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On the relationship between speech production and vocabulary size in 3-5 year olds

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Abstract

Language acquisition is a multifaceted process, including distinct yet complimentary elements such as word comprehension and speech production . There is evidence that these skills develop together. We studied a group of preschool children to measure the strength of the relationship between receptive vocabulary and speech production at the start and the end of a six-month period, as well as to document any improvement in these domains. A linear regression revealed that vocabulary size at the initial testing time predicted speech production accuracy at the final session, and vice versa. We discuss the null result of no sex differences for either speech or vocabulary. Our results highlight the inter-connectedness of speech production and vocabulary.

Index Terms: speech production, receptive vocabulary, child development

1. Introduction

Language rapidly develops during the preschool years. When typically developing children start preschool around age three, they understand the basic syntactic structures of language and, through multiple vocabulary "bursts", have a solid foundation for further language development [1]. Comprehending and producing new words require the ability to mentally represent the phonemes, also known as phonological awareness (PA) [2]. Meanwhile, with the existing vocabulary, children are able to abstract away from the lexicon the invariant features of phonological categories, thus enabling PA and speech production [3]. There have been multiple studies that suggest that PA is dependent on vocabulary [4]. A specific example comes from a study that measured vocabulary size in relation to non-word repetition (NWR) ability [5]. This study found that better vocabulary is related to a better ability to repeat non-words, which is mediated by PA [5]. NWR calls upon similar but different phonetic skills compared to common word-repetition (WR) tasks, as explained by Vance et al. [6]. In a WR task, a child can access a stored lexical representation of the word, whereas in a NWR task, the child relies on their ability to perceive and discriminate the sounds since they have not heard the "word" before [6]. In the current study, we looked at the relationship between children's ability to produce speech sounds in a WR task and their vocabulary size.

The relationship between speech production abilities and vocabulary size in preschool-aged children has not been well-documented; however, in one study [7], they found that the ability to produce certain fricatives was correlated with vocabulary size in preschool age children. In a more recent study by Benway et al.[8], on the relationship between vocabulary, speech perception, and phonological awareness in school-aged children with speech sound disorders, they found that vocabulary did not mediate the relationship between speech perception and PA.

One topic that has been well discussed in the literature is the relationship between sex and language abilities. The research mainly shows that in children aged 8 months to 6 years, girls outperform boys by showing increased language competence [9, 10, 11, 12, 13]. In a study by Lundberg et al.[14], measurements of PA in children were taken at two time points (T1 and T2). At T1, the children were 69-80 months-old and the time between T1 and T2 was about 8 months. They found that PA at T1 influenced PA at T2, and that girls were significantly better in their PA skills at T1 and improved more than boys between T1 and T2. In contrast, another study by Burt et al. [15], found no differences in PA between girls and boys (ages 46-58 months), but found that age was a significant factor, with older children demonstrating more phonological awareness than younger children.

The purpose of the present study is to further investigate the relationship between vocabulary size and speech production abilities in preschool children across the school year. We predicted that children aged three to five years old would improve both their vocabulary and speech production clarity over a six-month period, and that vocabulary size would influence speech production skills, and vice versa. Given the bulk of research supporting sex differences in language development, we also predicted that girls in this age group would outperform boys in their speech production abilities and have a larger vocabulary. Speech production was measured via a word-repetition task. We scored the percent errors in children's speech sound productions. Vocabulary size was measured using the standardized assessment, the Peabody Picture Vocabulary Test-V (PPVT-V).

2. Methods

2.1. Participants

Forty five children (22 girls) were registered by their parents for this study. Children were assessed twice (T1 And T2), with a mean period of 6.15 months (SD = ± 1.37) in between tests. Some children were absent at either T1 or T2, and data from 39 children are included in the analysis. The participants' ages at T1 ranged from three to five years old (M = 56.03 months, SD = ± 10.79 months). We recruited through local daycares and early learning centers in Lethbridge, Alberta, Canada. Parents provided written consent for their children to participate in this study. They also completed five questionnaires about their children's development. The questionnaires included: Ages and Stages Questionnaire-3, Ages and Stages Questionnaire-Social Emotional, Social Responsiveness Scale-2 (SRS-2), Behavior Rating Inventory of Executive Function- Preschool (BRIEF-P), and a developmental survey created to determine if their child

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met age-appropriate milestones. The results of the T1 questionnaires are reported in (reference removed for anonymous review). These also showed that two children had been diagnosed with ADHD, four obtained abnormal scores on the SRS-2, and three on the BRIEF-P questionnaires. Several of these children had atypical scores on more than one questionnaire, but are still included in the study. Parents were compensated at the conclusion of T1 with an activity bag and/or a ten dollar gift card to a local coffee shop.

2.2. Materials

The children completed a total of 11 tasks [16, 17]. For the current study, we focused on receptive vocabulary and speech production. We used the PPVT-V to assess receptive vocabulary. The test consists of a booklet with four large images on each page. The booklet is placed directly in front of the child, and the experimenter reads a target word for each page. The child is instructed to point to the image that represents the word. If the child expressed uncertainty, they were encouraged to guess. The test is started at an age-appropriate level, and continued until the child makes eight consecutive errors. For the speech production task, we used a method identical to that reported in [18]. The child sat in front of a laptop, where the image of a duck and a ladder appeared on the left side of the screen. The child was shown a recording device (Zoom H4N Pro 4-Track portable recorder) and instructed to repeat the words they heard from the computer loudly and clearly into the device. Once the task started, the computer played a word and showed a matching image, and as the child pronounced the word, the duck would move up the ladder. At the end of the task, the duck reached the top of the ladder. The child was prompted to produce a total of 53 unique words that all had developmentally challenging phonemes in the initial consonant position. These phonemes included: /s/, /ʃ/, /r/, /l/, /w/, and /θ/. At the end of each testing session, the child was given a sticker in exchange for their participation.

We used a small, preschooler-sized table and chair for the participant. A video camera recorded the child's performance during the PPVT-V task. The PPVT-V testing booklet and tracking sheets were used to administer a test of receptive vocabulary. We used a 44.1 kHz sampling rate with 16-bit quantization. The speech production task also required a laptop (12 inch) with the custom program "Show and Play" [19] installed on the device.

2.3. Child Assessment Procedure

Children were tested in the early learning/childcare centers in a separate classroom, office, or hallway. At the start of the assessment, the child was shown a map with seven pictorial images organized in a pseudo-random linear sequence, and they were instructed to find the matching images around the testing room. Once the child found the matching image, one experimenter would operate a video camera to film the child while they performed the activity, and the other experimenter would set up and explain the activity to the child. The testing took place over one to three sessions, and each session lasted five- to thirty-minutes.

2.4. Analysis

The raw PPVT-V score was calculated by subtracting the total number of errors from the final level the child achieved. For the word error rate, a trained student listened to each speech production made by the child, and marked when the word was incorrectly pronounced. To calculate the word error rate, the total words that were not correctly pronounced was divided from the total words pronounced and multiplied by 100 to create a percentage. Phonetic error rate was calculated by rating each phoneme in the word list as pronounced correctly or incorrectly. Additions or deletions of sounds were also marked as errors. Similar to word error rate, the total phonetic errors were summed and divided from the total phonemes produced and multiplied by 100 to obtain a percentage. To validate this speech analysis, a senior researcher completed the same process with 20 % of the sample and used an intra-class correlation test to determine inter-rater reliability. Absolute agreement and a two-way mixed effects model was selected for the ICC test. The ICC (2,2) 0.863 (0.571-0.961, $p<0.001$) results suggest consistent rating between both scorers. All statistical analyses were completed in IBM SPSS Statistics (version 29.0.1.1)[20].

3. Results

3.1. Descriptive Statistics

The mean PPVT-V scores are listed in Table 1. The mean phonetic and word error rates are shown in Table 2 and Table 3 respectively. The raw (non-standardized) PPVT-V scores were used because the phonetic and word error rates were not standardized according to age. Unless otherwise stated, we included all children (including the atypically developing children) in this analysis. In cases where the atypically developing children changed the outcome of the analysis, we also report the results that only included the typically developing children.

Table 1: *Mean and standard deviations for PPVT-V (raw score). Includes values for all participants, typically developing children (TD only), and sex*

	N	PPVT raw score (T1)	PPVT raw score (T2)
All children	39	104.9 ± 29.3	111.4 ± 27.1
Males	18	101.9 ± 32.9	113.3 ± 29.0
Females	17	107.9 ± 25.8	109.4 ± 25.8
TD Only	27	106.6 ± 29.3	115.7 ± 27.4

Table 2: *Mean and standard deviations for phonetic error rate. Includes values for all participants, typically developing children (TD only), and sex*

	N	Phonetic Error Rate (T1)	Phonetic Error Rate (T2)
All children	39	29.0 ± 19.4	23.3 ± 18.8
Males	18	24.2 ± 14.5	17.9 ± 13.4
Females	17	33.2 ± 22.2	27.9 ± 21.8
TD Only	27	28.5 ± 19.2	21.8 ± 17.7

3.2. Pre- and post-test comparisons

Repeated measures ANOVAs with time (T1, T2) as the within subject factor and sex (male, female) as the between subject factor were conducted on the scores of the PPVT, phonetic error, and word error rates. No significant differences were found

Table 3: *Mean and standard deviations for word error rate. Includes values for all participants, typically developing children (TD only), and sex*

	N	Word Error Rate (T1)	Word error rate (T2)
All children	39	10.0 ± 7.3	8.4± 6.4
Males	18	8.2 ± 4.9	6.5 ± 4.6
Females	17	11.6 ± 8.7	9.9 ± 7.4
TD Only	27	9.5 ± 6.4	7.8 ± 5.9

for time, sex, or the interaction in the PPVT scores (all p>0.1). With respect to the phonetic error rates, there was a significant difference between T1 and T2 [F(1,37) = 12.3, p = 0.001], no main effect of sex [F(1,37) = 2.5, p>0.1], and no significant interaction between time and sex [F(1,37) = 0.0, p>0.1]. Regarding error rates, there was a main effect of time [F(1,37) = 18.9, p<0.001], no main effect of sex [F(1,37) = 2.6, p>0.1], and no significant interaction between time and sex [F(1,37) = 0.18, p>0.1]. In both cases, phonetic and word error rates, the main effect reflected that the children were better in their speech production skills after the 6-month period.

Repeated measures ANOVAs were conducted on the PPVT, phonetic error, and word error rates for only the typically developing children, with the same within subject factor and between subject factor as stated above. There was a significant difference between T1 and T2 for the PPVT scores [F(1,23) = 5.0, p = 0.035], no main effect of sex [F(1,23) = 0.04, p>0.1], and no interaction between time and sex [F(1,23) = 1.1, p>0.1]. This main effect of time reflected that children at T2 had larger vocabulary when compared to T1. The results between T1 and T2 and for the phonetic and word error rates did not significantly change when only the typically developing children were considered.

3.3. Correlation Analyses

Table 4 shows significant negative pearson-r correlations between the phonetic error rate/word error rate and PPVT scores at T1, and table 5 shows these relationships at T2. This suggests that lower phonetic and word error rates (more clear speech) related to higher PPVT scores (better vocabulary). The results also show, unsurprisingly, a significant positive correlation between the word error rate and phonetic error rate before and after the 6-month period. This suggests that the more errors made in phonetic pronunciation, the more errors made in the overall word pronunciation. The effect sizes ranged from medium to large, with the largest being observed between word error rate and phonetic error rate at both pre- and post-test (r = 0.973 at T1 and r = 0.982 at T2), then the phonetic error rate and PPVT scores (r = -0.663 at T1 and r = -0.790 at T2) and lastly the word error rate and PPVT score (r = -0.600 at T1 and r = -0.778 at T2).

3.4. Regression

First, we used a linear regression analysis to determine if receptive vocabulary at T1 (PPVT raw score) could predict phonetic error (or word error rate) at T2, while controlling for age (months). The results showed that T1 vocabulary (p = 0.011) and T1 age (p= 0.041) were significant predictors of phonetic error rate at T2 [F(2,33) = 17.26; p<0.001, r = 0.71]. Together, PPVT at T1 and age at T1 predicted 50 % of the variance in

Table 4: *Correlation of speech measures and receptive vocabulary at T1*

	Phonetic error rate	PPVT Score
Word error rate	r = 0.973 (p<0.001)	r = -0.600 (p<0.001)
Phonetic error rate		r = -0.663 (p<0.001)

Table 5: *Correlation of speech measures and receptive vocabulary at T2*

	Phonetic error rate	PPVT Score
Word error rate	r = 0.982 (p<0.001)	r = -0.778 (p<0.001)
Phonetic error rate		r = -0.790 (p<0.001)

phonetic error rate at T2. The results for word error rate were identical [F(2,34) = 15.81; p <0.001, r = 0.694]. Vocabulary and age at T1 predicted 48.2 % of the variance in word error rate at T2.

A final pair of regression analyses were conducted to test if T1 age (months), word error rate, or/and phonetic error rate predicted the PPVT score after the 6-month period. We ran two separate regressions due to the high degree of multicollinearity between phonetic error rate and word error rate. When T1 word error rate was included in the model to predict PPVT score at T2, The regression showed both T1 word error rate (p<0.001) and T1 age (p= 0.041) were significant predictors of T2 PPVT score [F(2,33) = 19.28; p <0.001, r = 0.73]. We ran a final regression with T1 phonetic error rate as a predictor variable, and observed similar results. Both T1 phonetic error rate (p <0.001) and age (p=0.028) were significant predictors of T2 PPVT score [F(2,33) = 26.56; p <0.001, r = 0.78]. Together, they predicted 61.7% of the variance in T2 PPVT score. This relationship is represented in Figure 1.

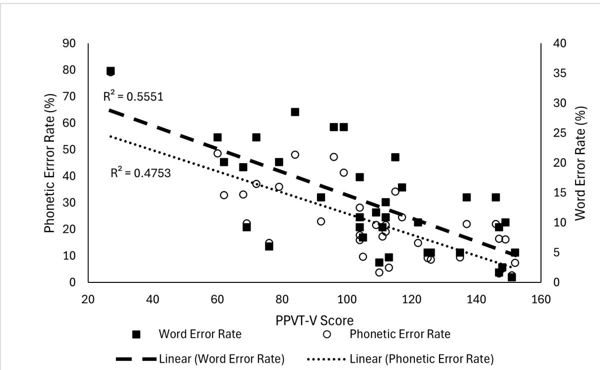

Figure 1: *The Relationship between the T1 phonetic error rate and word error rate and T2 PPVT score*

4. Discussion

The purpose of the current study was to examine the relationship between speech production abilities and vocabulary size in three-to-five year old children over a six-month period. We hypothesized that the children would increase their vocabulary size and improve speech production abilities at T2 compared to T1. Our findings demonstrated that this was the case for phonetic and word error rate. Contrary to our hypothesis, vocabulary size as measured by the PPVT did not significantly change when we included all participants. A significant improvement, however, was found when only the typically developing children were included. Because this was not the case for the speech production task, this finding suggests that receptive vocabulary is more sensitive to developmental disruptions [21]. We also predicted that girls would outperform boys in their speech production and vocabulary size; however, we found no support for this hypothesis at T1 or T2. There was a significant negative correlation between vocabulary size and both phonetic and word error rates at T1 and T2, suggesting that a child has a larger vocabulary size will also make fewer speech production mistakes. This is in line with our hypothesis that vocabulary size would influence speech production skills. Our findings are also consistent with the previous studies in suggesting that as the children got older, their speech production abilities increased. For example, a study done by Vance et al. [6], speech production abilities in children aged three to seven years were assessed. They used three measurements of speech production skills: picture naming, WR and NWR. They found that as children aged, their speech production abilities improved. One similarity between NWR and WR tasks is that they measure phonological short term memory (PTSM). There have been studies on the relationship between PTSM and vocabulary development through the measurement of NWR. Some of these studies provide support for our finding that better speech production abilities are correlated with better vocabulary development, on the basis that PTSM abilities are related to speech production. For example, Bowey [22] measured receptive vocabulary, receptive grammar, NWR, PA, and performance IQ at one time point, and a year later measured receptive vocabulary and NWR. This is similar to our two-time point approach used in this study. They found that NWR contributes directly to vocabulary in young children. This relates to our finding that speech production skills, as measured by the WR tasks, are correlated with vocabulary size.

Another finding that Bowey [22] discussed in their report was that the T1 NWR ability predicted T2 vocabulary skills. Therefore, early NWR skills predicted later vocabulary skills. This is consistent with our finding from the regression analysis that phonetic and word error rates at T1 predicted T2 vocabulary size. This suggests that early WR skills, similar to NWR skills, predict later vocabulary size. It is commonly theorized that vocabulary contributes to speech production skills [23], which we also showed with the reversed regression where vocabulary significantly predicted WR performance. Interestingly, we did not find sex differences on speech production or vocabulary skills. Regarding this topic, there are some contrasting reports in the literature. For example, Lange et al. [10], examined sex differences in language competence in three to six year old children, which included tests for vocabulary and pronunciation. They found that girls significantly outperformed boys and that these differences decreased with age. Furthermore, Lundberg et al.[14] examined sex differences in PA at two times and found that girls had better scores than boys. They also found that girls improved more than boys between T1 and T2. Other studies, however, have not found sex differences on language ability. Burt et al. [15] tested 46-58-month-old children in a variety of speech-related tasks including NWR and speech production. They found that girls and boys performed similarly. They also found that as children aged, they were more phonologically aware. This provides further support for our hypothesis regarding the interaction between time and speech discussed earlier.

We found that speech production abilities were significantly correlated with vocabulary at both T1 and T2. As discussed earlier, a report by Nicholson et al. [7] showed a similar relationship between speech production and vocabulary. They measured the ability of children (ages 2-5) to produce certain fricative phonemes (s and ʃ) in relation to vocabulary size, and found that the larger the vocabulary, the better the child was at producing these specific phonemes.

One limitation to this study is the sample size. Perhaps with more children we would have detected improvement between T1 and T2 in the PPVT. Similarly, with a large sample, sex differences might have emerged. On the other hand, the lack of sex effect in this study adds to existing literature that does not find a difference in vocabulary or speech production skills between girls and boys [24]. This review suggests that many factors contribute to commonly reported sex differences [24]. Another limitation to our study was that we did not account for socioeconomic status (SES). There have been multiple studies discussing the role of SES in language abilities in young children. For example, the study by Lundberg et al. [14] examined the influence of SES on PA. They found that children in less favorable SES environments showed lower PA abilities than children in more favorable SES environments. Similarly, Burt et al. [15] found that SES significantly influenced performance on a variety of speech related tasks, with children from more favorable SES environments performing better. In future studies, SES should be taken into account when measuring children's vocabulary and speech production skills.

In this study, we found a relationship between phonological development and comprehension over a six month period in preschool children. Speech production clarity at the initial measure predicted receptive vocabulary at post-test. This relationship also occurred when phonetic and word error rate was used as the dependent variable instead, initial receptive vocabulary was a significant predictor of final phonological development. While this relationship is documented in previous studies [7], a novel addition is the result that this reciprocal relationship exists in spite of a significant improvement in speech production skills that was absent for receptive vocabulary. We found that our full sample improved in phonetic and word error rate, but only the typically developing children improved in vocabulary. These results support the theory that speech and language comprehension are closely related, but ultimately separable skills in three-to-five year old children.

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