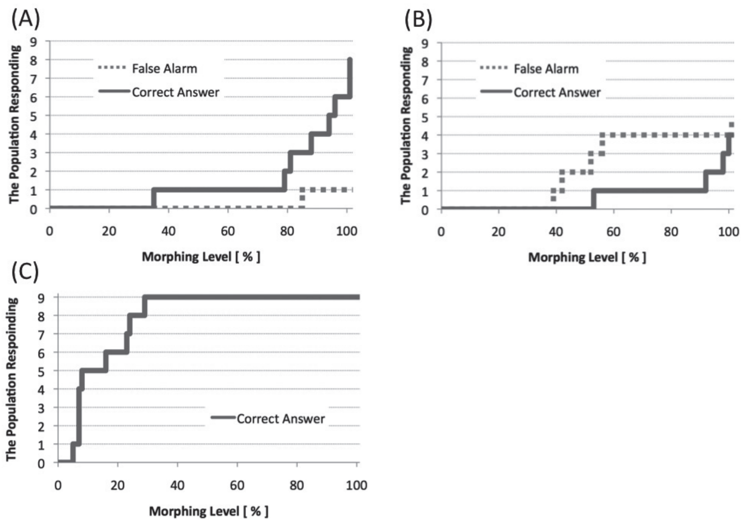

Figure 2. The cumulative number of correct respondents through the morphing stages.

In the case of the movie B, about a half of the viewers reached the correct answer. The remaining half, however, got wrong answers (False Alarm). It is true that they failed to have an accurate hidden figure perception, but they found different solution through "creative" perceptual processes. The sureness rating of the movie B (6.5±2.3) tended to be slightly lower than the movie A (8.9±1.3) ($p = 0.06$), suggesting that subjects had a precise metacognition of the diffidence, due to, for example, multiple interpretations or figure/ground inconsistency (Davenport & Potter, 2004). Further details of the methods and results are described elsewhere (Ishikawa et al., 2011). A functional imaging study of spontaneous visual one-shot learning is a promising method to demystify the neural basis of insight and creativity. Clarifying resemblance and difference between the perceptual and cognitive processes of verbal and visual problem solving by insight is an intriguing problem which merits further studies.

References

Ahissar, M., Hochstein, S. (1997) Task difficulty and the specificity of perceptual learning. *Nature*, 387, 401–406.

Auble, P. M., Franks, J. J., Soraci, S. A. (1979) Effort toward comprehension: Elaboration or "aha!"? *Memory & Cognition*, 7, 426–434.

Aziz-Zadeh, L., Kaplan, J. T., Iacoboni, M. (2009) "Aha!": The neural correlates of verbal insight solutions. *Hum. Brain Mapp*., 30(3), 908–916.

Bowden, E. M. (1997) The effect of reportable and unreportable hints on anagram solution and the aha! experience. Conscious. Cogn., 6(4), 545–573.

Bowden, E. M, Jung-Beeman, M., Fleck, J., Kounios, J. (2005) New approaches to demystifying insight. *Trends*. Cogn. Sci., 9(7), 322–328.

Bühler, K. L. (1907) Tatsachen und Probleme zu einer Psychologie der Denkvorgänge. I: Über Gedanken. *Archiv für die gesamte Psychologie*, 9, 297–365.

Davenport, J. L, Potter, M. C. (2004) Scene consistency in object and background perception. *Psychol*. *Sci*., 15(8), 559–564.

Dolan, R. J., Fink, G. R., Rolls, E., Booth, M., Holmes, A., Frackowiak, R. S., Friston, K. J. (1997) How the brain learns to see objects and faces in an impoverished context. *Nature*, 389, 596–599.

Gick, M. L, Lockhart, R. S. (1995) Cognitive and affective components of insight. In Sternberg, R. J., Davidson, J. E. (Eds.), *The nature of insight*, MIT Press, Cambridge, 197–228.

Gigerenzer, G. (2007) *Gut Feelings: The Intelligence of the Unconscious*, Viking Press, New York.

Giovannelli, F., Silingardi, D., Borgheresi, A., Feurra, M., Amati, G., Pizzorusso, T., et al. (2010) Involvement of the parietal cortex in perceptual learning (Eureka effect): an interference approach using rTMS. *Neuropsychologia*, 48(6), 1807–1812.

Hsieh, P. J., Vul, E., Kanwisher, N. (2010) Recognition alters the spatial pattern of fMRI activation in early retinotopic cortex. *J. Neurophysiol*., 103(3), 1501–1507.

Horvitz, L. A. (2002) *Eureka!: Scientific Breakthroughs that Changed the World*, John Wiley & Sons, Inc., New York.

Ishikawa, T., Mogi, K. (2010) Unsupervised visual one-shot learning as restoration of degraded images: a novel morphing paradigm. *Abst. for the 14th annual meeting of the Association for the Scientific Study of Consciousness*, Toronto, Canada, 63.

Ishikawa, T., Mogi, K. (2011) Visual One-shot Learning As An 'Anti-camouflage Device': A Novel Morphing Paradigm. *Cognitive Neurodynamics, in press*.

Jung-Beeman, M., Bowden, E. M., Haberman, J., Frymiare, J. L., Arambel-Liu, S., Greenblatt, R., et al. (2004) Neural activity when people solve verbal problems with insight. *PLoS Biology*, 2(4), e97.

Kekulé, A. (1890) Benzolfest: Rede, *Ber. Dtsch. Chem. Ges*., 23, 1302–1311.

Köhler, W. (1917) *Intelligenzenprüfungen an Anthro-poiden* [*The Mentality of Apes*], Winter, E., Trans. (1925) Harcourt, Brace, New York.

Luo, J., Niki, K. (2003) Function of hippocampus in "insight" of problem solving. *Hippocampus*, 13(3), 316–323.

Mogi, K., Sekine, T., Tamori, Y. (2005) Slow and fast processes in visual 'one-shot' learning. *Perception*, 34, ECVP Abst. Suppl., 15–16.

Mogi, K., Tamori, Y. (2006) Making good hidden figures. *Perception*, 35, ECVP Abst. Suppl., 200–201.

Mogi, K., Tamori, Y. (2007) Temporal characteristics of visual one-shot learning. *Perception*, 36, ECVP Abst. Suppl., 51–52.

Mooney, C. M. (1957) Age in the development of closure ability in children. *Can. J. Psychol*., 11, 219–226.

Morewedge, C. K., Kahneman, D. (2010) Associative processes in intuitive judgment. *Trends. Cogn. Sci*., 14(10), 435–440.

Nieder, A. (2002) Seeing more than meets the eye: processing of illusory contours in animals. *J. Comp. Physiol*. A., 188(4), 249–260.

Ramachandran, V. S. (1987) Visual perception of surfaces: a biological theory. In Petry, S., Meyer, G. E. (Eds.), *The perception of illusory contours*. Springer, Berlin Heidelberg, New York, 93–108.

Rodriguez, E., George, N., Lachaux, J. P., Martinerie, J., Renault, B., Varela, F. J. (1999) Perception's shadow: long-distance synchronization of human brain activity. *Nature*, 397, 430–433.

Rubin, N., Ludmer, K., Dudai, Y. (2006) Changes in stimulus appearance mediating abrupt improvements in perceptual tasks. *Perception*, 35, ECVP Abst. Suppl., 113–114.

Sandkühler, S., Bhattacharya, J. (2008) Deconstructing insight: EEG correlates of insightful problem solving. *PLoS One*, 3(1), e1459.

Stukeley, W. (1752) *Memoirs of Sir Isaac Newton's Life*, The Royal Society Library, London.

Vitruvius, M. P. (ca. 27 B.C.) *De Architectura*, Liber IX, praefatio 10.

Volz, K. G., von Cramon, D. Y. (2006) What neuroscience can tell about intuitive processes in the context of perceptual discovery. *J. Cogn. Neurosci*., 18(12), 2077–2087.