Chapter 12
Song Walker Harmony Space: Embodied Interaction Design for Complex Musical Skills

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Abstract Tonal Harmony is widely considered to be the most technical and complex part of music theory. Consequently harmonic skills can be hard to acquire. Furthermore, experience of the flexible manipulation of harmony in real time generally requires the ability to play an instrument. Even for those with instrumental skills, it can be difficult to gain clear insight into harmonic abstractions. The above state of affairs gives rise to substantial barriers not only for beginners but also for many experienced musicians. To address these problems, Harmony Space is an interactive digital music system designed to give insight into a wide range of musical tasks in tonal harmony, ranging from performance and composition to analysis. Harmony Space employs a principled set of spatial mappings to offer fluid, precise, intuitive control of harmony. These mappings give rise to sensory-motor and music-theoretic affordances that are hard to obtain in any other way. As a result, harmonic abstractions are rendered amenable to concrete, visible control by simple spatial manipulation. In the language of conceptual metaphor theory, many relationships in tonal harmony become accessible to rapid, universal, low-level, robust human inference mechanisms using image schemata such as containment, contact, centre-periphery, and source-path-goal. This process is more rapid, and imposes far less cognitive load, than slow, abstract symbolic reasoning. Using the

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above principles, several versions of Harmony Space have been designed to exploit specific interaction styles for different purposes. We note some key variants, such as the desktop version, the camera tracked version, while focusing principally on the most recent version, Song Walker, which employs whole body interaction. Preliminary results from a study of the Song Walker system are outlined, in which both beginners and expert musicians undertook a range of musical tasks involving the performance, composition and analysis of music. Finally, we offer a discussion of the limitations of the current system, and outline directions for future work.

12.1 Introduction

One potential source of insights about tonal harmony comes from rhythm. The Victorian music educator Emil Dalcroze (1865–1950) noticed that his students showed little insight into musical rhythm if they lacked experience of enacting rhythms with their own bodies. Dalcroze proposed that students needed to become competent in physically enacting representative rhythms before they could achieve mastery of rhythm. Dalcroze's findings seem to be a special case of a more general phenomenon. Sensory motor contingency theory (O'Regan and Noë 2001) suggests that, in order to learn how to organize and respond appropriately to sensory input in some new domain or context, it is typically an essential precursor that the individual learner's motor actions should have the power to affect relationships in the domain being sensed. In this way, the learner can repeatedly experience diverse outcomes that they have themselves influenced. In situations where this very specific kind of active engagement coupled with feedback is absent, competency has been observed to fail to develop. This principle has been demonstrated in many different contexts and time scales (O'Regan and Noë 2001).

We posit that a similar situation exists for musical harmony. Skills in harmony are generally difficult to acquire, and are often taught abstractly via symbolic notation. Explicit understanding of harmony involves knowledge of many abstract entities, categories and relationships, which are associated with an extensive specialised vocabulary. We assert that students have little opportunity to gain insight into musical harmony if they lack experience of enacting and manipulating those harmonies with their own bodies – an experience which is scant or non-existent for many students. As with rhythms, simply hearing harmonies repeatedly, or studying them on paper, does not appear to be adequate preparation for insightful skill.

The conventional way to enact full musical harmony with one's body is by learning to play a polyphonic musical instrument. However, learning to play a conventional polyphonic instrument (e.g. a piano) competently typically takes months or years. Thus, there are substantial barriers to achieving the prerequisites for mastery of harmony, not only for beginners but also for many musicians. But not even polyphonic skills invariably grant the experience of flexibly manipulating harmony at will. For example, players who focus solely on playing from written notation do not typically develop the ability to manipulate harmonic sequences at will in real time.

A related point is that only a minority of musicians appears to gain a working insight into larger scale harmonic abstractions. There are numerous open-ended harmonic structures and strategies, some of which are generic, others which are specific to particular scales, tunings, idioms, composers, or pieces – yet few musicians gain mastery of manipulating such structures – i.e. composing or improvising insightfully with harmonic materials. Reflecting on the achievements of musicians as diverse as Bach and the Beatles, both of whom manipulated harmony in highly original ways (Pedler 2001), to miss out on creative manipulation of harmony is arguably to miss out on one of the deepest joys of music.

In this chapter, we address these issues by presenting a system that enables creative experiences with tonal harmony, facilitates the understanding of harmonic concepts and relationships, and promotes insights into how specific pieces work. More specifically, we consider ways in which interaction design can be harnessed to help both novices and musicians to get experience of shaping and manipulating harmonic sequences in real time, and to gain awareness of higher-level harmonic abstractions.

12.2 The Song Walker System Design

Harmony Space (Holland 1989, 1994) is an interactive digital music system designed to give beginners and experts insight into a wide range of musical tasks ranging from performance and analysis to composition. The interaction design, as we will outline below, exploits mappings from spatial movement to musical abstractions, through the mechanisms of conceptual metaphor (Lakoff and Núñez 2000; Zbikowski 1997; Wilkie et al. 2013) and conceptual blending (Fauconnier and Turner 2002). The specific principled spatial mappings employed offer novices precise intuitive control of harmony by exploiting intuitions about bodily movement and navigation. The result is that a wide range of harmonic abstractions are rendered amenable to concrete, visible manipulation via spatial navigation in different layers of the interface. In the language of conceptual metaphor theory (Hurtienne and Blessing 2007), relationships in tonal harmony become accessible to rapid, universal, low-level, robust human inference mechanisms using image schemata such as containment, contact, centre-periphery, and source-path-goal. This process is rapid, and imposes far less cognitive load, than slow, abstract symbolic reasoning. While keeping the above principles invariant, different versions of Harmony Space have been designed to exploit different detailed interaction styles for different purposes. The most recent version, Song Walker (Holland et al. 2011), employs a variant of whole body interaction. In short, this encourages users to engage spatial intuitions by physically enacting the control of complex harmonic phenomena.

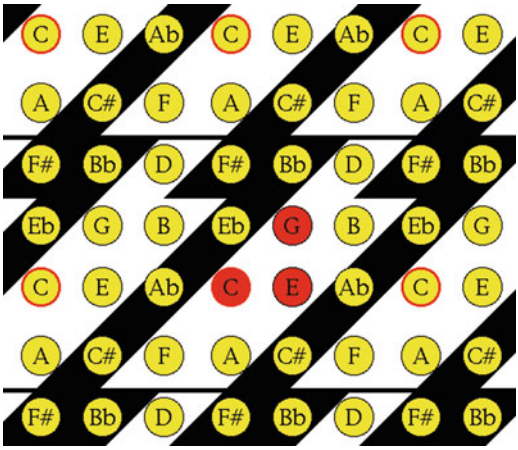

Fig. 12.1 Fragment of Harmony Space grid, highlighting a C major triad

12.2.1 Conceptual Metaphors

Harmony Space exploits a set of conceptual metaphors[1] that link concepts in tonal harmony to spatial concepts (Wilkie et al. 2009, 2010). The principal metaphors can be outlined as follows.

12.2.1.1 Pitch

- Different musical interval classes (octaves, semitones, perfect fifths, major thirds, minor thirds) correspond to steps in different directions in space.
- In particular, semitones, fifths, and octaves are at right angles to each other in the plane, and octaves lie vertically (i.e., on the z-axis).

These conceptual metaphors employ extensions of Longuet-Higgins' (1962) and Balzano's theories (1980) of harmonic perception, which may be seen as positing a three-dimensional image schema for tonal harmony.

12.2.1.2 Scales, Keys and Modes

- Common scales can be formed from the notes occurring in contiguous strips seven steps long in the fifths direction. Due to the repeating nature of the plane, these strips group into irregularly shaped two-dimensional areas (as illustrated in Fig. 12.1).

[1]Only the principal conceptual metaphors are noted here. For a more detailed discussion see Holland et al. (2011). An alternative but related kind of analysis uses conceptual integration (Fauconnier and Turner 2002).

- Key areas are scales spatially situated to represent "preferred territory" for journeys and chord elements within the diatonic scale (see the white area in Fig. 12.1).
- A modal centre is a privileged location within preferred territory, typically where journeys start, end or rest. In Fig. 12.1, the major or Ionian modal centre is ringed in red.

12.2.1.3 Chords

- Chord qualities are oriented geometrical shapes. Preservation of chord quality requires retention of shape and orientation. Altering the pitch of a fixed quality is change of location of the shape without rotation.
- The most common chord qualities, major and minor, correspond to the most frequent three-element chord shapes formed by the most compact shapes possible within the geometry of the most common scales.

12.2.1.4 Harmonic Movement

- Harmonic movement of a chord sequence is spatial trajectory.
- Composition is navigation, which may involve targets, directions, inertia, oscillatory movement and preferred territories.
- Tonal movement corresponds to trajectories along the diagonal from top right to bottom left or vice versa.
- Modal movement corresponds to trajectories along the diagonal from top left to bottom right or vice versa.

12.2.2 System Details and Interface

The Song Walker system employs whole body interaction through the use of dance mats, wireless controllers (Wii remotes and nunchuks), optional foot pedals, a large projection screen and a synthesizer. These are coordinated by a Harmony Space Server receiving data from controllers via HSP (Harmony Space protocol), a layer on top of OSC (Open Sound Control).

When played by a solo player (see Fig. 12.2), one dance mat is used to navigate a proxy for the player represented by a marker in the projected display. Squeezing the trigger on the Wii remote visibly and audibly plays the chord associated with the current location and situation.[2] When multiple players collaborate, additional

[2]The word "situation" here refers to the prevailing key and mode, but also to the default size of chords (e.g., triads, seventh, and ninth chords – also single notes and dyads) and to the particular chord vocabulary and voicing that is in play, and other factors. Players may choose which aspects of the situation to control dynamically during play. Other aspects are typically set for the duration of a piece.

Fig. 12.2 A solo activity, controlling Song Walker with dance mat and Wii remote

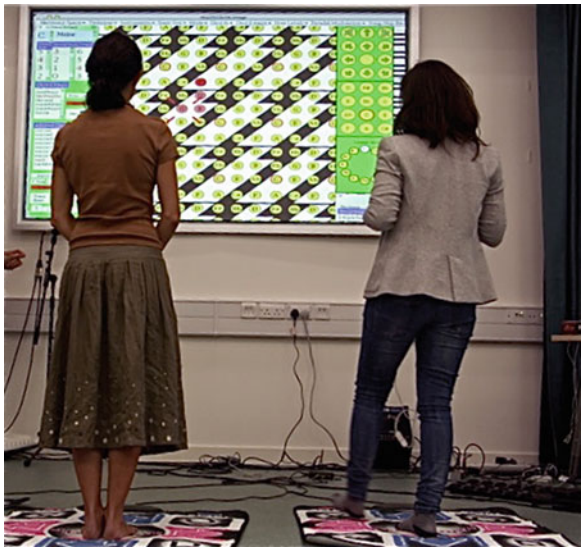

Fig. 12.3 Two players playing asymmetrical roles

dance mats and controllers (up to four) may be used in a variety of roles, e.g., to navigate key changes, to create harmonic inversions or otherwise alter the chords (see Fig. 12.3).

The Song Walker interaction design appears to offer affordances for experiencing and enacting the conceptual metaphors embodied in the multi-layered representation more directly than desktop versions of Harmony Space.

12.2.3 Asymmetrical Collaboration

Besides the potential advantages of whole body interaction for physical engagement with spatial phenomena, there are also potential advantages for the support of collaborative roles. Conventionally, when musicians collaborate to produce harmony, each musician contributes a single sounding part. For many purposes, this approach works well. However, in cases where players are novices, or where there is a desire to gain insights into the abstract structures of tonal harmony, an important drawback of this approach is that it leaves these abstractions intangible and invisible.

By contrast, in the case of Harmony Space, collaborative roles do not have to be split voice-wise (though this is readily supported), but may be split asymmetrically into heterogeneous spatial navigation and selection tasks, corresponding to abstractions of interest. For example, contrasting simultaneous asymmetrical roles available include the navigation of: the root path; changes of key; inversions and voicing; chord size; chord maps; altered chords; and bass lines. For playing many pieces of music, typically only two or three of these roles are required at a time. The combinatorial interplay of these factors yields the detail of harmonic sequences. When multiple dance mats are used, different colours are assigned to the visualization, so that each player can readily see what other players are doing.

12.3 Evaluation of Song Walker

To explore the potential of the Song Walker system for learning about tonal harmony, an evaluation study has been carried out. The focus of this study was on questions related to the embodied interface design, and issues related to collaborative learning.

12.3.1 Participants

16 people participated in the study. One participant did not fill in the questionnaire, so we present data of 15 participants – 8 women and 7 men, all adults aged 28–62, with an average of 36. Of these participants, ten were experienced musicians (with 5 or more years of experience), and five were beginners (with zero or very little experience). Participants varied widely in their self-reported knowledge of harmony, covering the whole range from absolute beginner (1) to expert (5), with a median of 3 on this scale of 1–5.

12.3.2 Setup

To support people using the system collaboratively, and to take advantage of the most important interface features, we developed specific musical tasks and instructions. The participants were asked to carry out three different tasks with the Song Walker system, working in pairs, with task instructions projected on the wall next to the Harmony Space projection. The tasks included the following:

1. Playing a chord sequence of a song;
2. Composing a new chord sequence;
3. Reharmonizing a chord sequence;
4. Analyzing chords and chord sequences;
5. Finding out about key tonality.

All participants were assigned task 1, and at least two other tasks. The exact number and types of tasks assigned depended on musical experience, user interest, and time available. Each session lasted at least 45 min, with approximately equal time allotted to each task. While this means that participants did not receive the same treatment, which may have affected the resulting experience, we believe the tasks had enough in common for all participants to get a working impression of the main functionality, interface, and conceptual basis of the system.

12.3.3 Results

12.3.3.1 Playing a Chord Sequence of a Song

After only a few minutes of training, all participants were able to play chord sequences of at least one well-known song to a recognizable degree (i.e., typically about four to eight chords per song). Songs played included Ticket to Ride (The Beatles, see Fig. 12.4), Isn't She Lovely (Stevie Wonder), Pachelbel's Canon, Giant Steps (John Coltrane), and Billie Jean (Michael Jackson). Many people had to resort to a tempo slower than the original song, though, and some had trouble with playing accidentally triggered chords, especially in the beginning. Participants were able to describe quite clearly what they had learned from this task, as the following quotes illustrate[3]:

"That harmonic structure can be realised in physical movements"

"Movements in chord sequences create very [definite] visual patterns"

[3]Note: wherever participants' handwriting was hard to read, we have indicated our most likely interpretation in square brackets.

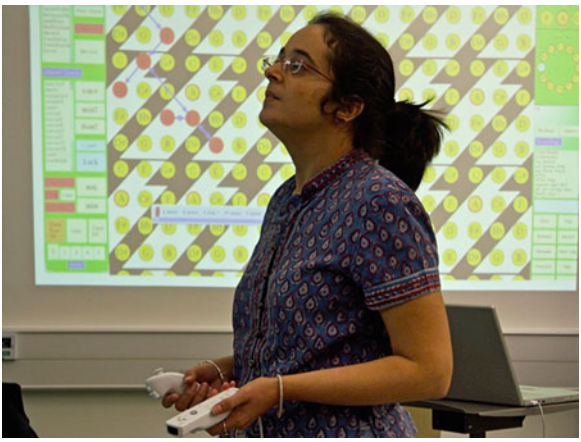

Fig. 12.4 Performing the Beatles' "Ticket To Ride"

12.3.3.2 Composing a New Chord Sequence

Regarding the open-ended collaborative composition task, all the participants who received this task succeeded in creating a chord sequence that they felt sounded good. Although part of the chord sequence was given, all pairs came up with unique chord sequence compositions. One pair of beginners spontaneously focused on inversions and explored these carefully, with much discussion. Another pair of users deployed altered chords in a similarly careful way to musically positive effect. Participants noted that they had learned the following from this task, among other things:

> *"Using economy of movement to great effect."*
>
> *"Mainly that you can create interesting chord (sequences) substitutions by thinking about what visual/spatial movements you want to make in Harmony Space (i.e. Diagonal vs. Vertical vs. Horizontal: each creating their own kind of substitution possibilities)"*

One person had drawn several shapes (i.e., two triangles, and a triangle with a vertical line upwards) to illustrate spatial movement of chords that she had learned as sounding good.

This task seemed to offer opportunities for musical experimentation, as suggested by the following quotes:

> *"To try stuff out to see what works"*
>
> *"Feeling free to really try and move from one chord to another"*
>
> *"Experimentation!"*

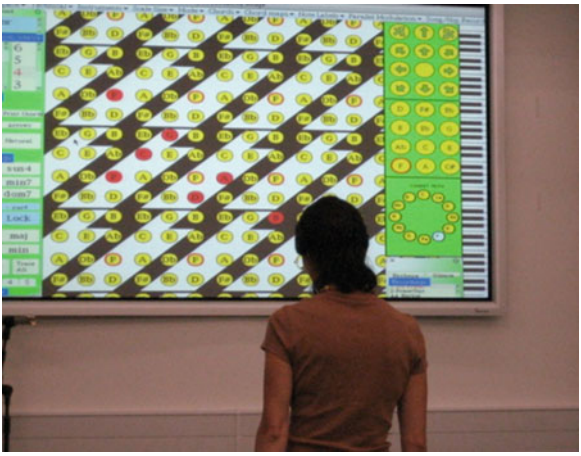

Fig. 12.5 Analyzing David Bowie's "Suffragette City"

12.3.3.3 Reharmonizing a Chord Sequence

All participants who received this task were able to create variations on the chord sequence (a common harmonic sequence in jazz) given below:

‖: **Cmaj7** | **Am7** | **Dm7** | **G7** :‖

This resulted in many (20) different variations overall, and led to lively discussions among the participants about strategies for which chord to change and how to search for possible substitutions.

The participants mentioned having learned the following from this task, among other things:

> *"The combination of both the visual + auditory input helped me understand how chords relate to each other."*
>
> *"The main point is that the spatial movements in the Harmony Space give me new metaphors, new ways of understanding relationships between chords"*
>
> *"Chord sequences can be [composed] as paths in a grid [system]"*

12.3.3.4 Finding Out About Key Tonality

Participants who were asked to harmonically analyse a piece, such as Suffragette City by David Bowie, were able to do so. This task required two steps. The first step was to identify the possible modes of the piece by physically shifting "territory" (the space-filling pattern of white and black areas underneath the chord roots played) by means of a dance mat (see Fig. 12.5). This allowed the visual identification of placements where the trace of the harmonic journey fell entirely within "permitted" (i.e. white) territory. The second step involved observing where chord journeys

tended to start and finish relative to the shape of the permitted (white) territory. These steps are complicated to describe verbally, but are straightforward to carry out as a practical, spatial task. One participant with some previous musical knowledge noted the following learning effect for this task:

> *"Reminded me that songs can sound both major + minor if the chord sequences leave out the 3rd (i.e. The main note that determines it as either major or minor)."*

Another participant noted having learned the following:

> *"Can see puddles of sound much more easily – cluster chords."*

12.3.3.5 General Comments

Several users commented on the degree of physical engagement they brought to the tasks. To illustrate this, one initially skeptical user was able to learn to play the complete harmony of Pachelbel's canon after about 10 min. Initially he said variously *"I haven't got this musically in my head at all"*, *"I don't have a sense of what's going on cognitively – how the visual representation is helping me remember it"*, and *"visually overwhelming"*. However, about 30 min later, having played several more songs, he commented, *"Love the kinaesthetic quality"* and *"Once you're used to it, you could dance songs"* (in the sense that Song Walker allows one to generate the harmony for a song by dancing to it).

Comments on the degree of physical engagement might be unremarkable in the case of, for example, arcade games, but are unusual in the context of tasks that are generally taught in knowledge-intensive ways using rule-based, symbolic, and quasi-mathematical approaches. Also, conventional approaches to learning these tasks generally take one or two orders of magnitude longer (i.e. weeks instead of minutes).

12.3.3.6 Questionnaire

To find out if people's views on harmony changed after interacting with the Song Walker system, the questionnaire included the following question:

> Before/After the experiment, did you consider the concept of harmony to be ... theoretical, practical, abstract, spatial, relating to physical movement, entertaining, dry, visual? (tick all that apply).

Compared to before the experiment, after the experiment, eight more people associated harmony with "relating to physical movement", seven with "spatial", five with "visual", and four with "entertaining"

To find out to what extent people liked the various tasks, we asked:

> How much did you like the task of ... using Harmony Space Song Walker? (1: I disliked it very much, 2: I disliked it a little, 3: I feel neutral about it, 4: I liked it a little, 5: I liked it very much)

Table 12.1 Likert scale results for the various musical tasks

Task	Median	Min	Max	N
1. Playing a chord sequence of a song	5	4	5	14
2. Composing a new chord sequence	5	3	5	15
3. Reharmonizing a chord sequence	4.5	3	5	14
4. Analyzing chords and chord sequences	4	3	5	7
5. Finding out about key tonality	4	4	5	5

This question was asked for the five different activities. The results are shown per activity in Table 12.1. The number of N differs per activity because not all participants carried out the same tasks (tasks 4 and 5 were only performed by seven and five people, respectively), and two participants did not fill in a score for tasks 1 and 3, respectively.

The results in Table 12.1 show that the participants liked all tasks more than a little, on average, with the first two tasks scoring highest (median score of 5), and the other tasks slightly lower (median scores of 4–4.5). Interestingly, the scores for how much they had liked a task were positively related to how much they felt they had learned from the task.

With respect to the interface, we asked how comfortable it was to use the interface. Participants scored a little above neutral, on average, although there was much variation for this question (Median = 4, Min = 1, Max = 4, on the following scale: 1: very uncomfortable, 2: a little uncomfortable, 3: neutral, 4: reasonably comfortable, 5: very comfortable). They responded that the feeling of comfort generally became a little better during the experiment.

They felt that the dance mat interface was a reasonably usable way to move around, change key, and play bass notes in Harmony Space, and they felt that the Wii remote interface was a more than reasonable way to carry out actions and make settings.

On the other hand, participants encountered several problems interacting with the dance mat, as indicated by reported issues related to keeping balance, changing feet, overshooting due to the small size of the mat, accidental presses, not being able to move fast enough to move smoothly, the mat becoming buckled up, and (sometimes) jumping notes or no response to the tapping.

With respect to the Wii remote and nunchuck, most participants did not encounter problems, except one, reporting on oversensitivity of the joystick.

The participants reported thinking this technology helped them in their understanding of harmony (Median = 2, Min = 2, Max = 3, on a scale of 1: Not at all; 2: A little; 3: A lot).

Participants' suggestions for improving the system included the following, indicating individual differences in preference for the interface modalities:

- adding a metronome (at a slow tempo);
- for a beginner, hide complexity;
- increase the size of the mat and move more functionality to it;

– interact directly with the representation, e.g., using a tabletop;
– move as much functionality as possible to the Wii remote and nunchuck;
– improve the visualization of "where you are";
– use the keyboard to the right of the screen to display chord inversions.

Overall, 13 out of the 15 participants enjoyed the experiment very much (Median = 5, the maximum score), with two participants scoring 4 (I liked it a little), on a scale of 1: I disliked it very much, 2: I disliked it a little, 3: I feel neutral about it, 4: I liked it a little, 5: I liked it very much.

12.4 Work in Progress

In order to further explore how experience of physically enacting and manipulating harmony can be linked to appropriate conceptual metaphors, we are in the process of developing versions of Harmony Space that will employ gesture-tracking devices such as Microsoft Kinect. Although frame rate and resolution are limited, the Kinect offers a useful complement to the architectural scale of the camera tracked Harmony Space system (Holland et al. 2009) and the detailed expressivity of Song Walker, while offering improved portability.

12.5 Conclusions

Implications of this work relate to the themes of this book in a variety of ways. Song Walker Harmony Space demonstrates in detail how spatial reasoning can be used to carry out complex tasks in tonal harmony that generally require formal symbol systems for their description, explanation and teaching. In this way, Song Walker suggests a candidate model for how the human cognitive system might take cognitive resources for dealing with the movement of the body or movements in the environment and reappropriate them to undertake the creation, manipulation and understanding of tonal harmony. Whether or not the human cognitive system generally approaches tonal harmony in this way, the present case study demonstrates in concrete terms that, with the right scaffolding, people can rapidly learn to reappropriate spatial skills to perform a range of harmonic tasks. More specifically, there are three implications for Music and Human-Computer Interaction. Firstly, Song Walker Harmony Space offers a useful case study in extended uses of conceptual metaphor in interface design (Hurtienne and Blessing 2007; Hurtienne et al. 2008) that is applicable to mainstream interaction design. This is noteworthy because the design makes extensive use of conceptual metaphors (Lakoff and Núñez 2000) and conceptual integration (Fauconnier and Turner 2002), two theories which have been relatively neglected as systematic tools for interaction design. Secondly, the work is suggestive of ways in which whole body interaction can help users

to operationalize spatial intuitions to take advantage of spatial metaphors applied in an interaction design. Finally, the work provides a case study of a family of tools for a complex symbolic domain where the interaction design is able to transform symbolic entities, relationships and rules into relatively simple spatial tasks amenable to low level spatial inference (Bird et al. 2008). Other case studies exist, but the present example is notable because of the highly complex, layered and abstract nature of tonal harmony.

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