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Using Constraints to Create Novelty: A Case Study

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The development of Richard Serra's sculpture is presented as a case study using a constraint-based model of novelty (Stokes, 2005, 2007). The model was developed from two problem-solving precedents: Reitman's (1965) idea that paired constraints direct and limit search in a problem space; and Simon's (1973), that search can only lead to novel solutions if the problem space is ill-structured. Ill-structured means that a problem space is incompletely specified or defined. The study shows how paired constraints restructure problem spaces in ways that make novelty possible and probable (Stokes, 2007). Possible means that novelty may or may not happen; probable, that paired constraints facilitate the happening.

Keywords: variability, novelty, constraints, problem-solving

If I asked a psychology (not an art) student to draw an apple, she'd probably produce a circle with a little appendage indicating its stem and perhaps a single leaf. This drawing, shown on the left in Figure 1, would be correct, reflecting what my student knows (her associative network) about apples, but it would not be novel. However, if this was the Bauhaus and I was Paul Klee, she would be directed to do something much more difficult. With Klee (1961), whose interest lay not in form, but in the act of forming, the task would be: take a line for a walk, inside and outside the apple. The line in this case is continuous, the pen never lifted from the page.[1] The result, shown on the right in Figure 1, would not only be correct, it would also be unconventional.

In this example, the difference between the normative and the novel depends, in large part, on the kind of problem each set of directions represents and the constraints each imposes. My version is a well-structured problem; the single constraint (draw an apple) promotes an obvious, unsurprising solution.[2] Klee's version is ill-structured; his multiple constraints not only preclude predictable responses, they promote surprising, albeit specific, ones. Paired constraints of this kind characterize the current model.

The Constraint Model of Novelty

Definitions

Variability, Novelty, Creativity

Variability can be visualized as a continuum with stereotyped, entirely predictable responses at one end, and random, unexpected ones at the other (Stokes, 1999, 2007). As depicted in Figure 2, most behaviors fall between these extremes, ranging from reliable, often-rewarded responses (solving an addition problem, writing a memo) to the novel, not-yet-tested ones (solving Fermat's theorem, writing a play).

Most responses are reliable, often-repeated, and often-rewarded, and are thus found at the low-variability end of the continuum. In learning terms, these are operants (Skinner, 1953); in problem-solving terms, default rules (Holland, Holyoak, Nisbett, & Thagard, 1987). For novel responses to appear, reliable ones must be exhausted (Maltzman, 1960; Mednick, 1962), ineffective (Luchins & Luchins, 1959), or precluded (Eisenberger & Armeli, 1998). Ample experimental work supports this idea. Common associations for words and conventional uses for objects appear before unusual ones (Runco, 1986); idea generation conforms to familiar exemplars (Smith, Ward, & Schumacher, 1993; Ward, 1999). Acquired algorithmic solutions interfere with noticing more efficient ones (Atwood & Polson, 1976). Since students—as well as experts—are most often rewarded for reliability, novelty often depends on instructions to do things differently (Eisenberger & Rhoades, 2001).

Given the above, novelty appears at the high end of the variability continuum. Creativity is seen a subset of novelty, involving new responses/things that are also judged useful (Amabile, 1996; Cropley, 1999; Weisberg, 2006), generative, and at the highest level influential (Boden, 1994; Csikszentmihalyi, 1996; Simonton, 2004). Useful means that the new thing solves a problem; generative that it leads to other ideas or things; influential that it expands a domain or area of knowledge (Csikszentmihalyi, 1990), changing the way other people look at, listen to, think about, or do things like it (Stokes, 2005). However, as domains change so do their criteria for what is considered creative. For example, Monet's large, late *Nympheads* were regarded as the product of poor eyesight when he painted them; only when Abstract Expressionism developed were they called creative.

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[1] All drawings in the paper were done by the author, a psychologist trained as a painter. The constraint model itself takes the maker's (painter, sculptor, etc.) point of view, in which stylistic change is a technical rather than a motivational or theoretical problem.

[2] Contexts also influence orientations and outcomes. In a school setting, students are more often rewarded for being reliable than for being creative (Eisenberger & Rhoades, 2001). Thus, without instructions to do something "different" a simple sketch with recognizably "apple" features should result.

In this view (Stokes, 1999, 2005), novelty is a kind of variability; creativity, a culturally defined kind of novelty.[3] Since novelty is objectively defined, it is easier to measure, model, and potentially, maximize.

Problem Spaces

The current model considers novelty the product of a problem-solving process that takes place in what is called a problem space. A problem space has three parts: an initial state, a goal state with a criterion for knowing that you've reached the goal, and—between the two—a search space. In traditional problem-solving models (Newell & Simon, 1972), the search space is negotiated using operators. An operator is an "if. . .then" rule that indicates the action (then) to be taken in a specific condition (if). Operators are generated by constraint pairs (see next section), which limit and direct search for a solution path.

In a *well-defined or well-structured problem*, all the information needed to construct a solution path is given (Greeno & Simon, 1988; Robertson, 2001). Table 1 presents the problem space for a well-structured problem, cross-stitching a pillow cover.

The initial state is a stamped piece of cloth, the stamped outline corresponds to a numbered cartoon and also numbered skeins of thread or wool. The goal is matching a photo of the completed cover, which serves as the criterion. There are two operators. The first specifies the type of stitch; the second specifies the color thread used for the stitches. Applied recursively, the needlework will easily meet its criterion. Notice, however, that its single "correct" solution precludes novelty, which is only possible with an ill-defined problem.

The information provided by an *ill-defined or ill-structured problem* is insufficient to construct a solution path (Simon, 1973, 1978; Stokes & Fisher, 2005; Voss & Post, 1988). These kinds of problems not only permit, but also require novel solutions. Thus, I call them novelty problems. All novelty problems share three characteristics: one, they are ill-structured; two, their solution paths are generated by specifically paired constraints; and three,

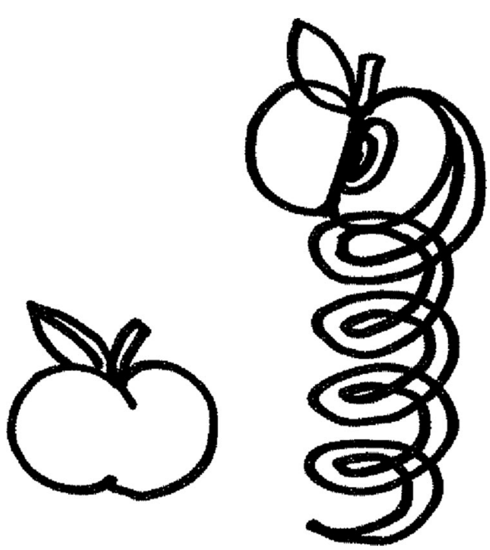

Figure 1. Normative and nonconventional drawings of an apple.

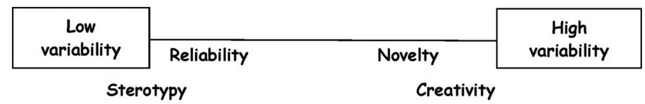

Figure 2. Variability continuum.

these constraints structure the problem space by precluding search among predictable responses and promoting it among surprising ones (Stokes, in press).

As the case study will demonstrate, novelty can be both generated and sustained by *restructuring* a well-defined problem in ways that make it ill-defined. Said another way, the initial state of a novelty problem is often a currently accepted solution.

Constraints

In everyday speech, constraints are one-sided, seen solely as barriers or strictures. In problem solving, they are two-sided, paired. One of the pair retains its function as stricture, limiting or precluding search in some parts of a problem space; the other directs or promotes search in different parts (Reitman, 1965). Novel solutions follow from precluding reliable, existing responses and promoting riskier, often opposite ones (Stokes, 2005). These preclude-promote pairs replace operators in the search space of the current model, which includes four kinds of constraints: goal, source, task, and subject. Goal constraints are overall criteria that establish and define accepted styles; source constraints provide elements for recombination in novel ways; subject constraints specify content or motif, and task constraints govern materials and their application.

Applications

Example: Realism (What You See) to Cubism (What You Know)

As already mentioned, an accepted, well-defined style is often the initial state (what you start from, work against, preclude) of a novelty problem; an emerging style with a yet-to-be-defined criterion is the goal state.[4] The problem is solved incrementally by choosing constraint pairs to construct a novel solution path from initial to goal state. Our example comes from the history of art.

No ambitious young artist, however accomplished, can become famous painting in the-style-of an accepted, established style. In 1906, in the case of Braque and Picasso, that style was realism.[5] To do something new, the pair had to restructure the problem space for representational painting. The first step was identifying specific aspects of realism to preclude. The most important aspect was the

[3] Csikszentmihalyi's systems model (1990) also defines creativity as a cultural phenomenon: The individual masters a culturally defined domain before producing variants that are accepted or rejected by the gatekeepers of that domain.

[4] The idea that creativity requires rejecting (Gardner, 1993) or replacing (Boden, 1994) existing styles is not new. What is new is modeling the rejection(preclude)-replacement(promote) process.

[5] At the time, realism included paintings in-the-styles of Manet (outlined objects) Monet (broken or scumbled brushstrokes) and Matisse (saturated colors). Despite differences in how each saw the world, the artists shared a number of basic characteristics, listed in Table 1.

goal criterion: representational painting is recognizable, the painter paints an object as he and we see it, from a single point of view. Braque and Picasso painted what they knew about an object by looking at it from different points of view: a glass, say, seen from straight ahead, from above, and from below.[6]

Had Picasso and Braque made a list of things to preclude, it would have included a single viewpoint (straight ahead), an intact object (an apple), local color (painted red), and depth (shaded on one side). The opposing list would have promoted multiple viewpoints, fragmented object (the apple morphed into multiple parts), monochromatic (painted in browns), patterned (the parts arranged rhythmically), and flat (non illusionistic shading).

The same basic process recurred in the mid20th century when Abstract Expressionism[7] was eclipsed by three styles, similar only in precluding the emotional, the spontaneous, the complex, and the painterly. One style was Pop, which concentrated on ordinary objects, simplified by hard-edged shapes and primary colors: think of Andy Warhol's fake Brillo boxes or Roy Lichtenstein's blown-up cartoons. The other two, Minimalism and Conceptualism, served as initial states in the first phase of sculptor Richard Serra's career.[8] As such, they are considered in the next section.

Case Study: Richard Serra, Post-Modernism to Abstract Materialism

A major retrospective covering all phases of Serra's development was mounted at the Museum of Modern Art in New York City during 2007. That show was both impetus and source for this case study.

Phase one. Minimalism and Conceptualism were abstract in subject, but like Pop, promoted preplanning (no spontaneity), intellectual distance (no emotion), and restraint (no complexity) in form and finish. Minimalism favored multiple, uniform elements, like sculptor Donald Judd's industrially finished, identical shapes (Morris, 1968; Rose, 1968). They are easy to imagine: a row of shine-y, silver toned, same-size, square boxes.

Conceptualism permitted permutations (systematic arrangements) of different elements (Rormier, 2001). For example, collectors don't buy a Sol LeWitt wall drawing or painting; they buy a template, a complicated kind of paint-by-number. The template is a grid, each block is numbered to correspond to a small set of elements, say four colors. Figure 3 shows a simplified template in which the number one indicates red; two green; three, blue; and four, yellow. The order of the numbers (colors to be filled in) is determined by a mathematical formula.

Minimalism and Conceptualism were both movements within what is called Post-Modernism. Post-Modernists emphasize the

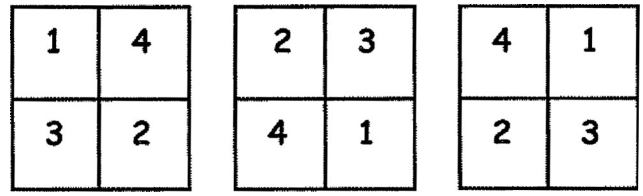

Figure 3. Template for Sol LeWitt type wall painting with four colors.

idea, the "what." For artists of this persuasion, "goals for a particular work can usually be stated precisely, before its production, either as a desired image or as a desired process for the work's execution" (Galenson, 2006). The execution itself is thus preplanned, systematic. The product may be surprising to the audience, but not to the artist.

In contrast, Serra's criterion is Modernist: like the Abstract Expressionists, Serra gives primacy to materials and process, the "how" (Cooke & Serra, 2007). As a work develops, earlier trials and errors are masked or memorialized as *pentimenti*. Since the exact outcome is unknown, both artist and audience may be surprised by the product. This made Abstract Expressionism a source constraint in phase one of the artist's career, providing elements for the artist to work with.[9]

How Serra reconstructed Minimalism and Conceptualism to produce novel forms is summarized in Table 3, which includes initial states, subgoals, and task constraints for all phases of his career.

The goal state is constant, promoting an emerging style, which I call "Abstract Material-ism." The reason for the label is straightforward: Serra manipulates materials in order to create new abstract forms. "I don't want to be at the receiving end of the standardized use of materials," he said, "I would like to be able to use material to invent forms that haven't been invented before" (Cooke & Govan, 1997, p. 23).

The pivotal piece in Phase 1 was not a sculpture, but a piece of paper—the *Verb List* (1967–1968) [10] on which Serra inscribed a list of how materials could be manipulated—the list included "to hang" and "to cast." *Belts* (1966–1967), diagrammed[11] in the upper right box of Figure 4, was made with discarded pieces of vulcanized rubber that the artist "hung." The Splash Pieces (1969)

Table 1
Problem Space for Cross-Stitch

Problem parts	Description
Initial State	Stamped cloth, numbered cartoon and thread.
Operators	If stitching, make an "x" shape by crossing two short straight stitches.
	If number on cartoon is 1, use thread marked 1.
	If number on cartoon is 2, use thread marked 2.
	Etc.
Goal State	Match photo on cover of cross-stitch kit.

[6] Cezanne had already done something similar. The difference is this: the Cubists painted multiple views of the *same* object; Cezanne painted multiple viewpoints of *different* objects, for example, in *Still Life on a Table* (1893-87), we view a jar from above, a plate from below, and a bowl at eye level.

[7] Another name for the style was Action Painting; its practitioners included Jackson Pollock, Wilheim deKooning, and Franz Kline.

[8] What the history of modern art suggests is that the next "new" style is predictable to the extent that it will preclude specific aspects of its predecessors.

[9] Another possible source was Constructivism (Foster, 1998, p. 17), the Russian avant-garde movement in which sculpture was abstract, with emphasis on the literal use of materials (Morris, 1968).

[10] Dates for Serra pieces are taken from McShine & Cooke, 2007, and Schwander, 1996.

[11] This sketch, like others in the paper, is mine.

were made by "casting" (that is, throwing) molten lead against a wall. The work from this period, created by subjecting different materials to predetermined processes, was uncouth, unfinished, and often ugly; it was the antithesis of Minimalism and Conceptualism. How did Serra get from these unattractive, unaesthetic things to the elegant ellipses in his 2007 retrospective at MOMA? By precluding, in two stages, specific things in his own work.

Phase two. From the *Verb List*, Serra now concentrated on items like "to support, to balance, of gravity." The goal state remained the same. The source became engineering—the products of which support and balance compressed, weighty materials. The solution to be precluded was Serra's own. As indicated in Table 2, the subgoal signaled a shift in focus from process to properties. The task constraints precluded properties that were painterly and promoted sculptural ones in their stead.[12] The Prop Pieces of this period are weighty, lead slabs and poles propped against a wall or against each other. Figure 4 includes my sketch of *One Ton Prop (House of Cards*) from 1969. The drawing emphasizes the systematic overlapping of the slabs at their tops. Like all the Prop Pieces, the stability of *House of Cards* depends solely on weight and gravity; it is perceived as precarious precisely because the balancing is real and not illusory.

Phase three. The *Verb List* retained its relevance: "to roll, to twist, to encircle" are things realized in Phase Three. Once again, Serra restructured his own problem space, emphasizing perception in place of properties. What Serra wanted the viewer to focus on was the *shaping of space* and the *alteration of time*. Each has its own source constraints: for time, the Zen gardens in Kyoto; for space, European churches with small, enclosed spaces.

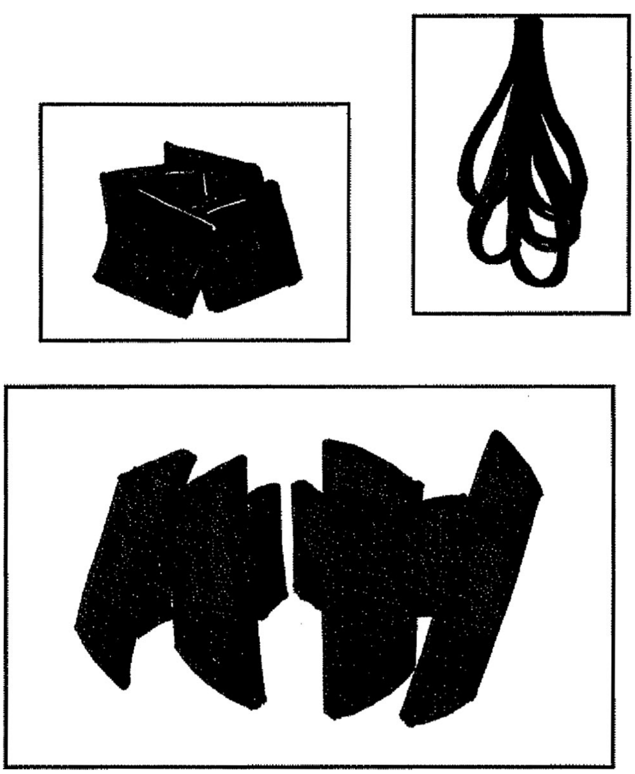

Figure 4. Schematic drawings of Belts (upper right), House of Cards (upper left), and Intersection (bottom).

Table 2
Problem Space for Cubism

Problem parts	Description
Initial State (Preclude)	Representation: Paint what you see (mimesis)
Search Space	Preclude single viewpoint → Promote multiple viewpoints
	Preclude integral object → Promote fragmented object
	Preclude local color → Promote monochromatic palette
	Preclude illusion of depth → Promote flat patterned picture plane
Goal State (Promote)	Cubism: Paint what you know (analysis)

Gardens and Time: Serra has spoken many times about the Zen gardens in Kyoto. "The space in the gardens," he said, "is inescapably temporal" (Taylor, 1997, p. 35). Describing the placement of temples and stone gardens at Myoshin-jin, he noted that the "articulation of discrete elements within the field and the sense of the field as a whole emerged only by constant looking. The necessity of *peripatetic perception* [italics mine] is characteristic of Myoshin-jin. . .The gardens demanded clarity of attention" (Bach, 1980, p. 48).

Clarity of attention meant "concentrating differently every two feet" because "the artifice forces you to pay attention, to slow down" (Cooke & Serra, 2007, p.). The artifice in the gardens is the pattern of small raked stones arrayed around larger ones. For example, standing at Point A and paying attention, you perceive the pattern on the left of Figure 5. Moving slowly around to Point B, you perceive the pattern on the right. As you slow down, time expands. Serra reversed this equation. The Ellipses make you move faster, compressing your experience of time. As you move in relation to their movement, they also, in the sculptor's words "agitate you" (Sylvester, 2001, p. 315).

Churches and Space: Romanesque churches have thick walls that enclose small spaces. The compactness of the interiors makes the space perceptible and even tangible. Space, compressed and compacted, turns into substance. As Serra put it, "You can touch the volume" (Cooke & Serra, 2007, p.). The same is true of Corbusier's curved-walled chapel at Ronchamp, and of Boromini's Church of San Carlo in Rome. San Carlo's importance to Serra came from the shape that encloses its volume. The church is elliptical, an elongated circle with straight walls. The straight walls mean that the orientation of the ellipse is identical at top and bottom. This relationship too Serra changed.

In the torqued ellipses, the shape stay the same, but the orientation shifts and with it, the space. Think of lifting and twisting a Slinky[13]: the concavity or convexity of the walls follows the angle of the torque. The shift in orientation is what makes you move faster, compressing your experience of time. Figure 6 shows how the orientation shifts.

[12] Serra himself pointed out that *Belts* was an "extended painted space" ("Richard Serra sculpture," 2007). *Belts* and the Splash Pieces were "figures" against the wall or floor, which functioned as a "ground" or background.

[13] A Slinky is a toy made of coiled wire. When manipulated, the coils expand and contract in sequence.

Table 3
Constraint Changes During Serra's Career

Initial state	Subgoal	Task constraints
Phase 1:		
Preclude Minimalism & Conceptualism	Preclude predetermined forms → Promote predetermined processes	Preclude "tooling" of materials → Promote integrity of materials Preclude the ascetic, sterile → Promote the voluptuous, messy
Phase 2:		
Preclude work from Phase 1	Preclude emphasis process → Promote emphasis on physical properties	Preclude painterly → Promote sculptural Preclude figure-ground relationship → Promote inter-part relationships
Phase 3:		
Preclude work from Phase 2	Preclude emphasis properties → Promote emphasis on perception	Preclude the sculptural → Promote the architectural Preclude the experience of weight → Promote the experience of the void Preclude the vertical and straight → Promote the tilted and curved Preclude compression of mass → Promote compression of time
Goal State	Abstract Materialism: Manipulating materials to invent forms	

The sketch on the left shows how *Torqued Ellipse IV* (1998) looks from above. The right panel shows the ellipses at top and bottom. They are identical in size and shape. If you superimpose one shape over the other, they will line up perfectly.

The inward and outward tilting creates starkly dramatic shapes (almost drawings in space if you follow the edges) that change as you move inside and around them. The same is true of the arched and serpentine pieces. One was in MOMA's garden during the 2007 retrospective; another, called *Intersection* (1992), belongs to the city of Basel, Switzerland. *Intersection* is constructed from four sheets of rolled sheets of steel that tilt toward and away from the center. It is the bottom-most sketch in Figure 4.

Questions

We conclude with three questions: the first is concerned with the limitations of the case study method; the second, with something (spontaneity) not included in the constraint model; the third, with implications of the current study.

Question one. Case studies (Stokes, 2005, 2007, in press; Stokes & Fisher, 2005) appear to support the constraint model of novelty, have experimental studies done the same?

Answer. Yes, many studies have compared the effects of different materials, instructions, or examples (precluding some and promoting others) on novelty. Among these, precluding choice (in either or both materials/inventive categories) promoted novel responding; allowing choice precluded creative and promoted conventional thinking (Finke, 1990; Finke, Ward, & Smith, 1992). Instructions to be flexible increased (promoted) responses from different categories, but decreased (precluded) unusual or rare ones (Runco & Okuda, 1991). Conversely, instructions to be original increased unusual responding, but decreased the number of different categories into which the responses were sorted (Runco, 1986). Instructions to respond in different ways (e.g., make many words from letter strings, or think of many uses for a common object) promoted novel responses and precluded more common ones. The reverse occurred when instructions did not specify high variability (Eisenberger & Armeli, 1998; Eisenberger & Selbst, 1994). An ongoing study (Stokes & Simon, 2008) is focused on how examples influence originality in a drawing task. Children are given a sheet with a set of empty circles and asked to make pictures using the circles. Preliminary results indicate that a single example, the image completely inside the circle (a smile-y face), promotes

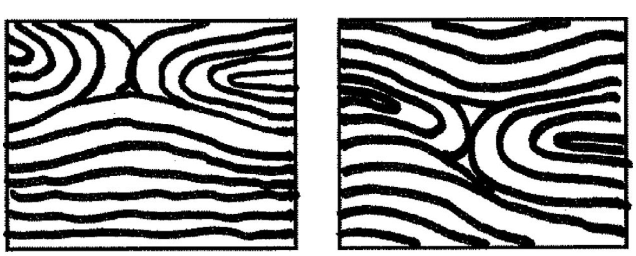

Figure 5. Close-up views of two raked stone patterns.

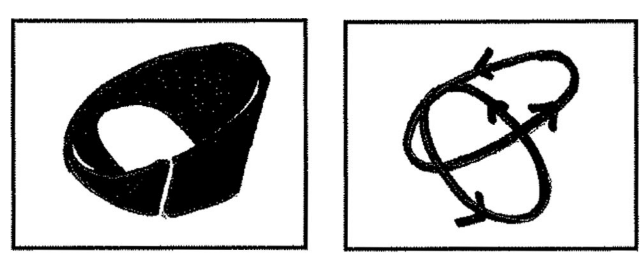

Figure 6. Torqued Ellipse IV drawn from above (left panel) and identical shapes of the ellipses at top and bottom (right panel).

unsurprising, much repeated pictures. In contrast, two examples with the circle as part of a larger outside-the-shape drawing (a fish bowl and a bicycle) preclude commonalities and promote novel (often highly detailed) pictures.

Question two. Does spontaneity play any part in the constraint model?

Answer. Yes, although not its primary thrust, the model can encompass both deliberation (constraint selection/satisfaction) and spontaneity (skilled execution).

Spontaneity in this sense requires and reflects expertise, depending on the implicit, procedural knowledge we call skill. Implicit means both unspoken and automatic. In a situation requiring domain-specific skills, an expert responds automatically, knowing what to do and how to do it. For example, to improvise on a given first chorus (a subject constraint), a jazz performer must be sufficiently skilled (in music generally, at paraphrase specifically) to apply those skills spontaneously/automatically in performance.

Question three. What have we learned about novelty and constraints from our analyses of Richard Serra's development?

Answer. Three things.

First, *novelty often depends on restructuring a well-defined problem space.*[14] The initial state of the novelty problem is an existing style or solution. The solver begins by pairing constraints: precluding reliable, expected things in this style in order to promote riskier, surprising, and often opposite alternatives. The things—both precluded and promoted—are strategically selected in order to realize a novel goal, and in the process specify its criterion.

Second, *if the goal is narrow, the shifts will be few and slight.* If the goal is broad, they will be many and more important. "Inventing novel forms from manipulating materials" is very broad—and as generative as Monet's goal, "show how light breaks up" (for an analysis of Monet's three-phases,[15] see Stokes, 2001, p. 357; 2005, p. 37). Like Monet, Serra restructured his own problem spaces, in the process creating an elegant, exquisite novel form—the torqued ellipse.

Third, *artistic freedom consists solely in the choice of one's own constraints* (Stokes, in press; Stokes & Fisher, 2005). All artists/innovators begin as novices in a domain; skill acquisition depends on mastering existing constraints that define currently accepted solutions. Only with mastery is choice—and true novelty—possible.[16]

[14] In this sense, all stylistic shifts are to some degree predictable.

[15] The phases included showing how light broke up on things, between things, and finally, by itself.

[16] The qualification "true" novelty points to the difference between novelty on the individual level (we all reinvent some sort of wheel at some time in our development) and on the domain level (expanding an area of expertise).

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