A Non-Musical Paradigm That Isolates Pitch Recognition Mechanisms

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Absolute Pitch (AP) is the ability to label and/or reproduce a given pitch without external reference. There exists a close relationship between AP development and pitch memory skills. At the root of these skills are pitch perception mechanisms that are loosely understood. Prior research has probed these by modeling AP validation tests, which fail to effectively isolate, develop, and examine such mechanisms. Moreover, where recent research suggests that AP development diminishes quickly by the teen years, this study explores whether the contrary may be plausible by examining pitch perception skills in students around the critical developmental age. To do this, a computerized training method which included both visual and auditory stimuli, similar to the Simon TM game, was developed. During the game, visual stimuli were removed, requiring participants to perceive and further label the supplied pitches. The method demonstrated that a simple computer program can be used to isolate and develop pitch perception mechanisms ($p < 0.01$). The research also suggests that pitch perception is still functional among those above the critical age range ($p < 0.001$). It is therefore suggested that non-musical paradigms, distinct from traditional validation tests, be used for the further investigation of pitch perception mechanisms and a better understanding of AP.

Absolute pitch (AP) is the ability to label and/or reproduce a given pitch without external reference. It is a rare ability showing up in the general population in as few as one in 10,000 (Profita & Bidder, 1988), although it has been found to be more prevalent among music institutions (Levitin, 1996), and among the ethnic group of Asians, often attributed to the tonal nature of Asian languages (Deuscht, Henthorn, & Dolson,1999). The skill is also more prevalent among those who have had formal music education at a young age (Sergent,1969;Wellek,1938), largely before the cognitive shift(ages0~6)(Takeuchi&Hulse,1993), after which development decreases rapidly afterwards (Brady, 1970; Cuddy,1968,1970; Meyer,1899). By the age of 12, development has been found to be greatly diminished (Levitin,1994). While some research (Profita & Bidder, 1988; Baharloo, Johnston, Service, Gitschier, & Freimer, 1998) suggests an underlying genetic basis, most researchers believe the acquisition of absolute pitch is affected by both genetics and early music training(Chin, 2003; Levitin, 1994), as well as the familial environment (Baharloo, Service, Risch, Gitschier, & Freimer, 2000).

Furthermore, several studies suggest that AP possessors perceive pitches much more categorically, analogous to other sensory stimuli perception, such as color (Peacock, 1984; Rogers, 1987) and phonemes (Siegel & Siegel, 1977), than do non-possessors. For example, previous research(Siegel,1974)found that AP-possessors demonstrated superior pitch memory only when a categorical system was in place, which in the study’s case was pitch names. Meanwhile non-possessors are thought to perceive pitch as a physical continuum, only identifiable from known reference pitches, the basis for relative pitch.

It follows then that both absolute and relative pitch are based in pitch memory with differences arising from the reference pitches: AP relies on pitch memory in that an external tone is matched against an internal sound bank, and the appropriate label can then be produced; whereas with relative pitch, a reference pitch is substituted for the internal sound bank, and the appropriate label is given by the distance from the reference pitch. This fundamental difference in reference pitches with respect to the commonality of pitch memory between the rarely-possessed skill of AP and the largely-held ability of relative pitch suggests then that pitch perception mechanisms, which are at the root of pitch memory, may be isolated to better understand the two skills. This is not a novel idea, either, as other AP studies have involved pitch memory tasks, such as those in Siegel's 1974 study. Most of these studies, however, have focused on the contrasting of AP possessors and nonpossessors through pitch memory tasks that often parallel AP validation tests, in that participants are asked to identify single pitches or choose a correct pitch from a given set, in order to shed some light on the otherwise unclear ability. By modeling studies in this fashion, the pitch perception mechanisms are only being examined, not isolated and developed in a systematic, categorical manner.

Indeed, development and examination of truly isolated pitch perception mechanisms, coupled with a categorical labeling system, may very well simulate conditions similar to those of AP-possessors. Therefore, if these pitch perception mechanisms can be isolated in such a manner, then the mechanisms can be developed through a rigorous training method that will ultimately culminate in an ability not unlike AP, representing the primary hypothesis of this study. In this way, a better understanding of the cognitive functions of AP, and thereby its development, can be achieved. Moreover, if such a model can be developed, then a reassessment of the developmental differences around the critical ages can be conducted to shed further light on the issue, forming the secondary hypothesis.

Method

Model Development

In order to develop a model that both isolated and developed pitch perception mechanisms in a categorical manner, as opposed to simple examination, pitch memory tasks were disguised as a non-musical game involving both visual and auditory stimuli. Inspiration of such a model stemmed from the Simon™ game, which consists of following randomly generated sequential orders around a pie comprised of four sections of unique flashing colors and pitches. It was observed that memorization of the series of the pitches, rather than color or spatial position around the pie, often proved to be an effective gameplay strategy. This would then suggest that a game environment like that above may create a favorable setting for isolating pitch perception mechanisms, thereby providing a basis for the experimental paradigm.

The SimonTM concept was expanded to include 12 sections of unique colors and pitches to account for the 12 chromatic pitches in an octave. The initial presence of visual stimuli would aid memorization of the pitches by providing additional associations, analogous to flash cards for the pitches. Furthermore, there were no positional adjustments around the pie among levels as the game progressed. Therefore, the gradual removal of visual stimuli would increase dependence upon pitch perception and labeling. Colors and note names were chosen as the visual stimuli due to their use in a previous study(Rogers, 1987); their contributions were not evaluated, however, since the stimuli were ultimately removed by the final level. In this way, the game was characterized by three levels: (1) the dictated order was given by flashing colors, note names, and pitches, while colors remained on the pie, (2) the dictated order was given only by pitches, while colors remained on the pie, (3) the dictated order was only given by pitches, while the colors were removed and replaced with gray sections (Figure 1).

The game progressed through the following procession of levels: 3-1-2-3. The initial third level provided a controlled environment where players were naïve with respect to the relationship between the pitches and their corresponding positions. This provided a basis from which performance at the final instance of the third level could be accurately assessed. Pitch memory could then be evaluated in terms of game performance; that is, the maximum sequential length given by the application that was successfully matched by the user during the third levels.

Participants

Participants consisted of 266 middle school students (Mage=10.8, SDage=2.6) from the School of the Osage campus located in Kaiser, Missouri. Age breakdown comprised two major groups: (a) 3rd and 4th graders (<12 years old) and (b) 6th and 8th graders (>12 years old). The sample space was predominantly Caucasian (n>260) and there were no significant gender variations observed. The institutional review board waived guardian consent due to (a) lack of psychological stress,(b) anonymous collection of data, and (c) the teachers' willingness to incorporate the program into their normal classroom settings. However, informational fliers were still sent to parents to make them aware of their child's participation in the program.

Production of the Computerized Training Program

The game environment described above was implemented by a local programmer for free using the programming languages of ASP.NET and Flash. This provided an internet version of the game that was easily accessible to anyone. The resultant data consisted of (a) a user number which was linked to the user's age and gender, (b) which pitch was given, and (c) whether the user's response was correct or not. Pitches were generated using sine waves produced from a Yamaha PSR1100 electronic keyboard starting from middle C chromatically up to the next B pitch. Pitches were exactly one second in length with 50 ms decays. Pitches administered in sequence from the game had a 100ms interval between each pitch. Each game instance had a specific seed number that randomly positioned the 12 pitches around the 12 positions of the pie; this seed and the resulting positions of the pitches on the pie remained constant throughout all levels. Sequences given by the computer ("Simon") were randomized, starting with a single pitch, and upon each successive round, the sequence was lengthened by one pitch. Upon failing a round, a new sequence was randomly generated at that current level starting with a sequence length of one.

Experimental Training and Evaluation

Experimental participants, after explanation of the game and study, created an anonymous user account, and were taken directly to the third level as a control test. Consistent with Figure 1, these participants had no exposure to the relationship among pitch, position, and color. Upon missing a note, the participants were taken to the first level where they remained until 10 correct pitches in a row had been achieved. Success in the first level brought them to the second level, whereupon 10 consecutive successful pitch identifications admitted participants to the third and final level. Exposure to the first two levels was to familiarize the participant with the pitches and their corresponding positions, and to strengthen those correlations, respectively. Upon completion of these training levels, the group was given one attempt at the last level. Performance was again measured and compared to their initial pre-evaluation.

Analysis

Game performance, in terms of maximum sequential length achieved during the third level (without visual stimuli) per individual and per group, formed the basis of all analyses. The baseline for sequential length was three pitches correctly identified in a row, determined by its corresponding low probability (0.058%) of incidence. It may be noted, however, that even one pitch being correctly identified results in an 8.3% probability. Despite this, three or more pitches in a row clearly indicated a developed pitch memory within the confines of the model.

The event of semitones, pitches one chromatic step away from the desired pitch (for example, C# and C), must also be addressed. It was observed that some participants (N=7) consistently chose the correct pitch or one of that pitch's two semitones. The consistent nature of these participants negated coincidences caused by the randomization of the positions around the pie. Previous research (Levitin, 1994) had also taken semitones in account in evaluating correct pitch identifications. Therefore, semitones were accepted as correct pitches for those participants who consistently chose semitones, but not for coincidental identifications.

Results

In all, 266 participants' data were recorded and included into the results. An additional 17 participants completed the computerized training method, but large variations in age (15-53) voided inclusion of their data in this study. Frequencies of performance (n>3, 4, 5, 6 consecutively correct answers) were recorded for each session. No more than six pitches in a row were identified except for a few individuals (N=10).

Pre-Evaluation vs. Post-Evaluation

Of the pre-evaluation attempts, there was not one instance of three pitches being correctly identified in a row. There were several accounts of single pitches identified, however. In comparison, the post-evaluation data afforded 90 incidents of three or more consecutive pitches correctly identified. This accounts for 37.1% of the sample size. At four or more pitches, the post-evaluation data yielded 76 incidents, or a 31.4% representation. Five or more pitches resulted in 50 incidents, or a 20.7% representation. Six or more identification finally comprised 38 individuals, or a 15.7% representation. Total correct identifications were used in a paired t-test to validate these results with $p < 0.01$.

Age Groups

The age groups of 8 to 11 years old and 12 to 14 years old were also analyzed for comparison. The younger group (Mage=9.4) consisted of 162 participants, and the older group (Mage=13.2) consisted of 104 participants.

Performance evaluations at three or more correctly identified pitches resulted in 52 incidents (32.1% representation) for the younger group, and 38 incidents (36.5% representation) in the older group. Four or more pitches yielded 43 occurrences (26.5% representation) from the younger group and 33 occurrences (31.7% representation)from the older group. Five or more correct pitches afforded 31 incidents (19.1% representation) from the younger group and 19 incidents (18.3% representation) from the older group. Six or more pitches finally resulted in 25 occurrences (15.4% representation) from the younger group and 13 occurrences (12.5% representation) from the older group. A paired t-test for total correct identifications was also conducted for the two groups resulting in $p<0.001$ (Table 2).

Discussion

Comparisons between the pre-evaluation and post evaluation data clearly indicate a substantial difference in correct identifications and thereby pitch memory within the confines of the model. This seems valid as participants would not have any prior knowledge to the mapping of pitches to the positional elements of the pie during the pre-evaluation test. This strengthens the idea that by the time the post-evaluation test was reached, participants were able to effectively perceive and label the pitches. In this way, it may be surmised that through the instance of this model, pitch perception mechanisms were, indeed, isolated, and further developed to mimic AP-like conditions, supporting the primary hypothesis. That said, a further evaluation of the visual stimuli would provide a better understanding of their contributions.

To address the secondary hypothesis, comparisons between the two age groups afforded no dramatic differences. Indeed, identification densities (sample representations) were nearly identical for the two groups. This seems to suggest that both groups demonstrated an equal capacity to effectively perceive and label pitches when necessitated. This is there supportive of the secondary hypothesis stating that an age barrier does not exist for pitch isolation and recall processes as predicted by earlier research.

Of further interest, it was found that a large representation of the sample (~75%) demonstrated absolute memory for at least one pitch. These pitches may result from a “home” or reference pitch possessed by the individual, which may be attributed to the individual’s baseline pitch for speaking or the first exposed pitch of the game due to its highly repetitive frequency. Indeed, the latter seems to prevail, after assessing post-evaluation interviews with the classes.

In addition to these points of discussion, the most frequent identifications represented the pitches of C, D, and A#. This may be correlated to the pitches’ occurrence in Western music. The keys of C and D are common for many children’s songs, such as “Twinkle, Twinkle Little Star” and “Row, Row, Row Your Boat”, and many Western bands and orchestras, such as the school’s own, tune themselves to the key of A#. In this case, this would represent the formation of an experiential home pitch from which the students could easily identify, as illustrated by the data.

Conclusions

The study herein presented a non-musical paradigm to isolate and develop pitch perception mechanisms in an attempt to reproduce AP-like abilities within the confines of the model. By application of this model to individuals near the previously suggested critical age range for AP development, a further assessment of this age barrier for pitch perception was conducted. The deviation of this model, which was designed from a household game, from earlier paradigms that paralleled AP validation tests has been found to be effective in the isolation and development of inherent pitch perception mechanisms, supporting the initial hypothesis. Indeed, the game increased dependence on pitch perception by removing visual stimuli until only a pitch was given, finally requiring the individual to perceive and label the pitch by a positional element. A substantial increase in pitch memory was observed across the sample set when compared with the control, pre-evaluational runs, suggesting the development of the pitch perception mechanisms. Furthermore, both age groups, those above and below the critical age, were shown to perform nearly equally in their pitch perception skills, thereby contradicting previous studies, and supporting the secondary hypothesis that AP-like skills can be developed above and below the suggested critical development age. In this sense, the non-musical paradigm, distinct from AP validation tests, may therefore provide more accurate data on the functionality of pitch perception mechanisms and by consequence, the development of AP itself. While the AP-like ability was confined to the game, and individuals, when exposed to new timbres and octaves, failed to correctly identify pitches given to them, the model does offer an environment where further development may lead to a truer representation of AP at any age.

Acknowledgements

Special thanks must be given to Christopher Reeves, my high school research teacher for this project, for his invaluable advice and discussion on the project. Thanks must also be given to Tom Cordes as well for programming the Flash software and hosting the online version on his server. Additional thanks to Samuel White for allowing the use of his music students and helping proctor the tests, and also the faculty of the School of the Osage for their support in this study.