Variability, Constraints, and Creativity

Shedding Light on Claude Monet

Patricia D. Stokes
Columbia University

Recent experimental research suggests 2 things. The first is that along with learning how to do something, people also learn how variably or differently to continue doing it. The second is that high variability is maintained by constraining, precluding a currently successful, often repetitive solution to a problem. In this view, Claude Monet's habitually high level of variability in painting was acquired during his childhood and early apprenticeship and was maintained throughout his adult career by a continuous series of task constraints imposed by the artist on his own work. For Monet, variability was rewarded and rewarding.

Many creativity (Boden, 1991; D. T. Campbell, 1960; Perkins, 1994; for a review, see Simonton, 1999) and learning (Hebb, 1949; Holland, Holyoak, Nisbett, & Thagard, 1987; Palmer & Donahoe, 1992; Skinner, 1984) models share a common Darwinian mechanism: selection from a variable substrate. According to the learning models, selection occurs through consequences that either reinforce and increase or punish and decrease the behaviors that precede them. The creativity models have specific selection criteria: newness, usefulness (Amabile, 1996), appropriateness (Gardner, 1993), and influence (Csikszentmihalyi, 1996; Simonton, 1984).

Inherent in all selectionist models is a problem that is greater for creativity, which requires novelty, than for learning, which more often aims at reliability. The problem is this. *Selection reduces the variability on which it depends.* When people can do anything, they do what has been most successful in the past. Successful solutions tend to be predictable, not surprising, and repetitive, not novel.

How then do creative individuals maintain high levels of variability? I suggest two related possibilities. The first is that during skill acquisition, they learn how to do things and also how differently to do them: The "how differently" part involves *selection of variability* (Neuringer, 1993; Stokes, 1995). The second is that high variability is both acquired and maintained by the *use of constraints.* I examine evidence in support of these ideas—experimental first and Monet second.

Constraints and Variability: Experimental Evidence

Constraints preclude some things and promote others. Some (e.g., give the right answer, follow the directions, copy exactly) indeed preclude variability and promote stereotypy. Surprisingly, many increase variability. They do so by precluding reliable, repetitive responses and promoting unusual, unexpected ones. As we shall see, more restrictive constraints can sometimes generate and maintain higher variability levels than less severe ones.

The constraints covered in this section are usually referred to as contingencies. I prefer and use the term in its problem-solving sense of directing and limiting search for solutions (Reitman, 1965). I focus on variability and task constraints, both of which have temporary and sustained effects. For more extensive literature reviews, see Epstein and Laptosky (1999), Stokes (in press), and Winston and Baker (1985).

Variability Constraints

Variability constraints determine how differently something must be done. They do this by specifying levels or sorts of variability. Among the sorts of variability that are increased by immediate, repetitive reward are fluency, flexibility (Glover & Gary, 1976) and elaboration (J. A. Campbell & Willis, 1978), originality (Eisenberger & Armeli, 1997), and novelty (Goetz, 1982). Even porpoises have proved to be "creative," displaying new ways of swimming and diving and doing so closer to, or even at the start of, reward sessions as training proceeded (Pyror, Haag, & O'Reilly, 1969). Children's drawing or block-building forms increased in novelty (first instances across sessions) and diversity (first instances in any session) over reward sessions. When reward stopped, diversity remained high in the training domain and transferred to a related domain, for example, from drawing to painting (Holman, Goetz, & Baer, 1977). Transfer to unrelated domains has also been demonstrated. Rewarding novelty in words (Maltzman, Simon, Raskin, & Licht, 1960) or drawings (Funderbunk, 1977) increased originality on subsequent unusual-uses tasks. (Notice that, contrary to intrinsic motivation theorists such as Amabile, extrinsic reward in these studies led to increased variability. For an instructive analysis of these

Editor's note. Robert J. Sternberg and Nancy K. Dess developed this section on creativity.

Author's note. Correspondence concerning this article should be addressed to Patricia D. Stokes, Psychology Department, Barnard College, Columbia University, 3009 Broadway, New York, NY 10023. Electronic mail may be sent to pstokes@barnard.columbia.edu.

 0003-066X/01/$5.00
Vol. 56, No. 4, 355–359 DOI: 10.1037//0003-066X.56.4.355

contradictory literatures, see Eisenberger and Cameron, 1996.)

Rewarding less frequent or less probable responses (Machado, 1994) or requiring that a response differ from some number of prior responses also increments variability. The difference is called a lag. With a lag of three, a response sequence must differ from three immediately preceding sequences. In this case, the sequence AAA would be rewarded if it followed two different sequences (ABB, BAB, *AAA*) but not if it repeated one of them (AAA, BAB, *AAA*). With humans (Stokes, 1999a; Wong & Peacock, 1986) and other animals (Neuringer & Huntley, 1991; Page & Neuringer, 1985), variability increases as lag requirements increase. These constraints also have lasting as well as temporary effects. For example, in two different computer games, earlier exposure to high lag requirements led to higher sustained variability levels when the requirements were relaxed (Stokes, 1999a; Stokes & Balsam, in press).

In contrast to the *explicit* variability constraints in the aforementioned studies, accelerated learning programs—such as telescoping three years of academic work into two, or talent search programs that compress two years of high school algebra or geometry into three weeks of 5- to 6-hour day classes (Eby & Smutny, 1990)—have *implicit* variability constraints built into them. Students are acquiring skills at speeds that necessitate being highly variable in their application. They are learning how to do math, music, or art and to be very variable when they do it.

Task Constraints

Task constraints define domains, involve materials and conventions concerning their use, and determine how differently something can be done. More severe constraints (albeit ones that allow for variable responding) tend to generate higher variability. Work on creative inventions provides strong support for this idea. Experimenters (Finke, 1990; Finke, Ward, & Smith, 1992) correctly predicted that restriction to an arbitrary set of parts (e.g., hook, sphere, and ring) or to an inventive category (e.g., furniture, appliances, or toys) would discourage conventional thinking. The inventions of college students who could choose neither parts nor category were judged to be more creative than the inventions of college students who could choose one or both.

As we saw with variability constraints, more severe early task constraints tend to maintain higher later variability. Rats, for example, were more variable in the ways they pressed a bar when they were shaped with a more severe constraint (press with the right paw only) than with a less severe constraint (press any way). They also stayed more variable when the constraints were switched late in training (Stokes, 1995). When groups of college students learned to play the same computer game through a different series of training steps, higher variability levels were maintained in a group given a large challenge (a big shift in the number of required responses) earlier as compared with later in learning (Stokes, Mechner, & Balsam, 1999). Fewer allowable exit locations in a mazelike game increased initial search and led to higher sustained variability levels after these constraints were relaxed (Stokes, Harrison, & Kraut, 2000).

In sum, experimental evidence shows that constraints can increase variability. When introduced early in skill acquisition, constraints can also sustain high levels of variability. To show how these ideas about constraints apply to creativity, I now turn to Claude Monet.

Constraints and Creativity: Monet's Evidence

In this section, I aim to document two things. First is that intense, early, accelerated skill acquisition and the attention paid to its products produced Monet's high habitual variability level. Second is that Monet's use of self-imposed, continually shifting task constraints precluded repetition, promoted change, and—importantly—maintained the high variability. I investigate Monet's creative output in three phases, each influential in its own way. In the first phase, light was broken into its constituent colors, which pointed to Pointillism and was the prelude to Fauvism. The second phase provided a strategy—series painting—that is still used by many artists. The third, decorative phase was not influential until the 1950s, when paintings originally seen as the product of senility and failing eyesight became a major impetus behind abstract and lyrical Expressionism and color-field painting.

The Gifted Childhood: Learning to Be Highly Variable

Gifted children are speedy, greedy acquirers of expertise who delight in displaying their skill (Winner, 1996). Speedy, accelerated training is critical to skill development for gifted children in painting, chess, mathematics, and music (Feldman, 1991; Zimmerman, 1995). Key to my argument, it makes high variability possible, expected, and normative. By constraining repetition, it promotes and rewards high variability at the time when variability levels in a domain are established, early (Stokes, 1999b). Delight reflects the rewards of mastery, the attention and praise paid the work, and, indirectly, the highly variable way of working.

Both speed and delight are evidenced in the young Monet, who recollected drawing "everywhere and anywhere" (Wildenstein, 1996b, p. 12). In school, garlands filled the margins of his exercise books: "Fantastical ornaments, which included highly irreverent drawings of my masters . . . with maximum distortion" (Wildenstein, 1996b, p. 12) covered the pages. The drawings were regularly shown and given to his classmates (Wildenstein, 1996b). The contents of a sketchbook from 1857, when Monet was 16 years old, demonstrate well-wrought competence in traditional landscape techniques—composition, contour, shading, and simplification—as well as the caricaturist's skills, exaggeration and condensation (Forge, 1995). The apprenticeship in painting began a year later, in the summer of 1858. His first master was Boudin, whose bright and sketchy beach scenes were shown in the framer's shop that displayed Monet's caricatures. The brightness and the sketchiness resulted from Boudin's practice—

which became Monet's—of working rapidly, directly, and *en plein air* in preference to the studio (Seitz, 1982).

The Creative Phases: Maintaining High Variability

Influence, or changing a domain, involves clarifying and establishing new goal criteria, which serve as major constraints. Monet accomplished this goal by devising novel task constraints that initially replaced those of his domain and then—repetitively—replaced his own. These changes maintained his high variability.

Phase I: Constraining value. The dominant domain criteria for representational painting involved contrasting values. Lights modulated into darks. Darks were murky, blacks and browns. Even Monet painted this way. The waves at the *Mouth of the Seine at Honfleur* (1865)[1] are earth-colored—raw umber and burnt sienna.

Impressionism started with the scientific study of sensation. Although there had been earlier color wheels (including Newton's), a recently published one (by the French chemist Chevreul) attracted Monet's attention. The wheel, which broke up light into the four primary hues and their intermediaries, prompted Monet's initial, and initially ill-defined, goal constraint: representing *how light breaks up on things.* The task constraints followed. The first constrained modulated, carefully modeled value contrasts. Precluding contrast in value promoted contrast in hue.

How does light break up on things? In *Regata at Sainte-Addresse* (1867), light is broken up on things in bright, clear contrasting hues—cream sails casting Prussian blue shadows on a teal green sea. In *Hotel des Roches Noires, Trouville* (1870), light is broken up in front of the hotel in the quick, separate strokes of color sketch—red, cream, and blue patches become three flags and the sky and clouds behind, beside, and between them. Constraints proliferate (Reitman, 1965). Monet now constrained definition and depth. Objects with unmodeled surfaces and indistinct edges merged and flattened.

Phase 2: Constraining motif. The second, more elusive goal constraint concerned what Monet called the *enveloppe,* the constantly changing atmosphere. The problem became representing *how light breaks up between things.* To do this, Monet constrained his motif or subject in a way that turned repetition into variation. Precluding change of motif promoted change in the motif.

In 1891, Monet set his easel down in a field and painted 23 canvases named for the objects (the grainstacks) in them and the envelope (the effects) around them. He sat in a boat near Giverny and painted a second series, 24 paintings again named for similar objects (poplars) and differing effects (in overcast weather, at dusk, in the evening, at sunset, in the spring, in the autumn, and in the wind).

How does light break up between things? In *Grainstack at Sunset* (1891), it breaks up into the same hues—yellow, pink, blue, and lavender—everywhere. The envelope is continuous. It may be glaringly bright in sky, field, and hill and darker and cooler in the shadow of the stack, but it has no local color. Paint application and finish are constrained. The surface is a dense, uninterrupted web of color. Monet's brush strokes, still separate, are layered, interwoven, and scumbled. In *The Four Trees* (1891), color—and with it, focus and attention—is again scattered everywhere and at once. There is still a point of view, but it is no longer privileged. Soon, even it would be constrained.

Phase 3: Constraining things. The late *Grande Decorations* (1914–1925) were paradoxical. The goal constraint neither precluded nor required things. Lilies and pads and wisteria and willows were only—to use Monet's word—accompaniments. The motif was the invisible mirror, the continuously shifting, reflective surface of the pond. The constraint was deceptively simplified: representing *how light*—by itself, not on things or between things—*breaks up.*

The studies for the decorations amplified earlier constraints on depth, definition, finish, point of view, and focus. In *Water Lilies, Reflections of Weeping Willows* (c. 1916), we no longer look from the shore but from above the pond and very close to its surface. We look at fragments: lily pads horizontally, summarily stroked in dark, saturated blue-greens, with magenta outlines that fall outside or over the blue-greens; and reflections presented by separated vertical strokes, darker greens and blacks for the willows, and lighter lavender for the sky. Things are not clearly separated. The lavender is under and on top of everything. It even falls inside the magenta outlines of the lily pads.

Separateness was finally constrained in the decorations. In *Reflections of Clouds on the Water-Lily Pond* (c. 1920), there are no more things. Precluding things promoted pure fields of color. By itself at last, Monet's light broke up into atmospheric abstractions too new to be understood by his contemporaries.

Questions and Conclusion

There is a question that I would ask about Monet's series of self-imposed constraints. Was it difficult? The question relates to the experimental evidence that more severe constraints generate and maintain higher variability. Monet's letters indicate that it was very difficult. Throughout his career, he complained about not being able to complete anything, about destroying canvases, about giving up, and about the impossibility of realizing his sensations. A major difficulty was his ever-sharpening discrimination between effects, which, in fact, prompted the series paintings (Wildenstein, 1996b).

There is also the question of why Monet and why not Picasso or Matisse? The issue is broader than the choice of creator. It really asks how typical are the mechanisms—selection and maintenance of high variability through the use of constraints—posited for Monet. I suggest (see the Picasso section in Stokes, 1999a, 2001) that they are common in highly creative individuals. These processes are operative in less creative individuals as well, with the difference being that lower levels of variability are selected

[1] Dates for Monet's paintings are taken from Wildenstein (1996a).

and sustained. Competence is far more common than creativity. Pissarro was an expert Impressionist painter, but his influence is inconsequential compared with Monet's. Without the motivation to maintain high variability, the Pissarros of painting, music, architecture, and so forth have no need to constrain their currently successful solutions and, as a consequence, little possibility of changing their domains.

There are also terminology questions. Constraint is used instead of contingency because it specifies two things—what is precluded and what is promoted. Self-imposition of constraints is used instead of problem finding (Getzels & Csikszentmihalyi, 1975; Runco, 1994) for the same reason. The term, however, is not as important as the mechanism by which early constraints/contingencies and later constraint imposition/problem finding establish and maintain the high variability levels that accompany high levels of creativity.

In general, during an apprenticeship phase (the gifted childhood), constraints are derived from a domain, by teachers whose praise and attention—along with that of parents and peers—reinforces the variability on which early virtuoso performance rests. This is the period in which habitual variability levels are acquired. Once expertise is acquired (the creative phases), constraints are devised and self-imposed by the individual. The resulting variability is self-reinforcing when it maintains the acquired variability level and serves to meet a current goal. It is reinforced when its products are praised or collected by critics, dealers, and the public and—perhaps most importantly—recognized or adopted by other artists.

In Monet's case, evidence for these mechanisms is convincing. The gifted child who became Monet learned not only how to draw and paint but also how differently to draw and paint. High variability was selected early in skill acquisition. Monet's continued creativity rested on a series of self-imposed task constraints that served to maintain this learned, high variability level and to meet his changing goals. His paintings were and are highly valued. Variability was rewarded and rewarding.

REFERENCES

Amabile, T. M. (1996). *Creativity in context.* Boulder, CO: Westview Press.

Boden, M. A. (1991). *The creative mind: Myths and mechanisms.* New York: Basic Books.

Campbell, D. T. (1960). Blind variation and selective retention in creative thought as in other knowledge processes. *Psychological Review, 67,* 380–400.

Campbell, J. A., & Willis, J. (1978). Modifying components of "creative behavior" in the natural environment. *Behavior Modification, 2,* 549–565.

Csikszentmihalyi, M. (1996). *Creativity: Flow and the psychology of invention.* New York: Harper Collins.

Eby, J. W., & Smutny, J. F. (1990). *A thoughtful overview of gifted education.* New York: Longman.

Eisenberger, R., & Armeli, S. (1997). Can salient reward increase creative performance without reducing intrinsic interest? *Journal of Personality and Social Psychology, 72,* 704–714.

Eisenberger, R., & Cameron, J. (1996). Detrimental effects of reward: Reality or myth? *American Psychologist, 51,* 1153–1166.

Epstein, R., & Laptosky, G. (1999). Behavioral approaches to creativity. In M. A. Runco & S. R. Pritzker (Eds.), *Encyclopedia of creativity* (Vol. 1, pp. 175–183). New York: Academic Press.

Feldman, D. H. (1991). *Nature's gambit: Child prodigies and the development of human potential.* New York: Teachers College, Columbia University.

Finke, R. (1990). *Creative imagery: Discoveries and inventions in visualization.* Hillsdale, NJ: Erlbaum.

Finke, R. A., Ward, T. B., & Smith, S. M. (1992). *Creative cognition: Theory, research, and applications.* Cambridge, MA: MIT Press.

Forge, A. (1995). *Monet.* Chicago: Art Institute of Chicago.

Funderbunk, F. R. (1977). Reinforcement control of classroom creativity. In R. Brigham, R. Hawkins, J. W. Scott, & R. F. McLaughlin (Eds.), *Behavior analysis in education: Self-control and reading* (pp. 197–204). Dubuque, IA: Kendall/Hunt.

Gardner, H. (1993). *Creating minds.* New York: Basic Books.

Getzels, J. W., & Csikszentmihalyi, M. (1975). From problem-solving to problem-finding. In I. A. Taylor & J. W. Getzels (Eds.), *Perspectives in creativity* (pp. 90–116). Chicago: Aldine.

Glover, J. A., & Gary, A. L. (1976). Procedures to increase some aspects of creativity. *Journal of Applied Behavior Analysis, 9,* 79–84.

Goetz, E. M. (1982). A review of functional analyses of preschool children's creative behavior. *Child Study Journal, 11,* 55–67.

Hebb, D. O. (1949). *The organization of behavior.* New York: Wiley.

Holland, J. H., Holyoak, K. J., Nisbett, R. E., & Thagard, P. R. (1987). *Induction: Processes of inference, learning and discovery.* Cambridge, MA: MIT Press.

Holman, M. H. L., Goetz, E. M., & Baer, D. M. (1977). The training of creativity as an operant and an examination of its generalization characteristics. In B. C. Etzel, J. M. LeBlanc, & D. M. Baer (Eds.), *New developments in behavioral research: Theory, methods and applications* (pp. 441–447). Hillsdale, NJ: Erlbaum.

Machado, A. (1994). Polymorphic response patterns under frequency-dependent selection. *Animal Behavior and Learning, 22,* 241–263.

Maltzman, I., Simon, S., Raskin, D., & Licht, L. (1960). Experimental studies in the training of originality. *Psychological Monographs, 74*(Whole No. 493).

Neuringer, A. (1993). Reinforced variation and selection. *Animal Learning and Behavior, 21,* 83–91.

Neuringer, A., & Huntley, R. W. (1991). Reinforced variability in rats: Effects of gender, age, and contingency. *Physiology and Behavior, 51,* 145–149.

Page, S., & Neuringer, A. (1985). Variability is an operant. *Journal of Experimental Psychology, 11,* 429–452.

Palmer, D. C., & Donahoe, J. W. (1992). Essentialism and selectionism in cognitive science and behavior analysis. *American Psychologist, 47,* 1344–1358.

Perkins, P. N. (1994). Creativity: Beyond the Darwinian paradigm. In R. J. Weber & D. N. Perkins (Eds.), *Inventive minds: Creativity in technology* (pp. 238–250). New York: Oxford University Press.

Pyror, K. W., Haag, R., & O'Reilly, J. (1969). The creative porpoise: Training for novel behavior. *Journal of the Experimental Analysis of Behavior, 12,* 653–661.

Reitman, E. (1965). *Cognition and thought.* New York: Wiley.

Runco, M. A. (1994). *Problem finding, problem solving, and creativity.* Norwood, NJ: Ablex.

Seitz, W. C. (1982). *Claude Monet.* New York: Abrams.

Simonton, D. K. (1984). *Genius, creativity and leadership: Historiometric inquiries.* Cambridge, MA: Harvard University Press.

Simonton, D. K. (1999). *Origins of genius: Darwinian perspectives on creativity.* New York: Oxford University Press.

Skinner, B. F. (1984). Selection by consequences. *Behavioral and Brain Sciences, 7,* 477–510.

Stokes, P. D. (1995). Learned variability. *Animal Learning and Behavior, 23,* 164–176.

Stokes, P. D. (1999a). Learning variability levels: Implications for creativity. *Creativity Research Journal, 12,* 37–45.

Stokes, P. D. (1999b). Novelty. In M. A. Runco & S. R. Pritzker (Eds.), *Encyclopedia of creativity* (Vol. 2, pp. 297–304). New York: Academic Press.

Stokes, P. D. (2001). *Constraints and creativity in art, fashion, architecture, music, literature and children.* Manuscript in preparation.

Stokes, P. D. (in press). Creativity and operant research: Selection and

reorganization of responses. In M. A. Runco (Ed.), *Handbook of creativity research.* Cresskill, NJ: Hampton Press.

Stokes, P. D., & Balsam, P. (in press). An optimal period for setting sustained variability levels. *Psychonomic Bulletin and Review.*

Stokes, P. D., Harrison, H., & Kraut, R. (2000, March). *Constraints, problem representations and variability.* Paper presented at the meeting of the Eastern Psychological Association, Baltimore, MD.

Stokes, P. D., Mechner, F., & Balsam, P. (1999). Effects of different acquisition procedures on response variability. *Animal Learning and Behavior, 27,* 28–41.

Wildenstein, D. (1996a). *Monet: Catalogue raisonné.* Cologne, Germany: Taschen.

Wildenstein, D. (1996b). *Monet or the triumph of Impressionism.* Cologne, Germany: Taschen.

Winner, E. (1996). *Gifted children: Myths and realities.* New York: Basic Books.

Winston, A. S., & Baker, J. E. (1985). Behavior analytic studies of creativity: A critical review. *Behavior Analyst, 8,* 191–205.

Wong, P. T., & Peacock, E. J. (1986). When does reinforcement induce stereotypy? A test of the differential reinforcement hypothesis. *Learning and Motivation, 17,* 139–161.

Zimmerman, E. (1995). It was an incredible experience: The impact of education opportunities on a talented student's artistic development. In C. Golumb (Ed.), *The development of artistically gifted children: Selected case studies* (pp. 135–170). Hillsdale, NJ: Erlbaum.