Hearing with the eyes: A distributed cognition perspective on guitar song imitation

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Abstract

Many guitarists learn to play by imitating recordings. This style of learning allows guitarists to master both new songs and new techniques. To imitate a song, a guitarist repeatedly listens to a song recording until the entire song, or the desired portion of that song, can be reproduced by the guitarist. This kind of imitation can be a very difficult process particularly if the recorded guitarist plays fast and other instruments are involved. Besides the difficulty in *hearing* the guitar music, the many different ways to finger and articulate the same notes and chords on a guitar, can also make *playing* the music difficult. In this paper, we describe some of the knowledge guitarists use to minimize these difficulties. We then propose an external representation that guitarists can use to unload some of the cognitive burden imposed by the imitation process. This external representation — the bar chord — transform many of the imitation activities from those requiring both internal computations and memory to those that require the guitarist to merely look and see the desired results. Moreover, bar chords facilitate the social distribution of these individual benefits. This research contributes to the growing field of distributed cognition and to our understanding of both internal and external representations used during music learning and improvisation.

INTRODUCTION

There are many ways of learning how to play guitar. Among classical-style guitarists, the most common means of learning is by practicing sheet music — music encoded on paper in a standard notation — under the guidance of an instructor. The typical novice guitarist practices a piece for about a week, then visits the instructor for more fine-grained instruction. The instructor sits to the side of the budding guitarist, correcting mistakes, providing playing tips, offering encouragement, and at times administering a scolding. However, among guitarists, it is well-known that many of the founders of modern rock guitar (such as Jimi Hendrix and Eric Clapton) could not read standard music notation, viz., could not *sight-read*. Even today it is common to find well-known rock guitarists that cannot sight-read. Such musicians learned to play by imitating the guitar players on recorded songs.

This paper is an attempt to understand this unique kind of learning from a distributed cognition perspective. First, we describe the data collection method and the key features of the distributed cognition framework. This is followed by a short tutorial on the guitar and music. We then describe why imitating recorded music can be complex, followed by an analysis of some of the musical regularities and special knowledge that guitarist's possess which minimizes this complexity. Finally, we perform a cognitive analysis of an external representation — the bar chord — which can further reduce the complexity of imitating recorded songs, by transforming many of the imitation related tasks from "in-the-head" conceptual tasks into perceptual or "looking" tasks.

METHOD, BACKGROUND, AND REVIEW

This paper reports on a one and a half year study of rock-and-roll style guitar (hereafter, rock guitar) playing. Both authors are trained in classical guitar, have over five years of playing experience, and are proficient at sight-reading. However, rock guitar is very different from classical, in both training methods, techniques, and terminology. The primary author spent over a year and a half: (a) examining the available printed material; (b) interviewing guitarists from the undergraduate, graduate, and staff populations at Carnegie Mellon University; and (c) sitting in, whenever possible, in informal "jam sessions" with existing bands. Although we did not do a traditional field study, we believe the above activities provided the same end-result — an understanding of the guitar and music from the perspective of a rock guitar player.

The distributed cognition framework (Hutchins, 1995), was used to acquire further insights into the internal and external structures rock-guitarists employ during song imitation. Briefly, this framework views the boundary of cognition as dynamic and flexible; the boundary can expand beyond the individual's skull to include those external structures participating in a task's performance as cognitive structures, and not merely as inputs into a cognitive process inside the skull. Moreover, as Hutchins (1995) demonstrates, these external structures can act as more than just external memory. They can encode complex computations in their surface structure, which can transform certain tasks requiring internal memory and

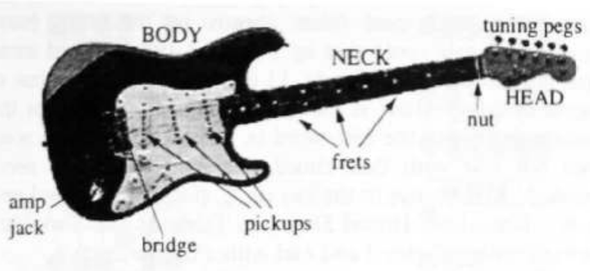


Figure 1. An electric guitar

processing, into tasks which instead use simple physical manipulation of external artifacts and the reading off of results. This framework focused our efforts on characterizing the cognitive consequences of external structures used by guitarists, such as the particular way the guitarists finger chords.

There is a surprising lack of studies on music imitation and improvisation. The key studies, are by Johnson-Laird (1988), Pressing (1988), and Sloboda (1985), who focused on characterizing internal processing capacity constraints on music improvisation. Johnson-Laird and Sloboda argue that the structure of improvised music is constrained (in terms of genres, song forms, and individual styles) so that less internal cognitive processing is required during performance time. However, neither Johnson-Laird (1988) nor Sloboda (1985) offer empirical evidence to support the view that improvised performances are so constrained or that cognitive capacity is limited. Pressing (1988) develops a psychological model of improvisation, but focuses on internal cognitive constraints on the process; external factors are not considered. This study both supports and augments these studies by focusing on how guitarists can *self-impose constraints* over song-form constraints by using external structures. Although this study focuses on external structures used during song imitation, the external structures described can also be used to facilitate guitar improvisation as well.

EXTERNAL STRUCTURES: GUITAR AND MUSIC

From a guitar player's perspective, the typical guitar consists of the following components (see Figure 1): six metal *strings*, attached at one end to *tuning pegs* located on the guitar's *head*, and attached at the other end to a *bridge* on the guitar's *body*. The guitar's head and body are connected via a *neck;* the neck is commonly divided into 19-22 different regions known as *frets*. Collectively, the frets make up the *fretboard*. The guitar body can be hollow, semi-hollow, or solid-body wood. Acoustic, and classical style guitars have hollow or semi-hollow bodies, and one or more *sound holes* which serve to amplify the sound of the vibrating strings. Electric guitars have solid bodies, and generate sound through a complex process: strings vibrating over one or more electromagnetic *pickups*, attached to the body, create an electrical signal which travels over a *cable* to an *amplifier* which finally converts the electrical signal into sound waves (see Figure 3).

Guitarist create music by playing individual notes, or combinations of notes known as chords. Guitarists play notes and chords by using their left hand to depress certain fret regions while their right hand simultaneously plucks or strum the strings along the body of the guitar. The guitarist can play 12 basic sounds (notes) — A, A#, B, C, C#, D, D#, E, F, F#, G, G# —and at least 3 different variations (or octaves) of the basic notes. Each guitar string is tuned to a different note E, A, D, G, B, and E (2 octaves higher than the first-E), so that plucking a string without pressing on the fretboard produces that corresponding note. Other notes are created by depressing strings over different frets, with frets closer to the body producing higher frequency notes than those close to the head (see Figure 2).

INTERNAL STRUCTURES: KNOWLEDGE FOR SONG IMITATION

In the typical imitation process, the guitarist alternates between two activities: playing and listening to a song fragment; and attempting to duplicate that fragment on the guitar (see Figure 3). The activities continue until the guitarist learns the entire song or the desired fragment. However, there are several factors which make the imitation process difficult.

First, on any given song, there are *multiple instruments playing* at the same time, e.g., a drum and a bass. The guitarist needs to learn how to identify the guitar independent of the other instruments. This may seem straightforward, but many modern guitarists attach special-effects instruments to their guitars such as fuzz, wah, and distortion, which can make it even more difficult to pick out the guitar parts in the recording. Even if the guitarist can pick out the guitar parts, a given note can be played on *multiple places* on the fretboard. Furthermore, there are

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
e	f	f#	g	g#	a	a#	b	•c	c#	d	•d#	*e*	*f*	*f#*	*g*	*g#*	*a*	*a#*	*b*	*c*	*c#*	*d*
B	*C*	*C#*	*D*	*D#*	e	f	f#	•g	g#	a	•a#	b	c	c#	*d*	*d#*	*e*	*f*	*f#*	*g*	*g#*	*a*
G	*G#*	*A*	*A#*	*B*	*C*	*C#*	*D*	•*D*	e	•f	f#	g	g#	a	a#	b	c	c#	d	d#	*e*	*f*
D	D#	*E*	*F*	*F#*	*G*	*G#*	*A*	•*A*	*B*	•*C*	*C#*	*D*	*D#*	e	f	f#	g	g#	a	a#	b	c
A	A#	B	C	C#	D	D#	*E*	•*F*	*F#*	•*G*	*G#*	*A*	*A#*	*B*	*C*	*C#*	*D*	*D#*	e	f	f#	g
E	F	F#	G	G#	A	A#	B	•C	C#	D	•D	*E*	*F*	*F#*	*G*	*G#*	*A*	*A#*	*B*	*C*	*C#*	*D*

Figure 2. Sideways depiction of the first 22 keyboard frets with the 12 different tones superimposed (double vertical lines indicate where the nut is). Column headings denote fret numbers. The top row corresponds to the frets under string 1, with the last row string 6. Different octaves of the same note are depicted with different fonts, e.g., the E note is represented 4 different times (E, *E*, e, *e*). Note the redundancy; *E* can be played on the (12th fret, 6th string), (7th fret, 5th string), or (2nd fret, 4th string). Bulleted frets cells depict notes in the C pentatonic scale.

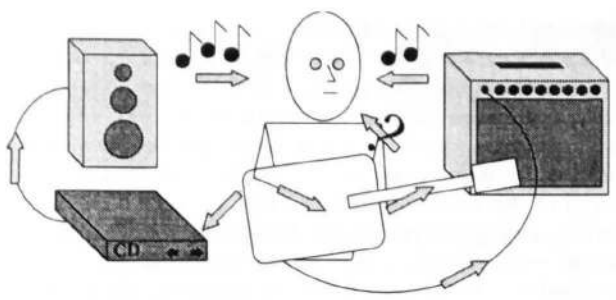


Figure 3. The guitarist's typical setup for imitating a recorded song. The arrows denote trajectories for moving information across different media. The guitarist uses the left-most loop to move a song fragment into memory. The rightmost "loop" is used during the imitation process. The arrow with the question mark denotes a possible visual pathway that can be exploited to assist the imitation process, a central topic of this paper.

multiple ways to play a note. For example, a given note may be played soft, loud, or dampened (palm-muted); or it may be sustained for several beats with or without a tremolo. Moreover, instead of simply depressing a fret location, a guitarist may depress a lower fret location and move the string sideways, an action known as *bending*. Bending simulates playing a higher fret location (for example, instead of playing a "**b**" by depressing the 7th fret, 1st string; a guitarist can depress the string over the 5th fret, an "**a**", and bend up to a "**b**"). Finally, most songs have a complex and *lengthy melody*, and reproducing the melody requires that the guitarist remembers a lengthy sequence of notes (see Table 1). Assuming all the notes and chords are heard and remembered correctly, the guitarist must still get the *timing* right; the notes and chords must be played, in the correct sequence, with a certain temporal spacing, and for a certain length. The following sections look at some of the ways guitarist work around these difficulties during song imitation.

Knowledge 1 & 2: The importance of chord changes and the song's key

Non-musicians think of the changing melody as the defining characteristic for a song. However, guitarists view a song's chord changes as its defining characteristic and thus focus on imitating chord changes instead of melody changes. An analysis of 45 Jimi Hendrix song transcriptions in the Internet guitar archive (ftp.nevada.edu), show that 31 of the songs included chord changes, and no explicit melody transcriptions. Imitating chord changes, instead of melody changes, has important implications for what needs to be remembered. A song can have a fairly complex and changing melody, but the chord changes underlying the melody are less complex. Consider the common nursery song "Twinkle twinkle little star" (hereafter, Twinkle*) by Hayden in the key of C (see Table 1). This song uses only three chords: C, F, and G. However, the melody uses six of the seven notes in the C-major scale. A song in the key of C means that C is the root sound. The root sound gives the song a sense of completion, and most other chords in the song move towards the root (note that in Twinkle* the C chord more than double the other chords, 11 out of 20). The notion of "sense of completion" is difficult to operationalize, but the analogy is that of the last word in a sentence. If the song does not end with that chord, the song does not seem finished. Most songs in the key of X, start off in X and end in X. Thus, both Hound Dog (see Table 2) and Twinkle* start off with a C chord and end with a C chord.

Table 1. Twinkle Twinkle Little Star by Hayden (in the key of C)

Chords	C F C G C G C
Melody	c c g g a a g f f e e d d c
Lyrics	Twinkle twinkle little star, How I wonder what you are
Chords	F C G C F C G
Melody	g gf f e e d g g f f e e d
Lyrics	Up above the world so high, Like a diamond in the sky
Chords	C F C G C G C
Melody	c c g g a a g f f e e d d c
Lyrics	Twinkle twinkle little star, How I wonder what you are

Table 2. Hound Dog by Elvis Presley (in the key of C)

Chords	C
Melody	d# d# d# d# d# d# c c d# g a c c
Lyrics	You aint nothing but a hound dog, Scratching all the time
Chords	F C
Melody	d# d# d# d# d# d# c d# d# g a c c
Lyrics	You aint nothing but a hound dog, Scratching all the time
Chords	G F C
Melody	d# d# d d d d d d d d d# d d c c
Lyrics	You aint never caught a rabbit & you ain't a friend of mine

One may think a rock and roll song is more complex than a common nursery song, but when comparing Hound Dog, by Elvis Presley with Twinkle* by Hayden, the complexity of the nursery song becomes apparent. Like Twinkle*, Hound Dog utilizes only three chords (C, F, G), and five different tones (c, d, d#, g, a). However, the chords change less often six times for Hound Dog (C, F, C, G, F, C) as opposed to twenty times for Twinkle Twinkle Little Star (C, F, C, G, C, G, C, F, C, G, C, F, C, G, C, F, C, G, C, G, C). In either case, the guitarist can reduce the memory requirements for imitating a song, by only imitating chord changes.

Knowledge 3: Many songs conform to standard chord progressions (I-IV-V)

The imitation task is further simplified by the following regularity: many rock and roll songs, and almost all blues style songs, follow a I-IV-V progression. For example Hound Dog is in the key of C, which means that the root chord is C. Assign C the value one (usually written as the roman numeral, I). Counting up, D would be assigned a two (II), E three (III), F four (IV), G five (V), A six (VI), and B seven (VII). Hound Dog's chord changes only involve C (I), F (IV), and G (V). Thus, it is a I-IV-V progression, even though the actual changes do not go strictly from I to IV to V. Twinkle* is also a I-IV-V progression. Thus a guitarist can classify songs based on chord progressions, further reducing the memory requirements for imitating a song.

Furthermore, during the initial stages of imitating chord progressions, knowing the key and a set of standard chord

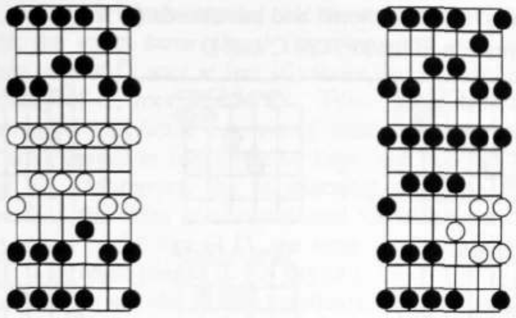


Figure 4. Two commonly used pentatonic scales in the key of A. These scales are represented as lightly-filled circles. The dark-filled circles denote other pentatonic scale members redundantly distributed across the fretboard. Almost all these notes sound "good" when improvised over a I-IV-V progressions.

progressions reduces the space of chords that need to be tried. Given that the guitarist has determined one of the chords, be it the I, IV, or the V, the next possible chord is limited to one of the other two chords. As a final note, space limitations only allow us to describe one of the common chord progressions, I-IV-V. There are also many other progressions such as the ii-V, I-vi-IV-V, and also regularities in changes *between* these chords that reduces the space of chords the guitarist has to consider during the imitation process. However, the basic idea is the same. Given that the guitarist knows: the song's key, has categorized the song as fitting a common progression, and knows at least one of the chords, the next chord is likely to be one of the remaining chords in the chord progression. Thus the decision space for the chords which the guitarist should try is reduced.

Knowledge 4: Pentatonic scales and Improvising

The typical rock song includes a guitar solo, which guitarists often imitate in addition to the chord changes. The guitar solo is usually played over a song's chord changes and substitutes for the melody line. Guitar solos, if imitated at all, are usually learned after the chord changes. When quizzed as to why, one informant explained: "Because you need to know the key the song is in." Recall that the key is usually associated with the last or first chord in a song. Once the key is known the guitarist can usually count on the solo's notes coming from a *pentatonic scale* whose root note is the same as the song's key. In the key of C, those notes are C, D#, F, G, and A# (see Figure 1); in the key of A, they are A, B#, D, E, G (see Figure 4). However, guitarist do not normally think of the pentatonic scale as a particular collection of notes. Instead they view the pentatonic scale as a particular pattern on the fretboard of the guitar starting on a given fret (see Figure 1 for a pentatonic scale in the key of C, starting on fret 8). This same pattern is transposable to other keys as well, thus eliminating the need to remember different scales for different keys. For example, the pentatonic scale in A is the exact same pattern as C, only shifted up 3 frets (starting on fret 5). As another example, the pentatonic scale in the key of D is the exact same pattern but shifted down two frets (starting on fret 10). Another interesting scale property, relevant to improvising, is that most of the notes in the scale sound good over the chord changes. Even a random selection of notes from the correct pentatonic scale sound good. This reduces the spaces of notes that have to be tried during improvisation, and can hide errors which the guitarist makes during improvisation.

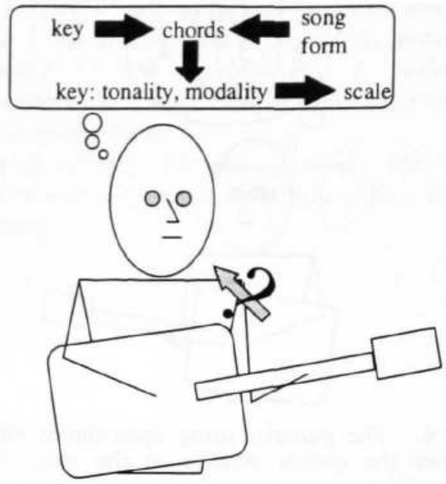


Figure 5. Some of the key pieces of knowledge possessed by rock guitarists. Can these structures be distributed?

Many guitarists do not imitate a song's guitar solo. Instead, the guitarists improvise their own solos by playing notes from a pentatonic scale. In fact, most guitarists think of improvisation as simply playing the correct scale over a sequence of chord changes. For rock and roll and blues songs, knowledge of pentatonic scales and a song's key is usually sufficient for improvising. However, with more complicated songs, a guitarist needs to know: (a) the tonal center of the song; and (b) the modality of the song. Collectively, these two items denote the song's key, which subsequently constrains different kinds of scale patterns.

RE-DISTRIBUTING COGNITION: CHANGING THE SONG IMITATION TASK INTO A LOOKING TASK

A central imitation activity is determining chord changes. The chord changes constrain a key, which in turn constrains a scale, which can then be used for improvising or to help with imitating a guitar solo (see Figure 5). Moreover, the rock guitarist can rely on most songs belonging to a set of common chord progressions, such as the I-IV-V. What was not discussed was how guitarists determine the other chords in a progression once the key (again, usually the first chord in a song) was known. Take for example, a I-IV-V progression in the key of C. By definition, the I-chord is a C-chord, but how does the guitarist determine that the IV chord and V chords are F and G, respectively. One way is for the guitarist to mentally count upwards from C. Alternatively, the guitarist can also memorize all twelve I-IV-V patterns. Both approaches can be difficult, the former requires internal computing effort while the latter requires memory (see Figure 6). However, an alternative approach based on

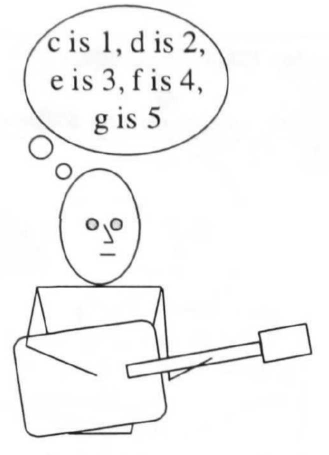


Figure 6. The guitarist using open-chords either has to remember the chords relative to the root, or mentally calculate them.

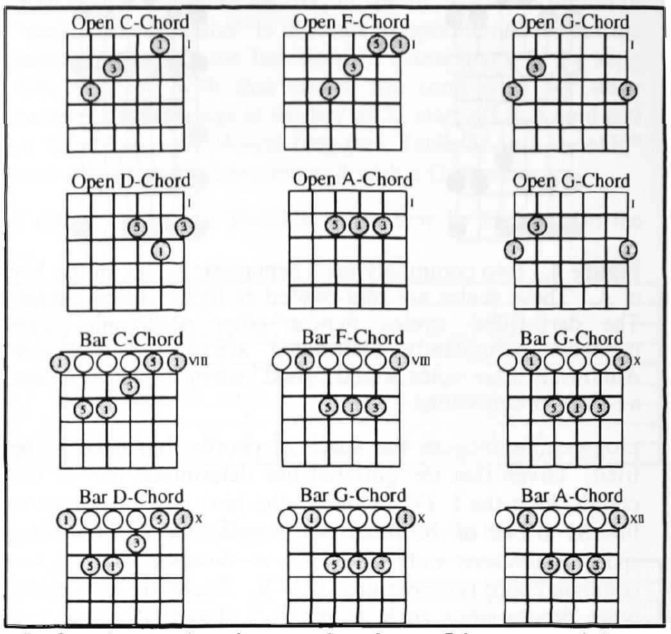
the distributed cognition framework, is to redistribute the cognition so that instead of relying on internal computations or internal memory, the task is transformed into one where more perceptual mechanisms are employed. Fortunately, the structure of the guitar's fretboard allows such a redistribution of cognition. To understand this redistribution, consider the use of open-chords versus bar chords.

Guitarists typically learn only the open chords when they start playing. Such chords are fingered within the first five frets of the guitar, and they are used by novices because they are easier to form than bar chords (see Figure 7, rows 1 and 2). Note how the root chord in the key of C (Figure 7, row 1, col 1) looks different from the root chord in the key of D (Figure 7, row 2, col 1). If a song does not follow the rule of the "first or last chord being the key," then there is no visual indication of the root. The guitarist must rely on the internal notion of "sense of completion" to determine the key. Moreover, the guitarist must memorize 12 different open-chord fingerings and given a root chord (I), must mentally calculate, or remember what the IV and V chords are for all twelve keys.

Bar-chord benefits 1 and 2: Seeing the root, and looking where the other chords should be

Consider, however, the use of bar-chords. There are two basic types, root-6 bar chords (see Figure 7, rows 3 & 4, col. 1), and root-5 bar chords (see Figure 7, rows 3 & 4, col. 1 & 2). Bar chords typically use the index finger to depress all the strings on a given fret, while the other fingers depress lower fret regions (see Figure 7, rows 3 and 4). Note how the root chord in the key of C (Figure 7, row 3, col. 1) looks the same as the root chord in the key of D (Figure 7, row 4, col. 1). Besides a structural regularity for the I-chord, the use of bar chords also introduce a spatial regularity. The four and five chords, however, look the same in both keys (Figure 7, rows 3 & 4, cols. 2 & 3). Thus, the guitarist does not need to remember different fingerings for the IV and V chords; only their bar location — the fret where the index finger makes a bar — changes.

Figure 7. Open-chords and bar-chords for a I-IV-V progression in the keys of C and D



In fact, by moving the root-6 and root-5 bars up and down the frets all 12 different possible chords can be generated, thus the guitarist only needs to remember 2 chord fingerings. Now one may complain that the guitarist still needs to remember the 12 different locations to place the bar for the 12 different chords. However, the fretboard imposes some spatial regularities which reduce the guitarist's need to remember where to place the bar chord. The IV chord is always to the left of the I-chord, and the V chord is always two frets below the IV chord. There are other spatial regularities for the other nine chords. Thus, given a key, the guitarist can rely on these spatial regularities, and just look and see where the other chords should be.

Finally, this spatial regularity means that given that the guitarist knows the key (root-chord), the guitarist can dispense with remembering the labels (C, F, G) for the various chords. The IV chords is just a position to the right of the root-chord, and the V chord is just a position to the right and down several frets from the root chord.

Bar-chord benefit 3: The similarity of external and internal representations

There are other benefits to using bar chords. To see this, consider a song with a I-IV-V chord progression (e.g., "Wild Thing" by the Troggs), played in both the keys of C and D. Most listeners will immediately recognize that the songs are the same, except that one (key of D song) sounds "higher" than the other (key of C song). However, the I-IV-V *open-chords* in the key of C, look very different from the I-IV-V *open-chords* in the key of D (see Figure 7, rows 1 and 2). This difference of open-chord appearance contradicts a person's internal sense that the songs are similar. Moreover, the relationship between the songs — that one sounds "higher" than the other — is not preserved when using the open chords. However, when using bar-chords, the exact same chord fingerings are used except that one (key of D, root at fret 10) starts two frets below the other (key of C, root at fret 8). Thus, using bar chords preserves an individual's sense of similarity between the same song played in two different keys (see Figure 7, rows 3 and 4). Moreover, the relationship that one sounds higher than the other is also depicted visually when using bar chords; in the key of D, the song is played two frets higher than when played in the key of C.

Lastly, there are also social implications from using bar-chords. For example, a guitar teacher that uses bar-chords makes the regularities and benefits described above available to the student. As another example, take a guitarist "sitting in" — a guest musician — during a jam session. If the guitarist sitting in forgets the chord changes to a song, and there is another guitarist in the band using bar chords, then the guitarist sitting in can watch the other guitarist for a while and more easily see what the chord changes are. Both examples illustrate how externally observable representations can provide social benefits as well.

SUMMARY

Guitarists can rely on both internal and external structures to help them imitate songs. The data from our study suggests that guitarists first imitate a song's chord progressions. The chord progressions define a key, which then constrains a scale which can be used either for improvising or to facilitate imitating the song's guitar solo. The imitation process can be difficult, but this difficulty can be alleviated by using the proper external structures. we proposed one such external structure, the bar chord, and showed how the bar chord could transform many of the imitation subtasks from ones which require internal processing and memory, to subtasks which involve merely looking in the world and reading a solution off the guitar's fretboard. Moreover, because bar-chords are visually available to other guitarists, they can facilitate learning and remembering in a social context, such as during a band jam session. We hope our research encourages others to understand naturally occurring cognitive activity as a distributed phenomenon.

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