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Effects of Integrating Different Types of Physical Activity into Virtual Rapid Word Learning Instruction for Children who are Deaf and Hard of Hearing

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Children who are deaf and hard of hearing (DHH) have documented deficits in vocabulary acquisition (e.g., Lund, 2016; Lund, Werfel et al., 2015; Wake et al., 2005; Werfel et al., 2022). Not only do children who are DHH know and use fewer words than children with typical hearing (TH; Lund, 2016), but their ability to learn new words is also reduced relative to these peers (Lund & Schuele, 2017; Nott et al., 2009; Pittman et al., 2005). Thus, a vital area of investigation in the field of educational speech-language pathology is the development of effective vocabulary interventions for children who are DHH. In this study, we focus on one step in the process of learning words: mapping a word form to a referent.

Word learning is not a single, one-time process but rather occurs in stages. Initial stages involve pairing a word with its referent. Specifically, a learner must (a) recognize that a new word form needs to be learned (triggering; Gray et al. 2020), (b) build an initial phonological and lexical representation of the word (configuration), and (c) integrate and retain that word in one's lexicon (engagement; Leach & Samuel, 2007). After an initial word form and referent pairing have been entered into one's lexicon (the focus of the current study), then the learner can begin to build other, deeper knowledge related to that vocabulary word (e.g., McKeown, 2019).

Word Learning Instruction

Although children with typical hearing can and do learn word form-referent pairings that are directly taught to them by teachers and other adults (Coyne et al., 2009), they are also efficient word learners in other circumstances. Children with typical hearing often learn new word forms and referents via naturalistic approaches to language acquisition, including follow-in labeling and incidental exposure. In follow-in labeling, the adult follows the child's lead and provides labels for objects or actions to which the child is paying attention (e.g., Baldwin, 1991; Kaiser & Roberts, 2013). Incidental exposure involves increasing the number of words a child is exposed to daily but not in any structured context (e.g., simply talking more); children with larger vocabularies are more efficient at learning new words

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from incidental exposure (Coyne et al., 2004). Direct instruction for all English words to be learned is not possible; therefore, although robust vocabulary instruction for children with typical hearing is suggested to involve direct instruction of *some* words, Beck et al. (2013) recommend that children with typical hearing be taught to learn words from context for the majority of words they will learn rather than directly be taught most individual words.

Impact of hearing loss on learning new word forms.

Limited audibility makes it difficult for children who are DHH to learn new word forms incidentally (i.e., by overhearing; Lund & Schuele, 2017). Extant data evaluating word learning in children who are DHH and learning spoken language indicates difficulties with form and referent pairing, which is a necessary prerequisite to efficient acquisition of deeper vocabulary knowledge (Houston et al., 2012; Lund, 2018; Pittman et al., 2017; Walker & McGregor, 2013). For example, children with cochlear implants struggle to pair unfamiliar words with new objects (Lund, 2018). Children with cochlear implants perform on initial learning and retention tasks similarly to younger children, but more poorly than their age-matched peers (Walker & McGregor, 2013). Learning appears to be influenced by early auditory experience, inclusive of age at initial sound access and severity of hearing loss (Houston et al., 2012). Similarly, children with hearing aids also struggle in rapid word learning tasks as compared to children with typical hearing (Pittman et al., 2017). Although there is evidence that the depth of semantic knowledge for children with typical hearing may differ from that of children who are DHH (e.g., Rush et al., 2023), word knowledge interventions must consider the effects of intervention on this first phase of learning for this population.

Becuase children who are DHH are less able than children with typical hearing to map word forms to referents, direct instruction of new words is often necessary for children who are DHH (Luckner & Cooke, 2010; Massaro & Light, 2004; Pittman, 2008). Lund and Douglas (2016) provide evidence that direct instruction, or instruction that contains an explicit introduction of new words, is a more effective teaching strategy for rapid word learning in children who are DHH than follow-in labeling of objects with which the child interacted or incidental exposure by overhearing. Across multiple early language and literacy skills, the extant evidence suggests that direct instruction of most targets is necessary for children who are DHH and little generalization occurs (e.g., Lund & Douglas, 2016; Werfel & Reynolds, 2019; Werfel & Schuele, 2012).

Impact of telepractice on word learning instruction effectiveness.

The evidence on the effective teaching of new word forms arises, however, from research on interventions that have been conducted in a face-to-face format. Several preliminary studies indicate that telepractice can be as effective as in-person service provision for early intervention and speech sound disorders intervention (Behl et al., 2017; Grogan-Johnson et al., 2013; Stredler-Brown, 2017). Given the long-standing impact of the COVID-19 pandemic on service delivery modalities for speech-language pathologists (SLPs) and the potential of telepractice to provide high-quality services to students who live in areas with SLP shortages, it is vital to understand how to maximize outcomes in interventions delivered via telepractice.

Physical Activity and Academic Instruction

General physical activity.

In this study we evaluated embedded physical activity in rapid word learning interventions via telepractice for two reasons. The first major consideration when implementing tele-interventions for SLPs who work with young children is maintaining the child's attention in a virtual environment (Tucker, 2012). Physical activity has been shown to increase attention in educational situations (Case-Smith et al., 2010; Ellemberg & St-Louis-Deschênes, 2010; Kubesch et al., 2009; Peck et al., 2005). Lund et al. (2017) reported that providing multiple short recesses during the day decreased students' listening effort compared to a traditional recess schedule.

Physical activity is associated with increased learning in general (Hart et al., 2022; Loprinzi et al., 2023; Robinson et al., 2023; Roig et al., 2013; Winter et al., 2007), and with increased word learning in particular (Lund et al., 2020; Mavilidi et al., 2015; Salis, 2013; Schmidt-Kassow et al., 2014). Often this physical activity is conceptualized as a break in the cognitive task of learning; for example, in a review paper, Mahar (2011) reported that short physical activity breaks resulted in a small to moderate increase in attention-on-task in school-age children. Beyond attention, a second major consideration is the relation of physical activity and learning. Importantly, Mahar reported that physical activities that occur during teaching resulted in better attention-to-task than physical activity breaks alone. To learn vocabulary lists, for instance, students would complete short bouts of physical activity in between each word, including hopping on one foot, running in place, and/or doing imaginary jump roping.

Semantic richness physical activity.

The second major consideration was that, even with high quality instruction, children who are DHH need more repetitions to learn new word form-referent mappings than children with typical hearing, and thus, they may need even more scaffolding during instruction. There is preliminary evidence that semantic richness physical activity, or physical activity that incorporates the concepts being taught, is even more effective than general physical activity alone. Semantic richness physical activity involves, for example, acting out a referent or a characteristic action of a referent or, in the case of the current study, positioning the body in postures that mimic physical characteristics of the referent. Specific to word learning interventions, semantic richness physical activity may be more effective than general movement for learning new word form-referent mappings (Lund, Douglas et al., 2015; Lund et al., 2020; Toumpaniari et al., 2015). That is, simply increasing the heart rate via physical activity (e.g., jumping jacks) may affect learning differently than movement that is related to the skill being learned (e.g., yoga, in which postures may represent physical characteristics or actions of a target word). Importantly, this work has been completed primarily with students with typical development to date. An important question to ask is if these findings generalize to populations of children known to have difficulties with word learning, such as children who are DHH.

The Current Study

The purpose of this study was to compare the effectiveness of virtual word learning in three conditions—traditional, general physical activity, and semantic richness physical activity—to compare the effectiveness of word learning intervention delivered via telepractice across three conditions of varying physical activity. In this study, we employed pseudowords to avoid confounding with prior word knowledge. We hypothesized that children would learn the most word-like forms in the semantic richness physical activity condition, fewer word-like forms in the general physical activity condition, and the fewest word-like forms in the traditional condition. Additionally, we hypothesized that there would not be an interaction of group and condition, such that both groups would learn the most word-like forms in the semantic richness physical activity condition and the fewest word-like forms in the traditional condition, but that children who are DHH would learn fewer word-like forms overall than children with typical hearing.

Method

A repeated measures, between-group design was used to address the research aims. Mapping of word-like forms and referents was compared across three learning conditions: traditional, general physical activity, and semantic richness physical activity. All study procedures were approved by the University of South Caroilna Institutional Review Board.

Participants

Participants were 14 children who are DHH (mean age = 5;4, *SD* = 0;6) and 14 children with typical hearing (mean age = 5;10, *SD* = 0;4). Children in the DHH group had permanent bilateral hearing loss, confirmed by audiologic diagnosis, and used amplification and spoken English. The TH children passed a hearing screening at 1k, 2k, and 4k Hz bilaterally. Maternal education in both groups was high: the DHH group had a median of bachelor's degree and the TH group had a median of graduate degree. The percent of children who identified as a racial or ethnic minority did not differ across groups (DHH: 21%, TH: 17%, X^2 (1, n = 27) = .163, p = .686). Participants were recruited from an ongoing longitudinal evaluation of language and literacy acquisition in children with hearing loss. All parents provided informed consent prior to study participation, and children provided verbal assent prior to each session.

All participants had nonverbal intelligence within normal limits as measured by the *Primary Test of Nonverbal Intelligence* (Ehrler & McGhee, 2008). Children with diagnoses other than hearing loss known to affect language or cognition were not eligible for participation. To describe the spoken language abilities of participants, we report their scores on standardized measures of omnibus language, the *Test of Early Language Development-4* (Hresko et al., 2018), and vocabulary, the *Peabody Picture Vocabulary Test-5* (Dunn, 2019), from the larger study. Children were recruited to participate in this study within one month of their most recent testing session from the larger study. Table 1 displays average language and cognitive standard scores of the participant groups. As expected, the groups differed across all language and cognitive variables.

Table 2 displays individual audiologic information for the DHH group. As a group, the mean age at identification was 7.5 months (*SD* = 12.30; range = 0–45; median = 2.5). The mean age at first hearing aid was 10.39 months (*SD* = 12.63; range = 2–48; median = 5.25). For the four participants who had a cochlear implant, mean age at first implant was 21.25 months (*SD* = 12.69; range = 12–40; median = 16.5).

Procedures

The study was conducted entirely online, using Zoom for Healthcare (https://www.zoom.com/en/industry/healthcare/). Zoom for Healthcare is a videoconferencing platform with features such as screen sharing and screen annotation, as well as enhanced security features. Sessions were video recorded. The intervention was completed by two trained graduate students in speech-language pathology. The same interventionist completed all three sessions for an individual child.

Parents used the app Decibel X (https://skypaw.com/decibelx.html) to ensure the interventionist's voice was at 60 dBA (typical conversation level) and to measure background noise. Background noise averaged 40.60 dBA and did not differ across groups, $t(81) = -0.001$, $p = .99$; DHH: 40.60, TH: 40.61, or conditions, $F(2,81) = 0.52$, $p = .59$; Traditional: 41.84, General Physical Activity: 40.04, Semantic Richness Physical Activity: 39.93. Thus, average signal-to-noise ratio during the intervention was approximately +20 dBA.

Study Materials—Intervention protocols, materials, and fidelity checklists can be found at https://doi.org/10.17605/OSF.IO/7Z6UW.

Pseudoword lists for intervention.: Thirty consonant-vowel-consonant pseudowords were selected from Storkel (2013) for use in this study. Pseudowords were selected to ensure that no participants had prior knowledge of the word forms or referents. Phonotactic probability and lexical neighborhood density were held constant at mid-probability, defined as a z-score between −0.5 and +0.5. Sounds selected to be included in the pseudowords were from the first sounds children learn to produce (classified as the "Early 8" and "Mid 8"), and the vowels, number of nasals, stop consonants, and fricatives were balanced across word lists. Three lists balanced for these phonological characteristics were created (see Table 3). Each of the three lists was randomly assigned a physical activity condition for each participant. Within condition, the pseudowords on the assigned list were presented in a randomized order for each child.

Line drawings of target pseudowords.: Thirty drawings of imaginary animals, one for each word-like form, were created by a graduate student for this study. Drawings were shown to children with typical hearing to ensure that children would not have labels for the animals before using them in the study. Three sets of line drawings were created, and for each child, the sets were randomly assigned to condition. The target pseudowords were randomly assigned to drawings for each child. Each line drawing was always paired with the same yoga posture in the semantic richness physical activity condition, to ensure that the yoga posture matched the physical representation of the imaginary animal (see Figure 1 for example illustration).

Assessment of pseudoword learning.: At the end of each intervention session, two posttests were administered to measure learning. First, the graduate student interventionist administered an expressive posttest. For the expressive posttest, the interventionist displayed the line drawings on the screen one at a time and asked the child to name the animals. The interventionist transcribed the child's response live on a provided scoresheet. Then, the interventionist administered a receptive posttest. For the receptive posttest, the interventionist displayed a slide on the screen that contained all 10 line drawings. One at a time, the interventionist said a pseudoword and asked the child to use the annotation tool to mark the animal it labeled. The interventionist cleared the annotation after each item and scored the child's response live on a provided scoresheet.

General Intervention Procedures—Each participant completed three virtual pseudoword learning intervention sessions, one session in each condition. Sessions occurred on three different days within one month, and the order of the physical activity conditions completed by each child was counterbalanced. Each condition targeted 10 pseudowords for learning and lasted approximately 45 minutes. The general intervention protocol across all three conditions included three intervention steps: (a) introduction of the pseudoword, (b) receptive practice, and (c) expressive practice (Lund et al., 2015).

Introduction.: During the introduction, the interventionist (hereafter, she) displayed a drawing using the share screen feature. She labeled the picture with a designated pseudoword and asked the child to repeat it. If the child misarticulated the target, she asked the child to repeat it again, emphasizing the error or missing sound. Then she asked the child to repeat the pseudoword two more times. Next, she provided two pieces of semantic information about the target. Information about the referent's appearance was always one of the two pieces of semantic information. For example, she displayed the line drawing for *zog*, said *zog*, had the child repeat *zog* three times, and provided two pieces of semantic information about a *zog*: A *zog* has a horn that bends back toward its face; A *zog* likes to eat leaves. The introduction procedures were then repeated for each target pseudoword. The interventionist used each target nine times in the introduction step, consistent with optimal word learning dosage for children with developmental language disorder (Storkel et al., 2017).

Receptive practice.: After the introduction phase of the session, she displayed a slide with six of the drawings via screen share. Then she said one of the target pseudowords and asked the child to use the screen annotation feature to stamp a star on the associated drawing. If the child was correct, she praised the child's choice, marked the nonword as complete on the receptive practice checklist, and displayed the next slide. Feedback on each item ceased after a correct response. If the child was incorrect, she displayed the same slide with the correct drawing circled. Then she displayed the next slide. She returned to any incorrectly identified psueodwords after the first round, and this process continued until the child correctly identified each one.

Expressive practice.: Following the receptive practice, the interventionist displayed via screen share one drawing at a time and asked the child to verbally name the picture. If the child correctly named the drawing, she praised the child, marked the nonword as complete on the expressive practice checklist, and displayed the next drawing. Feedback on each item ceased after a correct response. If the child incorrectly named the picture, the interventionist named the target pseudoword and displayed the next drawing. She returned to any incorrect items after the first round, and this process continued until the child had correctly labeled each pseudoword.

Intervention Conditions

Traditional.: In the traditional condition, the intervention procedures were followed exactly as described above.

General physical activity.: In the general physical activity condition, the child performed jumping jacks for 15 seconds per pseudoword during each step described above, similar to the academic content condition described in Mahar (2011). For example, in the introduction step, the child performed jumping jacks after the interventionist presented the semantic information for each target. In the receptive and expressive practice steps, the child performed jumping jacks for 15 seconds after each correct response.

Semantic richness physical activity.: In the semantic richness physical activity condition, the child held a yoga posture shaped like the target's line drawing for 15 seconds per pseudoword during each step described above. The yoga posture mimicked a physical characteristic of the referent, and the examiner explicitly pointed out the parallel of the referent and the physical activity. For example, in the introduction step, the interventionist told the child, "Now we are going to make our body look like a *zog*. See its horn? Let's bend our backs to look like a *zog*," and instructed the child to enter a camel pose. In the receptive and expressive practice steps, the child held the associated yoga pose for 15 seconds after each correct response. A description of each yoga pose is provided in Table 4.

Fidelity and Reliability

Prior to data collection, interventionists participated in two hours of live training to learn the study protocol. The authors described and presented examples of each intervention condition, and the interventionists practiced the intervention conditions with each other, and finally with the authors. A checklist was used to demonstrate to the interventionists how their implementation would be scored for fidelity. Any errors in implementation were discussed and interventionists practiced again until able to implement each condition with no errors.

During data collection, an independent observer reviewed 1/3 of all intervention session videos (one session per participant; condition was randomized) using a study-specific procedural fidelity checklist. Fidelity was 99.14% (range 92–100%).

Reliability of word learning assessment was completed for 1/3 of all assessment sessions; again, one session per child was selected with condition randomized separately from the randomization for fidelity checks. An independent observer scored the child's responses on posttests from the video recordings, and the observer's scores were compared to scores calculated by the interventionist. Inter-rater reliability was 99.40% overall (99.60% for receptive and 99.20% for expressive [range 90–100%]).

Data Analysis

To address the study aim, a repeated measures analysis of variance (ANOVA) with group as the between-subjects factor, physical activity condition as the within-subjects repeated measures factor, and number pseudowords correct on the posttest measure as the dependent variable was utilized to examine the effects of intervention condition on word-like form learning across groups. A power analysis was performed with traditional assumptions (alpha = .05 two-tailed, power ≥ .80; Cohen, 1988). With 14 participants per group, this study was powered to detect an effect size of $f = 0.25$, a medium effect.

Results

A visual depiction of the results is displayed in Figures 2 and 3. First, we present results on receptive identification of pseudowords across the physical activity conditions in Table 5. Repeated measures ANOVA revealed no effect of group, $F(1,26) = 0.473$, $MSE = 8.68$, $p = .45$, $\eta_p^2 = .018$, or condition, $F(2,25) = 0.247$, $MSE = 0.73$, $p = .782$, $\eta_p^2 = .009$, on receptive identification of pseudowords targeted in the intervention.

Results for expressive production of pseudowords across the conditions is presented in Table 5. In contrast to receptive identification, repeated measures ANOVA revealed an interaction of group and condition for expressive production of targeted pseudowords, $F(2, 52) = 3.666$, $MSE = 5.61$, $p = .03$, $\eta_p^2 = .124$. Follow-up analyses indicated that, as seen in Table 5, children in the DHH group named more pseudowords taught in the general physical activity condition than the traditional condition (Hedge's $g = 0.42$), whereas the TH group named more pseudowords taught in the semantic richness physical activity condition than the traditional condition (Hedge's $g = 0.36$). The effect size indicates a medium effect for children who are DHH and a small effect for TH children.

Discussion

The purpose of this study was to evaluate the impact of embedding physical activity into a virtual pseudoword learning intervention to facilitate the rapid mapping of word-like forms to referents by children who are DHH. We compared general physical activity and semantic richness physical activity to traditional pseudoword learning intervention across children who are DHH and children with TH. There were no differences in receptive learning of the pseudowords across groups or intervention conditions. In contrast, both groups exhibited benefits to expressive word-like form use by integrating physical activity into instruction delivered via telepractice; however, the types of physical activity that led to increased learning differed across the groups. For the TH group, as expected, this benefit was seen in the semantic richness physical activity condition. For the DHH group, however, the benefit to virtual pseudoword learning intervention was seen in the general physical activity condition. Thus, possible differences in the effects of physical activity on TH and DHH children should be considered.

Interaction of Benefit of Physical Activity Type and Group

Although our hypothesis that physical activity would enhance word-like learning was partially confirmed in both groups, each group also had a physical activity condition in which expressive outcomes did not differ from the traditional condition. Based on Lund et al. (2020), we had hypothesized that, in both groups, children would learn the fewest word-like forms in the traditional condition and the most in the semantic richness condition, with the general condition falling in between. This hypothesis was based on prior work that shows a benefit of general physical activity on attention-to-task (Case-Smith et al., 2010), as well as previous work indicating added benefit when the physical activity is in some way related to the skill being learned (Lund, Douglas et al., 2015; Lund et al., 2020; Toumpaniari et al., 2015). This hypothesis, however, was not fully confirmed. Children with TH learned more word-like forms in the yoga condition, in which the movement was related to word meaning; however, there was no benefit of general physical activity to learning beyond the traditional condition. In contrast, the DHH group learned more word-like forms in the jumping jacks condition, in which the movement was unrelated to meaning, but the semantic richness physical activity condition yielded no benefit beyond the traditional condition. These findings highlight potential differences in the relation of physical activity and learning across groups, as well as differences in this relation when the learning occurs in a virtual environment.

Possible Explanations of Performance Patterns

Attention and cognitive load.—For children in the DHH group, this pattern of findings was surprising because the semantic richness physical activity provided no additional benefits beyond the traditional word-like learning intervention condition. We propose that situating this finding within the Capacity Theory of Attention may explain differences in our results compared to prior literature. The Capacity Theory posits that an individual possesses a finite amount of cognitive resources that can be devoted simultaneously to different tasks (Kahneman, 1973). In this case, perhaps virtual pseuodword learning intervention adds enough to the cognitive load for children who are DHH such that providing additional semantic information exhausts resources that would otherwise be used to enhance learning. It is also possible that the potential novelty of the yoga condition required increased cognitive load for children to complete than the likely familiar jumping jacks condtion. Although our intervention was delivered at a +20 dBA SNR, computer sound cards compress the auditory signal in ways that don’t occur in a live voice. This added listening effort for children with hearing loss may contribute to fatigue, exhausting the available cognitive resources used for word learning (as described in Werfel & Hendricks, 2016). Prior work has suggested that children who are DHH indeed use cognitive resources inefficiently in complex listening tasks (Lewis et al., 2015). Future work should evaluate the hypothesis that virtual learning may increase cognitive load for learners who are neurodiverse.

Characteristics of the physical activity conditions.—Additionally, differences in the physical activity conditions may help explain our findings. The general physical activity condition involved jumping jacks, an aerobic exercise that increases heart rate, whereas the semantic richness physical activity condition was yoga-based, an anaerobic exercise that involves holding positions for extended periods. Prior work has demonstrated that aerobic exercise can improve cognitive capacity in children with typical development (Ellemberg & St-Louis-Deschênes, 2010). It is also possible that the yoga-based physical activity was more cognitively demanding than jumping jacks, a familiar physical activity for children, because the yoga required understanding of instructions across each posture and is a less-common activity for children.

A recent scoping review reported evidence of positive effects of school-based yoga programs on academic performance in neurotypical as well as neurodiverse populations (Hart et al., 2022). However, the yoga condition in our design did not result specifically in increased pseudoword learning for children who are DHH after one session. Lund et al. (2020) reported benefits of semantic richness physical activity for word learning in children with Down syndrome. The physical activity in Lund et al. involved acting out words, which differed from our design. It could be that acting out a word, as in Lund et al. (2020), is more beneficial to children who are neurodiverse than physical activity that depicts an appearance feature. This hypothesis may be consistent with recent work evaluating the shape bias in children who are DHH: children who are DHH may be less likely to extend novel words to objects of the same shape than children with TH (Perry et al., 2021). Additionally, the impact of yoga on academic performance may be more general, increasing attention and decreasing stress, rather than impart a specific benefit to a particular learning task. Future work should continue to elucidate the role that type of physical activity and type of semantic richness play in word learning.

Overall pseudoword learning in this study, in comparison to past in-person literature, also provides preliminary data about the effects of telepractice on learning in children who are DHH. In studies that measured immediate recall of words following a single-day word-learning experience (i.e., the target words were assessed on the same day that they were learned), preschool and early elementary school-age children who were DHH receptively learned approximately 30–50% of words presented (Pittman, 2008; Stelmachowicz et al., 2004; Walker & McGregor, 2013). In the present study, children receptively learned 30–40% of words presented across conditions, similar to prior work that occurred in-person. It may be reasonable, then, to hypothesize that telepractice intervention can be as effective as in-person intervention for children who are DHH, despite challenges associated with learning with a computer screen. Future work may consider how learning through telepractice may influence long-term retention, or how additional input sessions influence number of words learned and retained.

Our findings were also surprising for children with typical hearing. Although, as expected, they benefited most from the semantic richness physical activity condition, there was no added benefit to the general physical activity condition, in which they performed jumping jacks during teaching episodes. Previous work has shown increased learning, particularly in mapping words forms to referents, from embedding physical activity to in-person learning

(Mavilidi et al., 2015; Schmidt-Kassow et al., 2014). This benefit was not observed in this study. Future work should explore whether the in-person effects of general aerobic physical activity for learning generalize to virtual word learning.

Limitations and Conclusions

Our findings represent an initial study evaluating the impact of different types of physical activity on word learning instruction delivered via telepractice for children who are DHH. They should be interpreted with the following limitations in mind. First, our sample size, although powered to detect medium effects, was nevertheless small. Second, our sample of children who are DHH included only children who use primiarly spoken English and whose group mean on standardized language measures was in the average range (although performance ranged from scores of 65 to 155), and whose maternal education and subsequent other scores were relatively high. Future work should replicate these findings in larger samples and with other groups of children who are DHH. It is important that future work include sufficient sample size to determine the impact of current vocabulary knowledge, as well as children's language modality, on the relation of physical activity and word learning for children who are DHH.

As tele-interventions are further developed, with the possibility of reaching larger numbers of children who are DHH, it will be particularly important to identify components of intervention that may enhance or impede learning. This study presents preliminary evidence that children who are DHH can effectively learn word-like forms through tele-intervention, and that physical activity during learning opportunities may influence rapid word learning. Additionally, the study provides data indicating that type of physical activity may differentially influence learning based on whether or not a child is DHH.

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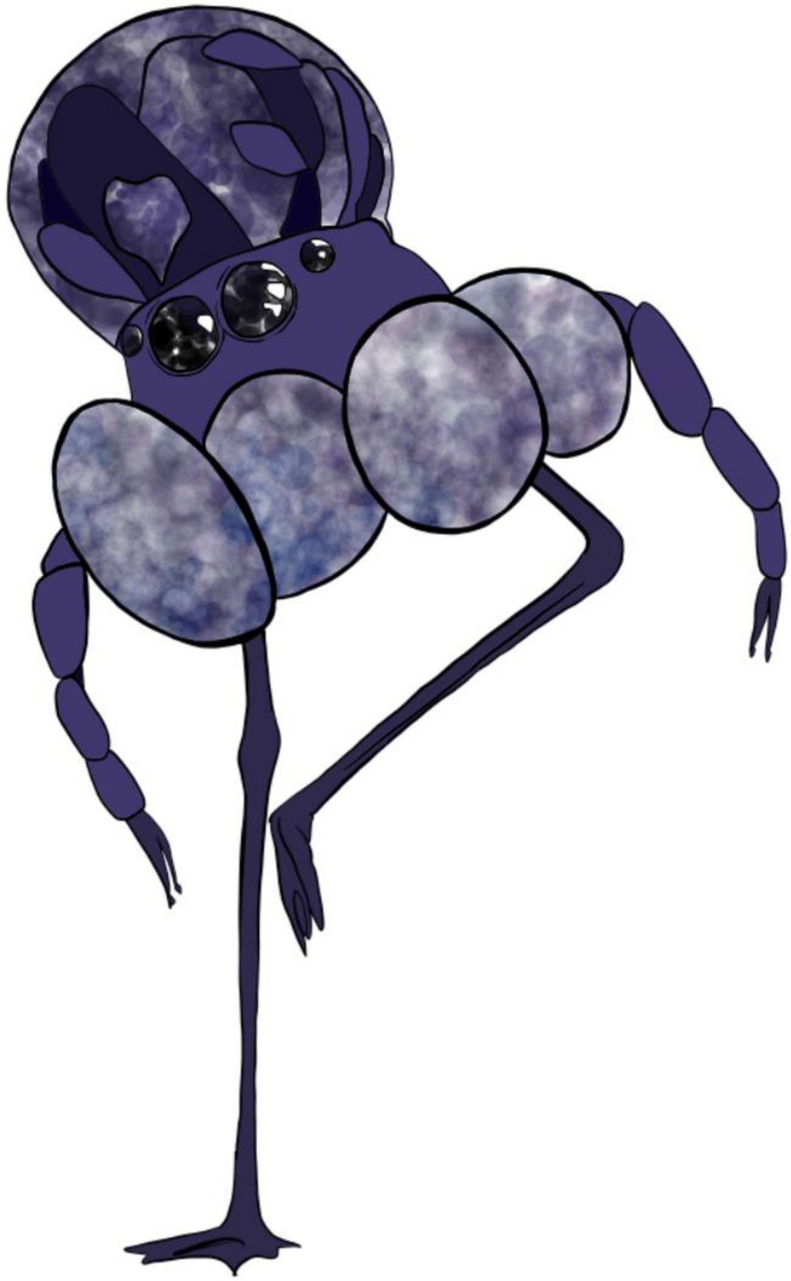

Figure 1.
Example illustration of imaginary animal for Tree Pose.

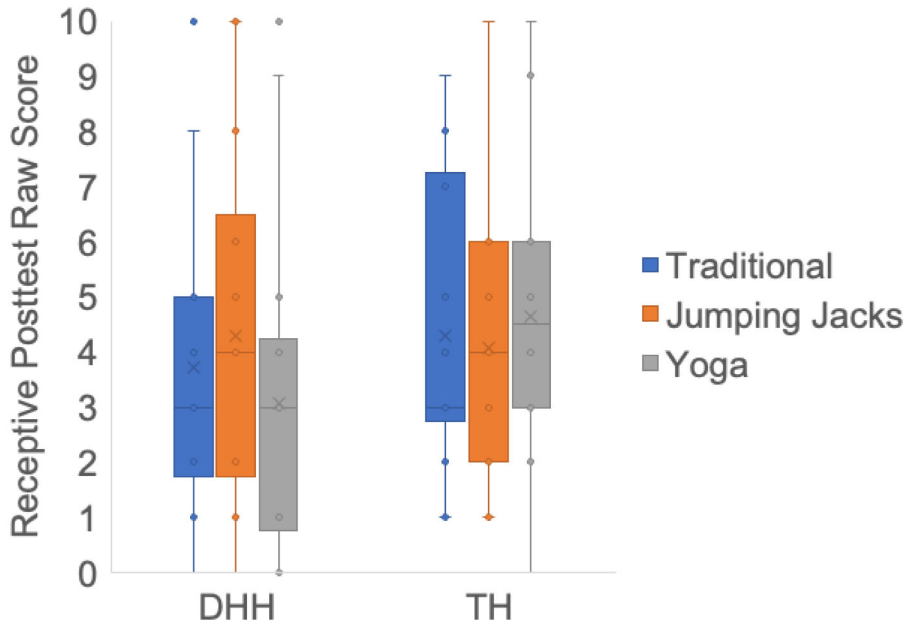

Figure 2.
Receptive posttest raw score by physical activity condition and group.

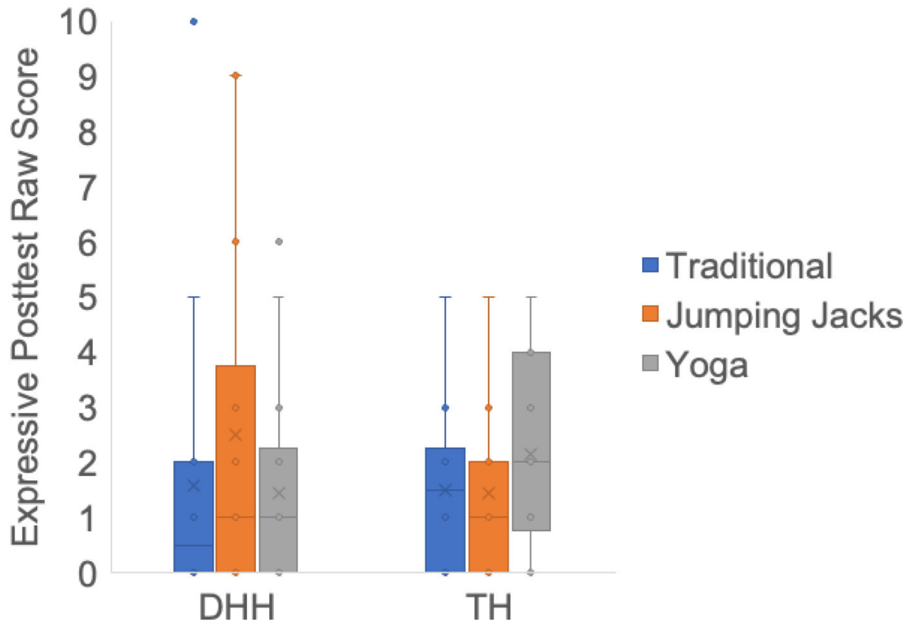

Figure 3.
Expressive posttest raw score by physical activity condition and group.

Table 1.

Descriptive information by group

	DHH ***M* (*SD*)**	**TH** ***M* (*SD*)**	***t* (df)**	***p***	***d***
PTONI	103.36 (14.18)	115.21 (9.55)	2.595 (26)	.015	0.98
TELD	102.71 (18.07)	117.07 (6.50)	2.797 (26)	.013	1.06
PPVT	96.71 (18.10)	116.64 (16.58)	3.308 (26)	.005	1.15

Note: All measures reported as standard scores. PPVT = Peabody Picture Vocabulary Test; PTONI = Primary Test of Nonverbal Intelligence; TELD = Test of Early Language Development.

Table 2.

Audiologic information for participants with hearing loss

Participant	Age in months at Identification	Age at First Hearing Aid	Age at First Implant	Amplification Type	Degree of Hearing Loss
1	45	48	--	HA	Mild to Moderate
2	0	7	--	HA	Mild to Moderate
3	11	18	--	HA	Mild to Moderate
4	2	4	--	HA	Mild to Moderate
5	1	2	--	HA	Mild to Moderate
6	0	7	--	HA	Mild to Moderate
7	0	2	--	HA	Moderate
8	0	3	--	HA	Moderate
9	20	24	--	HA	Moderate
10	6	6	--	HA	Moderate to Severe
11	2	3	40	Bimodal HA	Moderate to Severe
12	3	4.5	17	CI	Profound
13	12	13	16	CI	Profound
14	3	4	12	CI	Profound

Note. CI = cochlear implant, HA = hearing aid.

Table 3.

Pseudoword lists

List 1	List 2	List 3
yown	pame	baup
dabe	yood	nime
nopp	munn	mobe
bome	dupp	yide
womm	dowd	hume
yab	merd	nudd
wepp	bide	bem
herp	weem	wubb
nerm	hodd	heeb
pum	moop	pern

Table 4.

Yoga poses used in intervention

Posture	Description
Camel pose	The individual kneels with knees at a 90-degree angle and bends the back in order to touch the feet with the hands.
Garland pose	The individual squats with elbows pushing knees out and palms touching in front of chest.
Tree pose	The individual stands on one leg and places the other foot on the calf of the standing leg.
Cobra pose	The individual lies on the stomach and pushes upper body off the floor with their hands.
Boat pose	The individual sits on the floor and raises the legs straight at a 45-degree angle such that the body forms a “v”
Cat pose	The individual is on hands and knees and arches back.
Extended mountain pose	The individual stands with both feet on the ground and raises the arms straight overhead with palms touching.
Wide-legged forward bend	The individual stands with feet very wide apart and bends forward at the waist such that head is close to the floor.
Hero pose with a-okay eyes	The individual kneels, sitting on the backs of the legs, creates a circle with each hand using the thumb and forefinger, and holds circles over eyes.
Shark pose	The individual lies on the stomach and lifts the upper body off the floor, clasping the hands behind the back.

Table 5.

Receptive and expressive posttest scores across groups and conditions

	DHH *M (SD)*		TH *M (SD)*	
	Receptive	**Expressive**	**Receptive**	**Expressive**
Traditional	3.71 (2.76)	1.57 (2.79)	4.29 (2.67)	1.50 (1.51)
General Physical Activity	4.29 (3.27)	2.50 (3.18)	4.07 (2.49)	1.43 (1.40)
Semantic Richness Physical Activity	3.07 (3.15)	1.43 (1.95)	4.64 (2.62)	2.14 (1.86)

Note. Maximum score in each condition is 10.