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Visual Reinforcers Designed for Children with Developmental Disabilities

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Abstract

A library of visual reinforcers has been created to facilitate visual reinforcement audiometry (VRA) testing in children with developmental disabilities. The library includes 45 reinforcer sets—photos or videos grouped by a common theme—that were created based on commonly reported interests of children with developmental disabilities. Each reinforcer set contains a minimum of 20 unique photo or video files that can be downloaded in two formats: one for commercially available VRA reinforcement systems and another for a custom setup. The library is freely available for download online under a Creative Commons License (Creative Commons Attribution-NonCommercial 4.0 International License). Use of these materials has the potential to improve behavioral testing outcomes for children with developmental disabilities, including children with restricted interests. Future research is needed to determine the effectiveness of implementing these materials in clinical settings.

Keywords: developmental disabilities, visually reinforced audiometry, hearing test, restricted interests, autism, pediatric audiology

Acronyms: ABR = auditory brainstem response; ASD = autism spectrum disorder; CPA = conditioned play audiometry; OAE = otoacoustic emissions; VRA = visual reinforcement audiometry; VROCA = visually reinforced operant conditioning audiometry

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For infants (> 6 months) and children, an audiogram is the gold standard of hearing health care (American Academy of Audiology [AAA], 2020) and is the cornerstone upon which a correct differential diagnosis and access to the appropriate interventions are built. However, audiologists often report that it is difficult to obtain accurate behavioral thresholds for children with developmental disabilities (e.g., Gans & Gans, 1993; Widen, 1990). Developmental disabilities are a group of conditions that result in impairments in physical, language, learning, or behavior functioning and are estimated to occur in 8.4% of children under 5 years worldwide (Global Research on Developmental Disabilities Collaborators, 2018). When children's developmental profiles are mismatched with the developmental demands of the behavioral testing method, thresholds may not be obtained or it may require multiple visits to complete an audiogram. In this situation, audiologists may heavily rely on physiological measures (e.g., otoacoustic emissions [OAE] and auditory brainstem response [ABR]) to determine hearing status. Although these tests are vital components of the assessment battery, physiological measures only provide partial information about the auditory system's integrity which limits their ability to determining hearing abilities in children with auditory neuropathy spectrum disorder or other neural hearing losses (e.g., Berlin et al., 2010). OAEs are prone to missing mild hearing loss cases (Johnson et al., 2005); and although ABR thresholds generally predict behavioral thresholds by 5 to 10 dB, they can be misaligned for some children (e.g., McCreery et al., 2015). Furthermore,

children with developmental disabilities often require general anesthetics or sedation drugs for ABR testing (Rumm et al., 1990; Valenzuela et al., 2016) which may be contraindicated because of underlying medical conditions or concern of developmental harm (U.S. Food and Drug Administration, 2016). Limitations in our current behavioral testing methods leave children with developmental disabilities vulnerable to delays in the differential diagnosis process and in the enrollment of appropriate, targeted intervention services. Moreover, for children with permanent hearing loss, difficulty obtaining reliable behavioral thresholds can introduce error in the quality of the hearing aid fit—a key predictor of language outcomes (Tomblin et al., 2015)—placing children with developmental disabilities at increased risk for poor outcomes.

There are a variety of potential factors—related to the audiologist, the child, and the test method—that can make it difficult to collect reliable behavioral thresholds from children with developmental disabilities (McTee et al., 2019). First, some audiologists have limited training and/or experience with developmental disabilities (e.g., Dittman & Brueggeman, 2003; Peter et al., 2019; Peterman et al., 2018). Audiologists with limited experience may have difficulty instructing the child, training the child to perform the task, or judging the child's responses which may be atypical or inconsistent. Second, children may have specific conditions or challenges that make it difficult to have a successful testing session. Children with developmental disabilities can have sensory sensitivities, transition difficulties, or perceive aspects of the testing protocol or environment to be aversive (e.g., American Psychological Association [APA], 2013; Gomes et al., 2004; Richler et al., 2007). Furthermore, some developmental conditions are associated with a high prevalence of anxiety as a secondary diagnosis (e.g., White et al., 2009), which can result in children being anxious if working with an unfamiliar person and/or in a new setting. Finally, current behavioral methods are based on the assumptions of typical child development and auditory behavior (Diefendorf & Tharpe, 2017), making them not well-suited for children with diverse or complex developmental profiles.

One example of a clinical method that is based on the assumptions of typical development is visual reinforcement audiometry (VRA). VRA is the recommended method for obtaining behavioral thresholds from infants and children with a developmental age of 5 to 24 months (AAA, 2020). In this method, children are taught to make a head-turn response toward a visual reinforcer—mechanical toy or brief video—based on the observation that typically-developing infants make a reflexive head-turn response to sound (Muir et al., 1989; Widen, 1993). However, preschool children with autism spectrum disorder (ASD) are less likely than neurotypical, mental age-matched peers to orient to sounds in their environment (Dawson et al., 2004). A second example of a misalignment between the demands of the task and the abilities of children with developmental disabilities is that VRA requires frequent shifts in attention (e.g., shifting between the test assistant and the reinforcer). However, this is often an area of concern for children with intellectual disabilities and/or ASD (Liss et al., 2006). Another example, which will be discussed in detail below, is that the reinforcers commonly used in clinics may not align with the interests of some children with developmental disabilities, reducing their effectiveness. These examples highlight the limitations of VRA for evaluating hearing in children with developmental disabilities and may, at least in part, explain the reported challenges for measuring thresholds with VRA in this population (e.g., Gans & Gans, 1993; Greenberg et al., 1978; Meagher et al., 2020; Nightengale et al., 2020).

The motivation of this article is to improve behavioral assessment of children with developmental disabilities by creating a library of visual reinforcement materials that are tailored to the needs of this population. VRA data from typically-developing infants and young children have well established that the quality of the reinforcement affects the number of trials that are performed prior to habituation (Moore et al., 1975, 1977; Primus & Thompson, 1985). The above studies demonstrate a clear advantage for complex and/or novel reinforcement, with mechanical toys and brief videos being equally effective in clinical settings (Doggett et al., 2000; Lowery et al., 2009; Schmida et al., 2003). However, no VRA studies have compared the effectiveness of different reinforcement types for children with developmental disabilities. Because the reinforcers used in commercially available VRA reinforcement systems were designed for typically-developing infants, these reinforcers may not be appropriate for children with developmental disabilities for two reasons. First, because of their developmental abilities or sensory sensitivities, some children with developmental disabilities are tested with VRA outside of the chronological age range recommended for VRA. Current clinical reinforcers may not be engaging or motivating for some chronologically older children: they require reinforcers that are aligned with their developmental interests, not those of infants. Second, some children with developmental disabilities have restricted interests. Children with restricted interests demonstrate a strong or intense preoccupation with one or more specific topics or objects (APA, 2013). Having restricted interests is a hallmark feature of ASD (e.g., Richler et al., 2007) but is seen in other developmental conditions, including Down syndrome (e.g., Evans et al., 2014). Although circumscribed interests are unique to an individual, interests do vary in type and degree between developmental profiles and a child's interest(s) can change over time (Evans et al., 2014; Joseph et al., 2013; Richler et al., 2007). Previous ASD intervention research has demonstrated that using objects or games related to a child's circumscribed interests improves outcomes (e.g., Baker et al., 1998; Boyd et al., 2007; Kryzak et al., 2013; Kryzak & Jones, 2014). Drawing on this research, audiologists may be able to obtain more thresholds from children if the reinforcer is related to a child's circumscribed interest(s). Thus, we created a library of visual reinforcers that are based on commonly reported interests of children with developmental disabilities to facilitate behavioral testing. Here we provide a collection

of 45 reinforcer sets comprised of either photos or videos. A description of the material generation process, implementation recommendations, and access to the materials follows.

Creation of Materials

Selection of Themes for Reinforcer Sets

A list of potential themes for the reinforcers was generated based on commonly reported circumscribed interests for children with developmental disabilities by clinicians or in the literature (Anthony et al., 2013; Caldwell-Harris & Jordan, 2014; Klin et al., 2007; Turner-Brown et al., 2011). This list was reviewed by all authors, as well as by an additional external reviewer. Three of the authors and the external reviewer all have more than 10 years of experience working with children, including children with developmental disabilities, as an audiologist ($n = 2$), developmental psychologist ($n = 1$), or early childhood educator ($n = 1$). Reviewers were asked to provide feedback on the list of themes. Additionally, reviewers were asked to identify other topics that they thought would be appropriate based on their professional experience, especially for children with restricted interests. This process resulted in a list of 63 potential themes for the reinforcers.

Selection of Photos or Videos

Potential digital materials for each theme were identified using three open-access, online depositories: www.flickr.com, www.pexels.com, and www.pixabay.com. Based on the amount and quality of materials identified, a decision was made to use either photos or videos for each reinforcer set. For each reinforcer set, 20 to 40 unique photos or videos were selected. The one exception is that only 14 videos were identified for the theme of flushing water (e.g., toilets and drains). All digital materials were required to be of high-quality and be in the public domain or hold a Creative Commons (CC), Pexels, or Pixabay license that allowed us to freely build upon, enhance, or reuse the original work. Based on their cultural background and experience, two audiology students reviewed all selected digital materials to verify that they were appropriate for the reinforcer set and for children. The end result of this process was that materials were generated for a total of 45 reinforcer sets (representing 43 unique themes). Table 1 provides the theme, digital material type, and the number of unique photos or videos for each reinforcer set.

Format of Materials in Reinforcer Sets

All photo and video files were edited to be of standard properties. The minimum size of individual .jpg photo files was 1000X1000 or 1280X780 ppi. To be compatible with commercial systems, Microsoft Photos (version 2020.20090.1002.0) was used to convert individual photo files to 4-second or 10-second .mp4 files with a resolution of 1080 p. Videos were edited in Microsoft Photos and a 4-second or 10-second segment was selected that was judged to have a natural start and stop point. Individual videos were saved as an .mp4 file with resolution that ranged from 720 to 1080 p across videos. These individual files are stored by reinforcers set and can be downloaded from our library.

To facilitate the use of our materials in clinics or laboratories that do not have a commercial system, we provide slideshows for all reinforcer sets that can be used in a custom setup. Details on the custom setup can be found in the implementation section below. For each reinforcer set, a single slideshow (.pptx format) was created in Microsoft PowerPoint (version 16.0). All available photos or videos were compiled in the slideshow. A single, full-screen photo or video is provided per slide. Prior to each photo or video is a background slide that is solid black in color. To display the next photo or video, the slideshow must be manually advanced. To be consistent with commercial systems, the default display time for all reinforcer sets is 4 seconds, but this duration can be customized in PowerPoint. To assist the audiologist, the slideshow displays a running count for the number of photos or videos shown and an additional visual alert on the final 3 slides for the set. The slideshow will automatically restart when the last photo or video in the set is shown. Further details about this process and a blank template can be found in our online resource.

Online Access to the Materials

The library described here is being made freely available for access and download under a Creative Commons Attribution-NonCommercial 4.0 International License (CC BY-NC 4.0) at https://osf.io/bk6rc/ (Hemann et al., 2020). The library consists of 45 reinforcer sets and can be downloaded as either a Microsoft PowerPoint slideshow or as a folder of individual .mp4 files. The site also provides the associated metadata (e.g., citations for all photos or videos) and supplemental documentation for the material generation process and implementation strategies. A bulk export of the entire library can be performed to allow for rapid download.

Clinical Implementation of the Materials

Reinforcers can be implemented in commercially available VRA reinforcement systems or through a custom setup. In general, the same procedure used for installing custom videos should be followed here. Audiologists interested in integrating these materials in a commercial system can find support documentation on our online OSF resource for two commercial systems: Flex and Intelligent VRA systems. Audiologists using other systems are advised to contact their system's manufacturer if they need support. For clinics that do not have a commercial system, audiologists can use a custom setup with widely available and inexpensive technology. This set-up is achieved by connecting a computer in the control room to a secondary monitor that is mounted on the wall in the booth. Requirements of the computer are (a) appropriate hard drive storage for the files, (b) software to run the .pptx files (i.e., Microsoft PowerPoint), and (c) the ability to display to a second monitor. Any appropriately sized monitor can be used, but the ability to play sound may be desirable for some of the video reinforcers. Slide advancement can be

Table 1

Description of the Individual Visual Reinforcers by Theme Category

Category	Theme of Reinforcer Set	Media Type	Number of Images
Activities	Cleaning	Video	21
	Cooking	Video	21
	Shopping	Video	21
	Sports	Photo	32
Animals	African safari animals	Photo	33
	Big cats (e.g., lions, tigers, cougars)	Photo	33
	Birds	Photo	32
		Video	21
	Birds of prey	Photo	40
	Bugs	Photo	34
	Butterflies and moths	Photo	40
	Cats (domestic)	Video	21
	Dinosaurs	Photo	32
	Dogs	Video	21
	Farm animals	Photo	32
	Forest animals	Photo	32
	Frogs and toads	Photo	32
	Reptiles	Photo	35
	Sea creatures (e.g., fish, whales, dolphins, turtles)	Photo	31
	Snakes	Photo	32
	Zoo animals	Photo	32
People	Babies	Photo	37
	Faces	Photo	40
Science and Letters	Alphabet (i.e., street topography)	Photo	26
	Space	Photo	32
		Video	21
	Waterfalls	Video	21
	Weather	Video	21
Sensory	Bubbles	Video	21
	Clocks, timers, and counters	Video	21
	Fans and windmills spinning	Video	21
	Items moving or spinning (abstract)	Video	21
	People in motion	Video	21
	Rainbows and other colorful images	Photo	32
	Reflections	Video	21
	Rides at amusement parks	Video	21
	Water spinning (e.g., toilets, drains)	Video	14
Transportation and Equipment	Airplanes	Photo	31
	Boats	Photo	31
	Emergency vehicles	Photo	32
	Farm equipment	Photo	26
	General transportation vehicles	Video	21
	Race cars	Photo	32
	Semi-trucks and heavy construction equipment	Photo	32
	Trains	Photo	31

achieved through a key press on the computer or through a wireless presenter remote. One advantage of a remote is that it allows the slideshow to be discreetly controlled from inside of the booth by the test assistant.

To achieve success with these materials, we believe that it is critical that the audiologist identifies the reinforcement set(s) that will be engaging and motivating to the child. For children with restricted interests, the selected reinforcer set(s) should align with the child's circumscribed interest(s). Determining the child's interest(s) can be based either upon previous clinical interactions with the child or input from the child and/or caregiver. Our online resource includes a questionnaire that can be administered to caregivers to identify reinforcer set(s) from our library that may be appropriate for the child.

Once the reinforcer set(s) are identified for a child, there are a few parameters that the audiologist can customize. First, the display duration of the photos or videos in a reinforcer set can be 4 or 10 seconds. Consistent with commercial systems, we default to a 4-second display duration of photos or videos in our reinforcer sets. However, a longer display duration of the reinforcer may be beneficial for children that have difficulty learning the task or orienting to the monitor in a timely manner. For this scenario, 10-second files are provided for use with commercial systems or the duration can be changed manually in the custom setup. Second, a few video reinforcer sets contain sound. Audiologists may want to deactivate sound for children who have inadequate access and/or sensory sensitivities to auditory input. Third, for children with restricted interests, it may be desirable to reduce the number of photos or videos in a reinforcer set to increase the alignment of the available images with the child's circumscribed interest. For some children, it may be preferred to only use the photos or videos that correspond to their circumscribed interest. However, for other children, especially those with high cognitive abilities, it may be particularly motivating to continue with the original reinforcer set and to instruct them to look for the slides in that set that correspond to their circumscribed interest.

One final feature of these materials is that they can be used for behavioral methods other than VRA. Specifically, the reinforcement sets can be used in visually reinforced operant conditioning audiometry (VROCA) or conditioned play audiometry (CPA). The traditional implementation of VROCA involves training a child to push a lever when the signal is heard, then visual reinforcement is provided for a correct response (e.g., Thompson et al., 1989). This paradigm can be easily implemented with our materials by having the child respond by pushing a large button and the visual reinforcers can be displayed on the secondary monitor or a tablet in the booth using the custom setup. The visual reinforcers provided here can be used as supplemental reinforcement in CPA to guard against habituation (e.g., Bonino et al., 2019; Primus & Thompson, 1985). Thus, the materials provided here can be implemented in many of the common behavioral methods for measuring hearing in children.

Summary

A large library of video reinforcer sets is available for clinical and research use. Based on the design of these materials we expect that they will facilitate behavioral hearing evaluations of children with developmental disabilities, including children with restricted interests. Support for this idea comes from two lines of research from children with ASD. First, because children with ASD often struggle with in-person, social interactions, interventions that use videos have been shown to be effective (e.g., McCoy & Hermansen, 2007; Wang et al., 2011). For example, children with ASD have longer visual attention to a puppet show presented as a video compared to in person (Cardon & Azuma, 2012). Second, improved outcomes—social interaction and behaviors of joint attention—are observed if the intervention uses objects or games that are related to the child's circumscribed interests (e.g., Baker et al., 1998; Boyd et al., 2007). Moreover, children with ASD look longer and visually explore an object in a more detail-oriented manner if it is related to their circumscribed interests compared to an object that is not (e.g., Sasson et al., 2008; Thorup et al., 2017). For VRA, maximizing the child's looking time at the reinforcer may facilitate the audiologist's ability to judge the child's response. Plus, if the child is motivated and engaged by the reinforcer, it would be expected that training would be faster, the risk of habituation would be reduced, and on-task behavior would be improved. Data from Chebli and Lanovaz (2016) is consistent with this idea: children with ASD sat in their chair longer if viewing their more preferred videos compared to their less preferred videos. For these reasons, selecting a reinforcer set that is related to a child's circumscribed interests (like the ones presented in our library) is expected to result in an increased collection of behavioral data. Improving the number of thresholds obtained per encounter is expected to reduce the number of visits required to determine hearing status in children with developmental disabilities. In turn, reducing the number of visits has the potential to lower medical expenses, reduce family stress, and provide earlier access to intervention. For children with hearing aids, obtaining a complete audiogram means better fitting quality of their devices, which is a key predictor of language outcomes. Another possible benefit of our library of reinforcer sets is that it may facilitate behavioral testing of 18- to 36-month-old children that are typically developing: an age group that is notoriously difficult to test with current methods. The library shared here has the potential to improve clinical care, but further research is needed to verify the efficacy of our reinforcer sets and to evaluate our recommended implementation procedures with children with developmental disabilities in a clinical setting.

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