Analogy and Conceptual Blending are Part of a Visualization Toolkit for Artists and Scientists: Introducing the Cognitive Space Transfer

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ABSTRACT

This paper demonstrates knowledge representation mapping techniques common in both the domains of art and science. Analogical mapping systems take information from a source domain and map that data to a target domain located in another perceptual mode. I also explain conceptual blending, in which information from different sources combine into a new emergent structure. The theories that describe these visualization processes are conceptual metaphor theory (CMT) and conceptual blending theory (BT), which were orginally created by George Lakoff, Mark Johnson [15], Gilles Fauconnier and Mark Turner [4] more than thirty years ago. My own work of visualizing music also began in the late seventies, coincidentally during the same period of time that CMT and BT were being conceptualized and written down. I will illustrate the use of analogy as a basic visualization tool through describing visualizations of extant music, including the twentieth-century, intermedia masterpiece—the *Ursonate* by Kurt Schwitters. The *cognitive space transfer* is an important part of this process; it is a type of conceptual blend. I developed this method while creating art works, but predict that it can also contribute a rich, qualitative dimension to scientific visualization that adds in a substantial way to the story told by the information.

Keywords: Analogy, cognitive space, conceptual blend, metaphor, knowledge representation, model, visualization.

Index Terms: I.2.4 [Knowledge Representation Formalisms and Methods] Representations (procedural and rule-based); I.6 [Simulation and Modeling]: Model development; J.5 [Arts and Humanities]: Arts, fine and performing; Music; Language translation.

1 INTRODUCTION

> Even the most austerely 'scientific' models operate through analogy and metaphor. The Rutherford-Bohr model depicts a hydrogen atom as a miniature solar system. Darwin's concept of 'natural selection' is analogous to the 'artificial selection' process practiced by animal breeders [2].

Beginning in the seventeenth-century and continuing through to the present, science has developed strong analogical processes in order to create new knowledge and make concrete, originally abstract concepts. Scientific models are analogies [5, 11]. The mode of re-expression, or representation, is usually other than linguistic, for example visual and/ or sonic. A model is always a partial mapping; part of creating a successful model is the knowledge of what to filter out from the mapping process. It must be limited because including all information would be an uninteresting duplication of the original [11]. By looking at data in a new mode or domain, researchers are able to see it in different ways, sometimes bringing about a conceptual change that is dramatic enough to cause a frame shift.

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2 ANALOGY IS A SUB-CATEGORY OF STRUCTURE-MAPPING METAPHOR

> Similarity and association are two great forces of mental organization that hold across species. Although humans probably experience the same kinds of intuitive connections as do hamsters, our species also experiences a more sophisticated form of each of these two forces: namely, analogy (selective form of similarity) and causation (a selective form of association) [6].

Analogy is selective similarity, and structure-mapping is a "theory of human processing of analogy and similarity" [5]. In this paper I focus on analogy and what form it takes in specific, explanatory models. Analogy conveys a system of connected knowledge that focuses on the syntactical relations between objects in a domain. The systematicity can be seen if changing one element causes a shift through the system that preserves the relationships [7].

Analogy is a process of relational or syntactical thinking rather than one primarily consisting of semantic attributes. In other words—analogy maps structure and the structural relationships between entities. Dedre Gentner, psychologist and cognitive scientist, writes with her collaborators that a fundamental human achievement is the ability to pick out patterns and identify recurrences despite their variations. Humans then form concepts that are abstractions of these patterns and express those in different language systems that are often multimodal [8]. Structural information mapped to a new domain is a model, an analogical model. When we map structural information we order the construction in the new domain.

Aronson and Way [11] wrote that there are two basic kinds of models: *Descriptive models* simplify phenomena and *explanatory models* fill in knowledge gaps. The descriptive model embodies a combination of idealization and abstraction in the representation, as can be seen in musical scores and subway maps. The explanatory model is analogy, a mapping of the operations structure, a schema of the mechanics; this is the model I explore here.

Explanatory models are also known as analogue models. The analogue model shares the same pattern of abstract relationships with its target, rather than sharing a set of features; for instance, the same mathematical equation describes both a swinging pendulum and an oscillating electrical circuit. There is a distinction between analogy and literal similarity (or sameness); analogy consists of shared relations or syntax, whereas literal similarity is the sharing of object-attributes, such that the stripes of a zebra are similar to the bars in a jail cell. Analogy and literal similarity lie at different ends of a continuum that maps relative amounts of similarity [11].

3 Conceptual Blending Theory

> Conceptual blending is a basic mental operation that leads to new meaning, global insight, and conceptual compressions useful for memory and manipulation of otherwise diffuse ranges of meaning. It plays a fundamental role in the construction of meaning in everyday life, in the arts and sciences, and especially in the social and behavioural science [4].

3.1 Mental Spaces

One of the most important differences between analogy and conceptual blending is the former's use of domains versus the latter's use of mental spaces. Mental spaces are a special kind of domain; they have open possibilities for multiple references for an entity and they make the handling of the connections between them into a workable proposition. Lakoff followed Fauconnier's mental spaces theory, which was first published in 1985, and he included them in his cognitive models theory. Lakoff called mental spaces the "medium for conceptualization and thought" [16]. One can think of this description as a metaphor for cognitive soup, where elements come together and form into a gestalt organization. He and Rafael Núñez also make liberal use of blending theory and mental spaces in their book *Where Mathematics Comes From: How the Embodied Mind Brings Mathematics into Being* [17].

3.2 Double-Scope Conceptual Integration

Conceptual blends employ the *systematicity principle*, which is "a matching system of relations connected by higher-order constraining relations"[9]. Metaphoric mapping also requires a reasonable congruence between the cognitive topology of the source and target domains; image schemas define this structure. Mark Johnson described image schemas as:

> ... a recurrent pattern, shape, and regularity in, or of, these on-going ordering activities. These patterns emerge as meaningful structures for us chiefly at the level of bodily movements through space, our manipulation of objects, and our perceptual interactions [14].

They are basic-level gestalt perceptions. However, the general expectation of systematicity sets up the human mind for one of the greatest pleasures of blending—the unexpected *clash*. This is when two counterfactual elements are creatively blended into one. In fact, clashes are an important source for creativity in solving representational challenges [3].

The primary process associated with conceptual blending is the *double-scope network*; and that is what has allowed humans to produce creative acts in such realms as the arts, science, philosophy, and mathematics [4]. In the double-scope integration network each input has its own frame, or mental space. A well-known example is Fauconnier's *The Surgeon is a Butcher*. Figure 1 shows this conceptual blend in a double-scope diagram.

The top container has general names for entities that are common to both input spaces. In this case they are agent, undergoer, sharp instrument, workspace, and procedure. Input Space 1, on the left side, includes the surgeon (personally identified) who operates on a patient (also personally identified); a scalpel as the sharp instrument; an operating room as the workspace; the goal is to heal by means of surgery. The right side input space 2 contains a butcher who acts on a commodity (an animal); he uses a cleaver; and does this in the butcher shop; the goal is to successfully cut the meat through the process of butchering. The bottom space is the blended space that expresses the meaning that has emerged from blending to two oppositional input spaces together; that the surgeon is incompetent. This thought is not present in any of the input material and it only emerges through the blend.

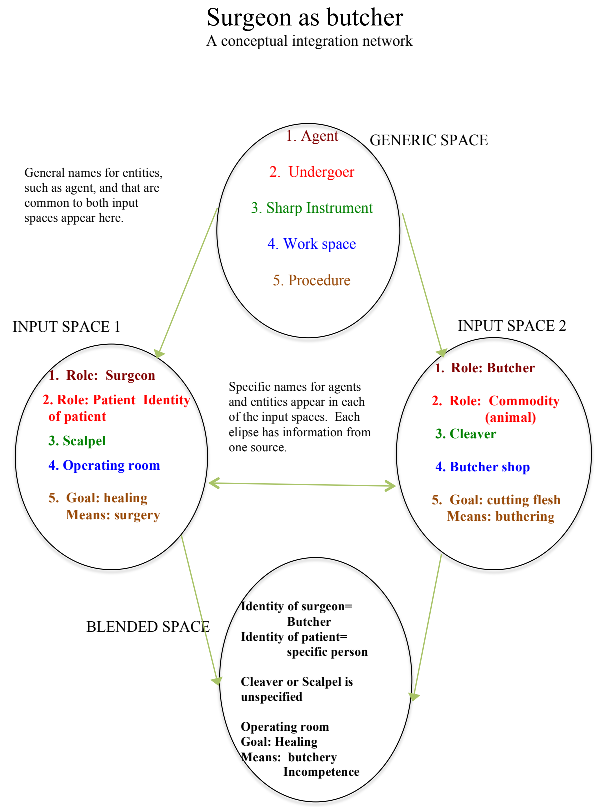

Figure 1: The conceptual blend of a surgeon and a butcher as conceived by Fauconnier and diagramed by Grady et al [10].

3.3 Clashing Tonal Space in Igor Stravinsky's Symphony in Three Movements

As I noted before, blending is often driven by incompatibilities. Mental spaces exist so that entities that are incompatible in the real world can be blended together. Logicians call this process *opacity, counterfactual reasoning, and presupposition projection*. The way that conceptual blending takes place in fluid, idiosyncratic mental spaces allows for some surprises, often created from the blending of entities that seem to clash; their coming together pro-vides unexpected exper-iences.

Igor Stravinsky's 1945 composition, *Symphony in Three Movements*, has a theme that is characterized by the quick changes between two V^7 (on the dominant of the key) chords. Within the constitutive principles of tonal music, each of the twelve keys in the

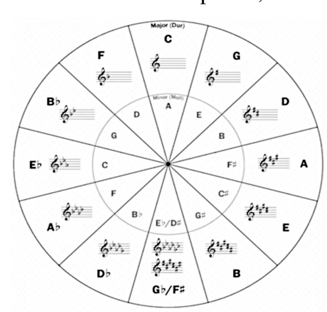

Figure 2: The circle-of-fifths

circle-of-fifths has exactly one dominant seventh chord; each of these chords establishes its home key in one's ear. Therefore, two dominant seventh chords stand apart from each other as if they both have a negative charge. All harmonic expectations are challenged in this situation.

The blend created by Stravinsky works well because even though there is a clash between the two chords, there is a structural consistency in that the chords are the same kind; they function in the same way. It is the tonal space that is different, similar to the way Picasso and Braque showed multiple perspectives in the same painting, on the same object. In the *Symphony In Three Movements* the chords have a structural consistency with each other, only challenging each other for control of the tonal space. The rules of tonal music supply the constitutive principles of Stravinsky's blend. (These rules function like the rules in chess or baseball.) The chords are a part of their home keys, but they also represent the entire key because of a metonymic compression of the keys. Both keys operate within the same rules because they live in the same domain of tonal music. These elements are represented by the double-arrow bar between the two input spaces in the conceptual integration diagram in Figure 3. There is a structural congruence between the two elements that are to be blended in the bottom elliptical container.

In the blend one hears an emergent tonal center with the changing dominant seventh chords hit in a sharp, percussive manner on the piano. It is shocking at first, but grows into something more than the sum of its parts. Even though the two keys are counterfactuals to each other, in this context they successfully occupy the same place in the blend.

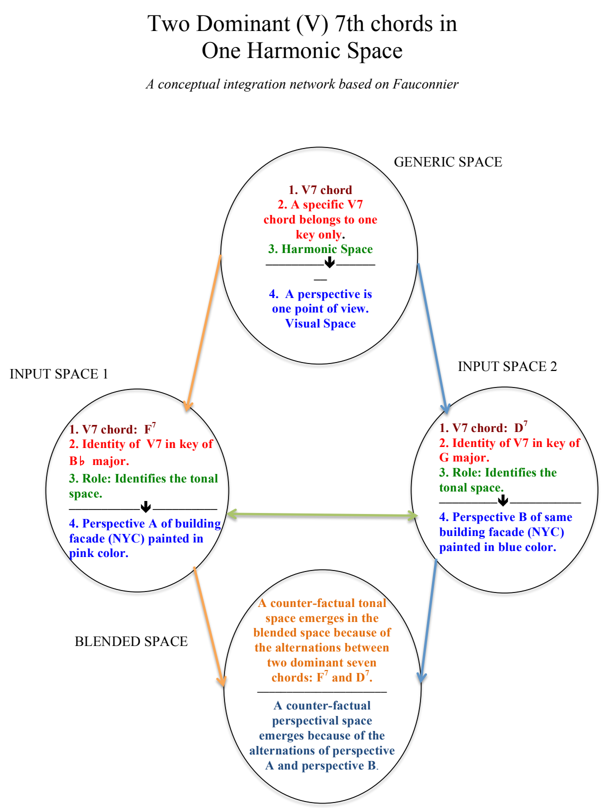

Figure 3: A conceptual integration network showing the emergent tonal space of Stravinsky's *Symphony in Three Movements* above the line in each ellipse and the blending of two perspectival views as a visualization in the lower part of each ellipse.

3.4 Preserving Stravinsky's Tonal Blend in the Visualization

I made a visualization of the section of Stravinsky's score seen in Figure 4 and created an analogous visual blend to his sonic blend. To be clear— I created a visualization of a section of the score (as in a visual performance) of *Symphony in Three Movements*. While doing this, I needed to replicate Stravinsky's tonal space in the visual realm. Therefore I mapped the two keys (G major and B♭ major) to different perspectival views of the same building facade. I hear a distinct point-of-view in a musical context when I feel like I am inside a key or tonal space; I then feel the change to a new neighbourhood as the key transitions to a new key. In the conceptual integration network diagram (Figure 3) I horizontally divided the egg shaped containers into two pieces. The top half has the musical information and in the bottom half are the visualization elements. The bottom container—the blended space, is free of mapping from music to visual because both halves of the egg are the results of the blending of their mapped parts.

Figure 4: A small segment from Stravinsky's score, *Symphony in Three Movements* the second time this theme is played and using the keys of G major and B♭Major (page 39) [22].

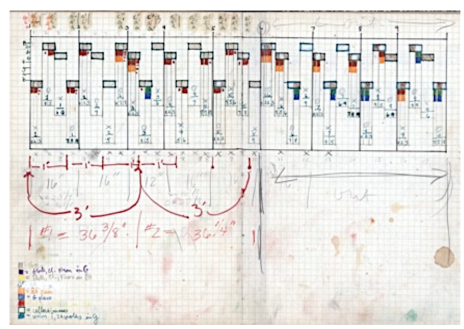

Figure 5: Page from Ox's notebook showing the visual score of Symphony in Three Movements, painting one.

There are two images that mirror each other in Figure 6. On the left is a New York City building seen from the right side; on the right is another version of this same building facade from the other side. The left image repre-sents the key of B♭ Major and the image on the right repre-sents the key of G Major. The section alter-nates between 4/4 and 3/4 time from measure to measure; the cellos and dou-ble basses play the full quarter notes in each measure. In the final blended painting, the cut image pieces fracture up and down, replicating the pitch lines of the bass instruments. The quarter notes alternate between the left and right building images; the windows divide into three sections, repli-cating the triplets found first in the violins and violas, later including piano, flute, oboe, clarinet and French horn. The three eighth notes of the triplets are played during the time of one-quarter note, creating compression in the blend. This can be seen in both the musical score (Figure 4) and the page from my notebook showing a schema for the painting (Figure 5).

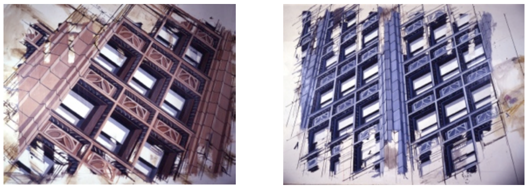

Figure 6: Two perspectival views of the same building in New York City by Ox for her painted visualization of Stravinsky's *Symphony in Three Movements* .


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Figure 7: The second half of Ox's first painting from Igor Stravinsky's *Symphony in Three Movements,* 8.2 feet by 5.5 feet. You can see how the images in figure 6 are blended together. Although the Stravinsky music is from 1945, this visualization by Ox was done in 1980.

3.5 Cognitive Space Transfer

Table 1 is the mapping system I developed when I made an eight-hundred square foot visualization of the *Ursonate* by the German dada and constructivist artist, Kurt Schwitters. In each of the cases listed in the table, there is a structure mapping from the source domain to the target domain. However, there are some other interesting things going on at the same time. The second item, *Voice sounding*, includes the visual images used as the image through which the mappings are perceivable; these particular images represent aspects of Kurt Schwitters' cognitive space.

For instance, I made drawings of some of his room size installations, such as the *Merzbau* that he constructed in his Hanover house; which was destroyed during WWII (Figure 8).

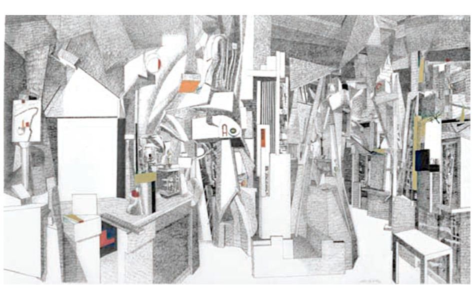

Figure 8: Theme 1, *Fümms bö wö tää zää Uu pögiff, KwiiEe*; drawing of Schwitters' Hannover *Merzbau* [1,19,20].

I also photographed and then made drawings of landscapes in which Kurt Schwitters lived and/or was photographed, sometimes drawing or painting the view. The landscapes come from Norwegian fjords and mountains, and the Lake District in the English Midlands. This was an attempt to include something of Schwitters' possible cognitive space in my visual performance of his composition. These images, which are subjective mental spaces, are blended with the metaphoric mappings (Table 1), which are also blended together in the final visualization. The finished visualization is a *complex metaphor blend*— the blending together of a metaphor system. In other words, every item in the target domain is blended together as a single-scope integration network. A single-scope network has two input spaces, but the blend comes from only one input space, the target domain side of table 1. All of these elements are blended together in the finished image (Figure 14).

There are more drawings and themes than I show here, but all of the images appearing in this paper are in Figure 14, which shows the first fifty-six feet of the finished visualization.

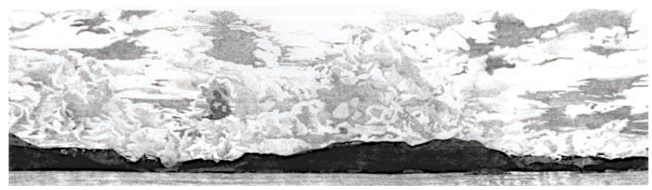

Figure 9: Theme 2, *Dedesnn nn rrrr, Ii Ee, mpiff tillff too, till, Jüü kaa?* This second theme of the *Ursonate* has rolling sounds that are similar to the rounded, rolling clouds over small islands just off the coast in the Molde Fjord, Norway. Schwitters had to be quite familiar with this landscape as he lived in a cottage on one island, Hjertoy [1,19,20].

Figure 10: Theme 3, *Rinnzekete bee bee nnz krr müü? ziiuu ennze, rinnzkrrmüü* is the third theme of Kurt Schwitters' *Ursonate*. Schwitters appears in several photographs in the Norwegian mountains near Djupvasshytta, around 1933. He was making a painting there, so the view became a part of his cognitive space [1,18,19,20].

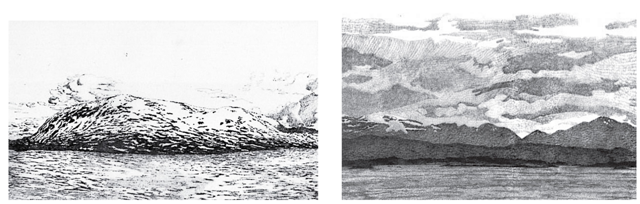

Figure 11: Theme 6 on the left, *Ooooooooooooooo* is an island in the Molde Fjord. The shape of the island suggests it has come from and 'o' shaped vessel; Theme 4 on the right, *Rrummpff tillff too?* [1,19,20].

3.6 The Mapping scheme of Kurt Schwitters' *Ursonate*

Table 1. The complete mapping scheme of the visualization of Kurt Schwitters sound-poem/ sonata called the *Ursonate* (1922-32) [19]

Source Domain	→	**Target Domain**
Time: one second	→	Space: one inch
Voice sounding	→	Images from Schwitters' Merz installations that would be familiar to him. There are also landscapes where Schwitters was photographed or that he had painted. All images are divided into vertically separated areas marking each phoneme's realm in the image-theme. They are also marked with pitch levels so that the image can be taken from the appropriate horizontal starting place.
Voice not sounding silence or pause	→	Solid colored sections, which are determined by the length of the silence, ranging from light yellow for a breath, to deep red, for around two seconds.
Pitch changes	→	Directional shifting of image sections, up for pitch rise, down for falling pitch.
Dynamic changes softness graduating up to loudness in a four-step scale.	→	In a louder section, the image appears at a larger scale, therefore showing less of the image width. Softer sounds show more of the image at a smaller scale.
Vowel Sounds There are sixteen German vowels. To see the color- vowel chart based on the International Phonetic Alphabet model— See Figure 12.	→	Transparent colors painted over phonemes based on a system determined by the tongue height and the forward/ backward position of where the vowel is produced in the vocal tract. Diphthongs are softly blended on their edges as the speaker moves from one vowel to the next. All rounded vowels come from the cool side of the color wheel, while unrounded vowels are from the warm side.
Consonants	→	Collage patterns and image manipulation including color inserts for fricatives.
Plosives	→	A voiced plosive has a vertical cut in the image section, the location of which is determined by whether it is a 'b' or 'd', and the right section is upended. Un-voiced plosives, such as 't' or 'p', are sliced horizontally in different places, with the upper segment turned around.
Fricatives	→	The voiceless 'f' has a diagonal cut from right to left in the top half of the image segment, with a thin strip of cerulean blue inserted, and 's' has a strip of yellow inserted in the cut. The voiced fricative 'v' is cut from left to right, diagonally in the top half of the image segment, with a strip of violet, and 'z' is the same direction with orange inserted.
Trills	→	Trills call for cutting the segments into 1/4-inch segments. Either every second one is upended, or the same image was painted forwards and backwards, and the trill strips alternate between strips from the two different paintings.
The themes of the *Ursonate*	→	Each theme has a different sound and feeling. Each image was chosen by the artist for a correspondence between the lines and patterns drawn aurally by Schwitters and the visual lines and patterns perceived in the landscapes.

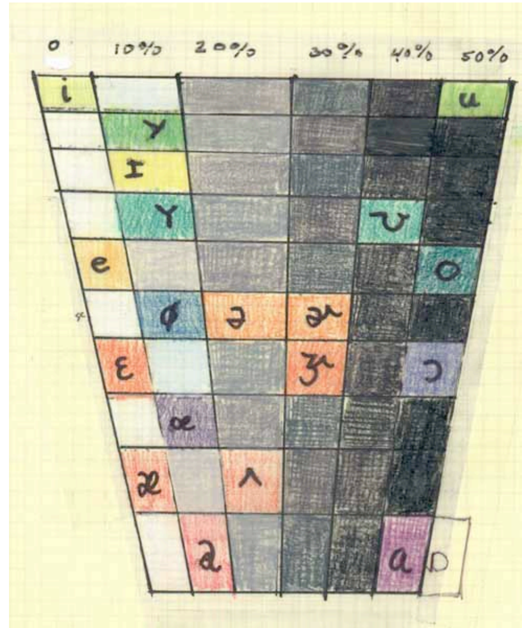

Figure 12: The color-mapping vowel chart used for the *Ursonate* that shows the sixteen German vowels— based on the International Phonetic Alphabet (IPA) model. In the above chart the front of the mouth is represented by the left side and the back of the vocal tract is on the right side of the chart. The tongue height is seen through the vertical placement of the vowels. Unrounded vowels are the warm colors, while rounded vowels are cool colors. The vowel colors move down the warm or cool list from lighter to darker values as vowels are formed by lowering the tongue in the mouth. As the location of the vowel sound moves towards the back of the vocal tract, the colors are mixed with an increasing percentage of its complementary color, from 0% to 50%. [1,19,20,21] .

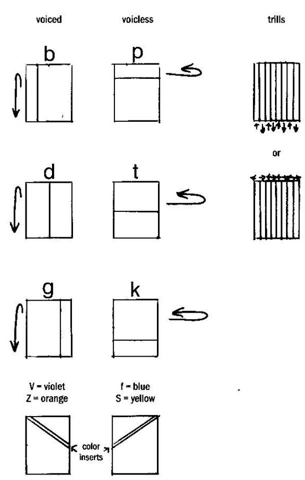

Figure 13: The fracturing and cutting patterns of the consonants as described in Table 1.

The transparent colors determined by the color-mapping vowel chart in Figure 12 are painted over the image strips that represent different phonemes in each syllable. Kurt Schwitters' *Ursonate* is composed entirely of German phonemes that are not meant to carry linguistic meaning. Part of the significance of this major twentieth-century work is its *intermedia* nature. Intermedia is the presence of the structural elements from two or more different media in one. This was defined by the Fluxus artist and theorist, Dick Higgins [12, 13]. In the *Ursonate* the structural blend is between the vocabulary of sound-poetry and the syntactical construction of the nineteenth-century sonata form from the domain of music. Creating a visualization is further inter-mediation.

One might wonder why the pauses, effectively silent, are represented by the brightest, most pure red, red-orange, orange, and yellow colors I can find. The late twentieth-century composer John Cage can be said to be in the line of Kurt Schwitters, influenced by his work and philosophy of making art. Therefore, I have taken something from the mind of John Cage to map back to Schwitters; for Cage, who wrote a book called *Silence*, there is always much going on in that space. It is certainly not negative or empty, but occupies a full voiced space. I also chose these brightly colored pauses because these colors often appear in Schwitters collages, and have a presence in his neutrally painted Merzbau (see Figure 8). The visualization would have suffered if I had chosen to use a more neutral color like grey, or even black or white. The colored pauses make one appreciate their importance in the *Ursonate*; the colors add a dimension that is based on the transfer of *qualities* rather than only quantifications.

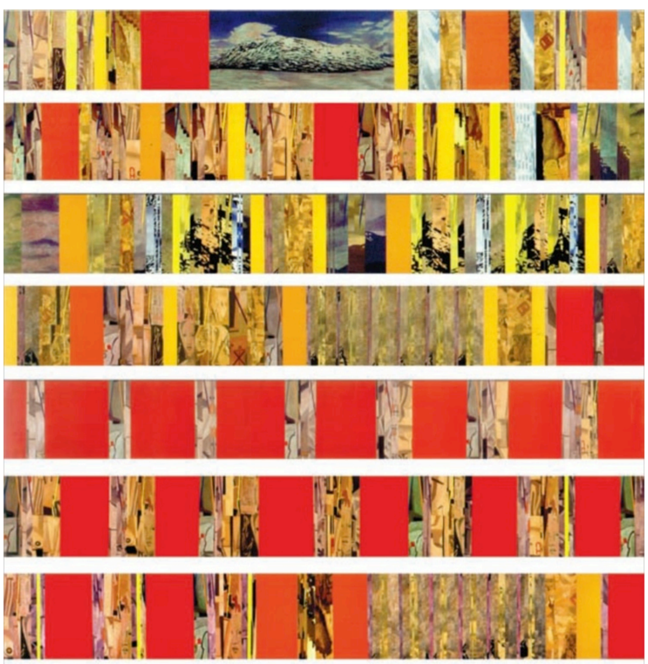

Figure 14: Segment from Ox visualization of Ursonate (1993). Each line in this image is eight feet wide by one foot tall. All of the mapped information has been blended into the painting, with the spoken parts separated by solid colored rectangles that are color coded to the length of the pause. One second is represented by one inch of space.

Figure 14 shows the first fifty-six running feet of my *Ursonate* visualization. The complete painting is one foot by eight hundred feet, which is hung in lines moving across the wall with 1/2 inch between each line. Figures 8-11 show the first five themes that occur in Figure 14. Table 1 shows the structural mapping of information such as a transparent glaze applied over the images that represent the voiced vowel sounds. Without the cognitive space images, it would be impossible to perceive the mapped information from pitch changes, or rhythmic values, both of which are seen through displacement of image segments from the cognitive space images.

4 Conclusion

In this paper I have demonstrated the use of structure-mapping techniques in music visualizations, a process that is familiar to scientists who create explanatory models to fill knowledge gaps. We have also seen how a system of metaphors can then be mixed together into an emergent conceptual blend, called a complex metaphor blend. While creating these visualizations, which were intended as art works, I developed a blending process that integrates the cognitive space of the original composer into the visualization. This technique could be useful to scientists who want to add qualitative information to visualizations.

However, the scope of this paper could only cover part of the complex, dynamic system known as conceptual metaphor and blending theories; other tools in the toolkit include categories, ontological metaphors, and metonymy. The system is completely interactive among its parts and promises to open up creative thinking when translating information from one mode to another. Visualization is really story telling in either time and/or space. It maps the interactions between parts, how each entity affects another; and it often does this with a sense of drama—of tension and release.

My future intention is to make concrete the toolkit, part of which was described in this paper as metaphor and blending processes. That means that these procedures must be described in code that can be used and added to by other knowledge representers. The toolkit will be completely open source as is correct when seeking federal funding. The processes described in this paper are all transferable to scientific visualization, sonification, and any other perceptualization where it proves feasible. Hopefully I have shown how scientific visualization can benefit from processes that were developed in the domain of art.

Acknowledgment

I would like to extend my thanks and acknowledgment to the Center for Advanced Research Computing (CARC) at the University of New Mexico for extending research resources and my office at the center.

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