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Crossing Disciplines: A Constraint-Based Model of the Creative/Innovative Process

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This paper argues that artistic creativity and organizational innovation share a common problem-solving process. The process per se is presented as a complement to the jazz metaphor for understanding organizational innovation. As modeled, it involves paired constraints that limit and direct search for a solution path. One of each pair identifies something to be precluded; the other specifies its substitute. The process can be initiated by necessity or by design. Once begun, the process is iterative: one substitution pair necessitates another. The creation/innovation is the novel solution path created by the substitution series. In-depth analyses of two artistic creators are accompanied by allusions to parallel examples in organizational innovation.

Introduction

If you want to study organizations, study something else.
Weick (1999, p. 541)

The "something else" presented in this paper is a problem-solving model originally developed to analyze (Reitman, 1965; Simon, 1973) and increment (Stokes, 1999, 2006, 2011) the creative process in the arts. Given that creation and innovation are similar, not only in the novelty, but also in the production, of their products, the model may prove a template for analyzing and structuring the innovative process in organizations. The model also supplements a much used metaphor (Cunha, Cunha, and Kamoche, 1999; Hatch, 1999; Zack, 2000) for organizational innovation. The jazz metaphor describes group interactions; the present model analyzes the actions taken to solve an innovation problem.

Since the model comes from the creativity/problem solving rather than business/economic literatures, definitions precede analyses and applications.

Innovation as a Problem-Solving Process

Problem Spaces

According to Simon and colleagues (Greeno and Simon, 1988; Newell and Simon, 1972), a problem space is a representation (subjective) of a given (objective) problem by its solver. Representations vary with domain (marketing, psychology, R&D) and level (trainee, mid-level, upper level) of expertise. While experience allows solvers to construct more elaborate and efficient problem spaces (Chi, Glaser, and Farr, 1988; Ericcson, 2006; Weisberg, 2006), the three parts of the problem space are the same.

As shown in Figure 1, the parts are an initial state, a goal state, and between the two, a search space in which a solution path is selected/constructed. The boxes in Figure 1 represent stages in the solution process; the lines represent paths between them. The solution path, chosen from all possible paths, will lead from the initial state (the given situation/the given problem) to the goal state (the desired situation/the solution). In the current model, constraint pairs guide path selection.

Well-Structured and Ill-Structured Problems

Problem spaces differ in how well defined or structured they are. If the problem is *well structured*, all parts of the space are specified: the result is a predictable, reliable solution. Rather than using toy problems (e.g., Tower of Hanoi) as examples, I will use painting problems. Paint-by-number is a well-structured problem. The initial state is a cartoon on a white canvas. The areas of the cartoon are marked with numbers that match the numbers on a small set of paints. The solution path is provided: fill the area marked one with the color marked one; reiterate until all numbered areas are filled.

Since there is a single solution (match the picture on the paint-by-number kit), there is no need for search. Substitutions are neither required nor desired. A problem like paint-by-number precludes innovation. An assembly line is another well-structured problem: parts are reliably, expertly put together in a predetermined, specific order. (Of course, either painter or assembler may choose to

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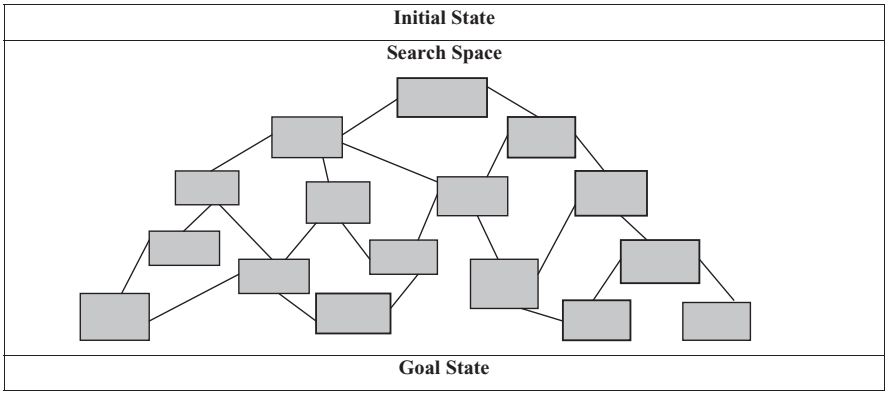

Figure 1. Basic Problem Space
Boxes represent all possible stages; lines, all possible paths.

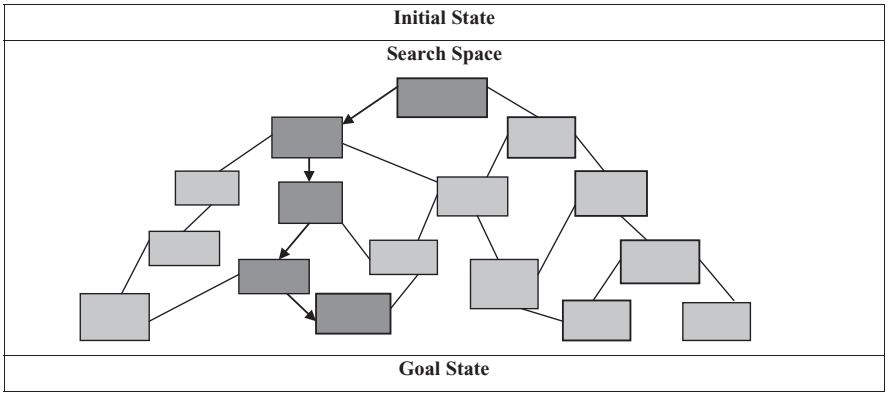

Figure 2. Well-Structured Problem Space
Black boxes joined by arrows show the set solution path.

ignore the specified path, thus making the problem ill structured).

In Figure 2, the darker boxes with arrows represent a set well-structured solution path.

Alternatively, if the problem is *ill structured*, the information provided is insufficient to construct a solution path (Robertson, 2001; Voss and Post, 1988). Such problems not only permit but require novel solutions. Since the novelty of interest here is innovation, we refer to these as innovation problems.

BIOGRAPHICAL SKETCH

Dr. Patricia D. Stokes teaches and does research at Barnard College, Columbia University. Her expertise on creativity is hands-on: prepsychology, she painted at Pratt, wrote advertising copy at J. Walter Thompson, and was a creative group head at Ted Bates & Co. Her approach is that of a practitioner, practical and incremental. Related research projects focus on variability: establishing habitually high or low levels in college students, examining the effects of variability on transference, and introducing a highly successful, high-variability pedagogy using the Japanese count and a grid with moveable parts to teach math in kindergarten and first grade. She would welcome a collaboration examining innovation in a business setting.

Innovation Problems

Often the first step in innovation is precluding specific elements of an existing well-structured problem (with its reliable, predictable solution). The precluding can be initiated internally by the innovator (e.g., the painter, programmer, manager), or externally by outside forces (e.g., resource constraints) with which the innovator must contend. In either case, a formerly well-defined problem space has been rendered ill structured. Solutions now require substitutions.

Figure 3 illustrates an innovation problem space. The darker boxes here represent a prior well-structured solution path. Let us assume that resource constraints, on materials or skills, have precluded (completely or in part) specific steps along this path. The horizontal arrows indi-

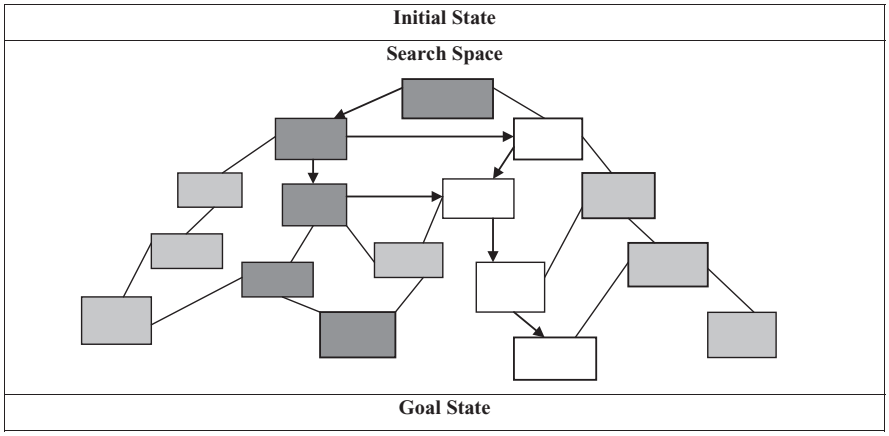

Figure 3. Innovation Problem Space
Black boxes represent the prior path; white, the new path.

cate possible substitutions (black to white boxes) for restructuring the solution path. The new path (white boxes connected by arrows), being the alteration that accomplishes or redefines the goal, is itself the innovation.

Accomplishing the goal refers to situations in which a similar end product, satisfying an initial criterion, is produced via a new path; *defining* refers to a situation in which the restructured path generates an altered end product, which satisfies a new criterion. In both cases, the path is new. In the second, the product is also new.

This simultaneity of path completion/goal specification is akin and central to Duggan's strategic intuition model. In his model, "the achievement and the goal arise at the same time" (Duggan, 2007, p. 23). Ahuja and Katila (2004) also describe similar solution paths in different, albeit corresponding, ways. In their terms, innovations emerge in two ways. One is by resolving existing problems in new ways. This they call path-deepening search, it corresponds to accomplishing an initial goal. The other is by solving new problems. This they term path-creating search, it corresponds to specifying a novel goal.

The next section introduces the constraint pairings that construct solution paths.

A Constraint-Based Model of Creation/Innovation

In economic terms, constraints are one sided. They connote scarcities, limited availabilities of materials, skills, monies, or time. In interaction with other variables (i.e., focus, challenge: Amabile, Hadley, and Kramer, 2002; team climate: Weiss, Hoegl, and Gibbert, 2011), the degree of limitation determines whether such constraints will inhibit or facilitate innovation (Baker and Nelson, 2005; Gibbert, Hoegl, and Valikangas, 2007; Katila and Shane, 2005). In problem-solving terms (Reitman, 1965), constraints are two-sided, paired tools that limit or preclude search for a solution path in specific parts of a problem space, and simultaneously promote or direct it to other parts (Stokes, 2008, 2009). In the current model, one of a pair starts the innovation process by precluding an element of a reliable, predictable solution; the other identifies an alternative. Whether by necessity (e.g., scarcity) or by choice (e.g., aspiration), the precluding starts the process.

There are four constraint pairings: on criterion, source, task, and subject. Each of the four pairings requires specifying an alternative. This sort of incremental, step-by-step substitution is the core of the model. Importantly, it precludes the modeling of stasis.

Criterion Constraints

A criterion is an agreed-upon standard that specifies or identifies a style, product, etc. The initial state of a problem is one that the solver/actor wishes to preclude by *resolving* or *replacement*. Resolving is usually initiated by necessity: a prior (but still-desirable) criterion can no longer be satisfied: it has been precluded, perhaps, by resource deficits. Replacement is initiated by aspiration: a prior criterion is precluded because a new one is desired; solution involves specifying/defining the new criterion. The goal state of a problem, which the solver/actor wishes to promote either satisfies the prior criterion or specifies/defines the new one. It is either the resolution or the replacement. Both replacement and resolution are

achieved via construction of novel solution paths; only replacement requires a novel criterion.

The questions asked in the current analysis are either, "how was this (original) criterion (newly) satisfied?" or "how was this (new) one defined?" The answers are found in the step-by-step specification of their respective solution paths.

Garud and Karnøe (2002) use language similar to the current constraint vocabulary, describing how solution paths, as they emerge, begin "enabling" (i.e., promoting) and "constraining" (i.e., precluding) the activities of involved actors" (p. 4). As mentioned earlier, Ahuja and Katila's (2004) arguments also have parallels with the constraint model. They propose that innovations emerge by *resolving existing problems* in new ways or by *solving new problems*. Resolving an existing problem (via path deepening or altering search) corresponds to satisfying an existing criterion; solving a new problem (via path-creating search) involves specifying a novel criterion.

Source Constraints

Source constraints define domains, specialized areas of knowledge with agreed upon performance and stylistic criteria (Abuhamdeh and Csikszentimihalyi, 2004). They provide elements for a solver to work with (*promote*) or against (*preclude*). Larry Rivers, a painter and jazz musician, called them "first choruses" on which the artist or performer improvises (1987). How solvers work with or against their selected sources comes under the next category of constraint.

Task Constraints

Task constraints involve materials and methods, ways of manipulating/combining materials. What is precluded may be internally/by choice or externally/by necessity determined. If by choice, there could be both a novel criterion and a novel solution path. If by necessity, only the solution path need be novel. "By necessity" corresponds nicely to making do/working with materials "at hand," a central concept in the literatures on bricolage (Levi-Strauss, 1967; Garud and Karnøe, 2002) and improvisation (Baker, Miner, and Eesley, 2003; Miner, Bassoff, and Moorman, 2001).

Choice and use of materials is tied directly to the skills of a solver. When one way of working is precluded, another (a substitution) is promoted. As our examples will show, task constraints cascade, one influencing/generating another. Importantly, as the expertise/skill and the experience of the solver/actor expand, so do the ways of working, the range of materials with which to work, and the ability to identify the methods/materials that will work best. This combination of skill and material are obvious in successful improvisation, as our second example will show. Similar points are found in the innovation literature. For example, Miner et al. (2001) state quite clearly that "stored knowledge and skills shape improvisation" (p. 304). Skills are identifiable not only with individuals but also with organizations, as shown by Baker and Nelson (2005), who observed "patterned variations" with "organizational antecedents" (p. 335) in recombining materials at hand.

Subject Constraints

Subject constraints are concerned with categories: representation or abstraction in art; dwelling, museum, or manufacturing plant in architecture; sport coupe, sedan, or SUV in automobiles.

Applying the Constraint Model: Innovation and Design

In this section, what is commonly called creativity is referred to as innovation. Given the influence of the artist on his domain, innovation in its original sense of making new (Latin root *innovare*, to renew) is an appropriate substitution.

Henri Matisse: Innovation in Painting

Matisse, who repeatedly rethought his own solutions, provides a perfect model for examining the constraint model's mechanism: *solution-by-substitution*. The substitutions solved—via numerous pairings—a new problem, the criterion for which was expressed by Matisse as the "condensation of sensations which constitutes a picture" (Flam, 1995, p. 38). The product of the condensation was decorative, patterned, an art of pure color and pure line. I analyze its development in three substitution steps, indicated by my sketches shown in Figure 4.

Solution by Substitution One: Color as Line

Matisse's early paintings are decidedly dull, dark, and practically colorless. A nude model, a plaster cast, and two students drawing in *L'atelier de Gustave Moreau* (1895) barely emerge from the overall brown-ness. This

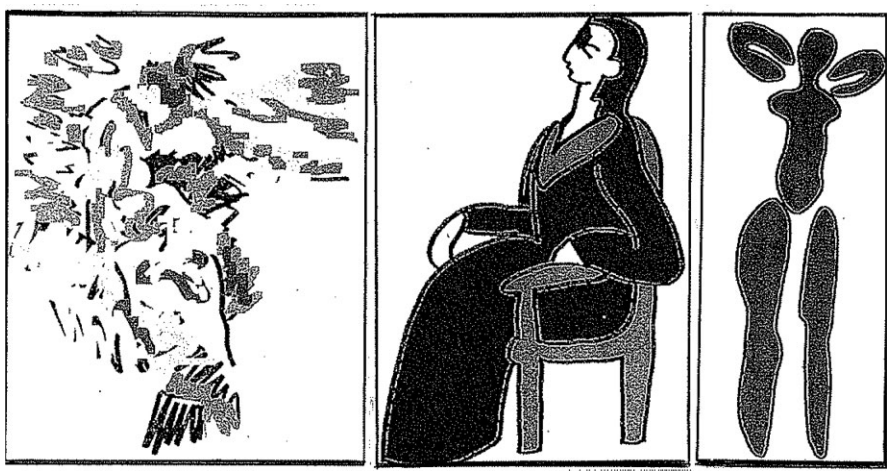

Figure 4. Black and White Sketches of Matisse Paintings

is the initial state for Matisse: representative painting in the style of the Ecole des Beaux-Arts in Paris. In the current model, the style represents a well-structured problem which, by definition, disallows innovation. Matisse made his painting problem ill structured by precluding specific aspects of the Beaux-Arts style.

Mme. Matisse in a Japanese Robe (1901) was a minor modification: her robe is muted blue-gray, she has a rose-hued ornament (or rose) in her hair, but the room in which she stands is still predominantly brown. By 1905, he radically repainted Madame and the robe. The title of the painting, *La Japonisme: Woman beside the Water*, tells us that there is a figure, but it is difficult to separate woman from water. Both have been reduced to brilliant slashes of color with blatantly bare spaces between. My simplified sketch of *La Japonisme* is shown in the left panel of Figure 4. Table 1 suggests the constraint pairs that accomplished the shift in style.

Elements in the preclude column are aspects of the Beaux-Arts style. The first is an initial criterion pairing precluding representation and promoting condensation. The critical question here is: *how does Matisse begin to specify this criterion*? The answer is by precluding specific aspects of the initial Beaux-Arts style. He begins by precluding shape. In its place sensation is compacted, summarized, in separate, brightly colored lines. Notice how this initial substitution necessitates a second, fragmentation in lieu of continuity, and a third, the colored sketch is no longer preliminary, it is the finished painting. Last on the list, but primary, pure colors replace local or perceived colors. "A pot of colors flung in the public's face," complained a critic (Elderfield, 1976, p. 43).

Table 1. Constraint Pairs for Phase One

Category	Pairings	
Criterion	Preclude representation	→ Promote condensation
Task	Preclude colored shapes	→ Promote colored lines
	Preclude continuity	→ Promote fragmentation
	Preclude sketch as preliminary	→ Promote sketch as finished painting
	Preclude perceived colors	→ Promote pure colors

Solution by Substitution Two: Color as Outlined Shape

The middle panel of Figure 4 also shows a woman in a robe. It is a section of a larger painting, *La conversation* (1908–1912). The patterning is no longer linear. Condensation now takes the form of outlined, flatly colored shapes that fill the canvas. The colors are still intense, but fewer and shared. The woman's hair and robe are black. The wall behind here is the same cobalt blue as the chair in which she sits. The shapes themselves are signs, icons of the objects they represent. The woman in *La Japonisme* is Madame Matisse. The woman in *La conversation* could be Madame Matisse, she could be any woman.

Our question now becomes: *how does Matisse continue realizing his novel criterion?* Table 2 indicates the answer.

Matisse now precludes elements of his own earlier approximations to an art of pure line and pure color. He introduces a subject constraint: substitute the iconographic for the idiosyncratic, the sign for the individual. The task pairings reiterate the previous paragraph: shapes substitute for lines, few colors replace many, continuity supplants fragmentation.

Table 2. Constraint Pairs for Phase Two

Category	Pairings	
Subject	Preclude the individual	→ Promote the iconographic
Task	Preclude colored lines	→ Promote flat, outlined shapes
	Preclude multiple colors	→ Promote shared colors
	Preclude fragmentation	→ Promote unity, continuity

Solution by Substitution Three: Color as Line and Shape

The right panel of Figure 4 (*Nu bleu debout*) demonstrates the culminating constraints. It is important here to notice what Matisse retains as well as what he changes. The woman is an icon, a sign painted in a single flat, primary color. Despite the fragmentation, her limbs, torso, and head are arranged, patterned, so as to appear continuous, unified.

Table 3 summarizes the last additions, the few and final constraint pairs. They are all task constraints. They preclude traditional materials and means.

Matisse is "drawing" again, this time with scissors instead of brush or pen. The act of cutting creates line and shape simultaneously. The act realizes the goal by completely specifying the new criterion: this is how sensation is condensed, this is what pure color and pure line look like.

Interestingly, the final constraints may be seen as the product of *bricolage*. Matisse is *making do with what he could do*. The resource constraints at play here did not involve materials at hand, but rather the way the artist was able to work with his hands. During this period, Matisse was confined to bed. Unable to paint with brushes at an easel, the artist cut shapes out of colored papers, pointing out their placements to assistants who pasted the cutouts onto larger pieces of colored paper. The final task constraints, imposed by necessity, completed the condensation.

Would it have been completed differently without the physical constraint? Perhaps. However, what Matisse said about the cutouts suggests that the forms were the inevitable product of a continuous process: "There is no break between my early pictures and my cutouts, except that with greater completeness and abstraction I have attained a *form filtered to its essentials* . . . I have kept only the *sign* that is sufficient to make the object exist in its own form and in the *ensemble* in which I conceived it" (Flam, 1995, p. 209; italics added). The essentials are color and line; the sign is the condensation of sensation, the ensemble is the decorative pattern. That there was "no break" indicates what Matisse did not say: the cutouts required, emerged from, the earlier colored lines and outlined shapes. The criterion was specified step by step.

Table 3. Constraint Pairs for Phase Three

Category	Pairings	
Task	Preclude painted canvas	→ Promote cut-and-pasted collage
	Preclude brush, pen, etc.	→ Promote scissors and paste

Wind Turbines: Innovation in Energy

Garud and Karnøe's (2002) study of wind turbine development in Denmark and the United States reveals similarities between their "steady accumulation of inputs to a technological path" (p. 1), or rather to two quite distinct technological solution paths, and Matisse's also "steady accumulation of inputs" to an artistic solution path.

Consider the three relevant constraint categories and a single example for each.

Criterion. The initial goal for both teams was expressed at the broadest level, e.g., a wind turbine of low- or high-tech design. As solution paths were generated, turbines of each type evolved in a series of substitutions that step by step generated the low- or high-tech criterion. Here, we ask the same question we asked of Matisse: *how did each team begin specifying the criterion* that produced/identified the final product? The answers are found in their choice of source materials to work with or against.

Sources. Source constraints involve selection of materials and manipulations in criterion-directed ways. To simplify, these obviously included existing wind turbines. The Danes, engaging in bricolage, began work with an early, already redesigned, relatively simple, wind turbine. The Americans, aiming at breakthrough, precluded the Danish design as "too simplistic" (p. 17), began instead with a more recent "three-bladed lightweight moderately sophisticated wind turbine" (p. 17).

Task. Materials and their manipulators interacted. Actors became "embedded in accumulating artifacts, tools, practices, rules and knowledge" (p. 44) that allowed them to interact in novel ways with available materials and each other as they constructed their emerging substitution paths. Path is also a key term in Garud

Table 4. Terminology for Thelonious

Term	Definition
Be-bop	Be-bop is a style of solo improvisation characterized by dissonance and complex, constantly changing rhythmic patterns. See collage improvisation below.
Chorus	A jazz chorus is a frame that structures an improvised performance. The most common structures are the blues' *12-bar format*, and the *32-bar song*. A bar is a line that divides a score into metrical sections. To "take a chorus" is to improvise in a particular section.
Denseness	Denseness is the product of *musical textures* woven from two elements, the melody, and the chords. The simplest texture is *monophonic*, built on a single melodic line. *Polyphonic* textures are denser, interweaving separate, independent melodies and chords.
Melody	A melody is a tune made up of tones or pitches taken from a particular scale.
	A *diatonic scale* consists of seven tones with whole and half-steps between them. Figure 5 shows a single octave on a piano keyboard. The steps between notes separated by a black key (F to G) are whole steps; those between white notes (E to F) or between white and black notes (F to G^{b}) are half steps. The black notes are sharps (one half-step up from a note) or, as shown in Figure 1, flats (one half-step down, indicated by ^{b}). The diatonic C major scale consists solely of white keys (C-D-E-F-G-A-B-C).
	A *blues scale* differs from a diatonic in having its third and seventh notes inflected one half-step downward. The blues scale starting at C would progress C-D-E^{b} (black note between D and E) F-G-A-B^{b} (black note between A and B).
Improvisation	The term is derived from the Latin "in" or not, and "provisos" or expected depending on the extent to which an original melody is transformed, an improvisation will be more or less expected or surprising.
	Ornamentation transforms a melody by embellishing a note or group of notes. The embellishment may be spontaneous or preplanned.
	Paraphrase improvisation is a form of ornamentation in which the original melody is recognizable because the soloist plays and embellishes it. This is the sort of improvisation associated with New Orleans-style jazz.
	Collage improvisation is more complicated because it references melodies other than the original or mixes fragments of the original melody with *licks,* short motives used, and identified with a particular soloist. This is the sort of improvisation associated with be-bop soloist Charlie Parker.
Stride	Stride is a pianistic technique in which the left hand "walks" a fixed bass line along the keyboard while the right hand improvises freely.

and Karnøe's analyses. In their words, it suggests "that the accumulation of inputs at every point in the development of a technology is as much a position that actors have *reached* as it is one that they may *depart from*" (p. 10; italics added). They indicate, in other words, the solution-by-substitution process that is the core of the current paired constraint model. Indeed, as each team proceeded, they, like Matisse, precluded their own interim approximations to a desired, but not yet completely specified, criterion. "Eventually," the authors tell us, "one path may come to prevail over others" (p. 4).

The path that prevails specifies the criterion: this is *how* sensation is condensed; this is *how* a wind turbine works.

Constraint Model: Innovation and Improvisation

This section presents an analysis of improvisation that complements and expands the jazz metaphor found in the organizational literature (Baker et al., 2003; Cunha et al., 1999; Zack, 2000). Improvisation, in that literature, occurs when the design and execution of novelty co-occur (Miner et al., 2001). In the current model, improvisation is a problem-solving process that can both precede and accompany execution.

Table 4 defines terms used in the following analysis. The octave on a piano keyboard drawn in Figure 5 is the accompaniment for the section on melody.

Thelonious Monk: Improvisation in Jazz

There is an irony in improvisation: spontaneity springs from, indeed depends on, preparation. The preparation is one part of the incremental process. The kind of preparation determines, by precluding and promoting particular solution paths, the kind and the degree of

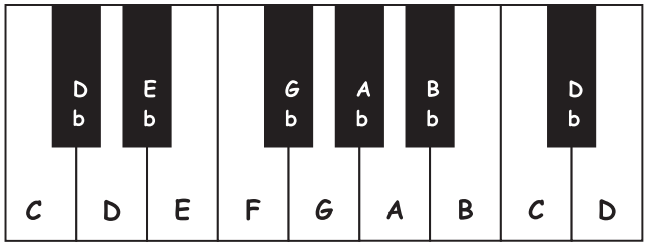

Figure 5. Piano Keyboard with Flats
Letters identify the notes.

Table 5. Constraint Pairs for Monk

Category	Pairings	
Criterion	Preclude structure of be-bop	→ Promote restructuring the blues
Task	Preclude collage improvisation	→ Promote paraphrase improvisation
	Preclude paraphrase on original theme of the original theme	→ Promote paraphrase on transformations
	Preclude monophony	→ Promote polyphony
	Preclude symmetry, continuity	→ Promote asymmetry, discontinuity
	Preclude denseness	→ Promote spareness

improvisation. There is also a particular irony in the career of Thelonious Monk. The pianist who revamped how jazz piano is played was not a classical virtuoso at the piano. Alyn Shipton (2001) writes that his playing was "in many aspects the antithesis of pianistic," describing how "Monk played from the shoulder, in an intensely physical manner, lifting his hands high at the end of each phrase, and keeping his fingers straight. . ." (p. 484). Monk's revamping thus involved the kind of *bricolage* noted in the section on Matisse. Like the bed-ridden Matisse, the nonvirtuoso Monk *made do with what he could do*.

My analysis of Monk is condensed into the single substitution set shown in Table 5.

Solution by Substitution: Restructuring the Blues

Like Miles, Monk meant to preclude be-bop's excesses, promoting simpler, sparser sounds. Unlike Miles, he did not preclude the traditional 12- or 32-bar chorus, which suggests a goal like restructuring classic blues form to create a distinctly modern sound.

How did Monk specify this sort of criterion? By precluding specific features of be-bop, often borrowing their substitutes from earlier jazz styles. Noticeable borrowings included stride piano, with its walking left-hand chords; boogie with its percussive style and rhythmic development of single themes; Count Basie's simplified piano style which (practically) precluded the left hand and promoted "punctuation" with the right (Hodier, 1986); as well as the already mentioned structure (12-bar blues, 32-bar songs) and the style (polyphonic, paraphrase) of New Orleans jazz.

Monk's task constraints—merely suggested in Table 5—were multiple, cascading one from the other. Collage improvisations add melodies other than the original or mix fragments of the original with licks, short motives used repeatedly by a particular soloist. This is the kind of virtuoso solo played by Charlie Parker and precluded by Monk. In its place, Monk substituted (and restructured) classic New Orleans–style paraphrase improvisation, in which the soloist plays and embellishes only the original melody. The restructuring took the form of precluding paraphrasing only the original theme. In its place, Monk substituted successive transformations of the original, e.g., paraphrases of paraphrases or, to paraphrase Andre Hodier "sequential variations" (1986, p. 175).

Monk also precluded monophony, substituting in its place the polyphonic, many-voiced style of New Orleans jazz. The "voices" are multiple melodic lines played at the same time. As indicated by the next-to-last constraint pair, Monk's restructuring here replaced continuity with discontinuity—lines appear, disappear, reappear. Finally, his playing precluded virtuosic embellishment, replacing the "harmonic densities of bop" with "spare, calculated melodies and carefully chosen notes, *graced with silences*. . ." (Szwed, 2000, pp. 172–3). The italics are mine: grace notes are embellishments added to a melodic line. What Monk did was the opposite—he subtracted.

Listening to Monk

To hear how these constraints "sound," the reader should listen to two Monk classics, *Misterioso* and *Straight, No Chaser*.

Misterioso opens with walking sixths, like stride but played with the right hand. The scale is B^b major: B^b-C-D-E^b-F-G-A-B^b. The scale becomes "blue" in the second measure when Monk makes the third (D) and seventh (A) notes flat. Rhythmic asymmetries, unexpected pauses, make early appearances. Monk's piano punctuates Jackson's vibraphone solo, scattering dissonances based on the "blue" seventh (the A^b). His own stark, sparse solo includes runs and repetitions, discontinuities and displacements, dissonances, and polyphony. It often sounds as if Monk's hands are accompanying each other. The dissonances are always surprising (the asymmetry prevents prediction). The vibraphone reenters. The walking sixths reappear, sometimes separated. The end echoes the start, the sixths walk up to an arpeggio.

There is nothing *in extremis*. The surprises are subtle. The musical idea (walking sixths and their extension in the blues seventh, e.g., the flatted sixth note) is simple. The dissonance (made familiar by repetition) is minimal. The development (Monk's solo mirrors the upward movement of the walking sixths; Jackson's reiterates it) is logically structured by the traditional chorus form.

Straight, No Chaser is a concatenated, asymmetric transformation of a simple, short melodic motive. Its scale is B^b major, same as in *Misterioso*, with the same two "blues" notes (D and A). The motive (F-B^b-C-D^b-D) is sometimes played "straight," sometimes elongated. "Sometimes" is actually a good way to think about the harmonic and rhythmic asymmetries in *Straight, No Chaser*. Sometimes the blue notes are flat, which adds dissonance. The motive sometimes crosses the bar line; this displaces the accented beat which generally falls on the first note across the line. Sometimes the motive seems to disappear and we anticipate its return. At one point, its sound (on piano) shrinks and becomes "tinny" before it disappears under the (also low) drums and bass. The disappearance becomes a kind of "waiting for Thelonious," the tension built from the motive's absence rather than from its temporary move to another key (before returning "home"). Here, the return of the theme and its final reiterations and transformations provide the resolution.

Sometimes is what keeps *Straight, No Chaser* surprising.

Monk's Signature Sound

In essence, Monk is a classical musician, a composer of chamber music. His foundation is traditional (blues tonality, polyphony, paraphrase), but his sound is modern, sparse (virtuosic collage improvisation is precluded) and asymmetric rhythmically (in its starts and stops, its surprising shifts and silences) and melodically (notes are flattened sometimes; transformations of a motive are paraphrased). Basically, Monk made the blues sound modern by restructuring its sources.

Improvisation in Product Development

In the current innovation literature, Miner et al. (2001) characterize improvisation as the convergence of design and execution in time. This definition implies two things: the process is deliberate but also unplanned, extemporaneous. In the current analysis of Monk's improvisations, the process expands to include planning in advance of execution.

Again, this section points to parallels with the problem-solving literature and the constraint model per se, using the same three constraint pair categories discussed in the Wind Turbines: Innovation in Energy section. I also contrast improvisation of the kind reported by Miner et al. (2001) with Monk's and with that described by Tom Kelley (2001) in his book about IDEO, a product design firm per se.

Criterion. Miner et al. (2001, p. 316) refer to "factors that shaped the specific designs or compositions that unfolded in each case" as improvisational "referents." A referent for Monk was a melody on which he improvised successive paraphrases. Referents as described by Miner et al. as "unexpected problems, temporal gaps, and unanticipated opportunities" (p. 316) are somewhat different. The difference situates them in the criterion rather than the source constraint category.

They fit quite nicely too. As discussed earlier, the initial state of an innovation problem is one which the solver wishes to preclude by resolving or replacing. In the case of unexpected problems and temporal gaps, a desired, prior criterion can no longer be satisfied. The goal here is to *resolve* the problem by constructing a new solution path that satisfies/accomplishes the prior criterion. In the case of unanticipated opportunities, a prior criterion is precluded because a new one is desired. The goal here is to *replace* the old criterion by constructing a new solution path that will both specify and satisfy a new criterion.

Sources. Sources include domain-specific models, materials (like the melodies paraphrased by Monk), and, as suggested by Hatch (1999), existing routines which can be recombined in novel ways. Existing routines are, in terms of the current model, solution paths. Some sources will be precluded/worked against; others will be promoted/worked with. Expertise (musical, engineering, etc.) is based on extensive knowledge of and experience with multiple models, materials, and routines.

Task. Task constraints in improvisation involve available materials and the skills available for selecting and working with them. Available materials are those at hand. Cunha et al. (1999) argue that this means bricolage and improvisation belong to the same concept. I quote: "if improvisation means to respond in real time . . . it follows that improvisers cannot wait for optimal resources to be deployed and have to tackle the issues at hand with those that are currently available" (p. 307). I would argue that a qualification—in some situations, in some businesses—is in order. In the innovation literature, improvisation is an exception to preplanned, standardized processes. Miner et al. (2001) address this issue directly, asking if their examples are "really improvisation." Their answer (yes) is based on the contrast of informal to "highly formalized procedures" (p. 311) of

business as usual. In advertising agencies and design firms like IDEO, the opposite occurs: business as usual is highly informal, improvisation is the standard process. Moreover, it most often occurs without bricolage because required or desired materials are readily available. At IDEO, designers grab stuff from what Tom Kelley (2001) calls Tech Boxes to built prototypes. Monk too worked this way, grabbing melodies to paraphrase on his piano which is, literally, at hand.

Skills too must be available and at hand. An example from the innovation literature of the interaction between available materials and skills involves "scientist specials." A special is a physical mock-up or prototype not in a product's plans, but rather developed and produced "as they went along" by highly skilled engineers at a company Miner et al. (2001) call FastTrack. One such special, the product of the group's "*ongoing* actual *interaction* with the specific materials and behavior of the product" (p. 311, italics added) was a cover to improve product safety and performance. *Interaction* points to a critical feature of expert improvisation: responding to changes (iteratively to successive changes) in condition with appropriate (effective, apt) changes in action. *Ongoing* indicates that the improvisatory process was consistent with the constraint model: that is, it was incremental and involved a number of substitution steps, each iteration identifying some aspect of its predecessor to preclude and replace.

Iterative is also the word Tom Kelley (2001) uses to describe IDEO's approach to problems in their "culture of prototyping" (p. 105). Prototyping—in Kelley's words, "the shorthand of innovation"—involves building things and then making them better (step-by-substitution step). It is standard practice at IDEO. The practice is preplanned; the iterations are not.

Preparation for Improvisation

Prior work (Baker et al., 2003), or more specifically, prior ways of working, are a key part of preparation for improvisation. As suggested above, practice of one kind or another makes improvisation more or less probable and possible. Extensive practice (and the procedural knowledge it produces) allows improvisers to respond more or less quickly and appropriately to necessary or selected shifts in condition. Responding, in accord with the current model, can take the form of selecting an alternative, existing solution path, recombining parts of existing paths, or constructing (iteration-by-iteration) new ones.

In all cases, the process is incremental. Preplanning may be the initial step; prototype, product, or performance is merely the most recent one.

Summary

This paper presented a constraint-based, problem-solving model of the innovation process per se. The constraints in the model are paired: one of the pair precludes something; the other supplies/suggests a substitution. Solution proceeds iteratively: substitution-by-substitution step. However, iteration does not preclude preplanning. Rather, planning is seen as a first step: plans always aim at altering something. The innovation is the product of successive alternations/iterations: a novel solution path that satisfies an earlier criterion (resolution), or specifies a new one (replacement).

Strengths and Limitations

One strength of the model is its simplicity. It is purposively reductive: regardless of whether an innovation is the product of necessity or design, of whether the product is a prototype or a performance, the structure of the substitution process is the same. Another is that it offers an alternative to the jazz metaphor for organizational improvisation; a lens for examining, not the dynamics, but rather the *evolving structure* of the innovation process. The jazz metaphor applies to a group's interactions; the problem-solving model analyzes *the actions per se*. It also expands the content and time frame of the analysis. Improvisation, in the jazz model, occurs when design and execution co-occur (Miner et al., 2001), preplanning is precluded. In the problem-solving model, the innovation process can be initiated by preplanning. Constraints can thus be either aspirational or iterative. As discussed, Matisse's goal (the condensation of sensation) preceded the substitution process which, in turn, specified how sensations would be condensed (into pure colors and pure lines). With Monk too, the goal (restructure the blues) preceded the iterations.

The current limitations are not of the model per se, but of the examples provided. In lieu of sufficient data for a detailed constraint-pair analysis of a specific industrial innovation, my examples have been from the arts. This is not new to the organizational literature: the jazz metaphor too relies on art for its examples. Indeed, institutions have much to learn from innovators who (like Matisse) have left us not only artifacts but also ample information (letters and interviews) about their problem-solving processes. Restructuring an artist's solution path (as the

current analyses attempt) can provide a prototype for structuring for an organization's.

Suggestions and Conclusion

While the model has proved practical and insightful to artists (in performance, paint, and print), designers (in fashion and architecture), and educators (in classrooms) interviewed or consulted by the author (Stokes, 2006), its usefulness to engineers, managers, etc. is unproven but still suggestive. So, suggestions.

Suggestions

Useful, by definition, implies instrumental. The constraint model is an instrument that can be used to explicitly structure and guide the innovation process.

In advance, it becomes a *tool for planning*. The kinds of questions the model can address here include:

- What exactly is the problem up for solution? (A problem may arise from scarcity or from opportunity. Both are occasions for innovation).
- Is it to reach a current goal via a novel solution path? (This is the scarcity scenario).
- Is it to specify/define a new goal via a novel solution path? (This is the aspirational scenario.)
- How do we start constructing this solution path?
- What substitutions are necessary or desired?
- What subsequent substitutions will be required?

Used to record the innovation process as it unfolds, it becomes *a template, a tool for structuring future innovation*. If you know exactly how you reached a goal, you will be able not only to replicate but—more importantly—to vary your solution path in specific parts. Thus, the kinds of questions the model can address here include:

- Could other substitutions have been made?
- What would have been the consequences?

Conclusion

The constraint model presented in this paper is construed as a tool for analyzing and structuring organizational innovation. In business, as in the arts and education, conditions change, solutions are temporary. The problem-solving process is ongoing. A template for constructing and evaluating possible solutions paths could prove quite profitable, particularly in the face of resource constraints.

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