A Comparison of Video Versus Conventional Visual Reinforcement in 7- to 16-Month-Old Infants

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Purpose: To compare response patterns to video visual reinforcement audiometry (VVRA) and conventional visual reinforcement audiometry (CVRA) in infants 7–16 months of age.
Method: Fourteen normal-hearing infants aged 7–16 months (8 male, 6 female) participated. A repeated measures design was used. Each infant was tested with VVRA and CVRA over 2 different sessions. The total number of head turns prior to habituation, hit rate (response consistency), false alarm rate, and sensitivity for each reinforcement condition were evaluated.
Results: No significant differences were found between the 2 reinforcement methods for total number of head turns, hit rate, false alarm rate, or sensitivity. Overall, results showed no difference between the 2 reinforcer conditions in infants 7–16 months of age.
Conclusion: The results of the present study suggest that infants in the 7- to16-month-old age range respond similarly to VVRA and CVRA as measured by response consistency and false alarm rate. VVRA is, therefore, a viable option for testing hearing in infants. However, prior to clinical implementation, the effectiveness of VVRA should be explored in infants with hearing loss.

KEYWORDS: video visual reinforcement audiometry (VVRA), conventional visual reinforcement audiometry (CVRA), visual reinforcement audiometry (VRA)

Visual reinforcement audiometry (VRA) is a procedure routinely used to evaluate hearing sensitivity in infants and young children ages 6 months to 2 years. VRA has been extensively researched and found to be an effective method of obtaining reliable audiometric data from infants and young children (Moore, Thompson, & Thompson, 1975; Moore, Wilson, & Thompson, 1977; M. Thompson, Thompson, & Vethivelu, 1989). As it is used today, VRA involves the use of operant conditioning techniques used to maintain a head turn response to an auditory stimulus. When a sound is heard and the child makes a correct response (head turn) to the sound, he/she is rewarded with a visual stimulus, the reinforcement. Incorrect head turns are not reinforced. Traditionally, animated mechanical toys in combination with flashing lights have been used to reinforce the child's behavior in response to sound. This method of reinforcement is referred to as *conventional visual reinforcement audiometry* (CVRA). Although this method has been widely accepted and used as a reliable way to obtain audiometric thresholds on infants and young children, a drawback is that habituation to the test signal and/or to the reinforcer may occur before the testing sequence can be completed. This can result in delayed diagnosis and treatment, which can subsequently impact language development (Yoshinaga-Itano, Sedey, Coulter, & Mehl, 1998).

A number of factors affecting the efficacy of reinforcement audiometry have been investigated, including the frequency, intensity, and/or complexity of the eliciting stimuli (Hoversten & Moncur, 1969; Primus & Thompson, 1985; Thompson & Folsom, 1984, 1985), conditioning procedures (Thompson & Folsom, 1984), and reinforcer characteristics (Culpepper & Thompson, 1994; Primus & Thompson, 1985; Schmida, Peterson, & Tharpe, 2003). The goal of much of this research has focused on identifying procedures that maximize the number of responses obtained before an infant habituates to the signal. Various methods of addressing habituation during VRA have focused on different characteristics of the reinforcing event such as duration, novelty, and complexity. For example, Moore et al. (1977) concluded that infants below 12 months of age responded to significantly more auditory stimuli when reinforced with complex visual reinforcement (mechanical toy) as compared with no reinforcement. In addition, Moore et al. (1975) conducted a study on the auditory localization of infants as a function of reinforcement conditions. The reinforcement conditions were as follows: no reinforcement, social reinforcement, a "simple" blinking light, or a "complex" mechanical toy. The "complex" reinforcer group yielded the most responses, leading the authors to conclude that infants in the 12- to 18-month-old age range are influenced by reinforcer complexity. As an explanation, Moore et al. (1975) discussed a speculation made by Meyers and Cantor in 1967 that infants may require more time to mentally process a more complex image, thereby leading to the increased looking time.

The effects of reinforcer duration on pre-term 2-year-olds was examined by Culpepper and Thompson (1994), who found that responses habituated more rapidly when reinforced for 4.0 s compared with 0.5 s. Furthermore, Primus and Thompson (1985) reported that 2-year-olds habituated more rapidly than did 1-year-olds to VRA tasks and that the number of responses from 2-year-olds substantially increased with the introduction of a novel reinforcer following habituation to an initial reinforcer. In Primus and Thompson's study, two groups of children were presented with the same reinforcer during a head turn response paradigm until habituation occurred. Following habituation, one group was presented with the same reinforcer that was used previously, whereas the other group received a series of three novel reinforcers. The group receiving novel reinforcers exhibited a strong response recovery, suggesting that reinforcer novelty significantly affects habituation in 2-year-olds.

Schmida et al. (2003) investigated the effect of using complex video images (e.g., an animated Disney video) as a reinforcer instead of the animated mechanical toys used in the CVRA procedure. They hypothesized that video reinforcers are more complex than conventional toys and, therefore, would lead to increased number of responses from toddlers (19–24 months of age) before habituation occurred. Schmida et al. tested two groups of normal-hearing children using CVRA versus complex video images in order to determine the number of head turns elicited prior to habituation for both reinforcement conditions. The use of complex video images resulted in an average of about 4 more head turns (15.2 vs. 10.8) prior to habituation than did CVRA. These findings suggest that complex video images provide stronger reinforcement than those used in CVRA procedures and support the use of complex video images as reinforcers for 2-year-old children.

Because VRA is used with children as young as 6 months of age, it is beneficial to determine whether the use of complex video stimuli is feasible for use in young infants. Additionally, as video visual reinforcement audiometry (VVRA) is now commercially available to clinicians, it is important to establish the response characteristics of younger infants when using this method of reinforcement.

Visual attention and habituation are important factors to consider when examining visual reinforcement as a tool for audiologic assessment in children. The reinforcer must elicit a sufficient level of attraction if it is to keep the infant interested in the task. Otherwise, the child will not be motivated to respond to the stimulus being presented, therefore limiting the amount of information gathered in a testing session. Recent research suggests that attention to visual stimuli in infants and toddlers shows a developmental pattern associated with the complexity of the content of the visual stimulus. For example, Courage, Reynolds, and Richards (2006) examined developmental changes in infants' attention to patterned stimuli during the first year of life for groups of infants at 3.5, 5.0, 6.5, 9.7, and 13.0 months of age. Each infant was seated on a parent's lap approximately 55 cm from a color television monitor that displayed eight different stimuli, including a variety of still frames and moving frames (e.g., still frame from a Sesame Street video and an animated clip from the same video). The duration of the longest look toward each stimulus was measured and reported as an index of attention. It was found that dynamic images (the Sesame Street video clip) elicited longer looking times than did the static stimuli. Additionally, Courage et al. (2006) found that look duration, a measure of attention, was dependent upon age during the first year of life. Specifically, infants between the ages of 3.5 months and 6.5 months spent less time looking at stimuli than did infants older than 6.5 months, regardless of the type of stimuli. However, after 6.5 months, the time spent looking at the stimuli was dependent upon the type of stimulus being viewed. In addition, the infants' look duration declined with simple stimuli such as black and white patterns and increased with more complex stimuli such as Sesame

Street material and faces. Richards (1997) also showed that infants are more likely to visually examine a complex stimulus upon repeat exposure than a simple stimulus. In light of these findings, it is reasonable to hypothesize that a complex, dynamic video image presented briefly as a visual reinforcer will yield more responses prior to habituation than repeated presentations of the same mechanical toy. However, it may also result in higher rates of false alarms because it may be too interesting, evoking head turns in the absence of stimuli.

The purpose of the present study was to compare infants' response patterns to VVRA versus CVRA in 7- to 16-month-olds. It was hypothesized that video reinforcement, a more complex visual stimulus than conventional reinforcement, would result in an increased number of head turn responses prior to habituation relative to a less complex reinforcer. It was further hypothesized that video reinforcement might result in more false alarm responses. Specifically, the total number of head turns, hit rate (response consistency), false alarm rate, and sensitivity *(d')* for each reinforcement condition was evaluated. In addition, given that Schmida et al. (2003) concluded that 2-year-olds gave more head turns to VVRA than CVRA, individual performance was assessed between the two reinforcement conditions in order to determine if one condition provided benefit in terms of more head turns.

Method

Participants

Fourteen normal-hearing infants aged 7–16 months (M = 10.42 months) participated in this experiment (8 boys, 6 girls). All infants were tested with both methods. The condition order (VVRA vs. CVRA) was counterbalanced across the infants. Specifically, infants were randomly assigned to one of two experimental conditions. One group (7 infants) received VVRA during the first testing session and CVRA during the second testing session. The other group (7 infants) received the reinforcement conditions in the reverse order—CVRA during the first testing session and VVRA during the second testing session. Both sessions were conducted on different days approximately 1 week apart. No infant was tested with both methods on the same day. We recruited participants from the community by searching archives of birth announcements published in the local newspaper. In addition, flyers were posted at local child care facilities as well as the University of Tennessee Speech and Hearing Center. The University of Tennessee Institutional Review Board approved these recruiting methods. The criteria for inclusion in the study were (a) no parental concern regarding overall cognitive development; (b) no history of significant medical problems; (c) full-term birth history; (d) no parental concern regarding hearing, vision, or motor development; and (e) normal tympanometry (peak pressure between –150 and +100 mm H_20) and/or normal distortion product otoacoustic emissions (OAEs; signal-to-noise ratio [SNR] > 6 dB at 3 or more frequencies, distortion product ≥ –5) on the day of testing.

Equipment

All experimental testing was conducted in a sound-treated examination room (Industrial Acoustics Company, Winchester, United Kingdom) with ambient noise levels suitable for testing with ears uncovered (ANSI S3.1-1999). A GSI-38 Auto Tymp clinical immittance audiometer (Grason-Stadler, Milford, NH) was used for tympanometry. Distortion product OAE screenings were conducted using the GSI 60 DPOAE system (Grason-Stadler, Milford, NH; pediatric screening protocol 65/55 2–8 kHz). A Dell computer, using Super Lab Pro Version 2.0.4 software, was used to present all acoustic stimuli through a sound field speaker.

Setup

The setup for the experiment is shown in Figure 1. The infant participant sat on a caregiver's lap. Three examiners worked together to collect the data. Examiner 1 (E1) was in the test booth with the child and the caregiver; Examiners 2 (E2) and 3 (E3) were in the control room.

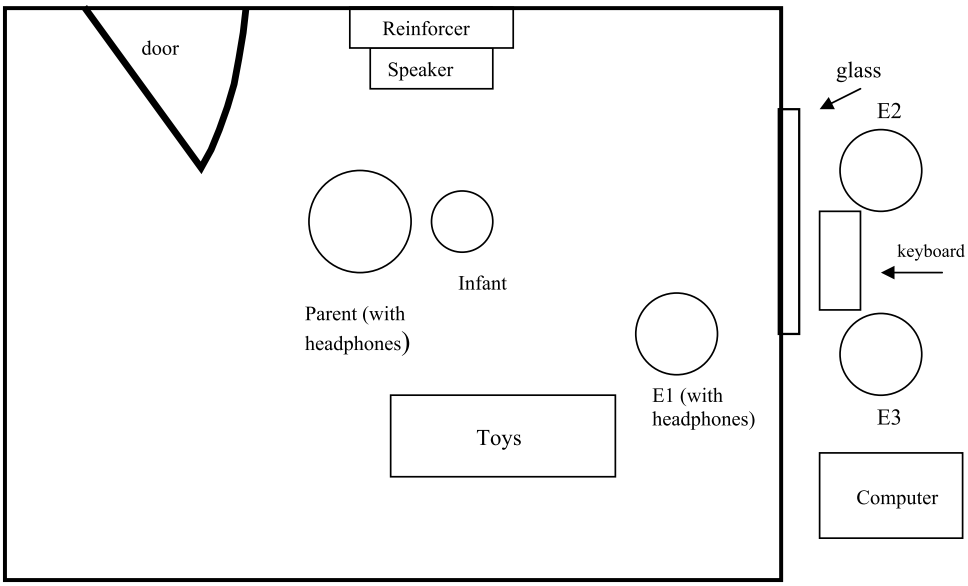
E1 was seated in front of and slightly to the right of the child during each testing session to ensure that the examiners in the control room had a clear view of the child as well as to avoid creating an obstacle between the child and the loudspeaker or visual reinforcer. E1 was in the test booth to provide a distraction for the child and to help ready the child for the task. Both E1 and the child's caregiver wore headphones and listened to music from Winamp media players, which were adjusted prior to testing to prevent them from hearing the test signal influencing the infant's responses.

E2 controlled the computer program that presented the stimuli in addition to judging if a head turn occurred. Both E1 and E2 were blind to the type of trial (test or control) being presented by the software. E3, also in the control room, was the only examiner who knew the nature of a given trial. E3 controlled the visual reinforcement (given only for responses to test trials). The role of all three examiners is detailed further in the *Procedure* section.

Stimuli and Reinforcers

The stimulus used to elicit the head turn response was speech noise presented at 35 dB SPL via a loudspeaker. The loudspeaker was positioned at 90° azimuth and was situated 1.5 m away from the infant. This level was

Figure 1. Testing setup used for both reinforcement conditions. E1 = Examiner 1; E2 = Examiner 2; E3 = Examiner 3.



adequate enough to elicit responses in normal-hearing children yet was low enough that the parent and examiner in the test room were unable to hear it while listening to music. Furthermore, it has been demonstrated that speech noise elicits more responses than frequency-specific stimuli (Hoversten & Moncur, 1969).

Both forms of visual reinforcement (video and conventional) were located near eye level of the child and were approximately 90° azimuth, near the speaker. The conventional reinforcement consisted of a mechanical toy placed within an 8.25 in. × 9.0 in. smoked Plexiglas box that was lit and animated when activated. The video reinforcer was the movie *Finding Nemo* (Disney), displayed on a 13-in. flat screen monitor, which was connected to a DVD player located in the control room next to the computer. The video images were displayed during reinforcement periods only. However, the video played continuously during testing, thus allowing for novel and dynamic video images to display during reinforcement periods. In the case of both CVRA and VVRA, the reinforcer was only visible during reinforcement periods, lasting approximately 2 s.

Procedure

Data collection consisted of two phases: conditioning and testing. In the conditioning stage, it was the examiner's (E2's) task to gradually "shape" or "condition" the infant to turn toward the reinforcer. During this phase, E2 activated the reinforcer immediately following the presentation of a trial in order to condition a head turn toward the stimulus. For this phase, speech noise was presented via a GSI-61 clinical audiometer (Grason-Stadler, Milford, NH) at a presentation level of 50 dB HL. Once the infant performed two head turns on his/her own, the experimental testing phase began. This procedure is a modification of a procedure suggested by Werker, Pegg, Polka, and Patterson (1998). It should be noted that no child in this experiment required more than three presentations to "condition."

The experimental/test phase was implemented on the computer using the SuperLab Pro Version 2.04 software, as described previously. The duration of each trial was 4 s (occurring from the onset of the 2-s stimulus presentation). During this phase, two types of trials were presented randomly: test and control. Test trials consisted of the speech noise stimulus. Control trials consisted of silent, "catch" trials. As indicated earlier, both E1 and E2 were blind to the trial type. When the child was deemed ready for the task, E2 (in the control room) communicated aloud the trial number (via the bone vibrator to E1) and presented a trial through the computer. As in the Schmida et al. (2003) study, only head turns occurring within 4 s of stimulus presentation were considered a response. When the infant responded correctly (head turn within 4 s of stimulus presentation), E2 pressed a "1" on the keyboard. E2's role was to independently keep track of scoring. E3, who was aware if a trial was a control or a test trial, appropriately reinforced (conventional or video) when applicable (a head turn to a test stimulus), independent of E2's scoring. If the child did not respond, then no key was pressed on the keyboard and no reinforcement was given. If the child responded with a head turn during a control trial, the experimenter pressed the "1" on the keyboard, marking it as a false positive, but E3 did not provide any reinforcement. These judgments were recorded online by the Super Lab Pro Version 2.0.4 software. During each trial, E1 (in the test booth) recorded independently if a response occurred. Obviously, E1 and E2 were aware if E3 determined that the child responded as desired if the reinforcer was presented; however, their judgments were independent of the reinforcer being presented. Communicating the trial number at the beginning of each test trial ensured accurate recordings on the response form and enabled E2 to inform E1 when the 4-s response interval had expired.

Testing continued until habituation occurred. *Habituation* was defined as "no response to four out of five consecutive stimulus trials as judged by two independent observers" (Schmida et al., 2003, p. 38). A slight modification of the Schmida et al. criterion for habituation was used. For the purpose of this study, one observer (E3) determined when habituation occurred on the basis of knowing whether any given trial was a control or a test trial. This information enabled E3 to determine when the child met the criteria to stop testing. Following the testing session, the response forms for E2 and E1 were compared to determine interexaminer reliability scores.

Results

Number of Head Turns

Figure 2 shows the number of (correct) head turns to sound trials, referred to as *hits,* for all participants in both conditions (video and conventional) along with their respective means (*M*s) and standard deviations (*SD*s). The mean number of hits for the video group was 25.79 (*SD* = 10.131, range = 10–47), and the mean number of hits for the conventional group was 26.71 (*SD* = 11.351, range = 8–42). A repeated measures analysis of variance (ANOVA) revealed that there was no significant difference in the number of correct head turns, or hits, between the video and conventional reinforcement conditions, $F(1, 13) = 0.102$, $p = .755$. A post hoc power analysis using a power level of .05 was completed using simple interactive statistical analysis and revealed that the sample was large enough to detect a difference, had one been present.

Response Consistency

Response consistency is defined as the percentage of responses to the test stimulus prior to habituation (Schmida et al., 2003). For each participant, the total number of correct head turns (hits) was divided by the total number of sound trials for each of the two conditions, video and conventional. Figure 3 shows response consistency, as measured by hit rate, for both conditions. Mean response consistency was 70% for VVRA (*SD* = .117, range = 0.55–0.94) and 73% for CVRA (*SD* = .131, range = 0.50–1.00). A repeated measures ANOVA revealed that there was no significant difference in response consistency between the video and conventional reinforcers, $F(1, 13) = 0.291$, $p = .599$. The response consistency was considered good for both tests.

False Alarm Rate

False alarm rate is a measure of a participant's (incorrect) head turns during a control trial. Each

Figure 2. Number of correct head turns for each participant for each reinforcement condition as well as the mean (*M*) and standard deviation (*SD*) for each condition. CVRA = conventional visual reinforcement audiometry; VVRA = video visual reinforcement audiometry.

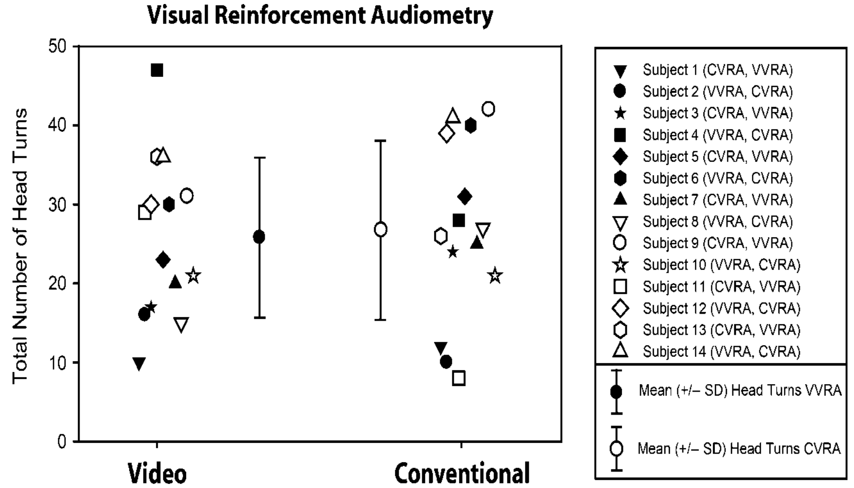
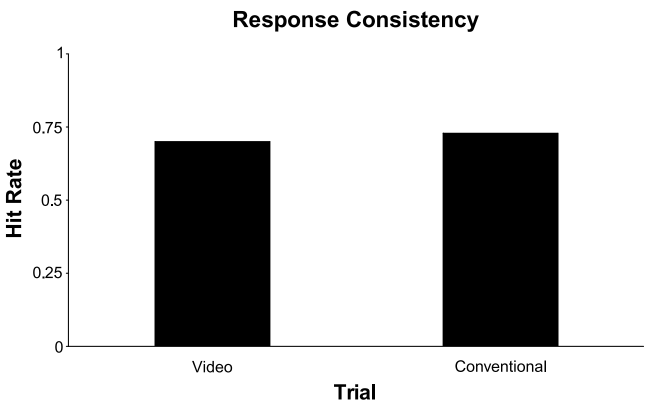


Figure 3. The proportion of responses to the test stimulus prior to habituation, as calculated by the total number of correct head turns divided by the total number of sound trials for each condition.



participant's false alarm rate was calculated for both test conditions by dividing the total number of false alarms by the total number of control presentations per condition. The mean false alarm rates were 4.9% for VVRA (*SD* = 0.097) and 4.3% for CVRA (*SD* = 0.099). A repeated measures ANOVA revealed that there was no significant difference in false alarm rates for the video and conventional reinforcers, $F(1, 13) = 0.051$, $p = .825$. The false alarm rate in this sample of children indicates that the infants remained similarly conditioned throughout the testing session for both conditions.

Test Sensitivity and Response Bias

Figure 4 shows the receiver operating characteristic (ROC) plots for the CVRA and VVRA methods. These graphs show hit rate as a function of false positive rate for the two test methods. Test sensitivity may be computed as the area under the ROC curve as

$$p(\mathrm{A}) = (0.5 \times f \times h) + (h \times [1 - f]) + (0.5 \times [1 - f] \times [1 - h]), \quad (1)$$

where f is the false alarm rate and h is the hit rate. An area of 1 represents perfect sensitivity; an area of 0.5 represents a less sensitive test. Values of 0.819 for CVRA and 0.827 for VVRA represent "good" test sensitivity for both methods. An index of sensitivity that is unaffected by any response bias may be computed as

$$d' = z(\text{hits}) - z(\text{false alarms}). \quad (2)$$

Results revealed a d' of 2.07 for VVRA and a d' of 2.13 for CVRA. These results suggest that VVRA and CVRA were equally sensitive measures for the sample of 7- to 16-month-olds tested.

Reinforcement Benefit

In addition, given that Schmida et al. (2003) concluded that 2-year-olds gave more head turns to VVRA than CVRA, showing VVRA benefit, individual performance was assessed between the two reinforcement conditions in order to determine if one condition provided benefit in terms of more head turns. The head turn data were plotted by age of participant in order to determine the presence of a developmental trend. For each participant, the number of correct head turns for CVRA was subtracted from the number of head turns obtained for VVRA (VVRA – CVRA), referred to as *VVRA benefit*. Figure 5 shows VVRA benefit as a function of age. Positive values indicate more head turns with VVRA, whereas negative values indicate more head turns with CVRA. The graph shows that there was no relationship between response pattern and age. Thus, VVRA benefit did not increase with age. Four (29%) of the infants gave more correct head turns during the video reinforcement condition, whereas 9 infants (64%) gave more correct head turns during the conventional reinforcement condition. One infant (7%) gave an equal number of head turn responses for both reinforcement conditions.

Interexaminer Reliability

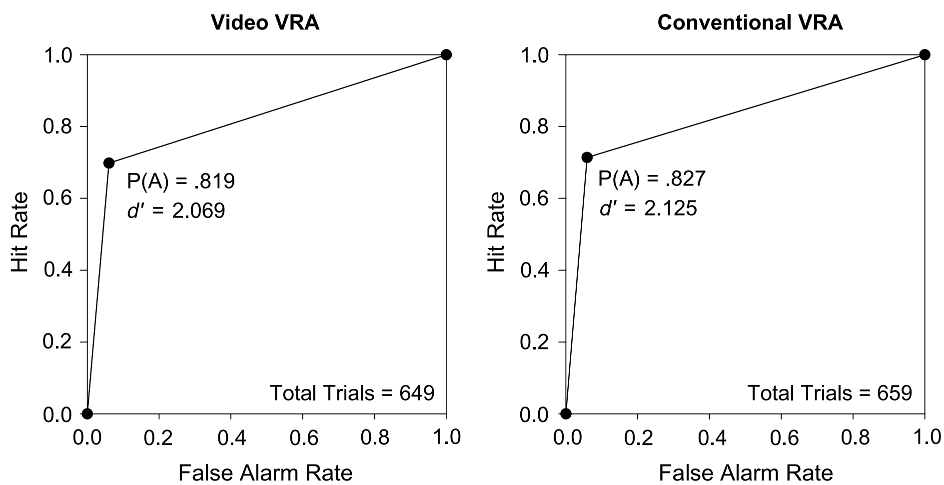
Interexaminer reliability was calculated per condition for each participant. Mean interexaminer agreement was 95% for VVRA, 92% for CVRA, and 93.5% overall. These results suggest that the examiners had good agreement in their judgment of the infants' behavioral response.

Discussion

VRA is an important diagnostic tool used with children as young as 6 months of age. Because developmental data on visual attention and habituation suggest an emergence of voluntary attention around the age of 6.5 months (Courage et al., 2006), this study sought to determine if this developmental outcome could be used to enhance the visual reinforcement strategy for VRA in 7- to 16-month-old infants. Schmida et al (2003) demonstrated that VVRA may yield slightly more responses prior to habituation than the CVRA approach in 20-month-old toddlers with normal hearing. Given that research on the development of visual attention suggests that infants and toddlers may respond differently to complex video stimuli (Courage et al., 2006; Richards, 1997), it is important to determine the VVRA response characteristics of younger infants before using this procedure in the standard clinical protocol.

The first goal of the present study was to determine if VVRA yielded different results than CVRA in 7- to 16-month-olds. The results revealed that there were no

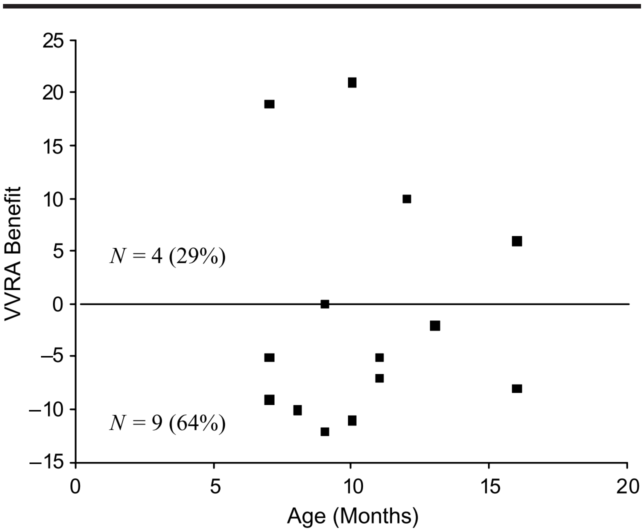
Figure 4. Receiver operating characteristic curves displaying P(A) and *d′* for each reinforcement condition. VRA = visual reinforcement audiometry.



differences between the two reinforcement conditions in terms of response consistency (hit rate), false alarm rate, and overall test sensitivity. This pattern of results was unexpected. It was hypothesized that VVRA would yield significantly more head turns than the CVRA and that younger infants would provide more false positive responses to the video images, affecting test sensitivity. However, the results showed similar outcomes for both reinforcer conditions.

These results suggest that 7- to 16-month-old infants are not more or less attentive to a dynamic video than to a mechanical toy reinforcer; therefore, they habituate at a similar rate. It was hypothesized that infants would be more visually attentive to the constantly changing video than to the mechanical toy, which moves but does not change shape or background. The results suggest that responses to the video reinforcer are not driven by constantly changing stimuli alone and that additional factors such as reinforcer familiarity and relevance may need to be considered for 7- to 16-month-olds. For example, recent parent surveys regarding television exposure in children suggest that approximately 48% of 12- to 23-month-olds watch television, compared with only 17% of infants 0–11 months of age (Barr et al., 2003). Thus, younger infants have less exposure to television and are less familiar with the media than are older toddlers. Whereas the video stimulus could be considered more novel than the mechanical toy, reduced familiarity with the media may have resulted in little to no preference for it compared with mechanical toys.

Figure 5. The number of correct head turns obtained during CVRA subtracted from the number of correct head turns obtained during VVRA for each participant. *N* = sample size.



The results of the present study for 7- to 16-month-olds differ from those reported by Schmida et al. (2003) for 19- to 24-month-old toddlers. Although the present study used similar stimuli protocol as Schmida et al. (stimuli intensity, duration, etc.), differences in participant age, design, and experimental procedures between the two studies should be taken into account when interpreting the results across the two studies. For example, the mean number of responses obtained for the present study was higher than that reported by Schmida et al., who reported the average number of head turns for VVRA as 15.2 and 10.8 for CVRA. This is likely due to the 10-month age difference in the groups studied by Schmida et al. (M = 20 months) and the present study (M = 10.4 months), given that 2-year-olds have been shown to habituate more quickly to (conventional) reinforcers than 1-year-olds (Primus & Thompson, 1985). Also, Schmida et al. found that the toddlers in their study produced significantly more head turns with video reinforcement than with conventional reinforcement. Additionally, 30% of the infants in their VVRA group were "high responders," who gave 20 or more head turns before habituation, compared with only 5% in their CVRA group. However, their participants were not tested with both methods of reinforcement; thus, we cannot know whether their high responders for VVRA also would have been high responders for CVRA. Using their $\geq$ 20 response criterion for high responders, to distinguish between "high" and "low" responders, 79% of the children in the current study remained within the same "responder" category (i.e., either low or high) for both reinforcement methods, regardless of the order in which they received reinforcement conditions. Only 21% of participants in the present study were "low responders" for one condition and "high responders" for the other condition.

Finally, because television exposure increases with age, the participants in the Schmida et al. (2003) study may well have been better suited to the video than conventional reinforcement, compared with the younger participants in the current study. Huston and Wright (1983) have suggested that in early development, formal features (visual and auditory changes) drive attention to television, but as children mature, comprehension drives attention (i.e., Anderson & Lorch, 1983). However, Huston and Wright suggested that videos tailored for toddlers may be more comprehensible than other videos and, therefore, may engage more cognitive processing. Thus, older toddlers may, in fact, respond more with VVRA than younger children, as their attention is driven by higher cognitive processing than by formal features. The absence of a relationship between age and method of reinforcement in the current study may have occurred because most (11 of 14) of the infants were under 12 months of age. Thus, future research should examine the relationship between age and video reinforcement benefit spanning the age range of both the present and the Schmida et al. studies.

Although no differences were found between the two reinforcement conditions, factors such as familiarity with the video content should be considered in future studies, as well. For example, Barr et al. (2003) found that 12- to 15-month-olds pay more attention to a familiar baby video than to an unfamiliar one. In the present study, caretakers were surveyed as to their infants' exposure to the movie *Finding Nemo* before participating. Only one parent reported that their child had seen the movie. In addition, the caretakers of only 5 participants reported that their infants watched television regularly, and all of them watched less than 1 hr per day. Thus, results might have been different had the children been familiar with the movie or had they been more familiar with video media.

The results of this study suggest that both VVRA and CVRA appear to be viable means of collecting information among 7- to 16-month-old children. However, it is important to highlight the fact that the participants in this study were children with normal hearing with no concerns regarding overall development. Because this is not likely to be the case for many infants seen in clinical settings, future research is needed to study the effects of VVRA in infants and toddlers whose hearing and developmental milestones are not within the normal range.

Because most clinics may have access to only one VRA system with which to test their infant/child population, and given that no differences were noted between the two types of reinforcers in a younger population, clinicians might prefer to use VVRA, as it may yield more head turns in toddlers. However, due to the research design differences noted earlier, and until more information is obtained in children with hearing loss, it remains unclear whether VVRA has an advantage over CVRA systems in older toddlers.

It may be interesting to consider using a combination of VVRA and CVRA during one testing session to determine if having more than one reinforcer could increase the number of head turns prior to habituation, allowing the clinician to obtain more information in a single test session. In addition, the effects of using several different videos during one testing session and/or the parents' bringing in their child's favorite video could be investigated.

Conclusion

The present study showed that infants in the 7- to 16-month-old age range do not perform significantly different in response to VVRA than they do in response to CVRA, as measured by response consistency (hit rate) and false alarm rate when familiarity to the video used is low. As the age of identification and intervention decreases, assessment methods that (a) improve a clinician's ability to more efficiently determine the auditory sensitivity of infants and (b) help corroborate electrophysiological findings will assist clinicians in meeting the requirements established by the Joint Committee on Infant Hearing (2007) for early diagnosis and intervention. Future studies should focus on continuing to understand the mechanisms that drive infant attention to visual stimuli so that these methods may be effectively implemented in audiologic practice.

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