1997

Children's performance on computer game audiometry versus manual audiometry

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DOI: <https://doi.org/10.31979/etd.r54a-3rh5>
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**Children's Performance on Computer Game Audiometry Versus
Manual Audiometry**

A Thesis

Presented to

The Faculty of the Division of

Special Education and Rehabilitative Services

Program in Communication Disorders and Sciences

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

By

Tammieh Vernon

December, 1997

UMI Number: 1388228

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ABSTRACT

Children's Performance on Computer Game Audiometry Versus Manual Audiometry

By Tammieh Vernon

The increased use of computers in audiology reflects developing technology and the exigency of utilizing "state of the art" equipment and testing methods. Game Audiometry (A1.0) has been developed as a multimedia approach for providing an accurate and reliable test for pure-tone air conduction thresholds. In this study, the Game Audiometry (A1.0) was administered to 24 normal-hearing children and compared with manual testing to establish test reliability and validity.

The results indicated that, while a statistically significant difference existed between the game and manual pure-tone audiometry, the difference of 2 dB was clinically insignificant. Test-retest variability was small. Subjectively, almost all of the children preferred the Game Audiometry to the manual testing method.

Further modification of the test algorithm and parameters may result in faster administration. The information obtained in this study will facilitate use of automated applications in the clinic.

ACKNOWLEDGMENTS

I would like to express my sincere gratitude and appreciation to the members of my committee: Malini Subramaniam, Ph.D., Bobbi Redinger, M.S., and thesis chair June McCullough, Ph.D.. I am especially grateful to June McCullough whose continual encouragement and commitment have made the completion of this thesis possible. I would also like to express my appreciation to Michael Abrahms, Ph.D., for his patience and support with the statistical analysis.

Special thanks to my family, who are always by my side, with reassurance and love. Your understanding, and kind words help me achieve goals such as the completion of this study.

Finally, I would like to send a special thank you to my husband, Bruce, who has not only given me support and encouragement throughout this project, but through all of my educational endeavors. Thank you Bruce, for your love and faith helps me fulfill my dreams.

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CHAPTER I

INTRODUCTION

Traditionally, pure-tone audiometry using a behavioral procedure has been the method of choice in testing hearing sensitivity in adults as well as children. Decisions regarding the management of hearing loss are made in a large part on the basis of the results of pure-tone audiometry. It is therefore imperative that the auditory behaviors observed in threshold audiometry are reliable and are of defensible validity (Yantis, 1994). With older children, manual pure-tone audiometry involves either hand raising or button pushing in response to sound. With younger children, “play audiometry” is used to obtain threshold. This procedure involves training a child to respond using a simple play-like activity, such as placing a block in a bucket when a sound is heard. Threshold is defined as the lowest intensity at which the signal is detected fifty percent of the time. This is repeated for several frequencies (ASHA, 1978).

Performance on pure-tone audiometry is influenced by the developmental and chronological levels of a child. Thus, an audiologist may benefit from the availability of several different techniques to elicit reliable threshold. In the last decade, as microprocessors have become increasingly common and technology has advanced, personal computers have become integral to clinical settings. The advantages of using a computer to test hearing include, an increase in speed of testing through automated algorithms, easy storage of information, and convenient transfer of information into report formats.

Children today are introduced to the use of computers at a younger and younger age. A software package (Game Audiometry, A1.0) has been developed that automates threshold testing for children in combination with a visual reinforcement paradigm (Decibel Instruments, Inc., 1996). The Game Audiometry procedure involves children interacting with a software program featuring a colored animal house displayed on a monitor. The child listens for tones and presses a game pad in response to sound. The child is reinforced visually as animals appear in the windows of the house, and through verbal statements presented via the earphones. The use of a “computer game” for testing hearing in children affords advantages both to the audiologist and to the child who is being tested. Specifically, the audiologist may find using game audiometry more time efficient, while the child is entertained.

The purpose of this study was to evaluate children’s performance using the new automated Game Audiometry, and to compare several aspects of performance with manual testing. Specifically, thresholds were obtained using the automated and manual test protocols in order to determine the validity of the Game Audiometry procedure. Also, testing was conducted on two separate occasions in order to establish the test-retest variability of the game audiometry protocol. Other procedural variables, such as time of administration and subjective performance, were also measured.

It was hypothesized that valid and reliable thresholds could be obtained in young children (ages four through seven) using the Game Audiometry procedure. Suggestions

for modifying the game protocol to maximize the clinical efficiency of the automated procedure were derived from the data and are presented in the discussion.

CHAPTER II

REVIEW OF THE LITERATURE

Presently, there is limited research available on the use of automated multimedia pure-tone testing in the pediatric population. A manual testing procedure is the most often used method with children. The use of a computer in pure-tone air conduction testing presents an interactive method where children use a familiar response style (game pad).

This literature review addresses several variables of automated and conventional testing. It describes the development of play audiometry and of different computer protocols in the clinical setting. The computer methods examined include speech testing with children, and automated algorithms with infants and children. The review also focuses on computer efficacy and procedural variables.

Conventional Pure-Tone Threshold Testing

Manual Threshold Test Procedures Used with Children

O'Neill, Oyer and Hillis (1961) studied the effectiveness of several audiometric procedures for obtaining pure-tone thresholds of young children. Fifty-eight children with a mean age 65.5 months, all less than 100 months, were tested. Fifty percent of the children were within a year of the median age of 64 months.

Testing began with a pre-test play period to familiarize the child with the environment, during which the examiner assessed the child's awareness of sound, and selected an appropriate testing procedure. Pre-test activities consisted of games in which the child made simple responses to auditory and visual stimuli, and an activity using a painted clown

face mounted on a test console. The actual test procedure was selected based on the mode of play the child preferred. Most of the children were conditioned to strike a drum, ring a bell, or pile blocks while a tone was presented.

Results from O'Neill et al.'s investigation showed that 84% of the children tested responded consistently on play audiometry. They also found that earphones/bone vibrators could be used for testing, making it possible to obtain both air and bone conduction thresholds in each ear individually.

Children above the age of four were more easily tested with more complex testing methods, including the Haug Pediacoumeter, based on a "peep-show" principle. Here the child may have seen any one of seven jack-in-the-box figures emerge from the testing apparatus as a reward. Many older children were tested, or could have been tested accurately using traditional manual methods, but it was found that they were not as fearful and became more enthusiastic and cooperative when play audiometry was used.

The results of O'Neill et al.'s study suggest that even older children (i.e., ages six and seven) may prefer a more play-like task when having their hearing tested.

Computerized Audiometry

Computers in a Clinical Setting

Computer systems are used in the clinical setting. Computer audiometry allows the professional to spend more time on the human, clinical aspects of patient care, through elimination of time previously spent on labor intensive, paper based tasks (Radcliffe,

1990). Computer systems can be used to gather, organize, store and manipulate data, allowing audiologists to make quicker and perhaps, better clinical judgments.

A principal advantage of computer technology is that ease of data transfer and retrieval reduces time in record keeping, while enhanced visual displays and printouts help the audiologist explain the results to the patient easily.

Use of Computers in Audiology

The development and use of computers in the audiologic setting is evolving continually. Development in computer clinical applications include the use of speech recognition testing, pure-tone audiometric functions, auditory evoked potentials, and otoacoustic emissions. The next expansion of computer testing involves pediatric models such as game audiometry, where pure-tone testing integrates with play audiometry.

Automated Pure-Tone Pediatric Tests

Keith and Smith (1987) reviewed the automated pediatric Playtone audiometer. The Playtone audiometer was described as an audiometer and monitor featuring animated color pictures on a video screen. The system initially displayed a train on the screen to catch the child's attention. It then changed screens to show a carriage with six windows, with a face appearing in the top right corner of the monitor. The child responded appropriately to tones by pressing a touch pad and if the response was appropriate, the face would go into the carriage and a new face would appear in the corner. When the carriage filled-up, the cycle would repeat with a new set of faces. The computer game

came with several color screen options such as a bus, a boat, an airplane, or a teddy bear that gets dressed.

Playtone operated off of four available modes using color images as reinforcement. Practice mode was used for conditioning. The screening mode used levels of 20 - 25 dBHL through an automatic sequence in the four main frequencies. The automatic mode used full air conduction threshold audiometry at four to nine frequencies in each ear. The audiometer could also function as a full audiometer with air and bone conduction testing. The threshold measures used either full Hughson - Westlake, or an optimal faster custom method.

The Playtone audiometer used adaptive timing in its automatic test mode to match the speed of the child. It used randomized inter-stimulus variables and the valid response period was adaptive to the child's response speed. Playtone performed validity checks to detect inappropriate responding in the screening and automatic mode. It also performed checks on false positives, did a 1000 Hz retest, and detected continuous pressing of the response button. It detected response hysteresis, i.e., excessive number of trials to find threshold and failure to respond as stimulus intensity increased up to 90 dBHL. Inappropriate responses halted the test and a warning signal would sound as an indicator to use caution in interpreting results. The audiometer further used a digital calibration method. The Playtone audiometer's results were able to be printed out on a built in printer, or simply viewed on the LCD screen.

In addition to the development and research on the Playtone audiometer, other styles of video animated assessment methods were explored. These instruments also attempted to create an interactive environment for pediatric testing.

VERA 103 Visual Reinforcement System

Hansen and Osterhammel (1990) reviewed the VERA 103, visual reinforcement system introduced by Madsen in the 1990's. This system comprised a control unit and color video monitor featuring animated color video pictures. The self contained VRA system did not include an audiometer, but was designed to be used in connection with almost any audiometer, and could be connected to all Madsen audiometers. The program had one unit with a happy clown's face on the front panel, whose nose was used as the response button. In the testing situation, the child was reassured by the clown, while attention was focused on the bright color picture.

Appropriate responses were rewarded by an action on the screen, such as a clown throwing a ball through a hoop, or a duckling joining its mother in a pond. The unit featured eight picture sequences, which differed in both subject matter and 21 separate actions.

Hansen & Osterhammel suggested that the VERA 103 system provided hearing health care professionals with the technology to facilitate the testing of the special population of pediatric audiology. While the VERA 103 could be set up with any audiometer other researchers and companies continued to develop programs that would work as an independent system.

Concurrent with computerized pure-tone pediatric test development, speech audiometry using a multimedia format expanded from traditional testing to an interactive method.

Clinical Computer Use: Speech Discrimination Testing

In addition to administering sensitivity tests, computers have been used to administer word recognition testing for auditory acuity. McCullough, Cunningham, and Wilson (1992) published research on the performance of children with the written portion of auditory-visual word identification materials measured using a computer. Specifically, the test used list 1A and 2A of the Picture Identification Task (PIT), with a fifty monosyllabic word list. The test words were within the reading ability of elementary school children, with 89% at or below the reading vocabulary of fourth graders. Twenty-four subjects were tested with each child seated in a double walled sound proof room in front of a computer monitor. Subjects were given a hearing evaluation consisting of otoscopy, tympanometry, screening acoustic reflex, and pure-tone, air-conduction threshold levels. Percent correct identification scores consisted of two signal-to-noise ratios in oral (open set) and pointing (closed) response modes establishing the relationship between the two response paradigms, and providing normative data for the pointing task in a computer format.

McCullough et al. found that the written word portion of the PIT can be utilized in a computer format to evaluate the word identification performance of children who read at

a fourth grade level or above. They suggested that the computer method was an accurate and enjoyable way of testing children who read at a fourth grade level or above.

Although the authors' did not use a computer driven paradigm for pure-tone testing, they showed children's ability to accurately respond to testing using a computer format. The next logical step is to evaluate the efficacy of computer automated programs in obtaining pure-tone thresholds and in determining the computer's efficacy with younger children.

Use and Efficacy of Computerized Algorithms in Testing Infants and Children

Eilers, Widen, Urbano, Hudson, and Gonzales (1991) examined the effects of variable starting and stopping rules as they interact with infant behavior in influencing the accuracy and efficiency of infant auditory threshold testing using a five-up, five-down automated staircase procedure. Their study compared outcomes generated by the infant response model used through a computer automated simulator. Simulations were used to test the effects of starting intensity, stopping rules and test accuracy in relation to infant behavior (deviation from true threshold) and the number of test trials to develop an efficient algorithm.

Eilers et al.'s study selected infant subjects from a public health well-baby clinic, graduates of neonatal care units, and volunteers. In all, 146 infants age 25-118 weeks, mean age 56.5 weeks served as subjects.

Infants were tested in a sound treated room by one of five examiners who used the sound field speaker system with the standard audiometer replaced by an IBM XT

microcomputer with special software (IVRA model 100, Intelligent hearing systems). The reinforcer consisted of a stuffed animated toy housed in a darkened Plexiglas box located above the loudspeaker. The software was designed to implement a staircase testing procedure, generate and present signals, initiate trials, administer reinforcement following a correct trial, and record all trial information. Each test signal was a series of four 500 ms warble tones with inter-stimulus intervals of 500 ms. Center frequencies of .5, 1.0, 2.0 and 4.0 kHz were digitally produced by frequency modulation (FM) of sine waves at 20 Hz to produce a frequency deviation of $\pm 20\%$ of the center frequency.

Data analysis included variance analysis using minimum response levels in dBHL at each of the four test frequencies (Eilers et al.). Using the computer simulation automated algorithm distinguished accurate minimal response levels. This simulation had little significance in the starting intensity and stopping rule. The algorithm successfully discriminated a group of infants with normal middle ear condition from those with abnormal middle ear status. The study indicates that an automated hearing test algorithm may be successfully used for assessing hearing status of infants between 6 months to 2 years of age. Although the accuracy of the test was largely unaffected by starting intensity and stopping rules, the stopping rule had a profound impact on test length.

Eilers et al.'s study contributes to the development of a pediatric computer protocol. As efficacy of testing methods are important, computer algorithms are affected by procedural variables, potentially varying test outcome. Review of the limitations and

benefits of using certain procedural variables help to effectively set the parameters of computer programs.

Procedural Variables

Although Hughson and Westlake (1944) proposed a standard audiological procedure and recommended that uniform audiological pure-tone tests be used, over time, adaptations for testing have been made. Most adaptations have retained a central feature from Hughson and Westlakes initial method, such that thresholds are estimated by trials at successively higher levels until a subject responds, at which point the level is decreased and another ascending trial is begun. Methods vary in the stopping rules determining when the measure is terminated.

Marshall and Hanna (1989) researched stopping rules for ascending audiological test procedures using a method termed Monte Carlo. The Monte Carlo method is a computer simulation allowing estimation of the effects of various procedural manipulations on performance with little investment of experimenter or subject time. With this simulation, subject populations may be precisely specified to test hypotheses concerning the relationship of test parameters to subject parameters. The idea in simulating different stopping rules is to see if parameters can be chosen to improve the reliability and speed of testing.

Marshall and Hanna also focused on using a procedural variation, termed a “true ascending series.” For this method, only responses immediately preceded by a stimulus at a lower level were used for threshold calculations. If at the end of an ascending series, a

response was obtained at 20 dB, followed immediately by a response at 10 dB, the response at 10 dB would not be counted as it was not immediately preceded by a lower level. When using the “true ascending series,” the authors found it had an advantage of yielding thresholds more uniformly located in terms of dB relative to the 50% point on the psychometric function.

The authors compared data derived using different stopping rules through the Monte Carlo simulation. It determined that threshold estimations were similar for all stopping rules. The standard deviation within levels was a measurement of the repeatability of the threshold estimate. All stopping rules had similar standard deviations within levels. The research reported consistency of threshold estimate across levels, such that the threshold estimate reflects accuracy as well as repeatability. The characteristics of the two response criteria (two responses out of four presentations) was found to be very similar to those with three response criterion (three responses out of six presentations). The advantage of using a two response criterion is that it requires fewer trials to obtain a threshold estimate than does the stopping rules using a three response criterion.

Using a two response stopping rule allowed accurate results, consistent with those determined using a three response rule. Marshall and Hanna suggest using the two response stopping rule is quicker, serving as a testing advantage.

Applicability of Computerized Play in Testing Normal Children and Mentally Retarded

Individuals

Martin, Richards, Blaesing, and Descouzis (1991) investigated an alternative audiologic testing method compared to standard play audiometry in assessment of normal functioning young children and mentally retarded persons. The authors used the Playtone audiometer, with computer graphics and video animation. They compared the speed and precision of two audiometric assessment procedures - traditional play audiometry and Playtone audiometry. The study researched differences in test time between the procedures within or between the subject groups and questioned if there were differences between the procedures in minimum response levels obtained within or between the subject groups.

Study subjects included two groups of fifteen individuals who had normal hearing at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz. All subjects were able to perform required visual and motor tasks. Group one consisted of fifteen normal-functioning children, aged three to five years. Group two included fifteen mentally retarded persons with the mental age of three and a half years.

Changes on a video display terminal served as visual reinforcement. The screen used the six windowed vehicles, where the subjects pressed the button in response to the auditory stimulus. Inappropriate responses were not reinforced by the audiometer, meaning no change occurred on the screen.

Test results were determined using a three way analysis of variance (ANOVA) on the data from all subjects to determine the significance of group, procedure, or frequency on minimal response level. No significant differences were found by frequency, however minimum response levels were significantly different by group and by procedure, and there was a significant interaction between groups and procedure. Significance of the inter-group measures was expected due to differences which the groupings were based, i.e., normal functioning and mentally retarded. Significance of the inter-procedure measures suggested that play audiometry and Playtone yielded very different mean minimum response levels. Playtone had higher minimum response levels compared to play audiometry.

A two way ANOVA was performed on data from all subjects to determine the significance of group or procedure on conditioning time. No significant interaction between group and procedures was found. Differences for the inter-group measure were expected due to the basis of group composition.

Playtone audiometry difficulties included the length of the response time window which made it difficult to condition mentally retarded subjects. The Playtone response period was also programmed so that responses occurring outside a specified time window were not reinforced. Subjects were confused by the lack of appropriate reinforcement, possibly leading to the long conditioning times noted for the mentally retarded group. The authors suggested installing a manual override of the audiometer program response period to alleviate the problem.

Martin et al. noted, in contrast with very slow responders, very fast subjects were not reinforced properly. Again, the absence of reinforcement may have muddled the conditioning process, affecting conditioning times.

The examiners' inability to change stimulus intensity until the reinforcement sequence had been completed presented another system inflexibility. Martin et al. suggested that the repetitious nature of the graphics may have had a negative effect on results obtained. As many children showed initial interest in the test, they quickly became bored. They suggested expanding the graphics to make the listening task more entertaining for children, which may reduce the test times or provide minimum response levels closer to true thresholds.

Summary and Conclusions

The development and evolution of computers and multimedia technology offers an opportunity to effectively apply principles of play audiometry in an easier and effective way, where the task can be made more interactive. Several investigators have demonstrated applicability of computers in testing children. Development in computerized pure-tone threshold and speech discrimination testing suggest that interactive microcomputer-controlled testing and animated video graphics reinforcers hold great promise for pediatric hearing assessment. Research on the computer efficacy and accuracy of particular procedural variables suggest that an automated staircase algorithm may be shortened without sacrificing accuracy and that using a two response stopping rule allows accurate results.

While previous computer- automated programs experienced inflexibility with the computer paradigm, further development in computer algorithms may reduce this problem. To date, none of the existing software has been shown to provide children with enough interaction and entertainment, while providing the audiologist with valid and reliable results, using a flexible automated program. The game software from Decibel Instruments, Inc. expands the software choices for automated Game Audiometry. The appropriateness of this video interactive software program for establishing threshold scores with children was the focus of this study.

CHAPTER III

METHODS

Introduction

The purpose of this study was to evaluate children's performance using the new automated Game Audiometry software, and to compare several aspects of performance with the traditional manual testing method. Pure-tone testing for young children (ages four through seven years) traditionally involves a manual method, i.e., the child raises a hand in response to a sound. The type of method used is contingent upon a child's developmental and chronological age. The multimedia Game Audiometry (A1.0) approach to pure-tone air conduction testing utilizes a computer monitor for visual reinforcement and entertainment, in conjunction with a game pad, which the child presses in response to auditory pure-tone stimuli. Incorporating computers into the clinical test battery may allow the audiologist a more time efficient method, with a faster, accurate, and reliable way of administering and scoring children's pure-tone threshold levels.

Subjects

Twenty-four children between the ages of four and seven years (± 11 months) served as subjects. The mean age was six years old. Four of the subjects were age four, seven were age five, seven were age six, and six were age seven. Twelve subjects were male and 12 were female. The subjects were randomly selected in response to circulated bulletins through preschools, or were volunteers, and represented several ethnicities and socioeconomic levels.

Test Environment

Subjects were tested individually under earphones (TDH - 50P) in a double-walled sound-treated room which met ambient noise levels for testing threshold according to ANSI standards (ANSI, 1977).

Instrumentation

This study utilized the Pro Digit 2000 (Excel Plus 486) clinical audiometer consisting of a personal computer with Decibel Instruments, Inc., software, Game Audiometry for Windows, version A1.0. Two monitors (Super VGA 1280 N1) were connected to the computer. One was in the test room, and the other in the control room.

Test Protocol

The Game Audiometry (A1.0) parameters were chosen “a priori” by the software developer at Decibel Instruments, Inc., in accordance with the ASHA recommended procedures for manual pure-tone audiometry, and adapted to the automated format. The goal was to keep the automated and manual variables as similar as possible in all of the procedural aspects of the protocol.

Several parameters for the Game Audiometry (A1.0) method were stipulated by the algorithm, including instrumentation presentation level, beginning test ear, signal duration, response time window, random delay, frequency testing order, bracketing parameters for threshold, and maximum number of presentations per frequency. Specifically, the automatic instructions were administered at 40 dBHL, and the left ear always served as the first test side. Signal duration was 1.0 second. The response time window (time

allowed for child's response) was 1.0 second for the first 10 subjects, and 1.5 seconds for the remaining 14 subjects. The response time window was changed by the examiner after the first 10 subjects had been tested because most of these subjects appeared to have difficulty responding within the Game Audiometry acceptable response time window. When the subject did not respond fast enough, the computer interpreted the response from the child as a "false positive," or a response given when no stimulus is present, and instructed the subject to wait until he or she heard the tone before they pressed the button. This resulted in some confusion for the child.

Random delay (interstimulus delay) refers to a randomly generated number between 0 and the selected value that was added to the response window. The random delay was 3.0 seconds for the first 10 subjects, and 2.5 seconds for the remaining 14 subjects. This parameter was changed to be consistent with the change in the response time window. The Game Audiometry algorithm specified that the selected random delay must be equal to, or greater than, the sum of the tone duration and the response window.

Six test frequencies were administered: 250, 500, 1000, 2000, 4000, 8000 Hz (re: ANSI, 1989). The beginning test frequency was 1000 Hz, followed by 2000 Hz, 4000 Hz, and 8000 Hz, then 500 Hz and 250 Hz, with a retest at 1000 Hz. The familiarization level of 30 dBHL was presented several times at 1000 Hz to allow the subject to practice and to ensure that the subject responded appropriately to the test signal, using the game pad. The actual test sequence then began at 1000 Hz, with the starting test level at 10 dB below the familiarization level. Each successive frequency was tested starting at 30 dB,

and if the child responded, the ascending staircase began, and if the child did not respond, the decibel level was increased until a tone was heard, or until the maximum presentation level was reached.

Threshold was determined as 50% (2 out of 4 responses), using the modified Hughson-Westlake ascending trial (re: ASHA, 1978), with an initial up 10 dBHL, down 10 dBHL (down 10, up 5) staircase. The maximum number of peaks per frequency (i.e., the maximum number of changes in direction during the threshold search) was set at 10 for the first 10 subjects, and 25 for the remaining 14 subjects. This parameter was modified to eliminate early test termination, as the original setting did not allow for enough direction shifts in determining threshold.

The maximum number of presentations per frequency (the amount of presentations or pure-tones the computer gave at one frequency before terminating the test) was fixed at 25 presentations initially. At times, this led to termination of the test without provision for continuation. The parameter was changed to 50 presentations per frequency, allowing the children a better opportunity to respond to the game without termination of the test.

Procedure

Subjects were tested in two sessions. Before session one, the examiner created a new file in the Game Audiometry system, entering the subject's personal data, such as name, file number, and test date. This information could later be retrieved for session two. At the beginning of session one, caregivers consented to subject participation with a signed permission slip. Caregivers were asked if the subjects had experienced any ear infections

in the past six months. For both sessions, each subject was given an otoscopic examination and subjects were evaluated for normal middle ear function utilizing a GSI 33 screening tympanometer (within ± 200 daPa). Study criterion required all subjects to have normal middle-ear admittance and pressure, and no subjects were eliminated.

In session one, thresholds were established using both the game and manual procedures. In session two, only Game Audiometry was administered to determine the re-test variability of the computer system in comparison to session one. The time interval between session one and two was an average of one week. In order to obtain “best performance” on Game Audiometry before the child’s attention span was exceeded, all subjects were first tested using the computer automated algorithm. Total session time for the first visit was 45 minutes, and 20 minutes for the second visit.

Game Audiometry, Version A1.0 Procedure

For the game procedure, each subject was seated in front of a computer monitor. The monitor displayed a color picture of a house with 19 windows, next to a lake; and pictured a clown in the upper left corner. The examiner for this test was a graduate student in audiology. While in the test room, the examiner instructed each subject to press down on the clown nose on the game pad (showing the child) whenever they heard a beep or tone.

The examiner initiated the test sequence on the computer by clicking on start, activating the computer automated game audiometry algorithm. The automatic instructions were, “Hi, my name’s Kiko. We are going to play a listening game. This is fun. (Test tone played). I heard that, did you hear that sound? Every time you hear the

sound, press the nose button down. Let's try it (test tone played again). Let's try it again (test tone played again). Good. All of my friends are hiding in the Animal House. Let's see how many you can find. Be sure to wait for the sound before you press the button down. Let's play our listening game." The examiner observed the subjects behavior and performance, and manually recorded the thresholds concurrent with the computer. A response was correct when the child pressed the clown nose immediately following the auditory stimulus. This resulted in visual reinforcement of an animal being placed in a window of the house, or moving from the house into the lake for a swim. Subjects were automatically re-instructed by the clown voice when inappropriate responses occurred i.e., "wait for the sound, before you press the button." Following appropriate responses, subjects were reinforced on a regular basis with terms such as, "good job," "terrific," or with giggling. After the house filled up with animals, subjects were also reinforced with, "you've found all the animals, now the animals would like to go to the lake for a swim, can you help them? Make sure you wait for the sound before you press the button." When the house was empty, the game instructed, "great, now you can help the animals go back into their house."

Manual Audiometry Procedure

Following completion of the Game Audiometry (A1.0), manual pure-tone audiometry began. A graduate student in audiology administered and scored this test. Stimuli were presented in a manner that closely replicated the game sequence. It was also performed in a setting consistent with normal pediatric audiological testing. Subjects were instructed to

raise their hands every time they heard a tone. As in the case of Game Audiometry, the left ear was tested first. Subjects were tested with manual audiometry using the modified Hughson-Westlake method and conforming to ANSI standards. Subjects were reinforced verbally many times throughout the test, similar to reinforcement in the Game Audiometry. Stimuli were generated and presented using the same instrument as the Game Audiometry with the Pro Digit 2000 configured for manual clinical audiometry.

Measurement of Test Time

The test time for each method was measured by a stop watch. As soon as the examiner asked the child if he or she were ready, the timer began. When the child finished the last response in each test method, the clock was stopped. When Game Audiometry (A1.0) terminated due to inconsistent responses, exceeding maximum number of presentations, or instrumentation failure, the clock continued to run, and the game method was re-started immediately.

Qualitative Assessment

A variety of subjective responses were recorded. This included: the amount of reinstruction given by the computer, children's statements to the game, any malfunction or termination of the game, and children's behavior during the game and manual methods. At the end of session one, the examiner asked each child which test he or she preferred and why.

Data Analysis

Thresholds obtained for each method were recorded for each subject. Data were analyzed using the Statistical Package for Social Sciences (SPSS), version 7.5, following the design for a six-way ANOVA that included both between-subject and within-subject variables.

CHAPTER IV

RESULTS

The results of group performance with Game Audiometry, session one, session two, and manual pure-tone audiometry were calculated for mean threshold and standard deviation. The results are presented in Table 1. A table of each age group's mean threshold and standard deviation is given in Appendix A.

A six-way ANOVA with a mixed model was performed. The between subjects variables were age (four, five, six, and seven years), gender (male and female), and time-window (1.0 and 1.5 seconds), and the within subject variables were ear (left and right), frequency (250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz and 8000 Hz), and testing method (Game Audiometry session one, Game Audiometry session two, and manual pure-tone audiometry). The dependent variable in all cases was threshold (dBHL). Three main effects were significant: method ($f = 2$; $p < .026$), frequency ($f = 6$; $p < .0001$), and gender ($f = 2$; $p < .041$). No other main effects were significant. None of the interactions between or among variables were significant. A table of ANOVA values is given in Appendix B.

The mean times for completing each method were computed for each age level. These data were not analyzed using a statistical approach since in session one, the Game Audiometry method always was administered first (ensuring that the subjects' attention spans were not exceeded). These data are presented and discussed in Chapter V.

Table 1. Group mean threshold and standard deviation for Game Audiometry session one, Game Audiometry session two, and manual pure-tone audiometry.

Method	Parameter	Test Frequency					
		250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Game Audiometry Session One	Mean	9.7	8.9	2.3	0.6	3.5	8.7
	N	46.0	46.0	48.0	47.0	46.0	46.0
	Std.	11.3	9.6	8.3	5.7	8.9	11.5
	Dev.						
Game Audiometry Session Two	Mean	6.1	4.3	1.7	0.2	0.5	5.9
	N	48.0	48.0	48.0	48.0	48.0	48.0
	Std.	7.2	5.1	5.0	3.9	6.2	7.2
	Dev.						
Manual Audiometry	Mean	6.9	5.2	1.2	-0.8	0.9	7.3
	N	40.0	41.0	41.0	42.0	41.0	41.0
	Std.	10.0	8.9	6.9	6.0	6.6	8.9
	Dev.						

Finally, the subjects' preference of test method (Game Audiometry versus manual audiometry) were recorded and tallied. These data also are presented and discussed in the following chapter.

CHAPTER V

DISCUSSION

Effects of Test Method on Performance

The results indicated that each test method (i.e., Game Audiometry versus manual) yielded significantly different results. Figure 1 shows mean thresholds (dBHL) for each method. The mean threshold was 4.7 dBHL for method one (Game Audiometry, session one), 3.1 dBHL for method one, session two, and 2.7 dBHL for method two (manual pure-tone audiometry). Although the differences in mean threshold levels were statistically significant, a change in threshold of less than 5 dBHL for any subject, is often considered normal re-test variability in the clinic. Thus, the 2 dB difference between the highest thresholds (Game Audiometry, session one) and the lowest thresholds (manual pure-tone audiometry) would not be of clinical significance; i.e. performance for both methods would be considered equal.

Figure 1 also shows that the mean thresholds for the Game Audiometry method improved by 1.6 dB from session one to session two. This indicates that the subjects experienced a small “practice effect.” The similar performance on the game from session one to session two suggests that the game was a reliable indicator of threshold.

In summary, although the effect of method was statistically significant, the small differences in threshold (2 dB or less) between the test methods indicates that the Game Audiometry software is a clinically valid and reliable method for testing young children.

Figure 1. Group mean threshold (dBHL) for Game Audiometry session one, session two, and conventional manual audiometry.

Effects of Frequency on Performance

The results of the ANOVA indicated that frequency had a significant effect on threshold. Figure 2 shows mean threshold levels for each of the six test frequencies. The highest thresholds were found at the extremes (250 Hz, 500 Hz, and 8000 Hz), where thresholds were 6.3, 5.3, and 6.6 dB respectively. Lower thresholds were found at 1000 Hz, 2000 Hz, and 4000 Hz, where thresholds were 1.28, -.389, and 1.99 dB respectively.

It is uncertain why the subjects experienced more difficulty with the higher and lower extremes of the frequency range, but it is likely that children may have difficulty perceptually in listening to these pitches and assigning meaning to them as test tones. Of course, this threshold pattern held for both the manual and Game Audiometry procedure.

Effects of Gender on Performance

Contrary to the initial expectation that performance by gender would be similar, the results indicated that males performed statistically significantly better than females. Mean thresholds of 2.1 dBHL were obtained for males, and mean thresholds of 4.9 were obtained for females (Figure 3). Although this mean was derived from all three methods, a breakdown of the data indicates that while both gender groups performed similarly with the manual pure-tone audiometry, males performed better with both sessions of the Game Audiometry (Figure 4). There was a great deal of variability between all subjects, and although there is a trend that males perform better with the game, there was no statistically significant data indicating an effect for method and gender. It is speculated that males may play more video games than females, and as a result, may exhibit a type of “practice

Figure 2. Group mean thresholds at the six test frequencies.

Figure 3. Differences in mean threshold between male and female test subjects.

Figure 4. Differences in mean threshold between male and female test subjects for Game Audiometry, session one, session two, and Manual Audiometry.

effect” for Game Audiometry. Subjectively, the examiner felt that at times, each gender group performed just as well as the other, however, it was observed that the male children showed great enthusiasm and interest in the protocol, while females were not as interested overall, and seemed to exhibit more frustration. Further studies are needed to verify these objective and subjective results.

Test Completion Time

The test completion time was the length of time it took each subject to perform and finish each test. The results are shown in Figure 5. The quickest test completion time was with manual pure-tone audiometry, taking a mean of 8.67 minutes. The Game Audiometry mean test times were 13.46 minutes for session one and 11.61 minutes for session two. The improved time length (shorter mean time) of session two indicates that the subjects may again have experienced a “practice effect.” These results indicate that manual pure-tone audiometry is quicker than the Game Audiometry, at least with the game’s current algorithm. Algorithm modification may help to shorten the Game Audiometry method. Of course, one of the advantages of the manual method is flexibility in test administration; thus, thresholds can be obtained in a timely fashion.

Figure 6 breaks down the differences in test completion time for individual age groups. It was expected initially that the seven year old group would perform the quickest, and that each younger group would successively have a longer completion time. However, greater variation between method and test time occurred at the seven and four year old age groups, compared to the five and six year olds.

Figure 5. Mean test completion time for Game Audiometry session one, session two and manual audiometry methods.

Figure 6. Mean test completion times for individual age groups for Game Audiometry session one, session two and manual audiometry methods.

The four year old group struggled, taking up to 21 minutes to complete the Game Audiometry, as opposed to 11.8 minutes for the manual testing. The Game Audiometry's lengthy test time may be due to subjects' fatigue, or to their lack of understanding the concept of the game and staying on that task. It was subjectively observed that this age group grew frustrated when unable to respond appropriately to the game algorithm and that subjects' easily lost interest in playing the game. The lack of reinforcement, and constant reinstruction may have impacted this age groups performance and test completion time.

For the seven year old age group, it was observed that while initially interested in the game, subjects became bored and may not have performed as well, requiring extended time for test completion. It is possible that if the Game Audiometry had additional graphics displaying greater action, the seven year old age group could sustain greater attention and maintain their focus.

Behavioral responses are a large part of audiometric testing and several minutes can often make the difference between obtaining significant test results before the child loses interest or becomes fatigued. In the pediatric population it is essential to obtain as much information as possible in an efficient manner, obtaining results from as many test frequencies as possible.

Subjective Observations

One of the goals of this study was to determine subjects' preferences for test method. All of the subjects were asked (following completion of session one) which testing method

they preferred, and why. The results are given in Table 2. All but one subject preferred playing the Game Audiometry; one child enjoyed both testing methods equally. Some of the most repeated comments about Game Audiometry were that the game was fun, exciting, and children liked the animals and colors. One child even said, “the game was like playing games on my computer at home.” Even children who had difficulty playing the game preferred its method over manual testing.

Although some adjustments and refinements of the game could be made to meet the needs of different age groups, the overwhelming preference for the Game Audiometry indicates a natural inclination for children to attend to tasks on a computer.

Suggestions for Modification of Game Software

Several aspects of the Game Audiometry software were observed by the examiner as having room for improvements that would allow for faster, frustration-reduced testing. These aspects include reinstruction procedures, reinforcement procedures, and the testing algorithm itself.

Reinstruction

All of the subjects required a minimal amount of computer reinstruction each time the game was played, similar to that in manual testing. The reinstruction was often given after children did not respond to a tone or when they responded outside the time response window. Approximately 20% of the subjects required moderate reinstruction (three to four times) playing the game, and another 20% required excessive reinstruction (five or

Table 2. Subject's age, gender, and preferred test method.

Subject	Age (years)	Gender	Preferred Test Method
S1	5	F	Game
S2	7	M	Game
S3	5	F	Game
S4	7	M	Game
S5	6	M	Game
S6	7	M	Game
S7	7	M	Game
S8	6	F	Game
S9	4	M	Manual
S10	7	M	Both
S11	6	F	Game
S12	5	F	Game
S13	6	F	Game
S14	6	M	Game
S15	4	F	Game
S16	6	M	Game
S17	7	F	Game
S18	4	F	Game
S19	6	F	Game
S20	5	M	Game
S21	7	M	Game
S22	5	F	Game
S23	5	F	Game
S24	4	M	Game

more times). This did not appear to be correlated to age, but seemed to be unique to the children's personalities.

It was observed during testing that two children attempted to anticipate the stimulus. One subject consistently counted to ten and pressed the game pad, and the other tried to guess at the presentation times. Both were reinstructed by the examiner, and subsequently performed the test as required. Again, this appeared to be due to their individual personalities, and not a problem with Game Audiometry.

The Reinforcer

For many subjects within all age groups, the clown became a real point of frustration, especially after excessive reinstruction. Individual reactions were recorded with the Game Audiometry (A1.0) sequence. One child, who was upset and felt the clown was laughing at her, stated, "stop laughing at me." The clown's laugh may need to be revised so that a different reinforcer could be used depending on the child. Another child did not like clowns, and because the game was not flexible in changing graphics and presentation, the testing method was not suitable for this child. In this instance, the monitor was turned off and the child listened to the game through the headset, and pressed the game pad button.

Based on these observations, it is suggested that future versions of the software may provide more flexibility in graphics and presentation, i.e., clowns and animals for the younger children, and action heroes, such as Batman, or Star Trek animation for older children. This would allow the child to choose from a variety of reinforcer displays.

Test Algorithm

On occasion, the Game Audiometry program continued presenting the same stimulus level, although threshold had been achieved. This seemed to occur when the ascending threshold sequence was unable to initially obtain a two-out-of-four score. When it finally obtained the 50% response needed, it continued to present the same stimulus several times consecutively, until on three occasions the Game Audiometry (A1.0) program stopped after exceeding the presentation parameter limit on the computer. It appears that an adjustment in the program could be made, and perhaps a manual override should be included. An override would allow the audiologist to move on to the next frequency and maintain test continuity.

At present, the computer monitors for both the audiologist and the child display the same information, such that anything seen on the clinician's screen (threshold levels, or literal messages), is also seen on the child's screen. For instance, if the audiologist wants to view the presentation levels, or the program displays test performance information, there is currently no way to eliminate this from displaying on the bottom of the child's monitor. This can present a distraction for the child as well as displaying information that might not be understood by children and caregivers. It would be helpful to have information appear on one monitor that would not necessarily appear on the other.

The data showed that it took children longer to complete the Game Audiometry, compared to manual audiometry. It may be advantageous to structure the game's protocol in such a way that information is obtained in a shorter period of time. This may include

using the Game Audiometry's "custom" test protocol. This capability permits the audiologist to set test parameters to their own specified test matrix (i.e., test frequency and screening level, test sequence, familiarization tone, and threshold determination). This "custom" algorithm may allow for a quicker test administration time. Further strategies to obtain test information in a timely fashion include alternating ears, and obtaining data at 1000 Hz through 4000 Hz first. If the child loses interest, becomes fatigued, and/or is unable to complete the test, the threshold levels for the critical speech frequencies have been tested, obtaining as much information as possible from both ears. This may provide more efficient time administration while obtaining as much key data as feasible.

The subjective data clearly shows that children enjoy playing Game Audiometry over manual pure-tone audiometry. Future versions of the game may address areas such as the variety of graphics, the length of presentation time within age groups, and a suitable reinforcer to match individual needs. Further study is needed with revised protocols to verify their increased effectiveness with young children.

CHAPTER VI

SUMMARY

The increased use of computers in audiology reflects developing technology and the exigency of utilizing “state of the art” equipment and testing methods. Game Audiometry (A1.0) has been developed as a multimedia approach for providing an accurate and reliable test for pure-tone air conduction thresholds. In this study, the Game Audiometry (A1.0) was administered to 24 normal-hearing children and compared with manual testing to establish test reliability and validity.

The results indicated that, while a statistically significant difference existed between the game and manual pure-tone audiometry, the difference of 2 dB was clinically insignificant. Test-retest, and method comparison for variability was small. Game Audiometry is as reliable as manual pure-tone audiometry for testing the pediatric population.

Subjectively, almost all of the children overwhelmingly preferred the Game Audiometry to the manual testing method. This advantage of Game Audiometry might be very helpful in obtaining information from children, because with behavioral testing, the child’s attention and interest in the task are a factor in achieving accurate results. An interactive program that excites this age group may entertain the child, keeping their interest in the test.

The study showed that Game Audiometry had a longer test completion time than manual pure-tone audiometry. It further indicated that there are differences in time requirements for test completion of Game Audiometry for each age group.

Further modification of the test algorithm and parameters may result in faster administration. The information obtained in this study will facilitate use of automated applications in the clinic.

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Appendix A

Mean Threshold Levels For Each Age Group

Game Audiometry (1)

Age	Parameter	Test Frequency					
		250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Seven	Mean	7.9	7.1	2.1	-0.8	5.4	4.2
	N	12.0	12.0	12.0	12.0	12.0	12.0
	Std. Deviation	8.9	7.5	8.9	3.6	6.2	9.7
Six	Mean	4.3	4.3	-2.9	-1.1	-1.4	6.1
	N	14.0	14.0	14.0	14.0	14.0	14.0
	Std. Deviation	11.4	10.0	5.8	7.1	9.5	12.3
Five	Mean	10.4	11.1	7.1	2.1	6.8	12.5
	N	14.0	14.0	14.0	14.0	14.0	14.0
	Std. Deviation	9.1	8.8	7.8	6.1	9.1	12.4
Four	Mean	24.2	18.3	3.1	3.6	3.3	15.0
	N	6.0	6.0	8.0	7.0	6.0	6.0
	Std. Deviation	8.6	7.5	8.0	2.4	8.8	6.3
Total	Mean	9.7	8.9	2.3	0.6	3.5	8.7
	N	46.0	46.0	48.0	47.0	46.0	46.0
	Std. Deviation	11.3	9.6	8.3	5.7	8.9	11.5

Game Audiometry (2)

Age	Parameter	Test Frequency					
		250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Seven	Mean	9.5	4.5	0.5	1.5	1.5	6.0
	N	10.0	10.0	10.0	10.0	10.0	10.0
	Std. Deviation	13.6	8.6	4.4	4.1	8.5	7.0
Six	Mean	1.8	1.1	-2.1	-1.8	-1.8	5.0
	N	14.0	14.0	14.0	14.0	14.0	14.0
	Std. Deviation	9.3	7.9	5.4	6.4	5.4	11.3
Five	Mean	7.9	8.3	5.4	-3.1	3.8	8.1
	N	12.0	12.0	12.0	13.0	13.0	13.0
	Std. Deviation	5.8	9.4	8.1	6.3	5.8	6.9
Four	Mean	15.0	11.0	2.0	3.0	-1.3	16.3
	N	4.0	5.0	5.0	5.0	4.0	4.0
	Std. Deviation	4.1	6.5	7.6	5.7	4.8	4.8
Total	Mean	6.9	5.2	1.2	-0.8	0.9	7.3
	N	40.0	41.0	41.0	42.0	41.0	41.0
	Std. Deviation	10.0	8.9	6.9	6.0	6.6	8.9

Manual Audiometry

Age	Parameter	Test Frequency					
		250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Seven	Mean	5.4	1.7	1.7	-0.4	1.3	5.8
	N	12.0	12.0	12.0	12.0	12.0	12.0
	Std. Deviation	6.2	7.5	7.5	3.3	5.3	8.7
Six	Mean	6.8	5.0	0.0	0.7	-1.1	2.9
	N	14.0	14.0	14.0	14.0	14.0	14.0
	Std. Deviation	7.2	3.4	3.4	4.7	8.4	7.5
Five	Mean	3.6	5.0	2.5	-0.7	2.1	7.5
	N	14.0	14.0	14.0	14.0	14.0	14.0
	Std. Deviation	6.0	3.9	4.3	3.9	5.1	5.8
Four	Mean	10.6	5.6	3.1	1.9	-0.6	8.8
	N	8.0	8.0	8.0	8.0	8.0	8.0
	Std. Deviation	9.4	4.2	3.7	2.6	5.0	5.2
Total	Mean	6.1	4.3	1.7	0.2	0.5	5.9
	N	48.0	48.0	48.0	48.0	48.0	48.0
	Std. Deviation	7.2	5.1	5.0	3.9	6.2	7.2

Appendix B

Tests of Within-Subject Effects

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncentered Parameter	Observed Power
EAR	89.979	1	89.979	0.791	0.395	0.791	0.127
EAR * AGE	386.158	3	128.719	1.132	0.382	0.340	0.220
EAR * GEND	38.502	1	38.502	0.339	0.574	0.339	0.082
EAR * WLDOW	6.790	1	6.790	0.001	0.981	0.001	0.050
EAR * AGE * GEND	9.062	2	4.531	0.040	0.961	0.080	0.055
EAR * AGE * WIN	87.707	1	87.707	0.771	0.400	0.771	0.125
EAR * GEND * WIN	0.000	0				0.000	
EAR * AGE * GEND * WIN	0.000	0				0.000	
Error (EAR)	1137.384	10	113.738		0.141		
METHOD	745.705	2	372.852	4.411	0.026	8.821	0.692
METHOD * AGE	852.578	6	142.096	1.681	0.178	10.085	0.501
METHOD * GEND	323.424	2	161.712	1.913	0.174	3.826	0.349
METHOD * WIN	291.927	2	145.964	1.727	0.203	3.453	0.319
METHOD * AGE * GEND	676.291	4	169.073	2.000	0.133	8.000	0.496
METHOD * AGE * WIN	20.106	2	10.053	0.119	0.889	0.238	0.066
METHOD * GEND * WIN	0.000	0				0.000	
METHOD * AGE * GEND * WIN	0.000	0				0.000	
Error (METHOD)	1690.741	20	84.537				
FREQ.	4695.846	5	939.169	8.936	0.000	44.680	1.000
FREQ. * AGE	1142.210	15	76.147	0.725	0.748	10.868	0.395
FREQ. * GEND	239.570	5	47.914	0.456	0.807	2.279	0.160
FREQ. * WIN	153.536	5	30.707	0.292	0.915	1.461	0.116
FREQ. * AGE * GEND	450.220	10	45.022	0.428	0.926	4.284	0.195
FREQ. * AGE * WIN	178.811	5	35.762	0.340	0.886	1.701	0.128
FREQ. * GEND * WIN	0.000	0				0.000	
FREQ. * AGE * GEND * WIN	0.000	0				0.000	
Error (FREQ.)	5254.977	50	105.100				
EAR * METHOD	52.527	2	26.264	0.638	0.539	1.277	0.142
EAR * METHOD * AGE	311.626	6	51.938	1.263	0.318	7.576	0.380
EAR * METHOD * GEND	31.811	2	15.905	0.387	0.684	0.773	0.174
EAR * METHOD * WIN	43.101	2	21.550	0.524	0.600	1.048	0.124
EAR * METHOD * AGE * GEND	36.874	4	9.219	0.224	0.922	0.896	0.089
EAR * METHOD * AGE * WIN	1.257	2	0.628	0.015	0.985	0.031	0.052
EAR * METHOD * GEND * WIN	0.000	0				0.000	
EAR * METH * AGE * GEND *WIN	0.000	0				0.000	
Error (EAR * method)	822.685	20	41.134				
EAR * FREQ.	427.660	5	85.532	2.416	0.049	12.079	0.718
EAR * FREQ. * AGE	869.175	15	57.945	1.637	0.097	24.549	0.819
EAR * FREQ. * GEND	156.237	5	31.247	0.883	0.500	4.413	0.289
EAR * FREQ. * WIN	166.211	5	33.242	0.939	0.464	4.695	0.307

EAR * FREQ. * AGE * GEND	425.161	10	42.516	1.201	0.313	12.008	0.548
EAR * FREQ. * AGE * WIN	266.113	5	53.223	1.503	0.206	7.516	0.484
EAR * FREQ. * GEND * WIN	0.000	0	.	.	.	0.000	.
EAR * FREQ. * AGE * GEND * WIN	0.000	0	.	.	.	0.000	.
Error (EAR * FREQ.)	1770.255	50	35.405				
METHOD * FREQ.	351.269	10	35.127	1.539	0.137	15.387	0.726
METHOD * FREQ. * AGE	920.061	30	30.669	1.343	0.141	40.303	0.930
METHOD * FREQ. * GEND	426.309	10	42.631	1.867	0.059	18.674	0.824
METHOD * FREQ. * WIN	214.087	10	21.409	0.938	0.502	9.378	0.467
METHOD * FREQ. * AGE * GEND	516.510	20	25.826	1.131	0.331	22.625	0.762
METHOD * FREQ. * AGE * WIN	107.275	10	10.728	0.470	0.906	4.699	0.231
METHOD * FREQ. * GEND * WIN	0.000	0	.	.	.	0.000	.
METHOD * FREQ. * AGE * GD * WIN	0.000	0	.	.	.	0.000	.
Error (METHOD * FREQ.)	2282.870	100	22.829				
EAR * METHOD * FREQ.	213.800	10	21.380	0.794	0.635	7.940	3.940
EAR * METHOD FREQ. * AGE	794.603	30	26.487	0.984	0.501	29.511	0.793
EAR * METHOD * FREQ. * GEND	317.281	10	31.728	1.178	0.314	11.783	0.582
EAR * METHOD * FREQ. * WIN	130.093	10	13.009	0.483	0.897	4.831	0.237
SDE * METH* FREQ. * AGE * GE	404.636	20	20.323	0.751	0.763	15.028	0.531
SDE * METH* FREQ. * AGE * WIN	106.680	10	10.668	0.396	0.946	3.962	0.196
SDE * METH* FREQ. * GEND * WIN	0.000	0	.	.	.	0.000	.
SD*METH* FREQ. * AG* SX * WN	0.000	0	.	.	.	0.000	.
Error (EAR * METHOD * FREQ.)	2692.593	100	26.929				

a. Computed using alpha = .05

Test of Between-Subjects Effects

Source	Type III Sum of Squares	df	mean square	F	Sig.	Non Centered Parameter	Observed Power a
Intercept	8134.56	1	8134.56	35.455	0	35.455	1
AGE	1737.117	3	579.039	2.524	0.117	7.571	0.454
GEND	1255.168	1	1255.168	5.471	0.041	5.471	0.56
WINDOW	375.028	1	375.028	1.635	0.23	1.635	0.212
AGE*GEND	1485.412	2	742.706	3.237	0.082	6.474	0.484
AGE*WINDOW	662.111	1	662.111	2.886	0.12	2.886	0.336
GEND*WINDOW	0	0	.	.	.	0	.
AGE*GEND*WINDOW	0	0	.	.	.	0	.
Error	2294.329	10	229.433				

a. Computed using alpha = .05