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Pitch Perception in Preschool-Age Children who are Deaf or Hard of Hearing

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Proposal Approved: _______________

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Pitch Perception in Preschool-Age Children who are Deaf or Hard of Hearing

Because of early hearing detection and intervention programs, combined with advances to hearing technology (e.g., digital hearing aids, cochlear implants), children who are deaf or hard of hearing (DHH) have the potential to develop listening and spoken language (LSL) similar to their same-aged hearing peers (Dettman, Wall, Constantinescu, & Dowell, 2013; Moeller, Carr, Seaver, Stredler, Brown, & Holzinger, 2013; Jackson & Schatschneider, 2014). In 2009, the Center for Disease Control (CDC) reported in its Hearing Screening and Follow-Up Survey that approximately 1.4 per 1,000 babies each year in the United States are born with permanent hearing loss. The development of LSL in children who are DHH requires consistent access to sound with appropriately fit hearing technology (e.g., hearing aids, cochlear implants, bone-anchored hearing devices, FM systems). An unprecedented number of infants are being fitted with digital hearing aids as young as four weeks of age and as of 2012, more than 38,000 children in the United States have received cochlear implants (NIDCD, 2013).

The ability to learn spoken language is contingent on the ability to hear the language being used. Although hearing aids and cochlear implants provide critical access to sound, the neurological pathways must be stimulated and strengthened to optimize comprehension of the auditory signal. Listening to speech in quiet constitutes the easiest listening environment. When young children are in the earliest stages of spoken language acquisition, exposure to the phonemic elements of speech without undue influences of surrounding noise is important to development and is a standard focus of speech and language intervention goals. However, because speech in quiet does not constitute the complexities of sounds in the child’s environment, interventions should also include the meaningful and rich complexities found in music. The speech, language, and academic outcomes of children who are DHH can be optimized when they receive early intervention and preschool services by professionals who understand their unique listening and language needs. For example, substantial emphasis on language and literacy development in preparation for kindergarten transition is essential for most children who are DHH. However, targeted and specific auditory perception (listening skills) goals must receive simultaneous attention and priority.

The systematic use of music beginning in infancy can provide important neurological auditory foundations. When children who are DHH turn three years of age and enter preschool, music can continue to be a strong educational component, embedded across the curriculum to effectively promote and support auditory perception development. In fact, the benefits of using music to promote language and academic gains in children, both with and without disabilities, has been reported for many years (The Royal Conservatory, 2014; Gold, 2011; Moreno et al., 2011).

Teachers who serve young children who are deaf or hard of hearing (DHH) in their classrooms may be reluctant to use music due to concerns that children with hearing loss may not benefit from musical input or that it might cause confusion or disruption to their listening environment. Although it is true that care should be taken to optimize the listening environment for children who are DHH and minimize background noise, providing children with opportunities to hear complex and meaningful auditory information can strengthen their auditory perception development.

This research thesis will 1) provide an overview of the psychoacoustics of music perception, particularly as related to the properties of pitch perception in young children and 2) describe the methods and outcomes of an exploratory study to evaluate the efficacy of obtaining pitch perception data from preschool age children with hearing loss.

Temporal Aspects of Music

Definitions

Hearing music involves recognizing temporal aspects, which contributes to the overall perception of music (Hsiao & Gfeller, 2012). The primary temporal aspects encompass rhythm, timbre recognition, pitch, and melody (Hsiao & Gfeller, 2012). McDermott (2004) found that, on average, adult cochlear implant (CI) users perceive rhythm almost as well as individuals who have normal hearing. According to Hsiao and Gfeller (2012), rhythm tasks encompass recognizing changes in tempo, varying meters (i.e., stresses in lyrical verses), and patterns held at a consistent tempo. Timbre recognition tasks involve identifying musical instruments that are played in isolation or together (Hsiao & Gfeller, 2012). For example, a note played on a piano will sound different than the same note played on a trumpet. Pitch-based tasks include discrimination, pitch ranking, recognition, and production (Hsiao & Gfeller, 2012). Pitch discrimination is the ability to determine whether two patterns of sound are the same, whereas pitch ranking is the ability to determine whether a pitch is higher or lower than a reference pitch point (Hsiao & Gfeller, 2012). Pitch recognition is the ability to identify specific musical intervals, pitch patterns, or melodies, whereas pitch production is the ability to correctly produce those specific musical intervals, pitch patterns, or melodies (Hsiao & Gfeller, 2012). According to Gfeller (2014), a melody is a sequential pitch pattern or a rhythmical sequence of notes that produce a musical phrase.

Pitch Perception as it Relates to Auditory Perception

Auditory perception can be described as the ability to discriminate and comprehend an auditory signal at the phonemic, word, sentence, or phrase level. The temporal aspects of music each contribute an important component to auditory perception development. For example, pitch perception is important to conversation as it highlights subtle cues of speech. In other words, the importance of pitch as it relates to music is similar to the importance of pitch as it relates to speech. Tone of voice provides the listener with important conversational markers, such as whether the speaker is making a statement or asking a question. If the speaker is making a statement, then the pitch will remain relatively constant, but if the speaker is asking a question, then the pitch will have a rising intonation at the end. Tone of voice will also provide the listener with insight into the speaker's mood. If the speaker is excited, then he/she will likely use a higher and more variable pitch, whereas if the speaker is apathetic, he/she will likely use a mid- or low-pitched monotone.

Pitch Perception Abilities

Between birth and the age of four years, infants are rapidly developing cognitive, language, and motor skills, including auditory development. By three months of age, infants should have auditory awareness, respond to loud sounds, and recognize the caregiver's/mother's voice. By six months of age, the infant should start to associate meaning to sounds and respond to changes in vocal inflections. Once an infant reaches one year of age, he should be able to discriminate content between vowels and syllables, localize sound from a distance and be able to discriminate a speaker's voice from other auditory stimuli. By two years of age, it is typical for the infant to have an auditory memory of two items and be able to discriminate songs, in addition to being able to imitate words. Auditory memory should be expanded to three items (i.e., three different words) and two pieces of information (i.e., two phrases or sentences) should be able to be sequenced together by three years of age. Longer directions should be able to be followed and more complex language should be able to be processed by four years of age (*Developmental Milestones,* 2016; Listen Learn and Talk, n.d.). Children with hearing loss will likely have difficulty achieving these developmental milestones within the normal age range. If gone untreated, failure to achieve these milestones within the developmentally appropriate timeframe can have a negative impact on the children's overall speech and language abilities.

Research by Dincer D'Alessandro et al. (2015) found that by age 8.5 years, children with normal hearing tend to demonstrate pitch perception abilities that coincide with what is normal at the adult level. Most research studies of auditory perception have shown that children who had no musical education demonstrate poorer auditory perception skills than children who did have musical education training. For example, Banai and Ahissar (2013) reported that cognitive ability, verbal memory span, and discrimination tasks improved after exposure to formal musical training and, importantly, correlated with reading-related skills.

Difficulties in pitch perception may impact individuals' ability to recognize simple melodies (Hsiao & Gfeller, 2012). This is particularly true for children with congenital or early-onset hearing loss, who may not have a mental representation of pitch variation and what constitutes "normal" pitch (Hsiao & Gfeller, 2012). This suggests that children who are deaf and hard of hearing are at risk for poor conceptualization of pitch elements, including discrimination, pitch ranking, recognition, and production (Hsiao &

Gfeller, 2012), given limited or insufficient auditory experiences. This is largely due to the fact that CIs do not pick up the full range in pitch (McDermott, 2004; Donnelly & Limb, 2009; Dincer D'Alessandro et al., 2015). Research has also shown that some children with CIs may be able to distinguish a pitch change but may not be able to determine its magnitude (Hsiao & Gfeller, 2012). This potential lack of pitch perception in music can carry over to reduced pitch perception in speech since pitch also correlates to the intonation used in speech. If children with hearing loss have difficulties with pitch perception, they will likely miss conversational cues, thus negatively impacting their conversational interpretations.

Embedding Music Throughout the School Day

Research has shown that music within academic instruction can have positive effects on children's development (The Royal Conservatory, 2014; Moreno et al., 2011; Gold, 2011). . Brain areas can be stimulated by playing instruments, singing, and even just listening to music. According to the Royal Conservatory (2014), stimulating the brain in such a way increases children's likelihood of reaching their full potential, both cognitively and academically. This comes as a result of increasing the children's neuroplasticity, which is the brain's ability to form new neural connections. Music training has also been linked with benefits in IQ, memory, focus, speech, reading ability (The Royal Conservatory, 2014), and behavior (Gold, 2011). Research has shown that children who participate in music tend to have better speech and language intelligibility (Moreno et al., 2011) and phonological skills, impacting both receptive and expressive language (The Royal Conservatory, 2014). Teachers who recognize the efficacy of using music throughout the day and embedding it across the curriculum can effectively impact the learning potential of children in the class. For example, Table 2 in the Appendix describes activities for embedding music into various subjects and times of the school day, including suggestions for increasing and decreasing the level of difficulty of each curriculum area of focus. These activities promote an added focus on the temporal aspects of music across the subjects of writing, math, spelling, science, and snack time. Incorporating music during these subjects and times provides complex listening opportunities and an additional dimension to the children's learning; they are no longer just learning about the subject material—they are also further developing their speech and language skills through musical instruction.

Embedding music across the curriculum can increase both pitch perception and auditory perception abilities in preschoolers who are DHH. Music activities focusing on the temporal aspects of music (rhythm, timbre recognition, pitch, and melody) can effectively promote auditory perception development. By incorporating music into the school day, teachers have the ability to improve students' skills related to the various temporal aspects of music, which, in turn, can positively impact the students' auditory perception skills. Similar to developing any type of skill, it is important to practice. Providing students with more time to practice these temporal aspects of music, teachers can embed music across the curriculum rather than having a designated music time.

The impact of incorporating music into the educational curriculum to improve pitch perception has been documented for elementary-age children with hearing loss (Putkinen, Saarikivi, Ojala, Tervaniemi, & Huotilainen, 2013b; Moreno et al., 2009). However, changes to pitch perception in preschool children as a result of focused music intervention embedded throughout the preschool day has received less empirical documentation due to the difficulty of objectively measuring pitch perception changes. In one of the few available studies, de Hoog et al. (2016), reported that preschoolers with CIs did not reach developmental norms in lexical (i.e., vocabulary) and morphosyntactic (i.e., knowledge of how words change in relation to verbs) language skills and that auditory perception appeared to play an important role in developing these lexical and morphosyntactic language skills. To obtain exploratory pilot data, a preliminary proof of concept study was initiated to evaluate the potential for accurately documenting pitch perception in children ages four to six. This exploratory study was approved by the Utah State University Institutional Review Board.

METHODS

Participants

Parents of children ages four to six who attended *Sound Beginnings* were invited to provide consent for their child to participate in the music perception exploratory study. *Sound Beginnings* is a specialized program that serves young children who are DHH who are developing LSL. To recruit participants for study participation, classroom teachers sent home written IRB-approved materials describing the study to parents of 11 children. Parents consented for their child to participate in the study by signing the Informed Consent document and returning it to their child's teacher.

Procedures

Each child completed a series of three tasks, including coaching and practice, single note perception, and pitch contrasts.

Coaching and Practice. Participants were shown a standard piano and oriented to the concept that some notes sound very low and some sound very high. The high notes were likened to a little bird and the low notes were likened to a big bear. Pitch contrasts were depicted on a vertical response chart (see Figure 1) utilizing a picture of a bird at the top and a picture of a bear at the bottom. Age-appropriate vocal play (i.e., “tweet” and “roar, respectively) also helped reinforce the concept of high and low-pitched sounds. The chart was placed so that each child could reach the top and the bottom of it, and the child completed a series of practice presentations in which notes were presented and the child indicated where they would appear on the response chart. Researchers commented and provided feedback regarding the child’s responses during the practice session to reinforce concepts of pitch perception and to ensure they understood the task.

Single Note Pitch Perception. To commence data collection, the study participant and one researcher stood before the vertical response chart and the second researcher sat at the piano. A barrier was placed between the test board and the piano so that the participant had no visual cues as to the notes being presented. A series of ten notes were played one at a time and the child indicated the position on the vertical chart that correlated with the pitch perceived.

Pitch Contrasts: The screen was pulled away so the child could see the piano during the pitch contrast practice. During this practice, the researchers coached the child on how to listen to a series of two notes and then indicate if the second note was higher or lower relative to the first note by touching the picture of the bird or bear after the second note was played. After the practice period, the visual barrier was again placed between the piano and the vertical response chart. An orange strip of paper was positioned on the chart to visually depict the reference note. The child was given a toy frog to hold on the orange strip of paper during the presentation of the first note. When the second note was played, the child would jump the frog higher or lower than the strip of paper, depending on whether the child thought the second note was higher or lower than the first. Test procedures were followed as outlined in Appendix A. Data were recorded using the Pitch Perception Data Collection sheet as shown in Appendix B. To obtain a response comparison, participants were tested in the same manner a second time so as to compare their responses with their original test series.

RESULTS

Participant Demographics

Nine children, ranging in ages 4 years 2 months to 7 years 1 month, participated in this exploratory study. Eight of the children were DHH and one child had normal hearing. All of the children with hearing loss used hearing technology and had hearing loss ranging from mild to profound. See demographic data in Table 1.

Table 1. Demographic Data

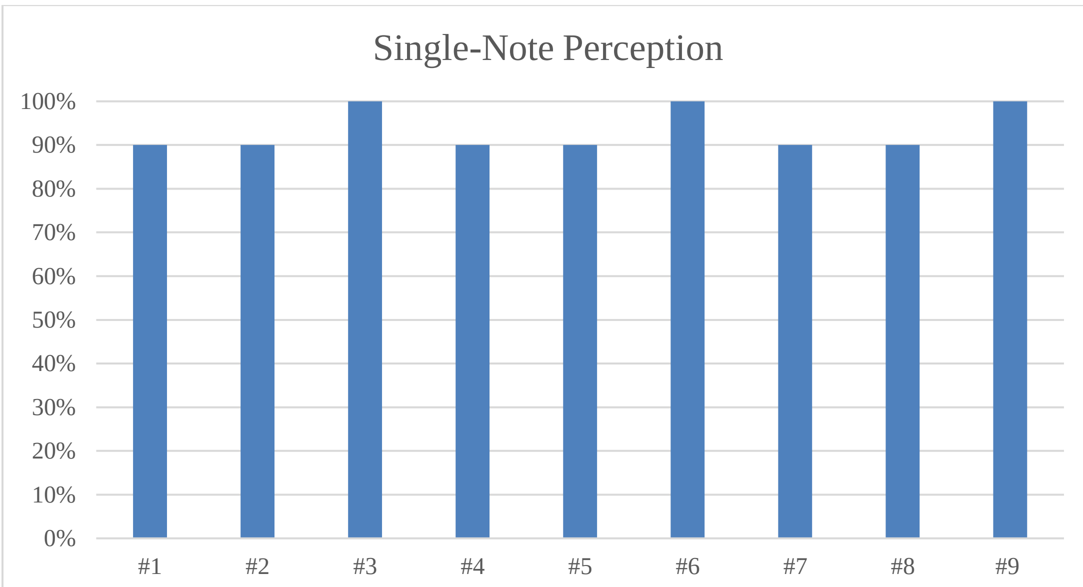
	Age *(yrs-mos)	Hearing Level	Amplification
Subject #1	7y 1m	Profound	Cochlear Implants
Subject #2	5y 5m	Mild	Hearing aids
Subject #3	4y 2m	Within Normal Limits	N/A
Subject #4	4y 4m	Mild/Mod	Hearing aids
Subject #5	4y 8m	Profound	Cochlear Implants
*Subject #6	5y 7m	Moderate	Hearing aids
Subject #7	6y 1m	Mod/Severe	Hearing aids
Subject #8	4y 4m	Mild/Mod	Hearing aids
Subject #9	4y 11m	Mod/Severe	Hearing aids

*child with additional disabilities

Single-Note Pitch Perception

As shown in Figure 1, all of the children readily understood the single-note pitch perception task. Six children scored 9/10 correct responses and three children scored 10/10 correct responses.

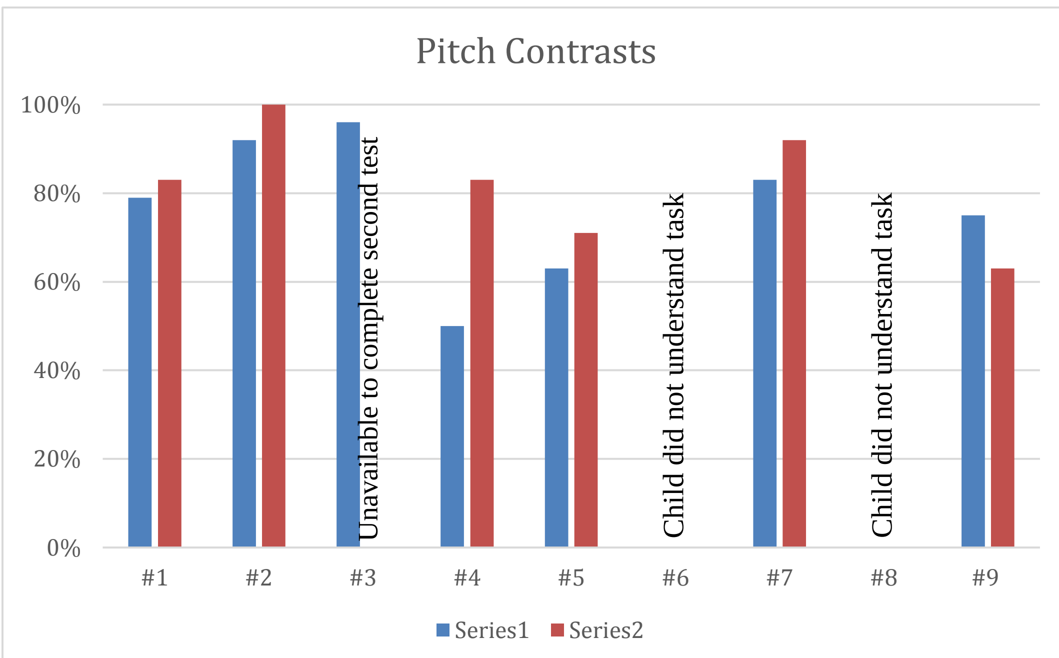
Figure 1. Single-Note Perception



Pitch Contrasts

Pitch contrast data were attempted for all nine subjects. In the first round of data collection, data were obtained for seven participants; two participants did not understand the task. Retest data were obtained for six participants approximately three months after the first round of testing (one child was no longer in the program and the same two children still did not understand the task). Each participant completed a total of 24 pitch contrast presentations, with percent correct calculated. As shown in Figure 2, pitch contrast performance across participants ranged from 50% to 96% correct for the first data collection period and 63% to 100% correct for the second data collection period. A simple *t*-test calculation suggested no statistically significant differences in pitch contrast performance between the first and second data collection sessions (*t*=.22). Because of the small sample size and the exploratory nature of the study, no further statistical analyses were completed.

Figure 2. Pitch Contrasts



SUMMARY AND NEXT STEPS

These exploratory findings suggested the procedures employed for the current study can result in reliable single-note pitch identification and pitch perception contrast data with most study subjects as young as age four. Based on the testing and implementation experiences during data collection and the overall study findings, the next phase of the study will involve a larger number of participants ranging in ages three to six, including children with normal hearing. The study will utilize similar baseline procedures for pitch identification and pitch contrast, with implementation of a pitch intervention curriculum. Procedures will also incorporate expressive pitch production tasks to combine both expressive and receptive components of pitch perception as a function of speech perception and production.

It will be important to include covariate analysis in the next study phase to control for effects of maturation. Additionally, analysis in the next study phase will document the number of semitone differences children can perceive in the pitch contrasts task.

The intervention component of the next study phase will explore outcomes when music is effectively embedded across the curriculum and not limited to a designated music time. By embedding music across the curriculum, it is theorized that preschoolers who are DHH will gain more access to the temporal aspects of music, resulting in improved pitch perception and speech production outcomes.

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Table 2

Activities for Embedding Music Across the Curriculum

Academic Goal	Activity
Writing: orienting to the direction of writing	Give each child a piece of writing paper that has solid lines for them to practice writing between (the dotted line in the middle of those lines is optional). Sing the following song to the tune of *Row, Row, Row Your Boat*: Write, write, write your name / Write between the lines / Start at the left and go to the right / From top to bottom. Repeat the song 2-3 times, pausing after each line and prompting the children to repeat the line.
Math: counting to 10	Have 10 of one type of toy (e.g., 10 starfish) with enough tape on the back to allow them to stick to the wall. Sing *Ten Little Indians*, replacing “Indians” with “starfish” and “boys” with “toys” at the end of the song. Every time you reach a new quantity, hold up another one of the starfish and then stick it to the wall. Repeat the song 2-3 times, pausing after each line and prompting the children to repeat the line.
Spelling: spelling out family members’ names	Read a story about a family that has a mother, father, sister, and brother. Have pictures of each family member who was mentioned in the story. Chant the following: “M-O-M, that spells Mom / She’s a special one / D-A-D, that spells Dad / He is lots of fun / S-I-S-T-E-R / Sister is a friend / B-R-O-T-H-E-R / Let’s pretend” (Cook, 2001). During each line of the song, hold up the picture of the respective family member from the story. Repeat the song 2-3 times, pausing after each line and prompting the children to repeat the line.
Science: learning about arachnids	Use pictures to help introduce the vocabulary that will be used in the song: arachnid, thorax, fangs, scurry. Sing the following song to the tune of *I’m a Little Teapot*: I am an arachnid / Black and round / Here is my thorax / Here are my fangs / When I get real scared / I scurry away / I run real fast / Using all 8 legs. Repeat the song 2-3 times, pausing after each line and prompting the children to repeat the line.
Snack: giving each child 10 goldfish crackers on a plate	Use the goldfish to “act out” a modified version of the song *10 Little Monkeys*. Change the words so that “monkeys” is replaced with whatever kind of snack you are using and “bed” is replaced with “plate”. Repeat the song 2-3 times, pausing after each line and prompting the children to repeat the line.

To increase the level of difficulty for these activities, provide less prompting and modeling and provide more pauses that grant the children opportunities to fill in the blanks; filling in the blanks will target the children’s auditory memory. To decrease the level of difficulty, provide additional prompting and modeling. Using visual aids (e.g., letters or numbers) or tactile aids (e.g., animal counters), may also prove to be beneficial. If necessary, the songs can also be shortened to a length appropriate for the children’s ability levels.

APPENDIX A

Pitch Perception Data Collection Protocol

Practice protocol:

1. Using the vertical chart, point to the picture of the bird at the top of the vertical chart and say, “Let’s make a high sound, like a bird.” Make a high-pitched noise resembling a bird (“tweet”) with the child.
2. Point to the picture of the bear at the bottom of the vertical chart and say, “Let’s make a low sound, like a bear.” Make a low-pitched noise resembling a bear (“rawr”) with the child. Say, “Now you try by yourself.” Give the child the same directions about making a higher/lower sound and have the child produce the sound independently.

*Complete practice item #1

3. Play C6, G6, and C7 on the piano, describing they sound high like a bird. Play C2, G2, and C3, describing they sound low like the bear. Relate this to the chart.

*Collect data on Single Note Perception (on next page)

*Complete practice item #2

4. Play C4 on the piano and say, “This is our starting sound.” Play C7 and ask, “Is this sound higher like a bird or lower like a bear than our starting sound?” Relate this back to the chart. Replay C4 and C7 2-3 times.
5. Play C4 on the piano and say, “This is our starting sound.” Play C2 and ask, “Is this sound higher or lower than our starting sound?” Relate this back to the chart. Replay C4 and C2 2-3 times.

*Complete practice item #3

Data collection protocol:

*Repeat directions 4 and 5 from above but collect data for C4 reference (do not help)

*Move colored bar

*Repeat directions 4 and 5 from above but collect data for C5 reference (do not help)

*Move colored bar

*Repeat directions 4 and 5 from above but collect data for C3 reference (do not help)

APPENDIX B

Pitch Perception Data Collection Sheet

Study subject # ______________________________ Date __________________

Practice

P1.	Tweet	+	-			
	Rawr	+	-			
	Rawr	+	-			
	Tweet	+	-			
P2.	C6	+	-	C2	+	-
	G2	+	-	C7	+	-
P3.	C4 --- C7 +	-		C4 --- C2 +	-	
	C5 --- E3 +	-		C3 --- G5 +	-	

Single Note—Perception:

G6	+	-	E2	+	-
G5	+	-	C3	+	-
E6	+	-	E5	+	-
C7	+	-	G3	+	-
C2	+	-	C6	+	-

Pitch Contrasts:

First Note	Last Note	Higher/Lower	Correct/Incorrect	# Notes Difference
C4	G7	Higher	+ -	25
C4	E6	Higher	+ -	16
C4	E3	Lower	+ -	5
C4	C6	Higher	+ -	14
C4	G3	Lower	+ -	3
C4	C3	Lower	+ -	7
C4	G4	Higher	+ -	4
C4	E4	Higher	+ -	2
C5	C3	Lower	+ -	14
C5	E6	Higher	+ -	10
C5	E3	Lower	+ -	12
C5	C6	Higher	+ -	7
C5	G3	Lower	+ -	10
C5	G7	Higher	+ -	18
C5	G4	Lower	+ -	3
C5	E4	Lower	+ -	5
C3	E2	Lower	+ -	5
C3	E5	Higher	+ -	16
C3	E3	Higher	+ -	2
C3	C6	Higher	+ -	21
C3	G3	Higher	+ -	4
C3	G2	Lower	+ -	3
C3	G4	Higher	+ -	11
C3	E4	Higher	+ -	9