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TECHNICAL REPORT

Language Skills and Speed of Auditory Processing in Young Children

Julie A. Avanzino[1], Marybel Gonzalez Robledo[2] and Gedeon O. Deák[2]

[1] Veterans Medical Research Foundation
[2] Department of Cognitive Science, University of California San Diego

Address for correspondence:

Julie A. Avanzino, Veterans Medical Research Foundation

3350 La Jolla Village Drive, San Diego, CA, 92161-116A

Phone: (858) 552-7598 Fax: (858) 642-3646 Email:javanzino@vapop.ucsd.edu

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Center for Research in Language, 0526
9500 Gilman Drive, University of California, San Diego 92093-0526
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Julie A. Avanzino (javanzino@vapop.ucsd.edu)
Veterans Medical Research Foundation, 3350 La Jolla Village Drive
San Diego, CA 92161-116A USA
Marybel Robledo Gonzalez (m1robledo@ucsd.edu)
Department of Cognitive Science, University of California, San Diego, 9500 Gilman Drive
La Jolla, CA 92093-0115 USA
Gedeon O. Deák (gdeak@ucsd.edu)
Department of Cognitive Science, University of California, San Diego, 9500 Gilman Drive
La Jolla, CA 92093-0115 USA

Abstract

Previous research examining auditory processing in school-age children and infants suggests a link between auditory event processing speed and specific language impairment. However, temporal auditory processing abilities have yet to be investigated in toddlers and preschoolers in the age range of 2 to 5 years. In this pilot study we tested the feasibility of a new behavioral test of thresholds for auditory processing speed in children 2 to 5 years of age. The results from n = 11 typically developing children show that accuracy was not significantly correlated with subsequent receptive and expressive language skills, although children who completed training more quickly tended to have higher receptive and expressive language scores. These results indicate the need for further work to develop a reliable, valid behavioral test of auditory change detection speed. Such a test could contribute to our understanding of individual differences and impairment of language ability during a crucial age range for language development.

Keywords: auditory perception; language; preschoolers; rapid auditory processing; specific language impairment; toddlers.

Introduction

Although most children acquire near fluency in their native language within 3 to 4 years, a subset of children show significant delays in this process. These children are diagnosed as having specific language impairment (SLI), a developmental language learning disorder that cannot be explained by hearing impairment, neurological disorder, autism, or unspecified general mental or physical impairment (Leonard & Weber-Fox, 2012). It is estimated that 6 to 8% of monolingual English-speaking children entering kindergarten meet diagnostic criteria for SLI (Tomblin, Records, Buckwalter, Zhang, Smith, & O'Biren, 1997). SLI has a familial linkage, as children who have a parent or sibling with language impairment are three times more likely to be diagnosed with SLI than children in families with no history of language impairment (Tomblin 1989; Tallal, Ross, & Curtiss, 1989). Additionally, the 70% concordance rate for monozygotic twins is significantly higher than the 46% concordance rate for dizygotic twins (Bishop, North, & Donlan, 1995), suggesting that the familial linkage is partly genetically influenced.

However, the mechanisms underlying the language deficits of SLI are still unknown. Infant speech perception appears to be a reliable predictor of subsequent language ability. Results of a recent meta-analysis show that a variety of measures of language-specific processing over the first year of life predict children's subsequent vocabulary size (Cristia, Seidl, Junge, Soderstrom, & Hagoort, 2014). One prevalent hypothesis is that inefficient processing and encoding of rapidly changing acoustic events contributes to language deficits (Tallal & Piercy, 1973; Benasich & Tallal, 2002). Acoustic transitions between phonemes in fluent speech can occur within 10 milliseconds, so a deficiency in rapid auditory processing could lead to speech-sound processing deficits (Leonard, 2000; Stevens, 2000). Deficits in speech perception would in turn retard receptive and expressive language ability (Benasich & Tallal, 2002; Trehub & Henderson, 1996).

Several lines of evidence support the hypothesis that individual differences in fundamental temporal auditory processing thresholds underlie the language deficits of children with SLI. For example, seven to nine year old children with SLI showed impaired detection of rapidly occurring tone-pairs as compared to children without a history of language impairment (Tallal & Piercy, 1973). Using a repetition method, children were asked to indicate the order in which acoustic tones were presented within tone-pairs by clicking one of two panels on a computer screen. Four tone-pairs were presented using a 54 Hz tone and 180 Hz tone, each 75 ms in duration. During testing trials, the inter-stimulus interval (ISI) was varied from 8 ms to 4,062 ms. Children with SLI had significantly lower accuracy than children without language impairment when the ISI was shorter than 305 ms (Tallal & Piercy, 1973). This suggests that the children with SLI were unable to perceive rapid acoustic changes designed to simulate the rapid transitions between phonemes in naturally occurring speech. However, children with SLI did not differ from controls in their ability to perceive slower acoustic transitions (Tallal & Piercy, 1973), indicating that neither low-level acuity deficits nor non-compliance with the task was involved. A recent investigation indicates that six to ten month old infants with a family history of language impairment also have difficulty processing rapidly presented tone-pairs (Benasich & Tallal, 2002). Infants' auditory processing thresholds were assessed using a reinforcement conditioned two-alternative forced-choice task. Infants learned to associate a low-low frequency tone-pair with a toy on their left lighting up and moving and a low-high frequency tone-pair with another toy on their right lighting up and moving (Benasich & Tallal, 2002). Temporal auditory processing thresholds were calculated by varying the ISI between 8 ms and 500 ms and assessing the accuracy of infants' direction of gaze shifts in response to the two tone-pairs (Benasich & Tallal, 2002). Infants with a family history of language impairment showed higher (average of 146.5 ms) thresholds than infants without a family history of language impairment (average of 70.6 ms) (Benasich & Tallal, 2002). Additionally, infants' language and cognitive abilities were tested at 12, 16, 24, and 36 months of age. Across both groups of infants, individual differences in auditory processing thresholds at 6 to 10 months predicted language test scores at 12, 16, 24, and 36 months (Benasich & Tallal, 2002). However, no association was found between auditory processing thresholds at 6 to 10 months and cognitive scores at any subsequent age of testing (Benasich & Tallal, 2002).

Although speed of auditory processing has been shown to relate to language abilities in both school age children and infants, little is known about temporal auditory processing thresholds of toddlers and preschoolers aged 2 to 5 years or the relation of these thresholds to the development of language abilities. From existing data, we would predict that toddlers and preschoolers show substantial individual differences in temporal auditory processing thresholds and that these thresholds are associated with individual differences in language abilities. Such evidence would interpolate previous findings for a more comprehensive developmental perspective on variability in language acquisition.

Additionally, a sensitive measure of individual differences in speed of auditory processing thresholds could be useful for screening SLI in toddlers and preschoolers. The period from 2 to 5 years is a crucial period for language development, during which children learn many new words, master basic syntactic structures, combine words to create longer and more complex sentences, and integrate sentences into richer narratives and more mature conversations. For children at risk for language delays in this period, it would be beneficial to receive interventions as early as possible. However, there are currently few tools to assess and predict language delays in this age range. Many of the existing tools rely on caregiver report (e.g., Ireton & Thwing 1972; Dale, Bates, Reznick, & Morisset 1989) which, although useful, has limitations (Chaffee, Cunningham, Secord-Gilbert, Elbard, & Richards, 1990; Feldman, Dollaghan, Campbell, Kurs-Lasky, Janosky, & Paradise, 2000; Heilmann, Weismer, Evans, & Hollar, 2005). If there is a robust relationship between auditory processing thresholds and later language skills, a behavioral test that can reliably measure that threshold could serve as a supplemental, converging screening tool for SLI. Unfortunately, the reinforcement conditioning paradigm that is useful for measuring auditory processing thresholds in infants (Benasich & Tallal, 2002) does not elicit useful results from children older than 12 months of age. Conversely, the behavioral tests used with school-aged children, based on adult psychophysics paradigms, are too difficult for young children. Therefore, we created a new behavioral test suitable for young children.

Here we report the results of a pilot study investigating the feasibility of this new test of auditory processing speed thresholds (APS test). The APS test was piloted on a sample of typically developing, English-learning children between the ages of 28 and 52 months. Additionally, participants' receptive and expressive language abilities were measured in follow-up visits, in order to assess the predictive validity of the APS. We hypothesized that the APS would be a feasible, valid test for children between 28 and 52 months of age and that there would be robust individual differences in auditory processing speed thresholds, even in typically developing young children. We also predicted that these differences would be associated with subsequent receptive and expressive language abilities of the children.

Method

Participants

Participants were 19 English speaking children between 28 and 52 months (mean age = 38.7 mo; 10 males) recruited from local parent support groups and from previous study participation at UCSD or SDSU. Exclusion criteria were any previous diagnosis of language delay, history of hearing dysfunction, visual or cognitive impairment, or any diagnosed or provisionally diagnosed developmental disorders. One child had a suspected language delay, which was confirmed as a provisional diagnosis after he was tested. His data were removed from all analyses. Three children did not meet a criterion of completing at least three testing trials per ISI and were therefore also excluded from analyses. A total of 15 participants were included in analyses (mean age = 39.2 mo, range = 28 to 52 mo; 6 males). Three of these participants were not available for follow-up language tests, and one participant's follow-up EVT was invalid. Therefore, 11 participants who completed the APS test and both language measures were included in the following analyses (mean age = 39.0 months, range = 28 to 52 months; 4 males). Of these 11 children, 6 were Caucasian, 1 was Asian, 1 was Hispanic, 2 were multiethnic, and 1 child's ethnicity was not reported. Nine of the children were exposed to English only, one had experience with English and Hindi, and one had experience with English and Italian. Demographic data were collected through questionnaires completed by the primary caregiver (see Table 1).

Table 1: Demographic data for children who completed the APS test and for children who completed both the APS test and the language measures.

	n = 15	*n* = 11
Mean child age, mos (*SD*)	39.2 (7.24)	39.0 (7.62)
Mean maternal education, yrs (*SD*)	16.8 (1.01)	16.5 (0.93)
Mean parental age, yrs (*SD*)	36.3 (3.9)	36.0 (3.61)
Parity: first born, second born (*n*)	(12, 3)	(9, 2)

Procedure

The protocol was approved by the UCSD Institutional Review Board, and written informed consent from all caregivers and verbal assent from all children were obtained prior to testing. At the first visit, the child's caregiver completed a demographics questionnaire providing information about the child's age, ethnicity, parity, and language exposure, the mother's level of education, and the age of parents. Participants read a storybook with the experimenter designed to familiarize the child with the APS test. The APS test was then administered in a sound attenuated room.

During a follow-up visit, participants completed the Peabody Picture Vocabulary Test, Third Edition (PPVT-III; Dunn & Dunn, 1997) and Expressive Vocabulary Test, Second Edition (EVT-2; Williams, 1997). Follow-up visits took place at the participant's home 3 to 14 months after the participant's initial lab visit. Children were an average of 48.9 months old (range = 41 to 65) at the time of the follow-up visit; all reported scores are normed to the child's age at the time of the visit.

Auditory processing speed threshold (APS) test

The stimuli were two tone-pairs consisting of two 70 ms complex tones, each with a rise and fall time of 20 ms. Tones were the same ones used in Benasich and Tallal's infant study (Benasich & Tallal, 2002). Tone 1 was 100 Hz and Tone 2 was 300 Hz. Both were synthetic sounds with rise and fall times of 20 ms and complex harmonics with a six decibel roll-off per octave. The first tone-pair consisted of Tone 1 followed by Tone 1. The second tone-pair consisted of Tone 1 followed by Tone 2. The ISI for each tone-pair was varied from 10 ms to 150 ms.

The APS was a two alternative, forced-choice test using age-appropriate rewards and collecting responses on a touch-screen computer (ACPI Uniprocessor PC, Intel Celeron 1.50 GHz) with a 48 cm monitor. The child was seated in a booster chair 16 cm from the touch-screen monitor in the center of a dimly lit room (see Figure 1). The caregiver was seated in a chair behind the child in the rear of the room. The experimenter sat on the floor to the right of the child. A laptop computer was placed to the right of the touch-screen monitor to deliver video reward, at a roughly 65 degree angle to the child's right. A black barrier was placed behind the touch-screen monitor to minimize extraneous visual distractions. The session was videotaped from two angles: one camera was placed behind the barrier (with a small hole for lens) and focused on the child's face and upper body; the other was placed to the rear-left of the child to record the child's touch responses. Video was later coded independently by a second researcher, who scored the child's responses, gaze direction, and attentiveness throughout the trial.

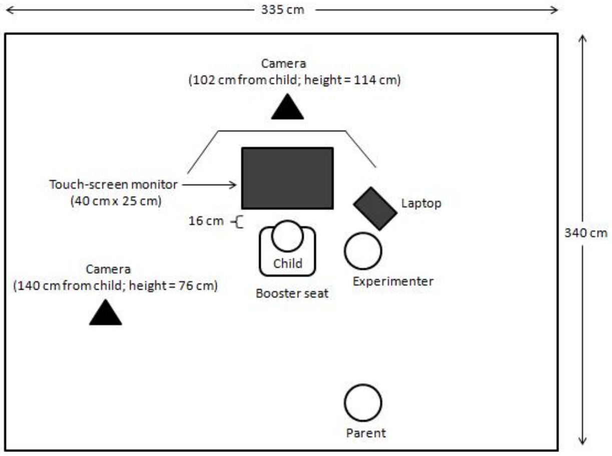

Figure 1: Testing room configuration.

For the APS test, the child was acquainted with a large monkey and a small monkey, each living in different-colored, different-sized barrels. The child was told that the monkeys only sing and come out of their barrels when they are hungry, and the child was trained to associate the same-frequency tone-pair (Tone 1 – Tone 1) with the large monkey (the large monkey singing) and the different-frequency tone-pair (Tone 1 – Tone 2) with the small monkey (the small monkey singing). The child was instructed to touch the barrel of the corresponding monkey when a tone-pair was presented and subsequently, the monkey would pop out and get a "treat" (see Figure 2). Additionally, the child received a sticker-sheet before beginning the test and then received a sticker for each correct response. After every 10 correct responses (one row of stickers), a 10 second video reward of a popular children's television show was played for the child on the laptop computer. The child's touch responses were used to assess discrimination of tone-pairs with various ISIs. All trials were initiated by the experimenter to ensure the child was oriented towards the touch-screen. If the child was inattentive during the presentation of auditory stimuli, the experimenter repeated the presented trial. The test was comprised of four phases: orientation, training, criterion, and testing.

Figure 2: Monkey associated with 100 Hz– 100 Hz trials (left) and monkey associated with 100 Hz– 300 Hz trials (right).

In the orientation phase, the test was explained and re-explained during six trials. During these trials, the visual cues (large or small monkey) appeared at the onset of the corresponding tone-pair. These trials were designed to introduce children to the sounds, images, and sound-image associations. If the child made an incorrect touch response, the experimenter would replay the tone-pair and demonstrate the correct response. The ISI of all orientation tone-pairs was 150 ms.

The training phase included eight trials with an ISI of 150 ms. These were designed to teach children the sound-image associations. The large or small monkey appeared at the onset of the corresponding tone-pair during the first four training trials but was not present during the next four trials. Children were instructed to touch the barrel of the monkey associated with the presented tone-pair. If the child made an incorrect response, the experimenter would show the child the correct response and advance to the next trial.

A criterion phase of four trials immediately followed, in which monkeys were not presented at the onset of the tone-pairs (ISI 150 ms). If the child made an incorrect response, no feedback was given but the next trial was presented. If the child made at least three out of four correct consecutive responses, the testing phase began. If the child made fewer than three out of four correct consecutive responses, another training block began. All children continued until the criterion was met except for one child, who did not want to play after completing the second training block.

Testing consisted of two blocks of 30 trials. The first 10 trials of each block contained 100 ms ISI tone-pairs, the second 10 trials of each block contained 70 ms ISI tone-pairs, and the third 10 trials of each block contained 10 ms ISI tone pairs. Same-frequency and different-frequency tone-pairs were presented in a quasi-random sequence. The large or small monkey was not presented with the onset of the tone-pairs. If the child made an incorrect touch response, no feedback or reward was given and the next trial was presented. If the child made a correct touch response, a sticker reward and verbal congratulations was given and the next trial was presented. If the child completed both blocks of 30 trials, the program was restarted and the child completed additional training and testing trials. The child continued performing the task until she or he indicated that she no longer wished to play. The task was programmed in Stim2007 by the second author.

Language Measures

Children completed the Peabody Picture Vocabulary Test, Third Edition (PPVT-III; Dunn & Dunn, 1997) and Expressive Vocabulary Test, Second Edition (EVT-2; Williams, 1997). The PPVT-III is a standardized test of single-word receptive comprehension (standard scores range from 40 to 169) that provides age-normed scores for individuals aged 2:6 years and above. The EVT-2 is a standardized measure of expressive vocabulary that provides age-normed scores for individuals aged 2:6 years and above (standard scores range from 20 to 160). Participants' age-standardized scores for both tests were used for the analyses below.

Results

Participants were coded as either attentive or inattentive during each APS trial, based on off-line scoring of video recordings. Inattentiveness was defined by any of the following behaviors: (1) looking away from the touch-screen during presentation of the audio-stimuli; (2) talking or making noise during presentation of the audio-stimuli; (3) touching the touch-screen monitor while the audio-stimuli were still playing; (4) moving the chair or producing gross motor actions during presentation of the audio-stimuli. Only attentive trials were used for the following analyses.

A total of 15 children completed a minimum of 30 test trials and were therefore included in the analyses. These children were attentive for an average of 48 completed test trials (*SD* = 14.7, range = 24 to 88). An average of 24% of trials per child (*SD* = 13.1%, range = 2 to 43%) were removed due to inattentiveness. Of the remaining attentive trials, children responded correctly to an average of 64.3% test trials (*SD* = 15.0%, range = 32.4 to 87.7%), demonstrating considerable individual variability. PPVT-III standardized scores for the 11 children who completed the language measures averaged 122.5 (*SD* = 13.4, range = 102 to 147). EVT-2 standardized scores for those 11 children averaged 123.4 (*SD* = 12.7, range = 103 to 144). These statistics are presented in Table 2.

For children at this age, persistence, test completion and compliance can be challenging. Moreover, the number of test trials completed affects the reliability of any given child's results. Therefore, it is noteworthy that there was a significant correlation between age and number of testing trials completed ($r_{(13)} = 0.664$, $p = 0.007$). Although older children completed more trials than younger children, it is not clear that they were more accurate than younger children: the association between age and accuracy as not significant, although the trend is suggestive ($r_{(13)} = 0.407$, $p = 0.132$).

Table 2: Descriptive statistics from children who completed the APS test and from the subset of children who additionally completed the language tests.

Dependent Measure	***n* = 15**	***n* = 11**
Mean # training trials (*SD*)	14.3 (10.00)	15.6 (11.25)
Mean # testing trials (*SD*)	48.2 (14.67)	50.2 (18.93)
Mean % correct 100 ms ISI (*SD*)	71.0 (14.24)	71.1 (15.71)
Mean % correct 70 ms ISI (*SD*)	62.1 (16.97)	60.9 (18.60)
Mean % correct 10 ms ISI (*SD*)	64.6 (16.24)	61.3 (14.04)
Mean testing % correct (*SD*)	64.3 (15.01)	62.5 (16.17)
Mean PPVT-III (*SD*)	N/A	122.5 (13.37)
Mean EVT-2 (*SD*)	N/A	123.4 (12.65)

Previous studies suggest that short ISIs are more difficult to detect than long ISIs. However, the current study did not replicate this pattern: for example, accuracy on trials with the longest ISIs tested (100 ms) was approximately 5% greater than on trials with the shortest ISI (10 ms; see Table 2). The difference was not statistically reliable ($t_{(14)} = 1.251$, $p = 0.231$).

Pearson correlations were calculated between children's tone-pair discrimination and later vocabulary scores. The association between APS accuracy and PPVT-III scores was not significant ($r_{(9)} = 0.365$, $p = 0.268$) (see Figure 3), nor was the association between APS accuracy and EVT-2 scores ($r_{(9)} = 0.486$, $p = 0.129$) (see Figure 4). However, both of these non-significant trends were in the predicted direction.

Another question regarding the feasibility of the APS test is whether children had an adequate understanding of the task demands, for example, the verbal instruction.

As exploratory analyses, we examined Pearson correlations between number of training trials necessary to reach criterion PPVT and EVT scores. There were significant negative correlations between number of training trials and PPVT scores ($r_{(9)} = -0.725$, $p = 0.012$) and EVT scores ($r_{(9)} = -0.888$, $p < 0.001$). That is, children who completed training faster had larger receptive and expressive vocabularies several months later. Notably, age was not significantly correlated with the number of training trials necessary to reach criterion.

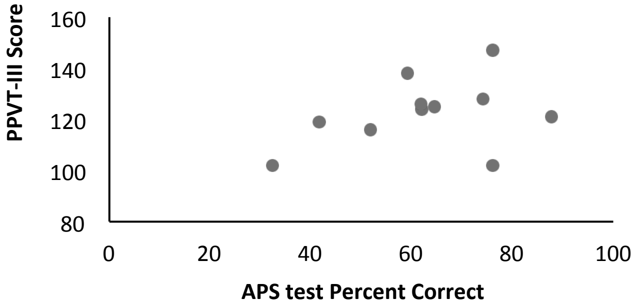

Figure 3: Percentage of correct APS test trial responses plotted against PPVT-III scores.

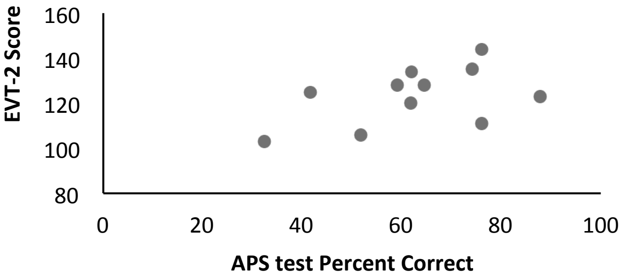

Figure 4: Percentage of correct APS test trial responses plotted against EVT-2 scores.

Discussion

In this study children aged 28 to 52 months completed a novel test of auditory discrimination. Older children who cannot discriminate low-low versus low-high tones when pairs are presented rapidly (i.e., with a short ISI) tend to have (or be related to others with) language and reading delays. Performance on the APS test was quite variable, ranging almost from 30 to 90% correct. However, accuracy was not related to age, nor, interestingly, to ISIs ranging from 10 to 100 ms. Accuracy was also not significantly related to receptive or expressive vocabulary although there are suggestive trends in the predicted direction.

Further testing is necessary to determine whether the APS test, or some variant, is a valid measure of auditory processing speed differences in young children. Our sample was relatively small, and several non-significant trends in the results warrant further investigation. Perhaps with a larger sample, the trends found in this exploratory pilot study will prove reliable. It should be noted that the small sample size was partly due to attrition. Regardless, the present results do not support the hypothesis that individual differences in 2 to 5 years olds' auditory processing speed predict later receptive and expressive vocabulary.

Although these pilot results revealed a great deal of individual variability in accuracy, it cannot be determined whether this variability is due to individual differences in auditory processing speed or to other variables. It was not reliably related to children's age: although older children completed more testing trials than younger children, their responses were not consistently more accurate, and they did not complete training faster. Therefore, older children might have been more compliant or more able to sustain task-related attention and effort than younger children, but there is no evidence that their auditory processing was faster. This is useful information because it seems that among children who learned the task, not only the older ones (e.g., 4-year-olds) but also the younger ones (e.g., 2½ to 3 ½-year-olds) were able to make the critical tone-pair discrimination.

One possible interpretation of these results is that auditory processing speed thresholds are related to language ability in infants and children but are not strongly related to those language skills measured by the PPVT-III or EVT-2 (i.e., vocabulary). Perhaps other measures of language ability would be more strongly predicted by auditory processing speed. Although it was not possible in this pilot study to administer a comprehensive age-appropriate battery of language ability tests, in future research it might be useful to test the relation between tone-difference detection thresholds and other language-related measures such as phoneme discrimination, sensitivity to subtle morphological cues and syntactic inflections, and speaker identification.

Another possible interpretation is that auditory processing speed thresholds do not predict language abilities in typically developing children in this age range. However, prior evidence suggests that such a relation is likely, as it encompasses both infants and older children (Benasich & Tallal, 2002; Tallal & Piercy, 1973). Moreover, Benasich and Tallal (2002) found that children aged 36 months (within our sample's age range) who had family members with language impairment had longer auditory processing thresholds than same-age control children. However, none of these previous findings directly show that individual differences in typically-developing preschool children's auditory processing speed is related to other language abilities. The current results, while suggestive, leave this question unanswered.

Another possibility is that individual differences in APS performance can be explained by cognitive variables other than auditory processing speed. These might include higher-order cognitive abilities, and task comprehension. For example, despite using a training criterion to assess task comprehension, it is possible that some children who did not fully comprehend the task, passed the training criterion and proceeded to testing trials. They might then have made some errors because they had only weakly learned the associations between tone pairs and monkeys. Similarly, some children might have learned the correct tone-monkey associations but forgot them as time passed during testing trials. Finally, it is possible that once the test trials began, events in the test trials competed for the preschoolers' attention, and distracted them from task-relevant information. This is consistent with evidence of the reduced attention span and selectivity of toddlers and preschoolers (e.g., Enns & Cameron, 1987). It would have been ideal to complete a longer, more engaging training procedure so that children could 'overlearn' the sound-image associations without losing motivation to complete the task. Although we attempted to maintain children's engagement with the task for as long as possible by providing a variety of rewards and age-appropriate materials and instructions, it is possible that even more extensive or finely-tuned training and reward procedures would yield more persistent task-appropriate performance, and reduce attrition.

Another cognitive factor that might have contributed to individual differences is children's varying ability to inhibit a touch response either before or after the auditory stimulus. Inhibitory control undergoes significant developmental change during this age range (e.g., Diamond & Taylor, 1996), and younger children are not able to inhibit their responses as quickly as older children and adults (Tamm, Menon, & Reiss, 2002). We do not find this possibility very plausible for several reasons: first, post-hoc video analyses eliminated any responses that occurred while the tone pair was still playing; second, response inhibition tends to improve with age, but we did not find a relation between age and accuracy; third, the task was untimed, and children were not encouraged to respond quickly. Despite these considerations, it would be interesting for future studies to investigate how the development of response inhibition affects children's performance on touch-screen tasks.

Additionally, individual differences in sustained attention and motivation might have contributed error variance to task performance. Although we attempted to control for this by coding for inattentive behaviors in every trial and removing any such trials from the analyses, inattentiveness cannot necessarily always be discerned from video recording of overt behavior. Children could be inattentive while quietly sitting still and facing the monitor, and we could not detect this from videos. Thus, some variability in task performance might still be due to inattentiveness during test trials.

Finally, it is possible that the training ISI of 150 ms was too brief for children with impaired language abilities to process and distinguish the tone-pairs. This explanation would fit previous evidence regarding tone-pair thresholds of children with SLI (Benasich & Tallal, 2002; Tallal & Piercy, 1973). However, this seems implausible because information from parents and from the standardized tests was used to eliminate any participants who were suspected of having any language impairment. Informally, we find that tone-pair ISIs far shorter than 150 ms are well above threshold – even 10 ms ISIs permit effortless, near-perfect tone-pair discrimination by adults with intact auditory systems.

In summary, our results indicate that a larger-scale study would be needed to determine whether individual differences in typical preschoolers' auditory discrimination speed contributes substantially to language abilities. It remains uncertain whether a behavioral task such as this one could be used on a large scale to assess auditory psychophysics in this age group. Months of pilot testing and progressive modification yielded a task that was well suited for this age group: factors such as motivation, distraction, and comprehension were extensively considered in the task design. The small sample size and the exclusion of children with SLI or other risk factors might have limited the robustness of our results. This is plausible because the correlations between auditory processing thresholds and language measures, albeit not statistically significant, were in the predicted directions. Future research utilizing electroencephalography and other physiological measures may provide greater measurement sensitivity and therefore further insight into the relationship between children's behavioral responses and auditory processing. In addition, tone-pair stimuli with even shorter ISIs might yield more robust individual differences. Future efforts such as these might eventually determine whether and how auditory processing thresholds contribute to language abilities in typically developing young children.

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