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Looking for the “Harmonic Inversion Effect”: The Impact of Musical  
Expertise on Memory for Retrograde and Inverted Harmonies

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A thesis submitted in partial fulfillment of the requirements for the Degree of  
Bachelor of Arts with Honors in Psychology

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## Abstract

Yin's (1969) study of the "Face Inversion Effect" revealed that most humans rely on a unique form of processing when encoding the particular "gestalt" of typical, upright faces, which in turn interferes with their encoding of inverted faces. We investigated whether this interference effect generalizes to the auditory (specifically, musical) domain, hindering memory for "atypical" (inverted and retrograde) stimuli. In the training phase of Experiment 1, participants heard tonal, forward-moving harmonic sequences, and backward (retrograde) versions of the same type. In the subsequent test phase, participants heard a set of sequences, half new and half old, and we assessed their memory of the items. We found that musical experts consistently remembered the items more accurately than novices, and that forward progressions were generally remembered more accurately than backward progressions. However, we found no interaction between expertise and direction on memory for the sequences. In the training phase of Experiment 2, participants heard tonal harmonic sequences and inverted (upside-down) versions of the same type. In the subsequent test phase, we again assessed their memory of the items heard in the first phase, using the same general procedure as in Experiment 1. We found a significant main effect of expertise on accuracy, but no main effect of orientation, and no interaction between expertise and orientation. Our overall findings suggest that musical experts are better at encoding chord progressions than non-musicians, and that forward progressions are easier to remember than backward ones. However, experts do not seem to be relatively worse at remembering backward or inverted progressions than forward or upright ones, compared to non-experts.

## Introduction

*Expertise and Categorization*

Expertise in a particular domain can dramatically impact cognitive processing of items and patterns that play an important role in that domain. People who are relative experts in a certain area, such as painting, music, chess, fashion design, gastronomy, or chick-sexing, may possess the ability to perceive much more precise distinctions between colors, pitches, configurations of chess pieces, fabric textures, or flavors, respectively, than the average non-expert (Biederman & Shiffrar, 1987; Winawer et al., 2007).

The puzzle of chick sexing—the art of categorizing day-old chickens by sex—has provided much insight into the effects of expertise on categorization. This skill is known to be very rare, and it strangely occurs in a disproportionately large number of Japanese farmers, compared to farmers from the rest of the world (Biederman & Shiffrar, 1987). It requires an understanding of subtle perceptual distinctions between the anatomy of male and female chicks. However, Horsey (2002) argues that chick-sexing is not particularly unique in its demand for knowledge of subtle cues. He points out that the world's expert chicken sexers come almost exclusively from Japan not because there is something inherently or genetically superior about those farmers' skills, but because they happened to develop a very efficient way of training people to internalize these crucial but subtle perceptual cues, thus enabling these people to recognize and pick out the most important features at a seemingly subconscious level. Similarly, most humans are actually experts at many categorization tasks, particularly those they accomplish very frequently, simply because they have familiarized themselves, over time, to direct their attention to subtle perceptual cues that distinguish the most important features of different category members from each other

(Tanaka & Gauthier, 1997; Winawer et al., 2007; Dror, Stevenage, & Ashworth, 2008).

Biederman and Shiffrar (1987) tested these ideas empirically, finding that over the course of their experiment, novice subjects could be trained to correctly categorize pictures of day-old chickens as either male or female, with a level of accuracy close to experts', simply by being told which critical aspects of the images to focus on. Crucially, the participants could not detect any differences between pictures of male and female chicks' genitals before the experiment, since this skill is known to be almost impossible for novices. However, a simple training session, in which they were taught which specific component of the images to look for, increased their accuracy rates tremendously. This study demonstrated that a small amount of perceptual learning—stemming from just a bit of guidance in visual organization—was sufficient to train novices to categorize chicks similarly to experts. Thus, context and very minimal knowledge of subtle perceptual cues were the critical factors in improving novices' overall understanding of the distinction between male and females, and their performance on a previously elusive and daunting task.

Not surprisingly, when the differences between these crucial perceptual cues—or features—are exaggerated, as in a caricature drawing, people tend to learn to distinguish stimuli more efficiently. For instance, Rhodes, Brennan, and Carey (1987) found that caricatured images of familiar faces were recognized with equivalent rates of accuracy but in significantly less time than undistorted versions of these same faces. This trend has been found to persist whether contour line drawings of faces (Stevenage, 1995) or high-resolution images of photographic quality (Benson & Perrett, 1991) are used. Similarly, Dror, Stevenage, and Ashworth (2008) found that when people are trained to recognize aircrafts using caricatures of various types,

which maximizes the visual differences between them by drawing attention to the most crucial perceptual cues that distinguish them, people tend to learn to categorize actual images of these aircrafts more effectively than when caricatures are not used. This effect is larger for more similar stimuli, thus mirroring the chicken-sexing study in its optimization of cue teaching to help people distinguish almost-identical images.

Researchers have found that training, familiarity, and even language can have profound effects on the boundaries between perceptual categories. For example, in the realm of color perception, Winawer et al. (2007) found that because of a significant linguistic division within the Russian category for “blue,” native Russian speakers were actually faster at recognizing distinctions that crossed the border between darker blues (“siniy”) and lighter blues (“goluboy”) than distinctions within the two categories. In other words, Russian speakers, being relative “experts” at naming those separate shades of blue, had essentially developed a tendency to perceive the two types of blue as distinct categories—a clear effect which was not reflected in native English speakers’ perceptual categorization of blue.

#### *Expertise and Non-Musical Chunking*

Like perception, memory can be significantly impacted by various forms of cognitive reorganization and optimization. Chunking, one such form of reorganization, involves adding together small elements of a list, picture, or series of items in order to minimize the number of pieces stored in memory. Chunking has been studied extensively, particularly in the context of expertise in playing games (de Groot, 1978; Chase & Simon, 1973; Charness, 1976; Gobet et al., 2001; Gobet, de Voogt, & Retschitzki, 2004). This process is often used most effectively by experts because they understand the relationships between items within a chunk, and can thus

group them together based on these relationships.

Chase and Simon (1973) famously found that chess masters could remember novel configurations of chess pieces more accurately than novices, since they efficiently chunk the configurations into meaningful, complex sections, based on their knowledge of chess rules and moves, and thus do not need to encode the individual location of every piece separately. Crucially, chess experts *only* demonstrated superior memory for configurations that were relevant to patterns and strategies typically found in games of chess; for random configurations of chess pieces, the experts' encoding skills plummeted, and their recall scores were not significantly better than novices'. Thus, experts appear to maximize their short-term memory storage capacity by using their knowledge of relevant positions and moves to minimize the number of separate items stored.

#### *Expertise and Musical Chunking*

In the field of music cognition, researchers have also attempted to discern the ways in which musicians' perceptual expertise and explicit knowledge of tonal rules might shape their experiences of music—especially chordal harmony. While learning about the structures inherent in music, student and professional musicians gradually form schemas, learning to group pitches into cognitive categories of chords, which are then grouped or chunked within a larger musical passage (Huron, 2006; Deutsch, 1980; Halpern & Bower, 1982; Lerdahl & Jackendoff, 1983).

Huron's (2006) probabilistic theory about the organization of harmonic schemas is based upon the relative probabilities of various chords (i.e., the probability that a given chord will follow some antecedent chord in a particular instance instead of the absolute probability of a full chord progression occurring). Thus, by

probabilistically mapping and weighing the relative occurrences of a tonic chord following a dominant (very likely), versus a diminished seventh followed by a major fourth (much less likely), it is possible to develop a cognitive, schematic diagram in which various harmonies are mentally connected to each other. The strength of these mental connections is weighted according to the probability of those chords occurring adjacent to each other. Different genres of music have different harmonic tendencies and can therefore be represented by different mappings. This theory potentially suggests, but does not clearly demonstrate, that these relative thicknesses add up to a form of chunking, in which related chords are most often grouped together within typical, tonal contexts that fulfil chord-by-chord expectations.

In a 1980 article, Deutsch describes two experiments that provide evidence for the strength of cognitive schemas, and the use of hierarchical chunking in the memorization of tonal sequences. Musically trained listeners notated each sequence after it was presented, and the accuracy of their notations revealed strong effects of sequence structure. Those sequences containing a tonal structure, which could be efficiently encoded in a hierarchical manner or which clearly outlined a contained harmony, were remembered much more easily, with fewer errors in notation, than those that were more randomly organized and could not be chunked into smaller, cognitively salient groups. In a second experiment, when pauses were added *within* harmonically-related groups, dictation performance was much worse than when these pauses only occurred between groups. So, there was a significant effect of temporal segmentation on performance, as well, showing that temporal proximity (and rhythmic grouping of notes based upon their harmonic relationships) can also aid this chunking procedure. These results show that we encode tonal, harmonic information by inferring—even if implicitly—inherent sequential structures in order to more

efficiently remember them, and that our memory can be aided by temporal segmentation that is harmonically-related, and disrupted by temporal segmentation that is not.

Levitin (1999, p. 297) suggests that musicians remember chords more easily than non-musicians, and excel at melodic dictation tasks (in which students are asked to write down music as they hear it), since they have learned to identify multi-note harmonies with just a single label (i.e., dominant seventh, or minor tonic) and thus do not have to remember three or four individual pitches at a time. Also, he theorizes that musicians—particularly those trained in theory or on a chordal instrument—plausibly chunk entire sequences of chords into meaningful segments to separate them out from a larger progression, since they have learned about typical chord order and have strong expectations for which chords come after others at a cadence. This way, even if one piece of a chunk is missing or falsely remembered, the listener still has a description of the holistic nature of the progression, and can thus make an educated guess about the chords in the chunk. Halpern and Bower (1982) have provided empirical evidence for this theory, as applied to melodies instead of harmonies. They found that although musicians were able to recall typically-structured melodies significantly more accurately than non-musician novices, the two groups' mean scores were not significantly different for randomly-structured melodies. This result demonstrates that experts' ability to parse melodies into meaningful chunks disappears when the melodies are randomly structured, due to the breakdown of the musicians' structurally-based tonal expectations.

*Yin's "Upside-Down Faces" Paradigm*

In 1969, Yin found that not only is human memory generally much more accurate for upright faces than inverted ones, but that this upright advantage is disproportionately larger than when other complex objects—such as houses, airplanes, and stick figures in motion—are used as stimuli. The unnatural inversion of faces, then, seems to produce a particularly strong interference effect on memory. This finding is rather surprising, since those other complex objects are, like faces, viewed most often in the upright position, and have a typical, complex configuration of features. For example, whereas a face typically has two eyebrows, two eyes, a nose, and a mouth, a house typically has a door, a couple of windows, a roof, and a chimney. The fact that memory for faces is disproportionately affected by inversion seems to indicate that humans have an elevated level of expertise for faces that does not generalize to objects with which they are less familiar. Importantly, it is potentially not specifically the *social* nature of these objects, but more generally, the fact that they are related to a particular type of expertise that most humans possess (Tanaka & Gauthier, 1997; Gauthier & Tarr, 1997b; Gauthier, Tarr, Anderson, Skudlarski, & Gore, 1999; Wong, Gauthier, Woroch, DeBuse, & Curran, 2005), which makes people more likely to efficiently encode the faces using a special technique. The results of this experiment suggest that during the normal processing of upright faces, people tend to process salient features—two eyes, a nose, and a mouth—to create a holistic “gestalt” for optimal efficiency of encoding. Crucially, this “gestalt” is built in a particular order, and with a particular orientation. As soon as this order is disrupted or the orientation reversed, the encoding system falls apart.

*Expertise and Configural Processing in Memory*

Configural processing, a term not specifically used in Yin's study, is an encoding process (distinct from chunking) that aids memory and is often used by experts to efficiently encode the "gestalt"—or holistic sense—of stimuli within their domain of expertise. Tanaka and Sengco (1997) studied configural processing for faces, specifically training subjects to remember faces in one particular configuration and then testing their recognition of an individual facial component (such as a nose) in different contexts—either as part of the old configuration, as part of a new configuration, or by itself. Subjects' recognition of a part was best when tested within the old configuration, followed by performance in the new configuration, and then performance when tested in isolation. Crucially, when the distance between the eyes was altered, recognition for other features (nose and mouth) became impaired, even though the spatial locations of those parts had not changed. Thus, memory for each individual component of the face was dependent on the original context in which it was presented—and thus linked to the *entire* group of facial components (eyes, nose, and mouth). These results demonstrate that configural processing involves a unitary, holistic representation of crucial features, in a particular order and occupying a particular space within a stimulus. They also strengthen the idea that Yin's (1969) finding was due to configural processing, since the particular orientation and position of the eyes, nose, and mouth, and their relative distance to the rest of the face, were altered in the inverted stimuli of Yin's experiment.

In order to confirm that the source of the face inversion effect is truly expertise, it is necessary to test participants who are non-experts at face processing. People with autism have been known to have trouble recognizing and interacting with faces (Dawson, 2005), so they seem to represent relative non-experts, compared to the

average person. Importantly, Joseph and Tanaka (2003) found that typically-developing children (age 9-11) were better at recognizing face parts presented as part of the whole than as individual parts, but only when these stimuli were presented upright, and that they remembered “eye” stimuli best. However, children with autism only showed this advantage—for parts first seen as part of the whole—for mouth stimuli, demonstrating that autistic children do not rely on holistic processing in the same way that normally-developing children do, and do not seem to place as much significance on the eyes as other children.

An ERP study of the interaction between familiarity and orientation lends electrophysiological support to the role of configural processing in encoding visual stimuli (Marzi & Viggiano, 2007). The N170 is the first posterior negative component of an event-related potential (ERP), peaking approximately 170 ms after the presentation of a stimulus. In a familiarity judgment task of famous (familiar) and unknown faces, familiarity affected the N170 component for upright faces, but affected later components for inverted faces, showing that the time course of the "familiarity decision" is prolonged when orientation is inverted. The N170 has often been associated with face-specific encoding (Bentin, Allison, Perez, Puce, & McCarthy, 1996), since it represents the peak of a negative ERP signal that responds preferentially to human faces and isolated human eyes, but not to items of furniture, cars, or nonsense stimuli. This peak is significantly more sensitive to face inversion, which delays it and increases its magnitude, than to inversion of these other, non-face objects (Rossion et al., 2000). However, the N170 has more recently been linked to general expertise, rather than face-specific expertise, since it has been found to respond more broadly to stimuli with which participants are particularly familiar (Busey & Vanderkolk, 2005; Wong, Gauthier, Woroch, DeBuse, & Curran, 2005).

Thus, Marzi and Viggiano's (2007) finding suggests that familiarity actually slows the retrieval process for inverted stimuli because these famous faces are so frequently seen upright that when they are seen with a different (upside-down) orientation, divorced from their normal context, memory is weakened due to a defiance of strong perceptual expectations.

The human face is not the only visual stimulus for which configural processing enhances experts' memory; fingerprint studies have also demonstrated a memory preference for the upright orientation of fingerprints in experts (such as criminal investigators), but not novices (Busey & Vanderkolk, 2005). This has been suggested to result from experts' superior knowledge of overall groupings or idiosyncratic patterns, both of which minimize the amount of information that must be stored in memory. Configural processing for overall human body shapes has also been demonstrated by recent behavioral studies showing that memory for inverted human body positions is impaired compared to memory for upright body positions (Reed, Stone, Grubb, & McGoldrick, 2006; Reed, Stone, Bozova, & Tanaka, 2003). Inverted stimuli were associated with decreased accuracy rates and slower RTs, compared to upright ones. Crucially, this interference effect for inverted positions did not generalize to scrambled or isolated body parts, showing that human bodies are indeed processed configurally (Reed et al., 2006).

A study of non-human stimuli has also provided insight into encoding processes for familiar images. Using human faces and dog profiles as stimuli, Diamond and Carey (1986) found that novices' (non-dog owners') memory performance was negatively affected by inversion for human faces, but not dog profiles. However, for dog experts (dog show judges and breeders), inversion negatively affected memory for dog profiles to a comparable degree that their

memory for human faces was affected. Thus, this inversion effect seems to have more to do with general expertise than with some unique or special properties of *human* faces or bodies.

*Does Configural Processing Operate in a Non-Visual Domain?*

The music studies discussed above (Huron, 2006; Deutsch, 1980; Halpern & Bower, 1982) suggest that musical experts chunk significant components to reduce space occupied in memory when encoding harmonically-structured information. This chunking process may seem similar to the configural processing referred to in visual cognition studies, but the two concepts can be distinguished. Chunking involves adding together the individual pieces of a stimulus to build meaningful units and minimize the number of items stored in memory. Within the realm of music, chunking specifically refers to a process of dividing music into manageable, memorable, harmonically-salient groups; for example, a musician might divide a ten-note melodic line into three harmonically-similar segments to aid the memorization process. Configural processing, however, as described earlier, is an encoding technique that captures the primary “gestalt” or holistic idea of an entire stimulus at once and depends on the originally-presented relations between parts (Gauthier & Tarr, 1997a). Importantly, configural processing is not simply the linear, incremental summation of each *section* of an image (such as an arbitrary square of skin on the cheek), but the clustering together of crucial *features* (such as eyes, nose, and lips), in a particular order and (as Yin, 1969, and Tanaka & Sengco, 1997, have shown) orientation.

Thus, studies specifically centering on musical chunking have failed to show evidence of configural processing for musical harmonies, which this thesis will aim to demonstrate by applying Yin’s (1969) paradigm to music. Currently, without a

stronger methodological connection between these previous studies of harmonic (auditory) processing and face (visual) processing, it is difficult to make theoretical comparisons between the mechanisms that affect memory for stimuli in these two domains.

Besides this failure to identify configural processing as a unique form of harmonic encoding used by musical experts, an additional looming problem in many music cognition studies is that researchers often neglect a crucial component necessary to link their findings with those in the greater realm of general cognition: the inclusion in their population of both a group of experts *and* a proper control group consisting of untrained non-experts. Without this comparison, it is hard to evaluate whether training in tonal, chordal theory truly catalyzes the development of these encoding techniques. Otherwise, it is entirely possible that non-musicians also use these techniques, and if this were true, formal training would not necessarily be the most crucial factor in developing and absorbing tonal schemata.

Thus, my thesis aims to fill in some of these gaps between the configural processing studies, pioneered by Yin's 1969 study and conducted in the realm of vision, and current studies of harmonic processing. I propose that the particular form of expertise effect found by Yin may not be domain-specific (i.e., constrained to visual perception), but might actually generalize to memory for music. Applying his visual paradigm to music, this project will take a two-pronged approach to this problem. Experiment 1 will test whether musicians (trained in Western, tonal theory, or trained on various instruments or voice) experience a similar interference effect on memory when recalling backward-moving, tonal chord progressions (corresponding to Yin's inverted faces), as opposed to forward-moving ones. Participants will complete a brief, computerized experimental procedure, in which they will listen to

two blocks of chord progressions (one forward block and one backward block) and then be tested on their memory for the respective types of progressions. Experiment 2 will be almost identical to Experiment 1, but inverted tonal progressions, (compared to normal, upright ones), will correspond to the inverted faces of Yin's experiment.

Since, as described above, musicians often develop strong tonal frameworks and hierarchies of expectations for certain harmonies to follow others (Huron, 2006; Deutsch, 1980), our reversal of the direction of these harmonies in Experiment 1 should significantly interfere with their usual configural processing, thereby blocking memory for those backward progressions much more than for forward ones. In addition, since musicians (particularly those trained in theory and familiar with the intricacies of tonal cadences) would expect chords to be vertically oriented in a certain way at cadences, our inversion of them in Experiment 2 should interfere with these experts' expectations—and therefore, their memory—for the inverted group more severely than for the normal, upright group. These effects should not occur as strongly in people untrained in music, since they have not learned these rules or developed these expectations through musical training. Therefore, musical experts' memory for forward and upright progressions should be significantly more accurate than their memory for backward and inverted progressions, but this difference should not be as prominent for non-experts.

## Experiment 1

### Introduction

In Experiment 1, we applied Yin's (1969) inverted face paradigm to harmonic progressions, using cadences—which contain the most crucial information about a progression's ultimate key and mode—as analogous components to important facial

features. Participants' accuracy rates on a memory test for forward ("typical") and backward ("atypical") progressions were compared, according to level and type of musical expertise.

## Method

### *Participants*

Ninety-five participants from a Psychology 101 class, who were offered extra credit in exchange for their participation, participated in the study. Forty-two other students, many of whom were trained in music theory, also participated and were compensated with a coupon for one ice cream cone at a local restaurant.

### *Stimuli*

Stimuli were constructed using Finale<sup>®</sup> (a music notation software program), according to the traditional voice-leading rules—epitomized in the style of J. S. Bach—of Baroque, four-voice counterpoint. Each stimulus was composed of two, four-beat measures of common (4/4) time, with six quarter-note triads (three-note chords), followed by a final half-note triad. Each overall harmonic progression was accompanied by a melodic line which helped to give the block chords a sense of direction, but it is important to note that this melody did not detract from the primarily *chordal* nature of the stimuli—it simply added an additional top note to each chord. The tempo was set at 120 beats per minute. All triads were major or minor chords. The backward stimuli (Appendix C) are retrograde versions of the forward stimuli (Appendix B). Importantly, a retrograde transformation refers not to an exact *acoustical* reversal of the original (forward) musical example, but to a musical reversal of the order of chords (so that the first chord of a forward example is heard last in the backward version). The stimuli were exported as MIDI sound files from

Finale<sup>®</sup> and converted into .wav format for use in the experiment. Before starting the experimental procedure, participants indicated, on a brief questionnaire (see Appendix A), their type and number of years of formal musical training in any of the following: singing, playing instruments (indicating chordal or melodic), as well as tonal and/or atonal music theory.

### *Procedure*

After filling out the questionnaire, each participant completed one fifteen-minute experimental session. Each participant sat in a soundproof cubicle and listened, with headphones, to two randomized blocks of fifteen musical chord progressions each, played on a computer program implemented in E-Prime. One block was comprised of fifteen tonal, forward-moving harmonic sequences, and the other was comprised of fifteen backward (retrograde) versions of the same type of sequence. The order of presentation of the two blocks (forward and backward) was also randomized across participants. Each clip was four seconds long. The participants then heard a set of sixty harmonic sequences. Thirty of these were ones that they had heard earlier, and thirty were new. For each stimulus, participants were asked whether they had heard this example earlier in the experiment. The participants indicated their responses on the keyboard by pressing either “yes” or “no”. No feedback was provided.

### Results

In both Experiment 1 and Experiment 2, participants were divided in three separate ways, according to varying levels of musical expertise. First, we compared complete novices with students trained in theory, in order to determine whether training in tonal harmony might be linked with expertise—and the use of configural

processing—in the context of memory for chords. Second, we compared musicians who have studied voice or melodic instruments with musicians who have studied a chordal instrument for at least ten years, and up until no more than 2 years ago. This comparison helped us determine whether specific familiarity with chords themselves might more strongly contribute to the use of configural processing than familiarity with melodies. Third, we grouped participants by overall level of musical background, with one group of novices, one of singers and performers of non-chordal instruments, one of students who have either played a chordal instrument or studied theory, and one of students trained in both music theory and a chordal instrument.<sup>1</sup>

In Experiment 1, we conducted several mixed model ANOVAs, with direction (forward or backward) as a repeated measure variable and expertise (defined differently in each of the three analyses) as a between-subjects variable. The first analysis compared non-musicians' ( $n = 43$ ) and theory students' ( $n = 37$ ) accuracy rates on our test of memory for backward and forward harmonic progressions (See Figure 1). We found a main effect of direction, such that accuracy rates were significantly higher for forward progressions ( $M = .67$ ,  $SD = .11$ ) than for backward progressions ( $M = .62$ ,  $SD = .11$ ),  $F(1, 78) = 13.77$ ,  $p < .01$ . This demonstrates that participants can more easily remember forward progressions than backward ones, on average. We also found a main effect of training in theory, such that accuracy rates were significantly higher for students who had taken music theory ( $M = .68$ ,  $SD = .12$ ) than for complete novices ( $M = .61$ ,  $SD = .11$ ),  $F(1, 78) = 18.42$ ,  $p < .01$ . This demonstrates that theory students' memory for both types of progressions is better than non-musicians' memory. Contrary to our predictions, however, we found no significant interaction effect between direction and background in theory,  $F < 1$ .

We conducted a similar ANOVA for accuracy rates of participants with backgrounds in music performance (See Figure 2). Specifically, we compared the accuracy rates of singers and instrumentalists who play non-chordal (melodic) instruments, such as flute and trumpet ( $n = 23$ ), with the accuracy rates of participants who have played chord-based instruments (such as piano and guitar) for at least ten years *and* within the last two years ( $n = 17$ ). We found a marginally significant effect of direction, such that accuracy rates within this entire sub-population of musicians were significantly higher, to a marginal degree, for forward progressions ( $M = .66$ ,  $SD = .12$ ) than for backward progressions ( $M = .62$ ,  $SD = .11$ ),  $F(1, 38) = 2.77$ ,  $p = .10$ . We also found a significant effect of expertise, such that the accuracy rates of students who had played chordal instruments for at least ten years, up until no more than 2 years ago, were significantly higher, overall ( $M = .67$ ,  $SD = .10$ ) than those of students who had only played non-chordal, melodic instruments ( $M = .61$ ,  $SD = .12$ ),  $F(1, 38) = 5.70$ ,  $p < .05$ . This demonstrates that students with significant experience playing chordal instruments generally perform better on memory tests of chord progressions than students who play non-chordal instruments. Contrary to our predictions, we found no significant interaction effect between direction and experience playing a chordal instrument,  $F < 1$ .

A third analysis compared all participants along a scale of overall points, from 1 to 4, corresponding to their relative level of experience with playing and analyzing chord progressions (See Figure 3). Complete novices were given scores of 1 ( $n = 42$ ), students who had only sung or played non-chordal, purely melodic instruments were given scores of 2 ( $n = 37$ ), students who had either played a chordal instrument or taken theory classes were given scores of 3 ( $n = 37$ ), and students who had both taken theory classes and had a significant performance background on a chordal instrument

were given scores of 4 ( $n = 19$ ). We found a significant main effect of overall expertise on overall accuracy rate, such that probability correct systematically increased across the four levels (see Table 1),  $F(3, 131) = 5.11, p < .01$ . We also found a significant main effect of direction across the whole population,  $F(1, 131) = 13.10, p < .01$ . However, we found no significant interaction between overall score and direction,  $F < 1$ .

### Discussion

Across all three analyses, we observed a consistent, significant main effect of direction on overall probability correct. This suggests that forward chord progressions are, as predicted, easier to remember than backward progressions, but that this is true for everyone (in general), not just experts. We also observed a consistent, significant main effect of expertise on overall probability correct across the three analyses, suggesting that on average, theory experts (in this case, students who have studied music theory) can more effectively remember both types of chord progressions (backward and forward) than non-musicians, and that students who have played a chordal instrument for a significant amount of time can remember chord progressions better than non-musicians and players of non-chordal instruments. Contrary to our predictions, we did not find a significant interaction effect between expertise and direction. After considering these results, we wondered whether a subtler form of inversion might selectively interfere with experts' encoding more effectively than the type of retrograde inversion used in Experiment 1. Thus, in Experiment 2, we decided to apply a vertical transformation to create the "atypical" stimuli.

## Experiment 2

### Introduction

In Experiment 2, we applied Yin's (1969) inverted face paradigm to harmonic progressions, this time using upright, normal vertical progressions (see Appendix D) as analogous to upright, "typical," faces, and inverted (upside-down) progressions (see Appendix E) as analogous to inverted, "atypical" faces. We chose vertically-inverted chords this time because they represent a subtler transformation than backward inversion and thus might selectively disrupt experts' memory more than non-experts'. In addition, this vertical inversion eliminates the temporal disruption inherent in backward chordal progressions, thereby making these inverted stimuli potentially more analogous to Yin's a-temporal, inverted stimuli than the backward stimuli of Experiment 1. Participants' accuracy rates on a memory test for forward ("typical") and backward ("atypical") progressions were again compared, according to level and type of musical expertise.

### Method

#### *Participants*

Forty participants from a Psychology 101 class, who were offered extra credit in exchange for their participation, participated in the study. Twenty-four other students, many of whom were trained in music and/or had taken music theory classes, also participated and were compensated with a coupon for one ice cream cone at a local restaurant.

#### *Stimuli*

Stimuli were once again constructed using Finale<sup>®</sup>, but this time were copied directly from a compilation of J. S. Bach's harmonized chorales (Bach, 1941), which

follow traditional voice-leading rules of Baroque, four-voice counterpoint. Each stimulus was composed of approximately two, four-beat measures of common (4/4) time, with seven quarter-note triads (three-note chords), followed by a final half-note triad. All triads were major, minor, or diminished chords, and some were connected with eighth-note passing or neighboring tones. The tempo was set at 100 beats per minute. We slowed the tempo slightly from Experiment 1 (which was 120 beats per minute) to allow participants more time to focus on each distinct stimulus. The inverted stimuli (Appendix E) are “upside-down” versions of the upright stimuli (Appendix D). Specifically, inversion refers to the process of vertically flipping a chord so that its bottom note is on top and its top note is on the bottom. Thus, a chord initially in “root position,” where the base or identifying chord note is placed at the bottom, would be inverted by switching the top and bottom notes, thus putting it in “second inversion.” Importantly, this transformation preserves the identity of the original chord, even though its notes are now in different positions. (For a visual depiction of this transformation, see Appendix F). Each participant completed the same questionnaire as in Experiment 1 (see Appendix A).

### *Procedure*

Before starting the experimental procedure, participants completed the same questionnaire as in Experiment 1 (see Appendix A). Each participant completed an almost identical experimental session as in Experiment 1, with several minor changes. This experiment took about 10 minutes instead of 15, and each participant heard two randomized blocks of eight musical chord progressions each. One block was comprised of eight tonal, upright harmonic sequences, and the other was comprised of eight inverted versions of the same type of sequence. Each clip was eight seconds long. We shortened the overall procedure (and lengthened each stimulus, as

mentioned above) because many participants in Experiment 1 had complained that the blocks were too long to hold their attention, and so here we tried to give them a better opportunity to distinguish the stimuli. The test section was identical to the one in Experiment 1, except that it included thirty-two harmonic sequences total—sixteen old and sixteen new.

### Results

In the second experiment, we conducted the same three mixed model ANOVAs (and divided participants in the same three ways) as in Experiment 1, but this time, orientation (upright or inverted) was the repeated measures variable, and expertise was again the between subjects variable. In the first analysis, which compared students trained in theory ( $n = 20$ ) to non-musician students ( $n = 31$ ), we found a significant main effect of expertise, such that probability correct means for students trained in theory ( $M = .71$ ,  $SD = .14$ ) were significantly higher than probability correct means for non-musician students ( $M = .61$ ,  $SD = .12$ ),  $F(1, 49) = 11.55$ ,  $p < .01$  (See Figure 4). We found no main effect of orientation, such that probability correct means for upright chord progressions ( $M = .65$ ,  $SD = .13$ ) and inverted progressions ( $M = .65$ ,  $SD = .14$ ) were not significantly different,  $F < 1$ . We also found no significant interaction effect between harmonic orientation (upright or inverted) and theory background,  $F < 1$ .

The second analysis (see Figure 5) compared musicians who have significant experience playing chordal instruments to musicians who have only sung or played non-chordal instruments. Here, we found a marginally significant main effect of expertise on overall accuracy, such that musicians who had played a chordal instrument for at least 10 years, and until no more than 2 years ago ( $n = 9$ ), had a

higher probability correct overall ( $M = .74$ ,  $SD = .13$ ) than musicians who had only sung or played a non-chordal, melodic instrument ( $n = 8$ ), ( $M = .66$ ,  $SD = .10$ ),  $F(1, 15) = 3.86$ ,  $p = .07$ . We found no main effect of orientation on accuracy rate, such that participants' accuracy rates were not significantly greater, on average, for upright progressions than for inverted progressions,  $F < 1$ . Again, we found no interaction effect between orientation and experience playing a chordal instrument,  $F < 1$ .

However, although there was no significant interaction effect, we noticed a trend in this pattern of means that is in accordance with our general hypothesis. Specifically, musicians with significant experience playing chordal instruments exhibited *slightly* better accuracy of memory for normal progressions than for inverted progressions ( $M = .75$  versus  $M = .74$ ), while musicians without experience playing chordal instruments exhibited better accuracy of memory for inverted progressions than normal ones ( $M = .69$  versus  $M = .64$ ).

The third analysis (see Figure 6) compared participants according to overall level of musical expertise. As in Experiment 1, we grouped participants according to overall musical score ( $n = 31$  for 1,  $n = 6$  for 2,  $n = 16$  for 3,  $n = 11$  for 4). We found a pattern of mean accuracy rates that increased less systematically than in Experiment 1. However, we still found a significant main effect of overall expertise on overall accuracy rate, such that probability correct generally increased across the four levels (see Table 2),  $F(3, 60) = 8.86$ ,  $p < .01$ . We found no main effect of orientation on accuracy rate,  $F < 1$ . We also found no interaction between expertise and orientation,  $F < 1$ .

## Discussion

Although we did not find the interaction effect we had originally predicted (between orientation and expertise) in any of these analyses, we did find a fairly consistent pattern of results in Experiment 2. Across all of the analyses, we found a significant main effect of expertise, showing that both experience playing a chordally-focused instrument (such as guitar or piano) and a background in music theory contribute positively to memory for chordal progressions, overall. Part of the reason we did not observe any significant main effects of orientation here (or any interaction effect) could be that inverted chords maintain the same fundamental notes and the same temporal structure as their upright counterparts. Thus, they do not sound as profoundly different from these counterparts as retrograde harmonies, which have arguably suffered a more severe disruption of the configural gestalt, especially since the cadence that comprises their crucial, final element has been reversed and therefore destroyed.

## General Discussion

### *Summary of Findings*

We expected to find a significant interaction between direction and expertise in Experiment 1, and orientation and expertise in Experiment 2, such that atypical (backward and inverted) harmonic progressions would be relatively harder for musical experts to remember than forward and upright progressions, compared to novices, thus demonstrating musicians' use of configural processing to encode normally-progressing chords. Our results do not indicate the use of configural processing by relative musical experts, compared to their non-musician and non-theoretically-trained peers. One clear effect we found in both experiments was the

tendency for performers and music theory students to generally score more accurately, overall, on our test of harmonic memory.

In Experiment 1, we also found one consistent main effect: participants—including every level and type of musician we tested as well as non-musicians—tended to remember forward-moving harmonic progressions, on average, more accurately than backward (retrograde) progressions. In addition, we found an overall main effect of expertise, such that in every analysis, relative experts scored generally more accurately than relative non-experts. However, Experiment 2 did not yield both of these results. Instead, here, we found only a main effect of expertise, but no main effect of orientation and no interaction between expertise and orientation. This difference between the levels of success of the two experiments is rather understandable. Although the transformation between “typical” and “atypical” stimuli might seem rather parallel between the two experiments—with the backward stimuli in Experiment 1 representing a horizontal transformation of the forward ones, and the inverted stimuli representing a vertical transformation of the normal (upright) ones—the musical distinction between these transformations is not at all trivial. The following two sections will discuss this distinction and its implications.

#### *Musical Implications of Vertical Inversion*

To invert, or vertically flip, a chord is to preserve its general quality. The resultant chord contains the same notes and preserves its name and “root” note, but it sounds slightly different since a note other than the root now holds the base-line (lowest) position in vertical space. Thus, the inverted stimuli in Experiment 2 consisted of the same essential type of chord *progression* as the upright ones, but they should have sounded slightly strange to ears particularly sensitive to the tonal voice-

leading rules of the Baroque and Classical periods. These rules once dictated the vertical order of notes in order to preserve a particular type of structural cohesion, but the tonality that has infused much current popular music often tends to ignore or at least downplay these antiquated rules (Chanan, 1994). Thus, musically-untrained modern ears would not necessarily be expected to discern the presence of an inverted harmony within a cadential phrase ending.

*Musical Implications of Horizontal (Retrograde) “Inversion”*

To reverse the direction of an entire chord progression, however, is an entirely different matter, particularly when these chords are part of a conclusive, cadential gesture. Our forward stimuli in Experiment 1 are indeed cadential in nature, and the retrograde versions of them completely lose the sense of harmonic closure of the originals, since the crucial final cadence chords now come at the beginning. The original sense of direction and purposeful movement of these progressions, toward a particular goal, is thus now overturned. Although the voice-leading rules mentioned above have largely disappeared from today’s tonal music, chord order—particularly at cadences—represents a crucial part of an aesthetic structure which *has* persisted until today (Lerdahl & Jackendoff, 1983; Johns, 1993). Thus, although the evolution of specific rules involving tonal voice-leading (which relates to Experiment 2) has involved some fluidity, there is still something constant about the temporal relationship between chords, and their particular order, at cadences (which relates to Experiment 1), that is as true in today’s pop and contemporary classical music as it was in the Renaissance (Kupkovic, 1980). This suggests that the backward stimuli in Experiment 1 might be more “atypical” and strange-sounding, due to their temporal reversal, than the inverted stimuli of Experiment 2, which flipped the vertical

structure of each chord but preserved the chords' original order. Therefore, many astute listeners could be reasonably expected to detect the unsettling and disruptive quality of these stimuli, even if they could not explicitly identify that they had undergone a retrograde transformation.

### *Potential Differences Between Vision and Audition*

One reason we may not have found evidence for configural processing in music is that it does not actually exist in the auditory domain. One negative result certainly does not imply that configural processing does not operate in the domain of auditory memory. However, if our results were replicated in the future, a consistent null effect would in itself be an interesting result, carrying important theoretical implications about the nature of configural processing. The absence of configurality effects in the auditory domain could potentially be explained by certain fundamental properties of sound, described below, that are irrelevant in visual memory studies.

First, sound has inherent duration, and thus exists in horizontal time, whereas visual stimuli exist in space, possessing two- or three-dimensional coordinates. Music—essentially organized sound—is arguably even more temporally-constrained than other forms of sound, since it is divided into rhythms, beats, and measures that keep track of time in a rather arbitrary, but consistent, manner, similarly to a clock. Thus, music cannot be fully heard, analyzed, or remembered without some acknowledgement of, and dependence upon, this temporal quality of notes and chords progressing toward something.

Experiment 1 specifically relied upon the inherent strangeness of temporally-reversed chord progressions. For participants to encode these stimuli, they had to necessarily incorporate time into the process of remembering. Each audio clip was not

presented as a flash—it instead lasted for almost five seconds, with approximately two chords being played per second. The process of remembering each progression requires not only noting each chord’s quality and duration, but the quality of the transitions between chords (whether smooth and expected or jagged and surprising), and the quality of the final, cadential chords, which arguably leave the greatest impression on listeners since they come last and are goal-oriented. This issue of encoding the accumulative movement of musical chords makes configural processing in music—if it exists—inherently different from configural processing in vision, since the holistic element or “gestalt” being picked out of the whole stimulus as most crucial does not exist simply in space but spans a particular duration. Thus, all of its elements are likely not experienced together, in the same exact moment.

There is an even larger issue with the transformation applied to the stimuli in Experiment 2. Unlike inverting a picture, which creates an image of the exact same size and vertical height, inverting a chord is not as simple a matter as flipping something upside-down. When inverting an image, the top layer of pixels simply becomes the bottom layer. Pitches are not as flexible in the positions that they can occupy, however, since they are inextricably mapped onto particular mathematical frequencies. Thus, each pitch only exists once per octave (or twelve-note series), and so inverting a chord involves placing the original bottom note (or “root”) either slightly above or slightly below the position of the original top note, and this process must occur for all three of the notes in each triadic harmony. Thus, our upside-down harmonies do not occupy the exact same height on the musical staff, or the same frequency range, as their corresponding upright harmonies. This is an unavoidable problem with harmonic manipulation, but it once again makes musical processing inherently different from visual processing, so that inverted harmonies do not

perfectly correspond to inverted faces or trees. As shown in Appendices E and F, each inverted stimulus involves expanding or contracting each chord so that the schematic height of each harmony is altered.

#### *Factors Potentially Confounded With Musical Background*

One other issue worth mentioning, since it could potentially explain the main effect of expertise on overall accuracy found in both experiments, is the difference in various characteristics between the expert and non-expert groups. This study consisted of two quasi-experiments, and thus we could not control for initial differences between the groups. For instance, intelligence is likely confounded with musical experience, and so the musicians we tested may have been simply better at remembering stimuli—in general—than the non-musicians. Not only could lessons in music performance and theory have boosted students' IQs and overall memory (not to mention memory for music) throughout their lifetimes (Rauscher, Shaw, & Ky, 1993; Gibson, Folley, & Park, 2009), but students who enrolled in these music classes in the first place might be more likely to have highly-educated parents with musical backgrounds and who play classical music in their households. In addition to intelligence, there are some other potentially confounding factors wrapped up in musical ability for which we did not control, such as attention span and willingness to try hard to maximize one's score on our test.

#### *Expertise in the General Population*

The significant effect of direction across all participants found in Experiment 1 seems to suggest that most Williams students demonstrate greater levels of expertise than we expected. Indeed, due to the dominant role of tonality in much of

today's popular music, it is entirely possible that most people internalize tonal structures to some extent, without gaining explicit knowledge of specific rules through training. Bigand (1990) found that both musicians and complete novices could categorize melodically-similar phrases into structurally (or harmonically) distinct groups, demonstrating their implicit knowledge of, and ability to abstract, underlying structures, even though the non-musicians might not be able to explicitly understand or explain these structures. This lends some support to our idea that musicians and novices, educated at a North American college with classes taught in English, actually have some implicit knowledge of tonal theory due to its prevalence in our culture. Indeed, tonality is almost ubiquitous among the sounds most people hear on a daily basis—pop radio, commercial jingles, television and movie soundtracks, or Classical background music (such as a Haydn string quartet or Mozart piano concerto) piped in to relax restaurant-goers or shoppers. And considering our culture's recent obsession with Classical music due to studies of the "Mozart effect" (Rauscher, Shaw, & Ky, 1993) and the skyrocketing sales of "Baby Mozart" and "Baby Bach" CDs, it is no surprise that many people listen to this type of quintessentially tonal music—teeming with schematic regularity and cadentially-focused chordal motion—at home.

*Cross-Cultural and Historical Issues with Musical Expertise*

The supposition that musical expertise (or, from a cross-cultural perspective, musical enculturation) can determine a person's structural interpretations of new musical stimuli seems to treat music similarly to language—as something which has learnable structures and rules originally specific to, and rooted in, a particular cultural context. Thus, the musical procedures used in this study (retrograde and vertical

inversion) could be seen as limited to the Western, tonal musical “language.” However, due to its vast dominance of popular music in much of the world through processes of imperialism and globalization, tonality is (admittedly) likely better understood, by the average human, than the musical structures found in Indonesia or Mali. In solely studying melodies, chords, and the twelve-tone chromatic scale, many researchers have therefore (whether with explicit intention or not) portrayed tonality as the prototypical or standard system of musical syntax and have almost exclusively studied it when investigating music cognition and perception. For instance, a 1983 book by Lerdahl and Jackendoff—*A Generative Theory of Tonal Music*—compares tonality to Chomsky’s universal grammar, treating tonal theory as a basic set of syntactical rules which all music should follow in order to be effective. The authors enumerate various aspects of Western tonal theory (harmony, melody, cadence, key) and their psychological and evolutionary origins, generally spreading the idea that tonality is a self-evident, overarching, and rather superior form of musical organization, providing the overall framework into which all of the world’s music should ideally fit.

However, even these authors admit that tonality has evolved over centuries, and has changed significantly since its emergence (or at least its initial explosion of popularity) in the seventeenth and eighteenth centuries. Ionian and Aeolian, the two ancient Greek modes that bear the closest resemblance to our major and minor, were certainly not the most dominant in ancient Athens. Even throughout the medieval and Renaissance periods, the semantic implications of these two modes still had not solidified (Chanan, 1994). Songs in the major mode—which would safely be interpreted as relatively “happy” today—were often mapped onto plaintive lyrics, even as late as the mid-sixteenth century. Until J. S. Bach began improvising

complex, chord-based chorales on the organ and harpsichord, tonal harmony, with all its cadentially-based rules of voice-leading, did not formally exist. Thus, the fixed tonal rules to which music cognition studies often refer are actually the temporary product of a gradual process of change. Indeed, musical rules that will be implicitly absorbed by the general population several centuries from now would likely be completely incomprehensible to our twenty-first century ears.

In conclusion, we did not find evidence of experts' unique use of configural processing for harmonic progressions, as we had predicted. Of course, we cannot make too much of a null result, but if this result were successfully replicated in future studies, it would suggest some important distinctions between visual and auditory memory, as discussed above. In addition, since the main effect of direction we found in Experiment 1 was not present in Experiment 2, we can conclude that the retrograde (backward) transformation of chord progressions is more disruptive to the average listener's memory than the vertical inversion of individual chords in a progression. A likely reason for this is the prevalence of horizontally-based tonal cadences in most modern popular music, which arguably made most participants "experts" in the context of our first experiment.

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## Footnote

<sup>1</sup>Students were divided this way to represent increasing levels of musical expertise. The students in category 1 (non-musicians or novices) served as a complete control group, and the students in category 4 represented the type of Williams student—explicitly knowledgeable about cadential structure and accustomed to playing and hearing series of chords—who would be most likely to use configural processing to efficiently encode forward-moving, upright (i.e., normal) harmonic progressions. In addition to those extreme cases, we included the two middle levels because they contained crucial information about whether a person had explicitly learned about, or frequently played, chords themselves. This distinction is helpful because the stimuli are chord-based (containing seven or eight vertical harmonies, instead of simple melodic lines or broken chords), and experience playing the piano, for instance, would likely make a person more knowledgeable about the typical structure and sound of chord progressions and cadences than playing the flute or French horn would.

## Tables, Figures and Appendices

**Table 1.**

Mean probability correct and standard deviations for memory task in Experiment 1

<u>Overall Score</u>	<u>Mean</u>	<u>Standard Deviation</u>
1	.61	.10
2	.62	.11
3	.66	.10
4	.68	.10

**Table 2.**

Mean probability correct and standard deviations for memory task in Experiment 2

<u>Overall Score</u>	<u>Mean</u>	<u>Standard Deviation</u>
1	.61	.12
2	.68	.05
3	.63	.13
4	.76	.11

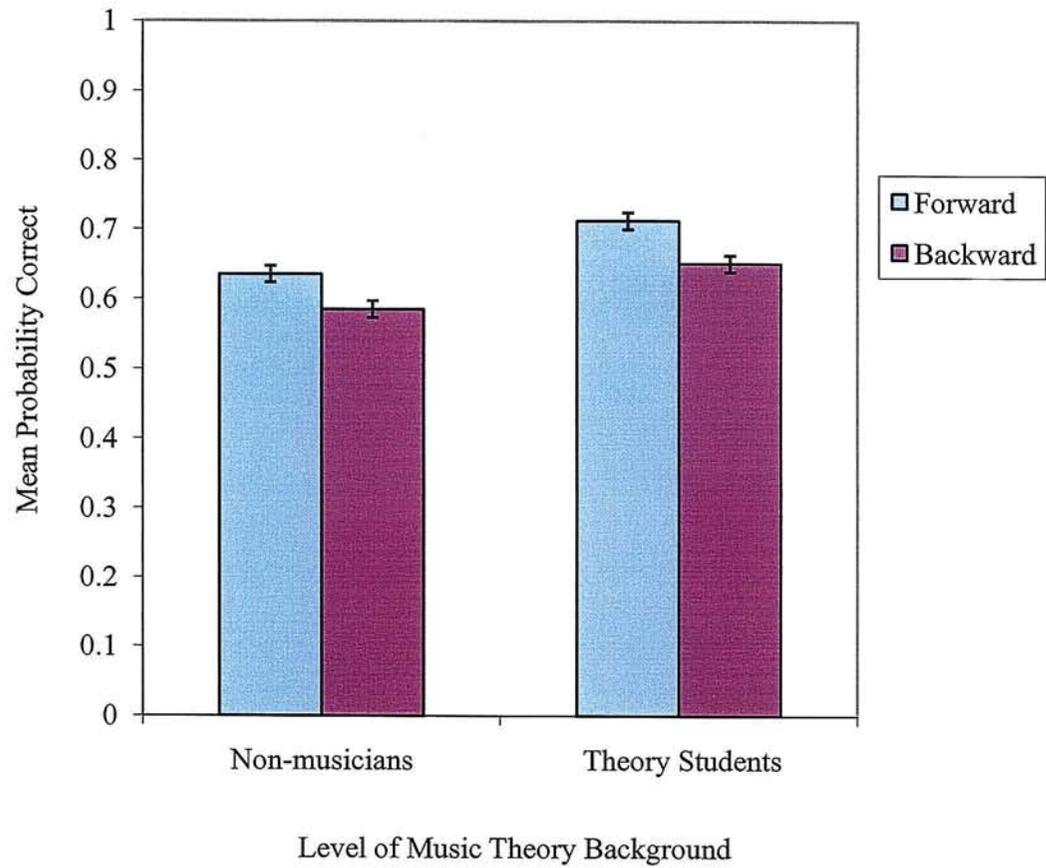


Figure 1. Mean probability correct ( $\pm 1$  SE) of memory for harmonic progressions for non-musicians and theory students in forward and backward test conditions in Experiment 1

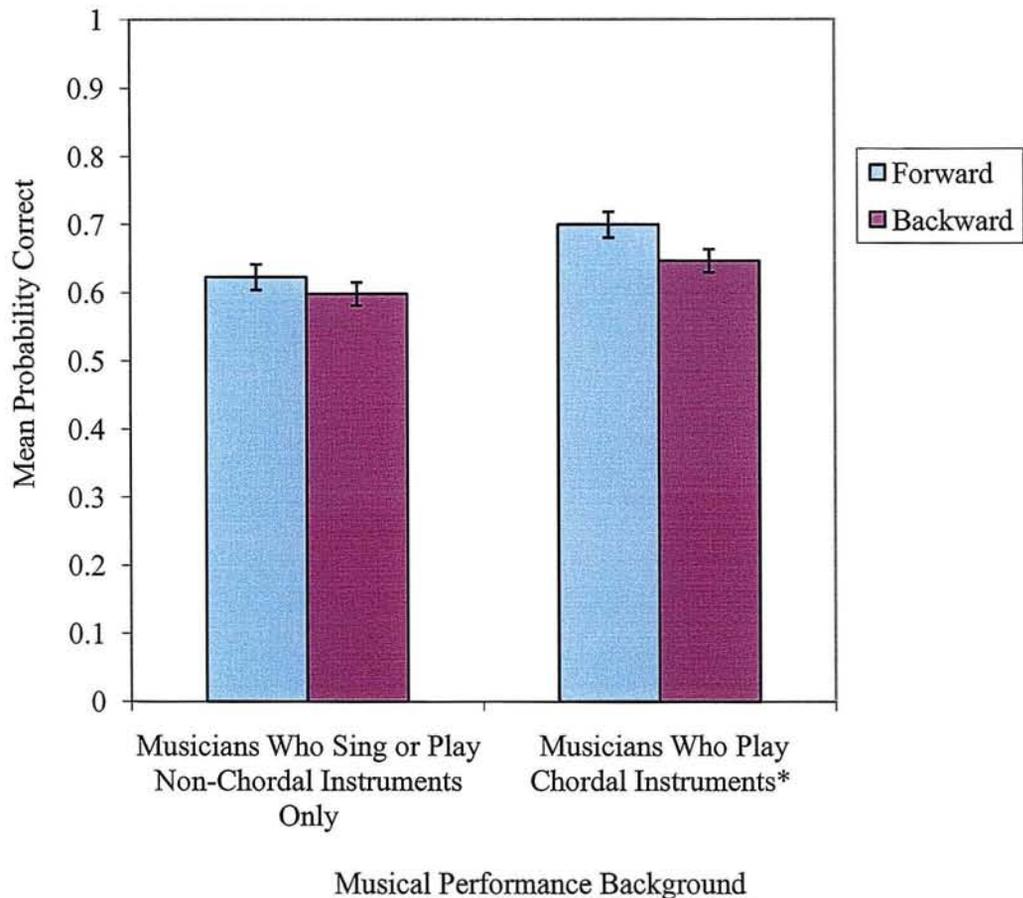


Figure 2. Mean probability correct ( $\pm 1$  SE) of memory for harmonic progressions for musicians who play non-chordal instruments and musicians who play chordal instruments in forward and backward test conditions in Experiment 1

\*Musicians Who Play Chordal Instruments = musicians who have played a chordal instrument for at least 10 years and as recently as fewer than 2 years ago

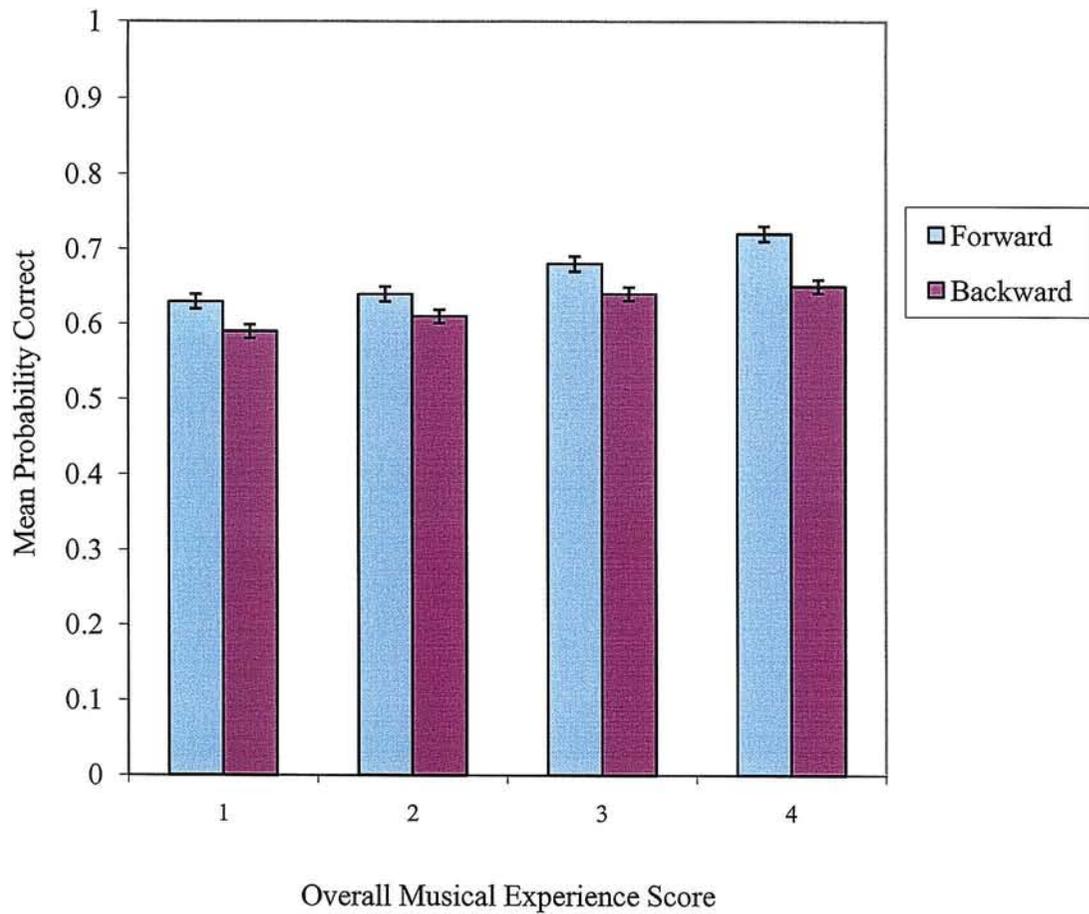


Figure 3. Mean probability correct ( $\pm 1$  SE) of memory for harmonic progressions for participants of each overall score (1-4) in forward and backward test conditions in Experiment 1

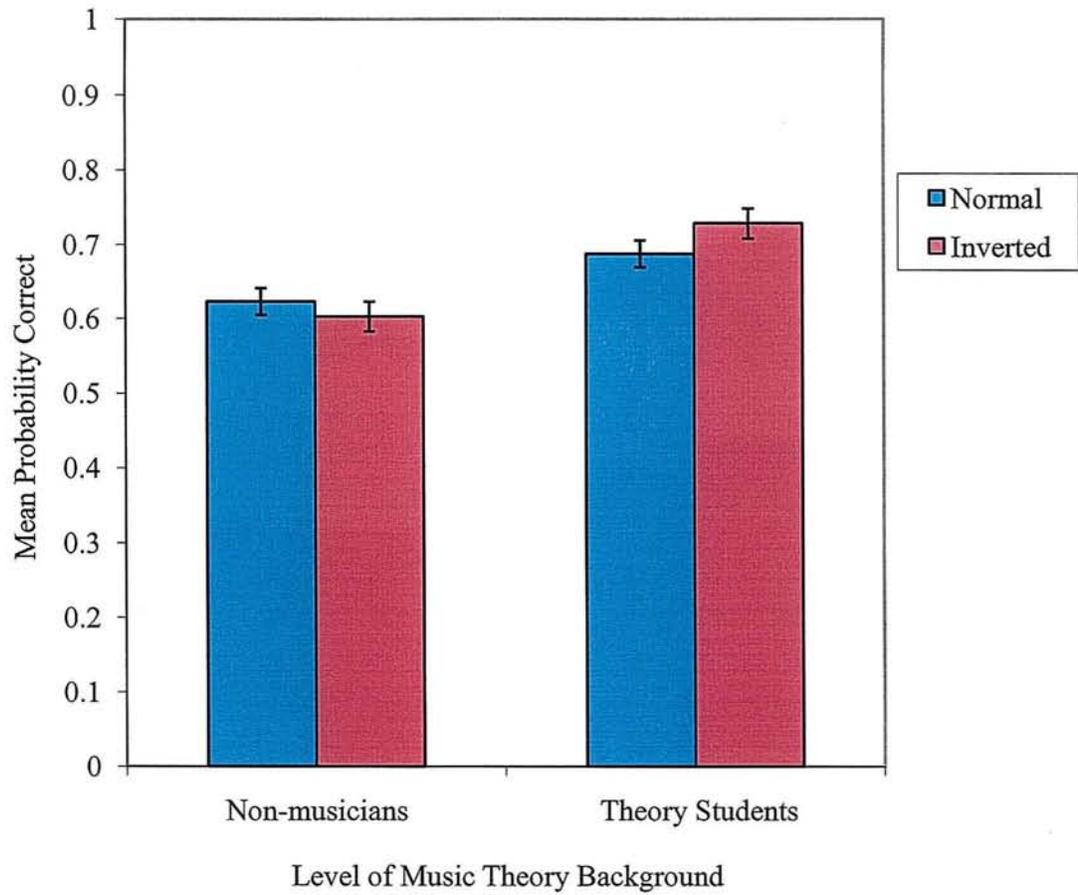


Figure 4. Mean probability correct ( $\pm 1$  SE) of memory for harmonic progressions for non-musicians and theory students in forward and backward test conditions in Experiment 2

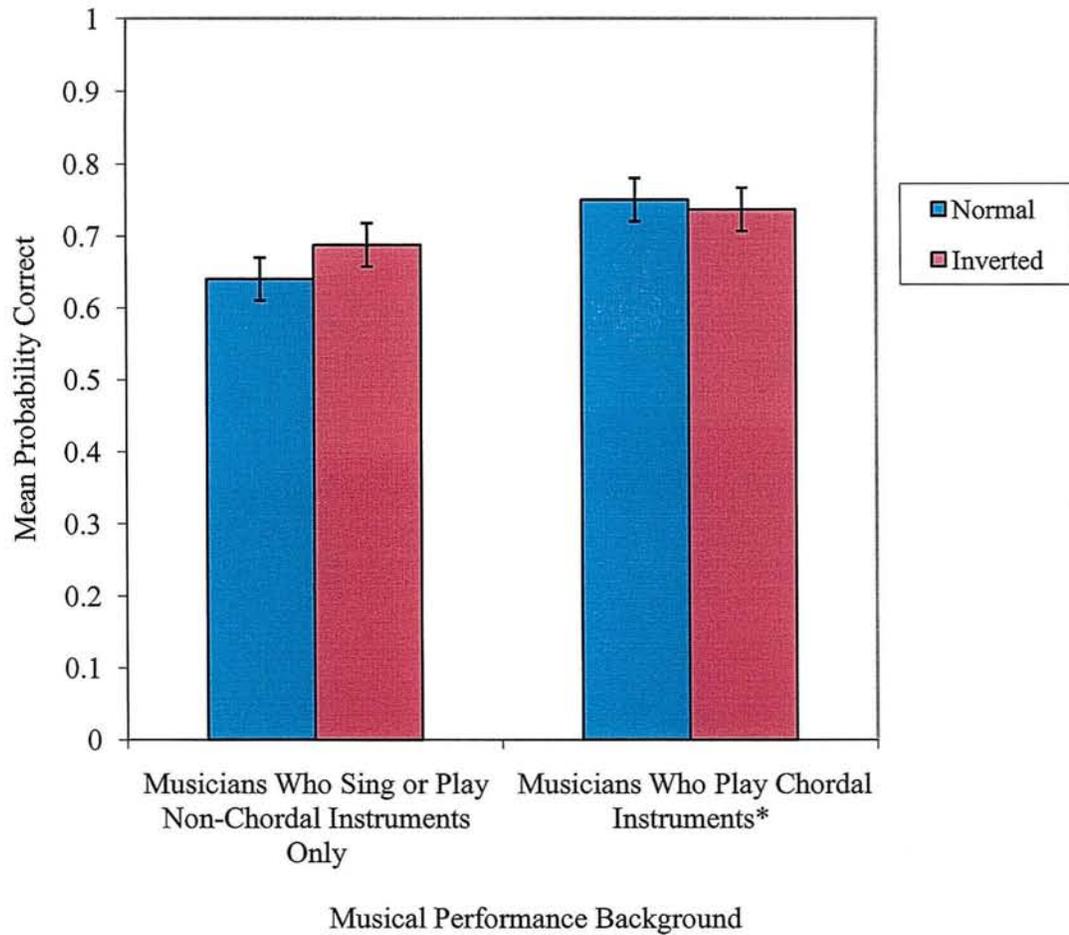


Figure 5. Mean probability correct ( $\pm 1$  SE) of memory for harmonic progressions for musicians who play non-chordal instruments and musicians who play chordal instruments in forward and backward test conditions in Experiment 2

\*Musicians Who Play Chordal Instruments = musicians who have played a chordal instrument for at least 10 years and as recently as fewer than 2 years ago

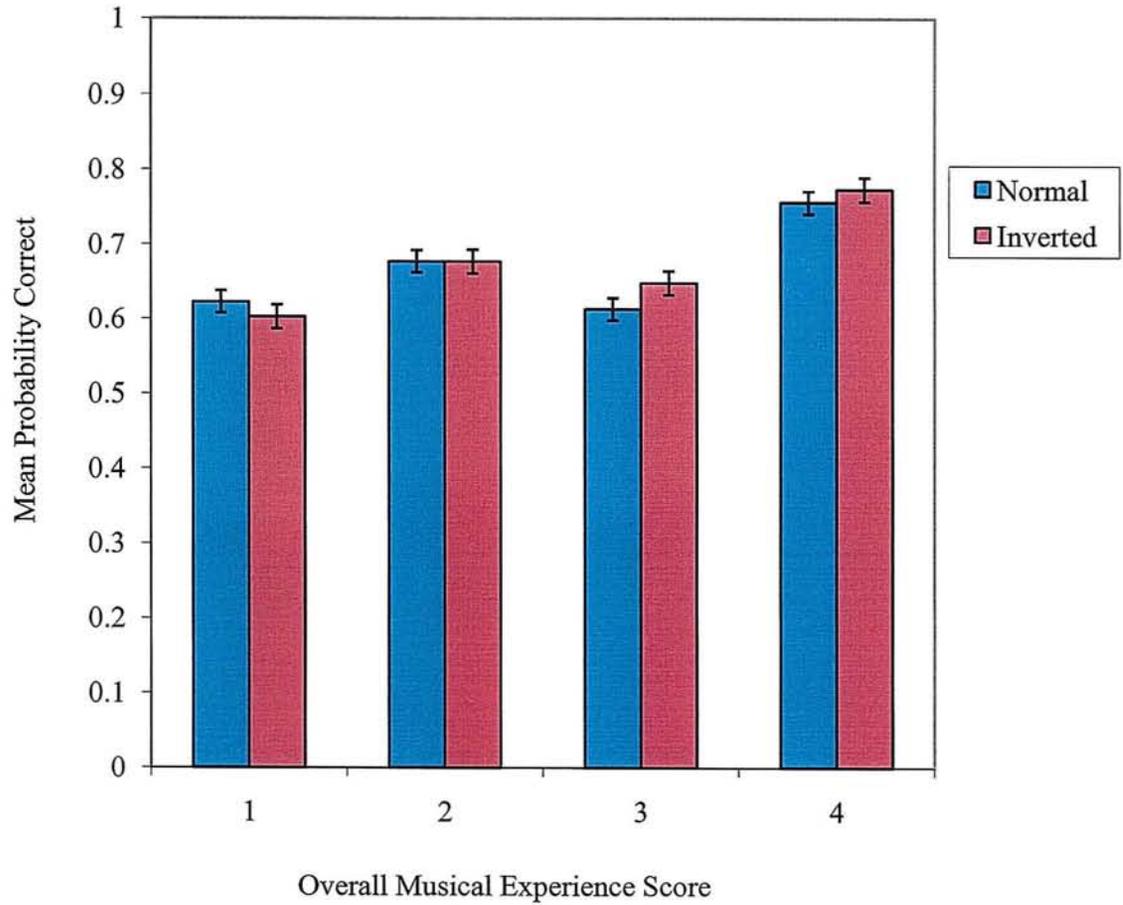


Figure 6. Mean probability correct ( $\pm 1$  SE) of memory for harmonic progressions for participants of each overall score (1-4) in forward and backward test conditions in Experiment 2

Appendix A

Questionnaire

1. Have you ever been trained in music? (i.e., singing or instrumental lessons, band/orchestra/choir, theory, composition, etc.)

Yes

No

2. IF YES, what is your **primary** (main) instrument (or voice part)?

During what age range did you play this instrument (or sing)?  
(Examples: From age 10 until age 13, or from age 15 until the present)

From age: \_\_\_\_\_

Until age: \_\_\_\_\_

3. If you play any other instruments, please list them below:

During what age range did you play this instrument?  
(Examples: From age 10 until age 13, or from age 15 until the present)

From age: \_\_\_\_\_

Until age: \_\_\_\_\_

4. Have you ever taken a music theory class?

Yes

No

5. IF YES, at what institution/with whom did you take it?

During what age range did you take music theory?

From age: \_\_\_\_\_

Until age: \_\_\_\_\_

Please briefly describe the most advanced topics you learned in this course (i.e., scales, chords, 20<sup>th</sup> C. atonal theory, etc.)

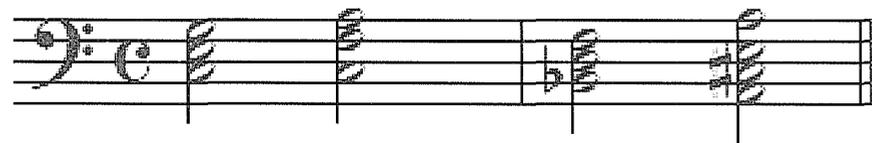
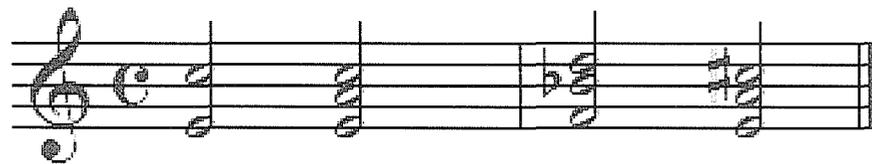
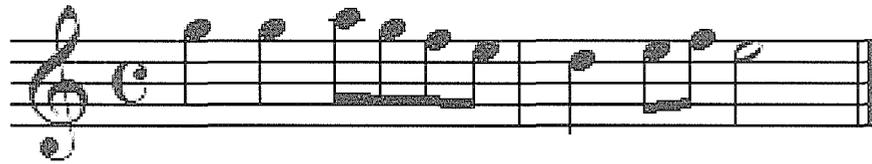
6. Do you have perfect pitch?

Yes

No

Appendix B

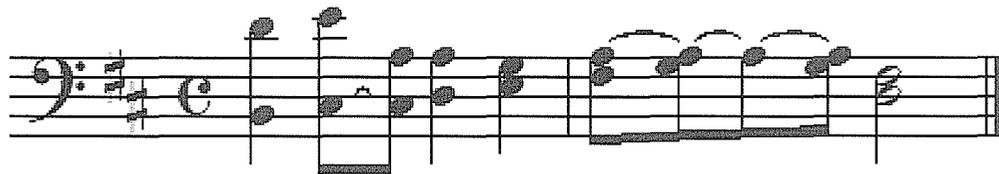
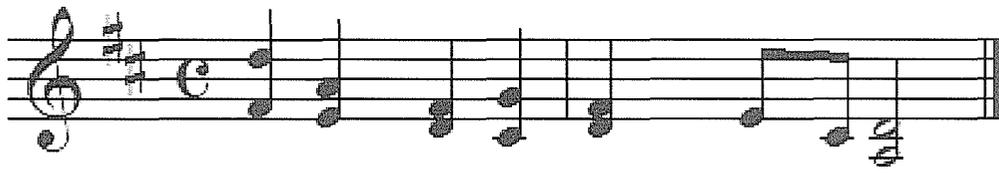
Example of a Forward Stimulus in Experiment 1





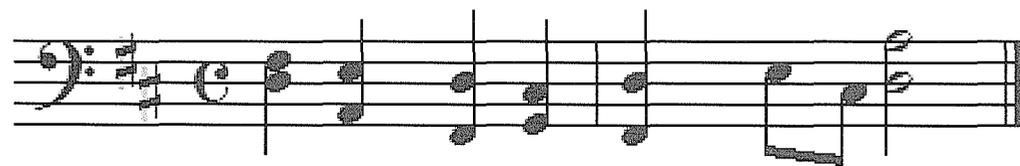
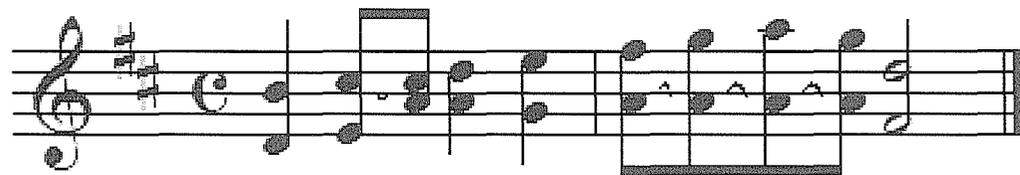
Appendix D

Example of an Upright Stimulus in Experiment 2



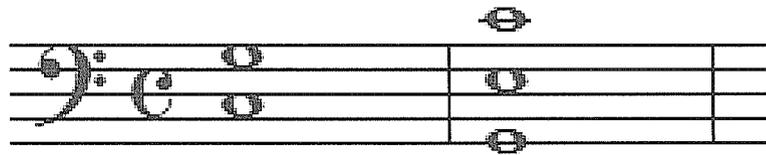
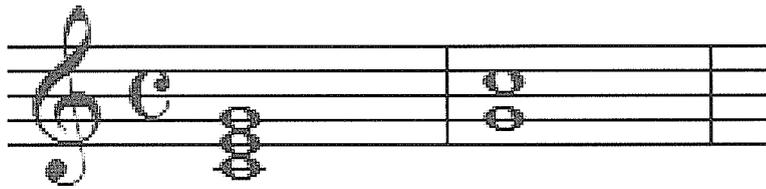
Appendix E

Example of an Inverted Stimulus in Experiment 2



Appendix F

Demonstration of Inversion Process



Original (root position)

Inverted