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It is difficult to create good interaction designs for music software or to substantially improve existing designs. One reason is that music involves diverse and complex concepts, entities, relationships, processes, terminologies, and notations. An open challenge for interaction designers is to find systematic ways of channeling the tacit, specialized knowledge of musicians into designs for intuitive user interfaces that can capably support musically skilled users, without excluding those with less technical musical knowledge.

One promising new approach to this challenge involves the application of research from the theory of image schemas and conceptual metaphors (Lakoff and Núñez 2000; Johnson 2005; Rohrer 2005, 2007). This theory posits that all human conceptual abilities are ultimately grounded in universal, prior, sensory-motor experiences of space, force, containment, and orientation, although the development of such groundings may be culturally influenced. The theory further posits that the nature of these groundings is amenable to empirical investigation, for example, by analyzing linguistic constructs in texts and discourse.

This theory has already been applied with some success to analyzing musical concepts (Saslaw 1996; Zbikowski 1997a, 1997b; Brower 2000; Eitan and Granot 2006; Eitan and Timmers 2010), mathematical concepts (Lakoff and Núñez 2000), general-purpose user-interface design (Hurtienne and Blessing 2007; Hurtienne and Israel 2007; Hurtienne, Israel, and Weber 2008), and sound-generation interaction designs involving simple musical parameters such as tempo, volume, and pitch (Antle, Droumeva, and Corness 2008; Antle, Corness, and Droumeva 2009). The present research appears to be the first to investigate the potential of conceptual metaphor theory for investigating music interaction designs for dealing with more complex musical con-

What Can the Language of Musicians Tell Us about Music Interaction Design?

cepts, such as harmonic progressions, modulation, and voice leading.

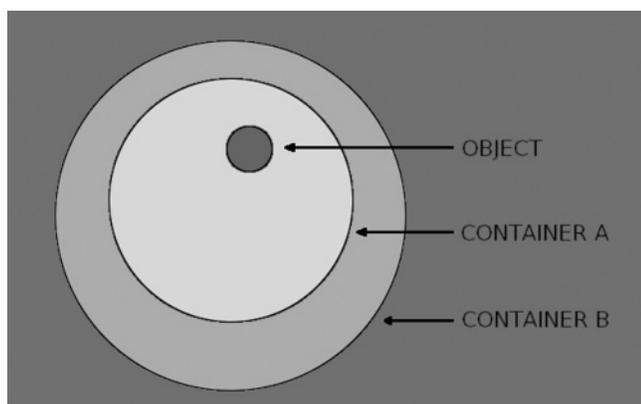
In the present study, we propose that by identifying the conceptual metaphors and image schemas used by musical experts when analyzing an excerpt of music, and then assessing the extent to which these conceptual metaphors are supported by existing music interaction designs, it is possible to identify areas where the designs do not match musicians' understanding of the domain concepts. This process provides a principled basis for identifying points at which designs could be improved to better support musicians' understanding and tasks, and for the provisional identification of possible improvements.

This article presents the results of an analysis of a short dialogue between three musicians as they discuss an excerpt of music. A methodology for the systematic identification of image schemas and conceptual metaphors is detailed. We report on the use of the results of the dialogue analysis to illuminate the designs of two contrasting examples of music software. Areas in which the designs might be made more intuitive are identified, and corresponding suggestions for improvements are outlined.

Embodied Cognition

Conceptual models are claimed to form the basis of our understanding of abstract domains (Johnson 2005). Research into the development of conceptual models has led to the hypothesis that our understanding of musical concepts, along with our understanding of all other abstract concepts, is grounded in our prior sensory-motor experiences (Saslaw 1996; Zbikowski 1997a, 1997b; Brower 2000; Lakoff and Núñez 2000; Johnson 2005; Rohrer 2005, 2007). It is useful to consider the detail of this hypothesis. Through the analysis of linguistic expressions, a number of constructs called *image schemas* have been identified. Image schemas represent perceptions of repeating patterns of bodily

Figure 1. Representation of the relationship between OBJECTS and nested CONTAINERS.

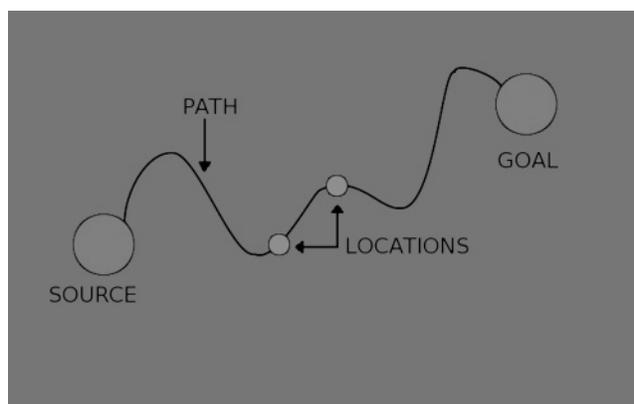


experiences of space, forces, and interaction with other bodies in our environment (Lakoff and Núñez 2000; Johnson 2005; Rohrer 2005, 2007).

For example, one common physical experience, often referred to in spoken and written language, is that of one object containing another. In image schematic terms, we refer to occurrences of the CONTAINER image schema. The CONTAINER image schema is used literally in phrases such as “put the toys in the box,” where the box is a physical container into which objects can be placed or from which they can be removed. More importantly however, the CONTAINER image schema can be used metaphorically in phrases such as “the music-computing students are in the computer science department,” and “the phrase is in the key of F major.” In both these examples, the container (i.e., the computer science department or the musical key), exists as an abstraction and not as a tangible entity.

The structure of the CONTAINER image schema gives rise to a number of entailments that can be used more or less effortlessly, even by young children, to carry out spatial-reasoning operations (Lakoff and Núñez 2000; Johnson 2005). As shown in Figure 1, for example, if an object is inside a container and that container is inside another container, then the object is inside both containers. Similarly, we can deduce that if “the music-computing students are in the computer science department” and “the computer science department is in the college of engineering,” then the music-computing students are also in the college of engineering.

Figure 2. Representation of the SOURCE-PATH-GOAL image schema.



More generally, in order to use image schemas to structure our understanding of abstract concepts such as, for example, harmonic progression in music or mathematical operations, it is necessary for an aspect of one domain, called the *source*, to be mapped onto a corresponding aspect of another domain, called the *target*, creating a *conceptual metaphor* (Lakoff and Núñez 2000; Johnson 2005). For example, if we consider the phrase “the melody starts in C, goes down to F, up to G, then up to A,” this can be viewed as a mapping of the UP-DOWN image schema onto the target domain of musical pitch using the conceptual metaphor HIGH PITCH IS UP; LOW PITCH IS DOWN.

Metaphorical entailment can then be used intuitively without the need for any domain knowledge, for example, to deduce that A is higher than F, ignoring any octave context. In addition to the CONTAINER image schema, we also can identify in the quoted phrase the mapping of the SOURCE-PATH-GOAL image schema, of which a visual representation is shown in Figure 2, onto a melodic progression, using the conceptual metaphor MELODY IS MOVEMENT ALONG A PATH. As with the CONTAINER image schema, application of the SOURCE-PATH-GOAL image schema can allow other, similarly effortless, intuitive inferences to be made, for example that A is sounded after F.

One important detail of the hypothesized mapping process by which we come to understand abstract concepts is that when mapping from the source domain to the target, only aspects of the source that are applicable to the target

domain are mapped onto the target. In this way, image-schematic structure is preserved by the mapping, a process known as the Invariance Principle (Zbikowski 1997b). For example, in the case of a mapping of the idea of a path onto melodic movement via the conceptual metaphor MELODY IS MOVEMENT ALONG A PATH, only the applicable aspects of paths—namely, starting points, finishing points, and locations along the path—are mapped onto the concept of a melody. In other words, a melody is similar to a path in that it has beginning and ending notes, and notes in the melody can be represented as locations along the path. According to the Invariance Principle, although there is always the possibility that an alternative mapping could be adopted to support any concept, the fewer the image-schematic correspondences between source and target domains, the less likely a mapping is to be successful. For example, as Zbikowski (1997b) notes, fruits are not readily mapped onto pitches, as the correspondences between the two domains are scant. Vertical height is a better fit for pitch, as both can be divided into a set of discrete ordered elements: In the case of verticality, positions can be ordered by height; also, in the case of pitch, notes can be ordered by pitch.

The ability to apply image schemas to abstract, otherwise unrelated, domains through the creation of conceptual metaphors makes image schemas not only extremely flexible and powerful for intuitive communication and informal reasoning, but it also makes them useful for analyzing conceptual models. As previously touched on, image-schema and conceptual-metaphor theories have already been successfully applied to diverse domains. The application of theories of image schema and conceptual metaphor to music theory, user-interface design, and sound-interaction design, respectively, will be discussed in more detail in the following sections.

Understanding Musical Concepts Using Image Schemas

Research into the application of image-schema and conceptual-metaphor theories to the domain of music has predominantly focused on the analysis

of theorists' descriptions of various musical concepts and the analysis of musical phenomena with respect to embodied experiences. For example, an analysis by Saslaw (1996) of the language used in Riemann's treatise *Systematic Study of Modulation as a Foundation for the Study of Musical Form* (1887) identifies the use of the image schemas CONTAINER and SOURCE-PATH-GOAL in Riemann's descriptions of harmonic progressions, modulations, and movement along a PATH from one key CONTAINER to another. Furthermore, Saslaw argues that Riemann's conceptual model of modulation is based on the use of FORCE image schemas to move from one key CONTAINER to another.

Brower (2000) extends this work in an attempt to develop a cognitive theory of musical meaning. She hypothesizes that musical meaning is derived from mapping the musical patterns heard by a listener onto intra-opus patterns (specific to the music being listened to), musical schemas (abstract patterns based on musical conventions such as tonal theory), and image schemas. Brower then identifies the image schemas most important to our understanding of music: CONTAINER, CYCLE, VERTICALITY, BALANCE, CENTER-PERIPHERY, and SOURCE-PATH-GOAL. She argues that these image schemas ground our understanding of various musical concepts, such as the relationships between different keys and the tonic, and the resolution of unstable pitches.

In a second strand of research, recent empirical studies have attempted to validate listeners' understanding of musical concepts. Eitan and Granot (2006) conducted experiments in an attempt to investigate associations between space, motion, and changes in musical parameters such as pitch and tempo. The experiments involved asking participants to specify the motion of an imaginary character in response to various musical stimuli. Interestingly, the results suggest that construal of various musical events focuses on differences rather than on symmetrically imagined directions as one might expect. For example, pitch descent is associated with spatial descent; however, pitch ascent is only weakly associated with spatial ascent. This finding is interesting when we consider that height, the basis for the UP-DOWN image schema—also

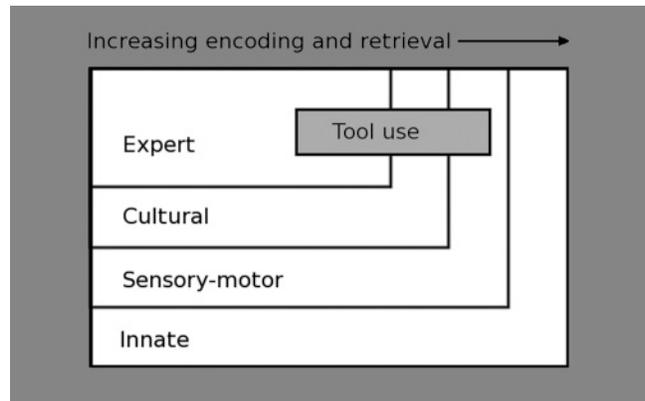
Figure 3. Continuum of prior knowledge. Based on Hurtienne and Blessing (2007).

known as VERTICALITY—is commonly seen to be mapped onto pitch in Western music, as reflected in the conceptual metaphor HIGH PITCH IS UP; LOW PITCH IS DOWN (Zbikowski 1997a, 1997b). However, further work is required to develop a deeper understanding of the parameters and dimensions of music as understood from this perspective by musicians and non-musicians alike.

In an attempt to establish whether a common basis for pitch mappings exists across cultures, Eitan and Timmers (2010) ran a series of experiments asking participants to match one term from a pair of antonyms based on the metaphors for pitch identified in a number of cultures—including non-Western ones—to a high or low pitch. Participants were also asked to rate the appropriateness of the antonyms as descriptions of two excerpts from a piano sonata by Beethoven. A significant number of the Western participants applied the non-Western metaphors correctly, suggesting that there may indeed be a common basis for the development of pitch metaphors, further illuminating the claim that bodily experiences form the basis of our understanding of various abstract concepts.

Use of Image Schemas in User-Interface Design

Interaction designers often recommend the use of metaphors, in the everyday sense of the word “metaphor,” as a technique for establishing a link between the user’s understanding and an interface design. However, the use of conceptual metaphors as a technique for user-interface design has received far less attention. Seeking to establish whether image schema and conceptual metaphor theories could form the basis of a new technique for user-interface design, Hurtienne and Blessing (2007) proposed that the term *intuitive*—at one time considered vague and best avoided in serious discussions of human computer interaction—could be given a precise meaning in the following way. They hypothesized that software should be considered intuitive, or intuitively usable, if the user is able to subconsciously apply their prior knowledge during interactions, where prior knowledge can be classified as innate, sensory-motor, embodied,



cultural, or expert; and where knowledge becomes increasingly universal as we progress from the top to the bottom of the continuum, as shown in Figure 3.

They further argued that, because image schemas occur at the sensory-motor level of prior knowledge, employing image schemas as a technique for user-interface design will lead to more intuitive user interfaces. They designed a number of experiments in which simple conceptual metaphors such as MORE IS UP, GOOD IS UP, VIRTUE IS UP, and MORE IS RIGHT had been applied to the layout and configuration of button and slider controls. Participants were asked either to select the most appropriate button or to move the slider in the appropriate direction, based on their response to a number of phrases such as “The staff is friendly.” These experiments were designed to test the most effective configuration of the controls by comparing designs whose physical layouts variously supported, ignored, or opposed the conceptual metaphors implicit in the task descriptions. For example, one design configured a vertical slider with the highest value at the top, while another had the value polarity reversed.

The results of the experiments indicated that, in general, response times were reduced when the controls were laid out and configured to support the conceptual metaphor implicit in the task. However, the experiments were limited to a small number of conceptual metaphors with just two user-interface components; therefore, further work is necessary before the hypothesis can be claimed to be well supported.

In a contrasting study, Hurtienne, Israel, and Weber (2008) investigated the potential for using image schemas as a “meta-language” during the analysis and design phases of a redesign of an invoice verification and posting application. The information, elicited through the context-of-use-analysis, led them to conclude that an image-schema-led approach helped to focus the analysis and design phases on the essential user-interface requirements. Again, however, further work is needed to establish the extent to which an image-schematic approach to requirements capture and design can assist in producing designs which can reasonably be considered more intuitive.

Using Conceptual Metaphors to Improve Sound Interaction Designs

Antle, Droumeva, and Corness (2008) and Antle, Corness, and Droumeva (2009) sought to investigate the advantages of integrating embodied metaphors into interactive systems designed for manipulating musical concepts such as pitch, tempo, and volume. They identified bodily movements associated with sound parameters (fast movement equating to a fast tempo, for example), and mapped these associations to the interaction layer of a sound-generation environment. In this way, the researchers were able to design a system that enabled users to generate sounds and modify sound parameters simply by moving their bodies. To establish whether this approach to interaction design enhanced the ability of children to learn about sound concepts, Antle, Droumeva, and Corness (2008) designed experiments using two versions of the system. One version used the identified embodied metaphor mappings; the other used a non-metaphor-based mapping. Pairs of children were asked to create specific sound sequences using the system (for example, by varying the output volume) and to describe the sequences they created. Although the results of the experiments did not conclusively demonstrate whether a system based on embodied metaphors could enhance the ability of children to learn musical concepts, the findings did indicate that it was easier to learn to use the system in the

embodied metaphor-based version. Furthermore, the results highlighted the importance of discoverability in the identification of appropriate embodied metaphors—as many children had difficulty discovering the embodied metaphor for pitch—irrespective of how intuitive that metaphor might be once discovered.

Study Design to Identify Conceptual Metaphors from Dialogue

In this section, we present the results of our analysis of a short dialogue between three musicians discussing a piece of music. The aim of this study was to identify conceptual metaphors used by domain experts when analyzing aspects of musical artifacts. The detailed methodology we devised to identify image schemas and conceptual metaphors is presented. This analysis allows us, in the subsequent section, to investigate the designs of two contrasting examples of music software and assess the extent to which the identified conceptual metaphors are supported by the interaction designs. This assessment is then used to provisionally identify areas in the design amenable to improvements that might yield more intuitive usability, as defined in the previous section on user-interface design.

Three participants were chosen to take part in the study, all of whom were skilled musicians with experience in musical performance and conducting. All held at least an undergraduate degree in music. An excerpt was chosen of a sacred motet for six voices, strings, and basso continuo entitled *Laudate Dominum* by Claudio Monteverdi (1567–1643). This particular piece was selected on the basis of its contrasting mix of lively melodies and homophonic movement. The participants were provided with a score of the first 22 bars of the excerpt.

The participants were asked to collaborate on answering a number of questions on melodic and harmonic movement within the piece, in addition to describing aspects of the music that interested them. By designing the questions to focus on specific aspects of the excerpt, such as the harmonic and melodic progressions used, we hoped to maximize the opportunities for eliciting image schemas

and conceptual metaphors. The decision for the participants to work together rather than separately was motivated by the same aim. The text, title, and composer of the excerpt were obscured to ensure that this information did not influence the direction of the discussion.

The dialogue between the musicians lasted approximately 30 minutes. A recording of the dialogue was transcribed and subsequently analyzed to identify the image schemas and conceptual metaphors the musicians used to inform their understanding. Image schemas were identified by comparing the catalogues and examples provided by other authors (Lakoff and Johnson 2003; Johnson 2005; Hurtienne and Blessing 2007; Hurtienne and Israel 2007; Hurtienne, Israel, and Weber 2008) with the comments made by the musicians. Image schemas not directly related to music were removed from the list.

The remaining image schemas were used to identify the associated conceptual metaphors, again using the examples and analyses provided by other authors (Lakoff and Johnson 2003; Johnson 2005; Hurtienne and Blessing 2007; Hurtienne and Israel 2007; Hurtienne, Israel, and Weber 2008) for comparison. To avoid the misidentification of conceptual metaphors for which evidence was marginal, those that were used by only one participant or used merely a small number of times were removed from the list.

In some cases, it was not clear which image schema was present. For example, the comment “The other parts stay on almost the same note all the way through” could be interpreted as a SOURCE-PATH-GOAL image schema, on the grounds that “all the way through” could imply movement from one location to another. However, we adopted the guideline that only comments where a PATH image schema was clearly implied, using prepositions such as “from” and “to,” should be identified as such. Similarly, in some cases the extrapolation of conceptual metaphors from identified image schemas could be interpreted in more than one way. For example, the identification of a MUSICAL REPETITION conceptual metaphor from the MATCHING image schema is based on the implication that, if musical notes are repeated,

they MATCH each other. Table 1 lists some sample comments made by the participants and shows some of the candidate image schemas and conceptual metaphors that were identified from the comments.

Table 2 lists the conceptual metaphors that appeared most frequently within the dialogue and that were subsequently used to investigate two contrasting examples of music software, Harmony Space and GarageBand, as discussed in the following sections. In instances where a particular aspect of music or a musical concept (e.g., quality or style of music) was referred to in the discussion in terms of quantity, such as in the comment “very Italian,” the conceptual metaphor identified is labeled with the term “CONTINUUM” to indicate this.

Previous research already identified a number of the conceptual metaphors elicited during the study, for example, HARMONIC PROGRESSION/MODULATION IS MOVEMENT ALONG A PATH (Saslaw 1996), and LOW PITCH IS DOWN (Zbikowski 1997a, 1997b; Eitan and Granot 2006; Eitan and Timmers 2010). Additionally, the relationship between chords was explored further by Brower (2000). This agreement between conceptual metaphors identified in different studies gives a measure of validation to the importance of their role in informing musicians’ understanding of certain musical concepts.

Conceptual Metaphor-Based Evaluation of Music Interaction Designs

The next step of our study investigated the extent to which the conceptual metaphors identified in the dialogue analysis were supported by particular music interaction designs. We will call this process *conceptual metaphor-based evaluation*. Two contrasting examples of music software were chosen: Harmony Space (Holland 1994) and GarageBand (Apple 2009). Harmony Space was chosen as a user interface that is systematically and richly designed to exploit spatial metaphors for harmonic concepts. Also, because Harmony Space was written by one of this article’s authors, this guaranteed the opportunity to implement any design changes suggested

Table 1. Sample Comments from the Dialogue, Showing Some of the Candidate Image Schemas and Conceptual Metaphors That Were Identified

<i>Sample Comment</i>	<i>Image Schemas</i>	<i>Conceptual Metaphors</i>
"... it just jumps from G into C... and then A minor... then D minor... then back to G major..."	SOURCE-PATH-GOAL CONTAINER	HARMONIC PROGRESSION IS MOVEMENT ALONG A PATH A CHORD/KEY IS A CONTAINER FOR NOTES
"... you've got a complete mind shift..."	DIVERSION	UNEXPECTED CHANGE IN MUSIC IS DIVERSION
"... it's just kind of hit a wall..."	BLOCKAGE	MUSICAL SILENCE IS A BLOCKAGE TO MOVEMENT
"The other parts stay on almost the same note all the way through."	PART-WHOLE MATCHING	A PIECE OF MUSIC IS CONSTRUCTED FROM A NUMBER OF PARTS MUSICAL REPETITION
"... what is the relation to the home key"	LINKAGE	KEYS/CHORDS ARE RELATED [TO THE TONIC]
"... A major down to F..."	UP-DOWN SOURCE- PATH-GOAL	HIGH PITCH IS UP/LOW PITCH IS DOWN HARMONIC PROGRESSION IS MOVEMENT ALONG A PATH

by this study. GarageBand was chosen owing to its wide availability and use of well-established conventions for representing musical concepts. These conventions borrow significantly from widely used Digital Audio Workstation designs such as Pro Tools and from ubiquitous sequencer software programs such as Cubase.

Another contrast between the two chosen applications is that Harmony Space is designed to support tasks associated with composition, analysis, and understanding, emphasizing harmonic aspects in each case; GarageBand is designed to support more general tasks associated with music generation and production. These contrasts facilitated the investigation of conceptual metaphors in the context of interaction design from diverse perspectives.

The conceptual-metaphor-based evaluation was carried out by comparing each of the conceptual metaphors identified in the dialogue analysis with aspects of the user interface, including the layout, behavior, and configuration of components. The level of support for a given set of conceptual metaphors is not necessarily an indication of a

design's quality with respect to intuitiveness and usability. For example, depending on the particular musical tasks to be supported, it may be useful for a design to emphasize certain musical concepts and ignore others. Nevertheless, establishing the level of support for conceptual metaphors provides a good foundation for judging this and other trade-offs, and it provides insights into potential areas for improvement.

Table 3 gives a broad quantitative measure of the extent to which various conceptual metaphors are supported. Deeper insights into the nature of conceptual metaphorical support and its implications can be gained from the following qualitative analyses.

Harmony Space

Based on theories of harmonic perception by Longuet-Higgins (1962) and Balzano (1980), Harmony Space (Holland 1994) is designed to teach novices principles of tonal harmony and harmonic progression by exploiting users' intuitive prior

Table 2. Frequency of Most Commonly Used Conceptual Metaphors

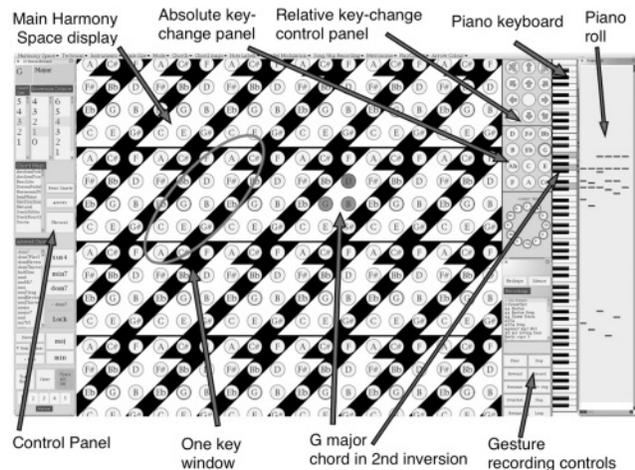
<i>Conceptual Metaphor</i>	<i>Frequency</i>	<i>Sample Comment</i>
HARMONIC PROGRESSION IS MOVEMENT ALONG A PATH	17	"... you've gone from A major to E major ..."
MUSICAL REPETITION	15	"... that delayed echo..."
A PIECE OF MUSIC IS CONSTRUCTED FROM A NUMBER OF PARTS	14	"Well first thing you notice is it's got vocal and instrumental parts ..."
A PIECE OF MUSIC IS AN OBJECT	14	"It's a nice piece."
MUSICAL STYLE IS A CONTINUUM	12	"... very Italian, early Baroque ..."
A KEY/CHORD IS A CONTAINER [FOR NOTES]	10	"... I'm in G major ..."
UNEXPECTED CHANGE IN MUSIC IS DIVERSION	9	"... you expected is to start developing these themes a little bit, spinning them out in that way that they do, and then actually you've got a complete mind shift."
A PIECE OF MUSIC IS MOVEMENT ALONG A PATH	8	"If you'd given me that and said what comes next, I wouldn't have said it suddenly goes homophonic ..."
A KEY/CHORD IS AN OBJECT	8	"This is the first big surprise isn't it, this A major chord. ..."
MUSICAL COMPLEXITY IS A CONTINUUM	7	"Because it's amazingly simple. ..."
A PIECE OF MUSIC IS A CONTAINER	7	"... and a big tutti coming in at bar thirteen"
HIGH PITCH IS UP/LOW PITCH IS DOWN	7	"... it goes down to E major."
DIFFERENCE IN PITCH IS SIZE	5	"There a little third. ..."
DIFFERENCE IN PITCH IS DISTANCE	5	"And then he jumps back down, down a third to A minor ..."
A REST IS AN OBJECT	5	"That rest! That rest!"
MUSICAL SILENCE IS A BLOCKAGE TO MOVEMENT	5	[Referring to the rest] "Yeah I mean it's just kind of hit a wall a bit doesn't it."
MUSICAL QUALITY IS A CONTINUUM	5	"it obviously is [an] incredibly well written piece of music"
KEY/CHORDS ARE RELATED [TO THE TONIC]	4	"... and when I see that chord I don't even need to, I don't need to analyze what it is in relationship to everything else. ..."

knowledge of, for example, straight-line movement, proximity judgments, and visual grouping. By this means, the need for prior specialized-domain knowledge of musical concepts is reduced. Different versions of Harmony Space exist, including a whole-body camera-driven version (Holland et al. 2009). The current desktop version was used in this evaluation, however.

Harmony Space (see Figure 4) displays the notes of the chromatic scale in a repeating two-dimensional grid. The grid is overlaid by a moveable black and white pattern showing the current key context. This pattern can be moved depending on the chosen

key or mode. White notes are in the key or mode; black notes lie outside (i.e., chromatic alterations). Selecting a note within a white "key window" will sound a chord whose root is that note, and whose form depends on the chosen key, chord size, and on other harmonic choices available in the interface. For example, under the default chord mapping, in the key of G major with a chord size of three selected, selecting the note G will sound the chord of G major. Similarly, selecting E will sound the chord of E minor, and so on. With the default diatonic chord mapping in force, the constituent notes visibly remain within the key window for each chord. Other

Figure 4. Screenshot of Harmony Space showing a G major chord in second inversion in the key of G major. The piano roll display was implemented as a result of the evaluation.



chord mappings are available, associated with other styles, including more chromatic mappings. Various tools for tracing, recording, and modifying notes played or routed through the interface are provided, along with certain secondary displays.

Evaluation Results

A conceptual-metaphor-based evaluation of Harmony Space was performed by comparing each of the conceptual metaphors identified in the dialogue in turn with the interactions available. This made it possible to identify aspects of the interaction designs, such as component choice, layout, configuration, or behavior, that supported, ignored, or contradicted each conceptual metaphor. The conceptual-metaphor evaluation revealed that Harmony Space supports many, but not all, of the conceptual metaphors identified in the dialogue analysis, variously through visual display, audio output, or interaction components. In particular, it provides much greater support for those conceptual metaphors associated with harmony and spatial movement than for conceptual metaphors associated with other aspects of music.

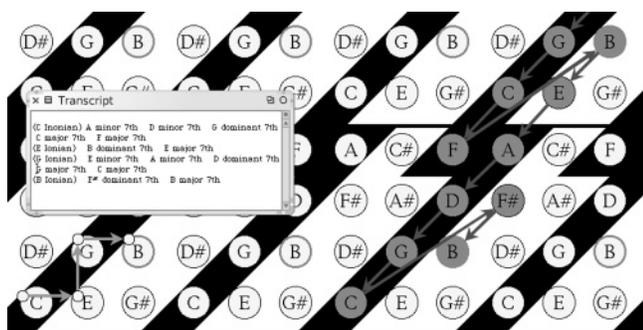
For example, the conceptual metaphor used most frequently in the dialogue, HARMONIC PROGRESSION IS MOVEMENT ALONG A PATH, is well supported by visibly moving the key window, corresponding to modulation into a different key or

Table 3. Summary of Results

Conceptual Metaphor	Harmony Space	GarageBand
HARMONIC PROGRESSION IS MOVEMENT ALONG A PATH	Y	N
MUSICAL REPETITION	P	P
A PIECE OF MUSIC IS CONSTRUCTED FROM A NUMBER OF PARTS	P	Y
A PIECE OF MUSIC IS AN OBJECT	Y	Y
MUSICAL STYLE IS A CONTINUUM	N	P
A KEY/CHORD IS A CONTAINER [FOR NOTES]	Y	Y
UNEXPECTED CHANGE IN MUSIC IS DIVERSION	P	P
A PIECE OF MUSIC IS MOVEMENT ALONG A PATH	Y	Y
A KEY/CHORD IS AN OBJECT	Y	P
MUSICAL COMPLEXITY IS A CONTINUUM	N	N
A PIECE OF MUSIC IS A CONTAINER	Y	Y
HIGH PITCH IS UP/LOW PITCH IS DOWN	P	Y
DIFFERENCE IN PITCH IS SIZE	P	Y
DIFFERENCE IN PITCH IS DISTANCE	P	Y
A REST IS AN OBJECT	N	P
MUSICAL SILENCE IS A BLOCKAGE TO MOVEMENT	N	P
MUSICAL QUALITY IS A CONTINUUM	N	N
KEY/CHORDS ARE RELATED [TO THE TONIC]	Y	N

Y = the conceptual metaphor is fully supported; P = partial support; N = no support.

Figure 5. In this example, the dark arrows (seen in the right half of the figure) trace chord roots. The light arrows (in the left half) indicate key and mode changes.



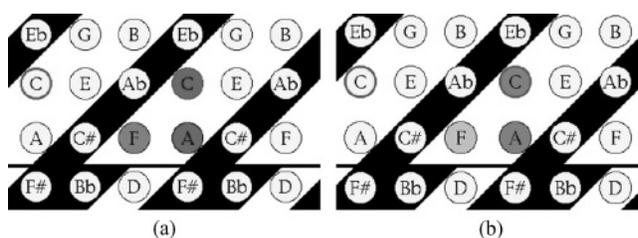
mode, and is supported by the chord-trace history, as shown in Figure 5. These features also support the conceptual metaphors A PIECE OF MUSIC IS MOVEMENT ALONG A PATH and UNEXPECTED CHANGE IN MUSIC IS DIVERSION, from a harmonic perspective.

A version of Harmony Space evaluated using an earlier, less-refined version of the dialogue-analysis methodology, and without the comparative evaluation of GarageBand (Wilkie, Holland, and Mulholland 2009), did not support a trace history of the movement of the key window, making it harder for the user to determine the history of the progressions from one key to another. This omission was identified by that evaluation. This finding spurred the designer to implement such a trace, a feature that had been part of the original design but not previously prioritized.

Other design issues were illuminated by a different set of conceptual metaphors identified in the current dialogue analysis, namely, DIFFERENCE IN PITCH IS SIZE, DIFFERENCE IN PITCH IS DISTANCE, and HIGH PITCH IS UP/LOW PITCH IS DOWN. These are not straightforwardly supported in the main grid area, though they are directly represented in the secondary vertical keyboard display, which can be seen in Figure 4. Indeed, the main display of Harmony Space, by design, represents pitch and harmonic relationships using three spatial dimensions (Holland 1994). (One dimension is represented by color, as explained subsequently.) This three-dimensional relationship may indicate the existence of other, as yet unidentified, conceptual metaphors that could conceivably afford a better conceptual model for certain categories of users.

Figure 6. (a) An F major chord in root position. The F major chord in (b) is in first inversion: Shade represents octave height,

and the root note (F) is shown in a lighter shade than the other notes in the triad, as it is in a higher octave.



Certainly, analysis elsewhere (Holland 1989, 1992, 1994) indicates that the three-dimensional metaphor used in Harmony Space is rich in correspondences between source and target domains that appear well suited to helping beginners carry out diverse harmonic tasks. However, conceptual metaphor-based evaluation focuses primarily on a different issue. Specifically, given conceptual metaphors that are commonly found in the dialogue between potential users, how well are they supported by the design? Approaching the analysis from this point of view, it was found that the main display of Harmony Space only partially supports the conceptual metaphors for pitch revealed by analyzing the dialogues.

Interestingly, this finding motivated the designer to implement an additional secondary piano roll view to better support the more frequently found conceptual metaphors for pitch. As with the previous feature encouraged by conceptual metaphor-based evaluation, this was a previously planned, but not prioritized, feature.

A related finding from the evaluation highlighted how an interaction design may trade off one conceptual metaphor against another. Harmony Space uses color to indicate octave height in its representation of a third spatial dimension, as shown in Figure 6. In this way, the design trades off the conceptual metaphor HIGH PITCH IS BRIGHT/LOW PITCH IS DARK against HIGH PITCH IS UP/LOW PITCH IS DOWN. Awareness of such tensions between support for different conceptual metaphors led to a refinement to the evaluation process noted earlier. Namely, design evaluations should not simply identify where conceptual metaphors are supported, ignored, or contradicted; they should also try to identify where conceptual metaphors are traded off against each other.

Support in the design for conceptual metaphors associated with aspects of music other than harmony, such as pitch and musical silence, was less well defined. For example, the conceptual metaphors A REST IS AN OBJECT and MUSICAL SILENCE IS A BLOCKAGE TO MOVEMENT are not explicitly supported, for example, by spatial symbolism. This to some extent may limit the suitability of the tool for aspects of analyzing melodic movement. This is not surprising, nor is it a particular problem, given that Harmony Space is specialized for harmony.

GarageBand

GarageBand (www.apple.com/ilife/garageband) is an application that provides users with functionality to record and mix songs through both MIDI and audio, play with a pre-set up band, and learn to play instruments and songs. GarageBand is included with versions of Apple's iLife software that is provided with new Apple computers, and thus is available to a wide and varied user base. Images of GarageBand and further details on functionality it provides are available at www.apple.com/ilife/garageband.

The music played by each instrument in the band is displayed as a corresponding track in the central area of the user interface. The user is able to add and remove tracks and configure the instruments for tracks, in addition to applying a number of effects such as fade out, reverb, and bass boosts. As the music plays, the central window area automatically scrolls horizontally so that the user is able to see what is being played. GarageBand also provides the functionality to change the key, tempo, and time signature of the music.

Evaluation Results

Evaluating GarageBand using the conceptual metaphors identified in the earlier study reveals that the user interface supports a number of the conceptual metaphors either fully or partially through the behavior, layout, or components of the design. For example, the interface supports the conceptual metaphor A PIECE OF MUSIC IS CONTRUCTED FROM A NUMBER OF PARTS well by represent-

ing each of the parts as an audio or MIDI track. This layout also supports the associated conceptual metaphor A PIECE OF MUSIC IS A CONTAINER; in this case, the piece of music can clearly be seen as containing a number of parts.

GarageBand provides strong support for the conceptual metaphor A PIECE OF MUSIC IS MOVEMENT ALONG A PATH as the central area of the user interface scrolls horizontally while the piece is playing, allowing the user to see what is being played back at any point in time. The horizontal scroll is assisted by a vertical line that moves along the time axis, showing the current instant in time. However, support for the related conceptual metaphor HARMONIC PROGRESSION IS MOVEMENT ALONG A PATH is not directly available, particularly in audio tracks, as it is not possible to clearly see the chords changing as the piece progresses. Similarly, the conceptual metaphor A CHORD IS A CONTAINER FOR NOTES is not directly supported, although the variant A KEY IS A CONTAINER FOR NOTES is supported through the functionality of changing the key signature of a piece, which, in the case of MIDI tracks, automatically transposes the notes and updates the visual display to show the vertical change in the position of the notes.

The pitch-specific conceptual metaphors HIGH PITCH IS UP/LOW PITCH IS DOWN, DIFFERENCE IN PITCH IS SIZE, and DIFFERENCE IN PITCH IS DISTANCE are supported to an extent in the MIDI tracks and to a greater extent in the piano-roll view. Pitch is displayed vertically in both cases, though only in the piano roll view (where a piano keyboard is shown vertically beside the notes, effectively providing a delineated vertical scale) is it possible to identify the pitches. Therefore, differences in pitch can clearly be seen as vertical distances between notes.

The concept of a rest or musical silence is supported in GarageBand, albeit weakly, by a visual lack of MIDI note or audio information within the tracks, indicating that the music stops for a specified time. However, the conceptual metaphor MUSICAL SILENCE IS A BLOCKAGE TO MOVEMENT is contradicted by the very strong support for the metaphor A PIECE OF MUSIC IS MOVEMENT

ALONG A PATH in the form of the automatic scrolling, implying that there is no blockage, as the piece continues to move.

GarageBand provides no obvious support for the conceptual metaphor *KEY/CHORDS ARE RELATED TO THE TONIC*; because GarageBand is not specifically designed for the analysis of harmonic relationships, however, lack of support for this conceptual metaphor is not a specific problem.

Discussion and Comparison of Results

In discussing the results, we begin by analyzing the broad implications of the new approaches advocated, before reviewing their limitations and future prospects. Finally, we summarize the insights uncovered using these methods for specific music interaction designs.

Broad Contributions

The dialogue analysis in this article has provided further support for various musical conceptual metaphors identified by other authors (Salsaw 1996; Zbikowski 1997a, 1997b; Brower 2000; Eitan and Granot 2006; Eitan and Timmers 2010). Additionally, it has revealed a number of new musical-conceptual metaphors, for example *DIFFERENCE IN PITCH IS SIZE* and *DIFFERENCE IN PITCH IS DISTANCE*. We have also provided here a detailed methodology for the systematic identification of image schemas and conceptual metaphors for musical concepts, using a dialogue between musicians as the primary data source. In particular, we have devised an approach for using conceptual metaphors to identify potential improvements to musical interaction designs—particularly interaction designs for complex and intangible musical concepts, such as harmonic progression and harmonic relationships.

We have built on work by Hurtienne and Blessing (2007) and Hurtienne, Israel, and Weber (2008) that showed that image schema have potential as a means for illuminating basic design decisions in interaction design. We have also built on related work by Antle, Droumeva, and Corness (2008) and Antle, Corness,

and Droumeva (2009) that demonstrated advantages of using a conceptual metaphor approach for simple musical concepts such as tempo, volume, and pitch height. In particular, we have devised a systematic approach for analyzing image schemas and conceptual metaphors from dialogue between musicians, and applied the results to identify ways to improve interaction designs for complex and intangible musical concepts such as harmonic progression and harmonic relationships.

In general, conceptual-metaphor-based evaluation can identify design issues and problems of various sorts, including missed opportunities to apply useful conceptual metaphors, designs that elicit actively unhelpful expectations from conceptual metaphors (e.g., a slider with values “upside down”), and designs that elicit contradictory expectations from two or more conceptual metaphors. The seriousness of these issues depends on their degree and the tasks for which the design is intended.

In the case of the particular interfaces we have analyzed, serious design flaws were not found, but the evaluation identified design tensions, design trade-offs, design choices that favor certain tasks over others, and several specific opportunities to improve or vary the designs.

Limitations and Further Work

The shortness of the musical excerpt used and the small number of participants involved meant that the opportunities for eliciting additional conceptual metaphors were limited. A number of potentially valid conceptual metaphors were eliminated owing to infrequency of use. Although the excerpt of music chosen for the study was believed to be suitable in terms of the amount of melodic and harmonic content, a musical excerpt in a different genre would likely have elicited a different set of conceptual metaphors, reflecting the different structural and stylistic emphases.

Similarly, the excerpt was presented using common music notation. Different modes of presentation, such as audio, may well have elicited different conceptual metaphors by re-directing a musician’s attention. We propose future studies involving the use of alternative representation

Table 4. Comparison of Harmony Space and GarageBand

<i>Aspect</i>	<i>Harmony Space</i>	<i>GarageBand</i>
Primary User Group	Primarily aimed at novices but no barrier to expert use.	Primarily aimed at novice and intermediate users but no barrier to expert use.
Primary Tasks Supported	Harmonic analysis of existing musical artifacts and generation of new harmonic progressions.	Music generation and production, learning to play songs and musical instruments.
User Interface	Custom design based on theories of harmonic perception. Harmonic and pitch relationships are organized spatially. Time is represented by time, augmented by traces.	Similar layout to other music production software such as Logic Audio. Musical content is organized by time. Time is represented by horizontal distance.

formats such as audio, piano roll, or guitar tablature with the aim of establishing a catalogue of representation-agnostic musical conceptual metaphors.

The evaluations of Harmony Space and GarageBand were limited in that the focus was on the general aspects of the interaction model and did not take into account other influential factors such as the terminology used in their interfaces. Furthermore, the user interfaces were designed to support different tasks, a factor that necessarily affects the extent to which they support different musical conceptual metaphors. Table 4 provides a comparison of the contrasting focuses of the applications. The conceptual metaphor-based evaluation of user interfaces revealed possible limitations in the dialogue analysis stage that might be addressed in refined versions of this technique. For example, it would be useful in the dialogue-analysis stage to attempt to differentiate between temporal and spatial applications of conceptual metaphors, and to find ways to analyze and classify the relationships between them. Similarly, in retrospect, the analysis of the support of conceptual metaphors for pitch in the interaction designs suggests that future version of the dialogue-analysis process might benefit from fine tuning to avoid possible conflation of certain domain concepts (e.g., distinguishing between pitch height and pitch class).

In some cases, interaction designs may support conceptual metaphors that fit given tasks well and

facilitate good use of prior knowledge, despite those conceptual metaphors being absent in the dialogue between potential users. To help illuminate such cases, conceptual-metaphor-based evaluation might in future be extended to investigate the extent to which specific conceptual metaphors support the Invariance Principle. The extent to which support for particular conceptual metaphors is likely to facilitate the exploitation of particular areas of prior knowledge might be elucidated by considering the degree of correspondence between source and target domains.

Discussion of Results

Reviewing the results of both conceptual-metaphor-based evaluations, it is clear the software designers have made trade-offs in their support for specific aspects of music, based on the intended audience and the tasks for which the software is designed. In the case of Harmony Space, support for conceptual metaphors that are specifically concerned with harmony and harmonic relationships is strong, whereas conceptual metaphors based on linear pitch and musical silence are either less supported or unsupported. When considering GarageBand, more or less the reverse is true, although in some cases (that of silence, especially), the support could be considered indirect and a result of the implementation rather than a direct attempt to support the metaphor. In both cases,

support for the conceptual metaphor A PIECE OF MUSIC IS MOVEMENT ALONG A PATH is strong, though each application takes a different approach to the visual implementation of the conceptual metaphor.

A number of relatively minor enhancements were identified that could provide better support for some conceptual metaphors in the case of both user interfaces. For example, in Harmony Space, arrow tracing of chords could be added to improve support for the HARMONIC PROGRESSION IS MOVEMENT ALONG A PATH conceptual metaphor, and the grid could be rotated and reflected to provide an indication of octave height, providing some basic support for the HIGH PITCH IS UP/LOW PITCH IS DOWN conceptual metaphor. The first of these improvements, previously planned, was prioritized and implemented as a result of the evaluation.

In the case of GarageBand, a vertical axis indicating pitch could be added to the MIDI tracks, helping users identify the pitch of a note, and therefore providing a means with which to identify the chords being played, thus adding some additional support for conceptual metaphors relating to harmonic progression.

Conclusion

Using conceptual metaphors elicited from discussions among experts as a technique for establishing the extent to which existing music interaction designs support musicians' understanding of domain concepts has been shown to hold promise. We anticipate that by designing or refining musical interactions in this way, we can create intuitive interaction models for expert users, while at the same time providing appropriate affordances for novice users based on prior sensory-motor experiences, thus reducing their requirement for prior specialist-domain knowledge. Future refinements of this work might use conceptual metaphors of established value, in particular musical contexts as foundations for a toolkit of interaction-design patterns aimed at facilitating diverse, intuitive musical interactions.

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