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Comprehension outscores production in language acquisition: Implications for Theories of Vocabulary Learning

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Abstract

It is well-documented that children comprehend many more words than they are able to produce. Without exception, a child appears to understand various words that they do not use in their own speech. These results are used to test three different theories of speech perception. Motor theory assumes that motor processes are necessarily recruited for speech perception. A common representation theory claims that the same representation exists for both comprehension and production. Comprehension can be viewed as a recognition task whereas production can be considered a recall task, and recall is necessarily more difficult than recognition. The third theory assumes that speech perception and speech production and their acquisition cannot be based on the same underlying representation. Speech perception follows prototypical pattern recognition processes whereas speech production involves intricate motor processes that attempt to match a speech target. We analyze data from the MacArthur-Bates Communicative Development Inventories (CDI) to determine 1) if difficulty of articulation and parental input frequency influence perception and production equivalently and 2) assess whether equivalent representations can account for perception and production. The results falsify motor theory and common representation theory and support the pattern recognition account of speech perception.

Keywords receptive language, expressive language, vocabulary learning, speech perception, speech production

1. Introduction

A persistent question of how the child seamlessly learns language is being informed by a variety of empirical and theoretical research findings (e.g., Werker, Yeung, & Yoshida, 2012). All researchers acknowledge the seemingly impossible challenge that the infant faces in accomplishing this feat. A prototypical example is a contemporary version of Gavagai (Quine, 1960, 1990/1992). A mother tells her child that “the cat is on the mat”. How does a child make sense of the continuous speech stream to arrive at some veridical understanding? What are the words, their meanings and what does their combination signify? For the purposes of the present paper, it is important to realize that this illustration is framed in terms of the understanding of

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language as opposed to its production. But surely an equally perplexing challenge is how a child would produce the proposition, even when it is signified by a single-word utterance such as cat. Phrasing the anecdote in terms of understanding rather than production reflects the intuitive belief that language understanding paves the way for language production. We expect that a child would necessarily have to understand an utterance or a similar utterance before being able to produce it. The goal of this paper is to assess predictions of theories of speech perception and production based on the well-known asymmetry of the acquisition of perceiving and producing words. We now describe three extant theories of speech perception.

1.1 Motor Theory for Speech Production

Speech provides a natural domain for a motor-theory account because speech perception and speech production appear to be so tightly linked. A motor theory of speech perception contains different assumptions for different theorists but they all tightly link speech perception with speech production. Our interpretation of motor theory is illustrated in Figure 1. As seen in the figure, speech production processes somehow intervene in speech understanding. In one review, the theory claims that speech production processes are necessarily recruited for speech perception and comprehension (Galantucci, Fowler, & Turvey, 2006). Associated with this motor theory, it is also sometimes assumed that an interlocutor perceives the intended phonetic gestures of the speaker rather than the more variable auditory speech. Arbib (2012), a long-time advocate of the motor theory of speech perception, assumes that we recognize the sounds of speech by creating a motor representation of how those sounds would be produced (Moulin-Frier & Arbib, 2013). Motor theory is favored by many, especially those committed to an embodied cognition framework (Glenberg, 2008; Glenberg & Gallese, 2012).

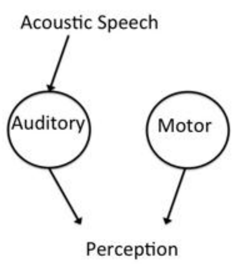

Figure 1. Schematic description of motor theories of speech perception in which a motor representation necessarily mediates speech perception.

We believe that it is fair to assume the engagement of the motor system illustrated in Figure 1 is assumed for all variants of motor theory. Massaro & Chen (2008) and Hickok (2009, 2014) question the viability of a motor theory. Hickok, Houde, and Rong (2011) agree that motor theory fails in its strong form. As evidence, they cite the accuracy of speech perception in individuals who have a variety of speech production deficits or temporally-induced interference with speech production processes. In addition, they emphasize that the putative existence of mirror neurons does not disqualify the existing evidence against motor theory.

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1.2 Common Representation for Speech Perception and Production

Figure 2 illustrates a second theory claiming that speech perception and speech production rely on the same underlying representation. Using an information processing analysis, any difference between the two forms of vocabulary knowledge emerges because of the differences in the two tasks required of the child (Huttenlocher, 1974). Comprehension can be viewed as a recognition task whereas production can be considered a recall task, and recall is necessarily more difficult than recognition. Using a signal detection framework, comprehension exists in a context with just a few response alternatives whereas recall occurs in a context of many response alternatives. In a recent formal model of McMurray, Horst, and Samuelson (2012), the child has many more competitor alternatives in production than in comprehension, and these alternatives necessarily lower performance in production relative to perception. The bottleneck in production relative to comprehension putatively occurs because there are many more competing production alternatives than comprehension alternatives. This difference exists even though the quantity and quality of the underlying representation is assumed to be equivalent in the comprehension and production scenarios.

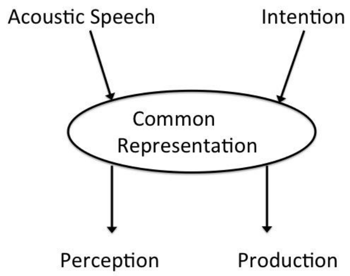

Figure 2. Schematic illustration of the view that speech perception and production use the same common representation.

McMurray et al.'s (2012) simulated results indicated that at a given stage of learning (20,000 trials), a production task was accurate on just 5 words whereas the comprehension tasks with 3, 5, and 10 alternatives were accurate on 32, 28, and 25 words, respectively. In addition, the production task gave roughly the same result as the 35-alternative comprehension task. We agree with the authors that receptive vocabulary will necessarily be larger than expressive vocabulary when the child uses the same representation for both perception and production. We question, however, whether the same representation is in fact used for these two functions. It might be too parsimonious to attribute differences between receptive and expressive vocabulary to simply task differences, and assume that "memory demands, difficulty planning articulation, or the earlier age at which speech perception develops" (McMurray et al., 2012, p. 845) do not play a role. Our analysis, therefore, focuses on whether it is reasonable to assume that equivalent representations are used for perception and production. In our data analysis, we ask whether simply an equivalent representation can account for the discrepancy between perception and production of individual children.

It is possible that an incomplete memory representation would allow accurate comprehension but not accurate production of some words. As illustrated in Figure 2, a receptive language advantage over production putatively occurs because the child has a sketchy representation that allows her to recognize a word but not recall it for accurate production. This test centers on whether there exists a memory representation that allows the child to understand a word but not produce it. The results give for each child the words she produces and the words she understands. Are there possible memory representations of these words that would allow correct understanding of the words but production of only a subset of these words? An ideal memory representation for the description in Figure 2 would be one that allowed perception of all of the words but production of only some of them. If a child comprehended only the words *mommy* and *bye* but did not produce them, a partial memory representation could account for the results. For example, *mommy* could be represented by a nasal sound and *bye* by an /ai/ as in the sound of the word *eye*. These two representations would allow recognition of the words but they would be insufficient for accurate production.

1.3 Pattern Recognition: Different Processing for Perception and Production

Figure 3 illustrates a class of explanations that assume that speech perception and speech production are fundamentally different functions and, therefore, their acquisition cannot be based on the same processing or the same underlying representation. In this view, speech perception follows prototypical pattern recognition processes whereas speech production involves intricate motor processes that attempt to match a speech target (Massaro, 1987, 1998; Guenther, 1995). The pattern-recognition explanation follows from language understanding research, which accounts for comprehension without regard to production processes (Massaro, 1975, 1998; Movellan & McClelland, 2001). An emerging fundamental principle is that there are highly analogous processes involved across speech perception, reading, and higher-order language processing (Massaro, 1975, 1987, 1998; Massaro, 2005). Language processing is a form of pattern recognition, is influenced by multiple cues or sources of information, and is quantitatively described by the Fuzzy Logical Model of Perception (FLMP; Christiansen et al., 1998; Movellan & McClelland, 2001). For example, the processing for perception in face-to-face situations can include information about visible speech, not just auditory speech, and information about many linguistic and contextual cues (Massaro, 1998). Generalizing from this view, the assumption is that comprehension develops somewhat independently of production so that processes involved in speech production cannot account for comprehension ability. This model considers that speech perception and speech production are served by separate mostly independent systems.

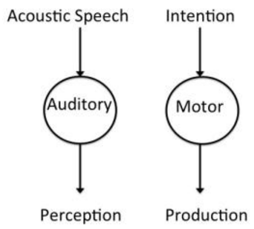

Figure 3. Schematic illustration of the view that speech perception and production use different representations.

These same pattern-recognition processes also occur in language acquisition, not just in accomplished language users (Fennell & Waxman, 2010; Gogate & Hollich, 2010; Hollich et al., 2000; Massaro, 1987, Chapter 8). An Emergentist Coalition Model describes how children rely on multiple cues over development in the mapping of words onto referents (Golinkoff & Hirsh-Pasek, 2008; Hirsh-Pasek et al., 2000). The use of and the weight given to these cues change across development. For example, infants initially rely mostly on perceptual cues and gradually begin to use a speaker's intent and linguistic cues to determine word reference. These cues and constraints are graded (not categorical) in nature, suggesting further that they must be combined to give a more reliable understanding of the input. Evidence to date indicates that this combination process is highly efficient or optimal, as described by Bayes Law (Massaro, 1987, 1998; Massaro, 2008). This type of Bayesian inference is consistent with predictive models, which are gaining in popularity in recent interdisciplinary accounts of behavior (Clark, 2013; Friston, 2010). If correct, a pattern recognition model of word comprehension would challenge the two views that production somehow intervenes in the comprehension of a word or that comprehension and production rely on exactly the same representation.

One formalization of this pattern recognition model at the neural level is the dual-route model that has ventral and dorsal processing streams (Hickok, 2008). The ventral stream processes the speech input for comprehension and utilizes structures in the superior and middle portions of the temporal lobe. The dorsal stream responsible for speech production utilizes the posterior planum temporale region and posterior frontal lobe. This stream maps the acoustic signal into an articulatory representation. It is also assumed that this stream can also generate articulatory representations with other sensory inputs such as visible speech and also without any input at all. Similar to the Bayesian approach just mentioned, the comprehension system is highly predictive in that it automatically exploits multiple sources of information to facilitate speech understanding.

1.4 Existing Evidence

We know that comprehension is accomplished well before production of many words. It is well-documented that children comprehend many more words than they are able to produce (Bates, 1993; Fenson et al., 2000). Without exception, a child appears to understand a variety of words that they do not use or use correctly in their own speech. Although there is no apparent controversy about the vocabulary advantage of perception over production, its explanation is still somewhat elusive. In this paper, we evaluate several possible explanations against a large database of results. As described, the explanations differ primarily in terms of whether speech production is somehow recruited for speech perception to succeed, whether the same representation is involved in perception and production, or whether speech perception is fundamentally pattern recognition and occurs relatively independent of speech production processes.

The MacArthur-Bates Communicative Development Inventories (CDI) has been used successfully to measure comprehension and production vocabulary. It uses a checklist to ask parents to report their child's word comprehension, word production, and grammar. One version provides norming data on age of acquisition for 396 individual words collected from the parents of children ages 0;8 to 2;6. For each word on the checklist, there are two boxes that can be checked. The check boxes are labeled 1) understands and 2) understands and says, respectively. The parent either does not put a mark in one of the two check boxes or marks just one. This design of the inventory form precludes a parent from indicating that a child produces a word but does not understand it. Thus, the results indicate whether each word on the list is understood by the child or is understood and produced by the child. A produced word requires that the child's utterance could be understood out of context by at least a parent or caregiver. The child is also not given credit for produced words that are simply imitated, as in the case when the parent simply asks the child, "Can you say 'banana'? These norms are available on the internet (http://www.sci.sdsu.edu/cdi/cdiwelcome.htm) and support the well-known finding that vocabulary comprehension far outpaces vocabulary production (Bates & Goodman, 1999; Fenson et al., 2000).

Notwithstanding various criticisms, the validity of these measures has been substantiated in various investigations (see Fenson et al., 1994; for a review; Fenson et al., 2007). One relevant issue is that it would not be surprising to find that parents might overestimate what their children know (Tomasello & Mervis, 1994). Particularly relevant to our inquiry about differences between perception and production, a parent might indeed score a word as produced even though their child mispronounced it. We believe, however, that this would not impact the results because a word produced is also scored as understood in the scoring of the CDI inventory. The principal metric to be used in our analyses is the difference between words understood and words produced. Thus, if anything, a liberal inclusion of words produced would diminish any difference between words produced and words understood.

The validity of the CDI procedure has also been substantiated by positive correlations with experimental tests of comprehension. Bates, Bretherton & Synder (1988) found that the CDI measure of comprehension correlated with an experimental test of comprehension for infants aged 1 year, 1 month. Further, comprehension at 1 year, 8 months correlated with a laboratory test (Dale, Bates, Reznick & Morisset, 1989). The strongest evidence for the validity of the CDI comes from event-related potentials (ERPs) of infants to auditorily-presented words that were either checked as understood or not (Mills, Coffey-Corina & Neville, 1993, 1997). The infants ERPs distinguished between these two classes of words as scored on the CDI.

The average production vocabulary has been analyzed as a function of comprehension vocabulary, as measured by the CDI (Fenson et al., 1994). Although there is a great deal of variability across children in both comprehension and production vocabulary, comprehension of words far exceeds their production throughout the first years of language development. An average child already understands 200 words by the time she or he produces 50 words.

Another study included 659 children whose age in months ranged from 8 to 18 months. For each word on the checklist of 396 items, the parent indicated which of the words on the list are understood by the child or understood and produced by the child (MacArthur-Bates Communicative Development Inventories American Cross-sectional CDI studies: Words & Gestures (American CDI, 2014; Dale & Fenson, 1996). At 8 months of age, 50% of the children in this sample comprehended the words *mommy*, *daddy*, *bye*, *peekaboo*, *bottle*, and *no*. None of these words was uttered by 50% of the children. At age 16 months, 175 words were comprehended and 20 words were produced by 50% of the children in the sample. Thus, there is a dramatic discrepancy between words understood and produced.

The conclusions from the CDI are supported by rigorous laboratory experiments. Similar to the MDCDI inventory, studies of word learning also find a big discrepancy between the learning of receptive and productive language. For example, Hahn and Gershkoff-Stowe (2010) found that two and three year olds were 60 and 70% correct in a four-alternative task in choosing the correct object for a previously paired nonsense word, but only 5 and 12% correct in producing the label. Similar results were found in a second study with eight alternatives. It is possible, however, that the receptive advantage over production is simply a guessing advantage when given a small number of response alternatives, consistent with the Common-Representation theory (Figure 2). A motor theory (Figure 1) might offer a similar explanation.

How might the observed acquisition asymmetry in the perception and production of words inform these theories of speech perception? As already noted, analyses to date have fallen short of any definitive choice among the theories. The current paper extends these analyses in several ways. When possible, the analyses will be carried out on individual children to better measure an individual child's perception and production capabilities at a given stage of language acquisition. An analysis on an individual child's results should be able to test whether the same representation of a word is sufficient to account for both perception and production. For example, showing that a word can be understood even though none of the segments in the word are produced would seem inconsistent with motor theory (Figure 1) in which production processes are assumed to mediate speech perception. Similarly, this same result would question whether perception of a word while failing to produce it can be described by the same memory representation (see Figure 2). On the other hand, this example result would be consistent with a pattern recognition process that assumes that speech perception is not constrained by production processes (Figure 3). We now carry out a more thorough and detailed analysis of existing results of individual children to evaluate the three theories of speech perception we have described.

2. Methodology

Our caveat is that to be completely valid, data analysis should be applied to an individual child's words rather than to group results. The database consisted of 396 words from the Words & Gestures American, organized in different words categories such as animal sounds and vehicles. There were 1089 unique cases in which the words produced and the words understood were tabulated for a given child at a given age (Fenson et al., 2007). The ages of the children in months ranged from 8 to 18 months. Each case was from a different child and the first time the CDI form was completed by a parent.
Table 1 gives a summary of the number of words understood and produced by the 1089 individuals divided into 6 groups based on the number of words produced. The range and number of words understood far exceeds the comparable results for words produced. As an example, there were 176 cases in which no words were produced, and only 5 of these cases also had no words understood. The remaining 171 cases of children with no expressive words at all had between 1 and 341 words understood with an average of 45.6 words understood. A similar discrepancy is apparent for the other five groups. The question remains whether motor theory or the task difference postulated by Huttenlocher (1974) and McMurray et al. (2012) could account for these huge discrepancies with the assumption that the same representation was used for perception and production.

Table 1. Six partitions of the individual results of 1089 children based on the number of words produced, giving the range and average of the number of words produced, the range and average number of words understood, and the number of cases contributing to each partition of the analysis.

Range Produced	Average Produced	Range Understood	Average Understood	Cases
0	0	0-341	45.63	176
1-3	1.91	1-261	58.70	194
4-7	5.39	7-243	76.74	183
8-17	12.59	41-280	116.21	172
18-49	29.29	45-261	168.44	211
51-376	120.11	112-396	264.69	153
Overall	28.22	Overall	121.74	1089

We counted the number of times each child understood and said the initial and final consonants of words based on the words they understood and said.

There were 1089 children with measures of words understood and words said. We determined the number of times each child understood a given consonant and the number of times the child said the consonant based on his or her words that were checked as 1) understood and 2) understood and said, respectively. Recognizing or producing a word boils down to having a memory representation of at least some of the segments that make it up. As mentioned, there were 171 children who understood some words but did not produce any. How is a child able to accurately distinguish dozens or even hundreds of words without being able to produce any of them? Recognizing (distinguishing among) a large number of words would require a fairly complete memory representation. If a child uses the same memory representation for perception and production, we should have expected that the child should be able produce at least some of the words.

3. Findings

3.1 Individual Subject Analyses.

To give an example of the results for an individual child, Table 2 gives the words understood and produced for a child who understood 121 words and produced only 17. Table 3 gives the number of times speech segments occurred in initial position for understood and said words for this child. As can be seen in the table, this child was able to understand words with all of the 22 possible initial phonemes but could produce words that begin with

Table 2. The words understood and produced (Table 2a) for a child who understood 121 words and produced only 17.

all gone	bubbles	ear	Ice cream	ouch	show	tongue	Woof woof
baa baa	bye	eat	juice	outside	sky	touch	yes
baby	careful	eye	jump	owie	slide	toy	yum yum
bad	car	finger	kiss	park	spaghetti	toothbrush	zipper
balloon	cat	fish	kitty	peas	splash	tummy	
ball	chicken	foot	leg	peekabo	spoon	tv	
banana	cherios	gentle	light	plant	stop	uh oh	
bathtub	cookie	girl	look	play	stroller	up	
bath	cracker	good	meow	please	swing	vroom	
bed	cup	go	milk	pull	teddy bear	walk	
bite	daddy	grandm a	mommy	puppy	show	wanna	
belly button	dance	hair	moon	push	teddy bear	wash	
blow	diaper	hand	mother	run	telephone	watch	
book	dog	help	name sitter	say	thirsty	water (2 meanings)	
bottle	doll	hit	night night	see	thank you	what	
boy	door	hot	nose	shh	throw	who	
broom	drink	hug	no	shoe	toast	wipe	

Table 2a. The words produced

baabaa	baby	banana	bottle	bubbles	bye	cat	daddy	dog
eye	kitty	mommy	nose	uhoh	vroom	what	woofwoof	

Table 3. The number of times initial phonemes were understood and produced for the child in Table 2 who understood 121 words and produced only 17.

Phonemes	Example Word	understood	said
b	bin	18	6
tS	chin	2	0
d	date	7	2
D	this	0	0
f	fax	3	0
g	gap	4	0
h	help	7	0
j	yacht	2	0
dZ	gin	3	0
k	king	8	2
l	leg	3	0
m	mail	5	1
n	nose	3	1
p	pin	9	0
9r	ring	1	0
s	sing	10	0
S	shop	3	0
t	tip	8	0
T	thing	2	0
v	very	1	1
w	will	8	2
z	zip	1	0

only 7 different phonemes. This child also understood words that begin with the consonant clusters /dr/, /sp/, /str/, and /sw/. The only consonant cluster that the child produced was /vr/ in the iconic vroom sound. It is clear that the child was able to recognize words with various consonants even though none of the words produced contained these consonants. For example, this child understood the words puppy, push, hug, help, and hot, but did not say words with /p/ or /h/ in initial position or words with /p/, /sh/, /g/, or /t/ in final position. This discrepancy makes it unlikely the advantage of comprehension can be explained by motor theory or common representation theory. Given that the child did not articulate many of the segments of words that she understood, it is unlikely that motor processes intervened in the perception of these words. Similarly, as evidence against the common representation theory, we claim that it is not possible to create a minimal representation of each of the 121 words that the child understood that would allow for comprehension but not production. To distinguish among all of the words in the child's vocabulary she would require essentially a nearly complete representation for each word.

It might be argued that the child exploits situational context in word understanding. This possibility is certainly predicted by models that postulate multiple influences such as context in speech perception. Bayesian models such as the FLMP have accounted for the simultaneous influence of bottom-up and top-down influences in language understanding (Massaro, 2012). Context might somehow facilitate the recognition of a word but not necessarily the pronunciation of that same word. The differences in the counts of understood and said words should not be due to context, however, because the MacArthur Bates Inventory requires the parent to indicate words that are produced or understood independently of context. In addition, it is not obvious how context effects would benefit perception more than production. Given that there are so many words that the child understands but is not able to produce in a way that can be understood, then the child's putative adumbrated representation of these words (McMurray et al., 2012) cannot be rich enough to mediate their perception. Similarly, these results are equally damaging to the central assumption of motor theory (Galantucci et al., 2006) that motor processes necessarily mediate speech perception. Thus the analysis of individual children's receptive and expressive language appears to be most consistent with a pattern recognition account that assumes speech perception occurs independently of speech production processes.

3.2 Group Analyses.

For each unique word in our database, we pooled the results across the 1089 children. The total number of children that were scored as saying the word and understanding the word was treated as dependent measures, as was the difference between understood and said words. Our goal was to determine what variables might influence saying or understanding a word and whether there might be dissociations between perceiving and saying a word. On the other hand, correlations between perception and production might appear to be a more direct method to assess the relationship between understood and said words. If understanding a word were intricately tied to its production (see Figure 1), then we would expect a high correlation between the words that are understood and said. As expected, the Spearman correlation between said and understood words was .757, $p < .001$.

There is necessarily a positive correlation between perception and production in this database because all words that are checked by the parents as said are also scored as understood. A positive correlation between perception and production might also reflect the influence of a third variable such as frequency of occurrence in the parents' speech. If such a variable influences speech perception we might also expect it to influence speech production even if perception and production are based on separate processes (Figure 3). For example, it is possible that consonants that are easier to perceive are also easier to produce. Thus we expect a strong positive correlation between perception and production for several possible reasons even if their processes are unrelated. Thus, we cannot use the correlation between said and understood words as deciding among the three theoretical alternatives. Our individual subject analyses have already demonstrated that a child understands many words that she is not able to produce and that the child's putative adumbrated representation of these words cannot be rich enough to mediate their perception. Another tact to distinguish among the theories would be to find a variable that differentially influences said and understood words. One possible variable is difficulty of articulation.

3.2.1 Correlations with Difficulty of Articulation.

Another possible test of the theories is to determine how a child's comprehension and production of words relates to the difficulty of articulation of segments of the words. If speech production processes are central to word acquisition, then we would expect words easiest to produce would tend to be both perceived and produced before words more difficult to produce. Further, if the same representation of a word was used for both comprehension and production or if production mediated comprehension, then we would expect that difficulty of articulation would inversely correlate with both comprehension and production. On the other hand, if perception and production processes are mostly independent of one another then it is possible that difficulty of articulation would influence production much more than it influences perception.

Although there are currently no established measures of difficulty of articulation (or difficulty of perception), we created a metric based on several relevant studies (Kirk, 2008; Kirk & Demuth, 2005; McAllister Byun, 2012; Rvachew, Chiang, & Evan, 2007; Smit 1993; Smit et al., 1990; Stoel-Gammon, 1987; Stoel-Gammon & Buder, 1999). Difficulty of Articulation of the consonant segments was defined as a 1-7 value on a scale of easy to difficult. These difficulty values for each of the phonemes are shown in Table 4. The metric for defining the difficulty of articulation of a word was simply the sum of the difficulty of articulation of each of its consonants. In this case, larger values correspond to a more difficult articulation. Although other factors such as coarticulation might also influence difficulty, there is even

Table 4. Two difficulty of articulation measures for each consonant used in computing the difficulty of articulation of each word (given by the sum of the difficulty measures of all of the consonants in the word).

Phonemes	Example Word	Difficulty of Articulation	Shriberg Acquisition Measure
b	bin	1	1
tS	chin	7	2
d	date	1	1
D	this	3	3
f	fax	2	2
g	gap	2	2
h	help	1	1
j	yacht	2	1
dZ	gin	6	2
k	king	2	2
l	leg	4	3
m	mail	1	1
n	nose	2	1
N	long	7	2
p	pin	1	1
9r	ring	7	3
s	sing	7	3
S	shop	6	3

t	tip	2	2
T	thing	3	3
v	very	5	2
w	will	3	1
z	zip	7	3
Z	vision	7	3

less guidance on creating a metric for this factor. Similarly, there is very little basis to create difficulty values for the vowels. Accordingly, this measure of difficulty of articulation for a word is based on only the consonants in the words. The Difficulty of Articulation values for each of the words are available on request.

3.2.2 Correlations with Parental Input Frequency.

We evaluated the influence of difficulty of articulation simultaneously with parental input frequency. Our measure of parent input frequency was determined from a database that can be searched at ParentFreq (2014). We initially evaluated both linear and log frequency but as expected found that log frequency gave the best predictions. Therefore, for ease of presentation, we use only log frequencies in our analyses. We analyzed a possible influence of difficulty of articulation in the data set of the 1089 children described previously in our individual subject analyses. After combining words that were repeated twice on the check list, there were 386 words in this data set. The dependent variables were the total number of children that understood each word, said each word, and an adjusted understood measure derived from subtracting the number of children who said a word from the number of children who understood the word. Each word was also assigned a word difficulty measure and linear and log parental input frequency.

We carried out Spearman and Pearson correlations among difficulty of articulation, parental input frequency, number of children that understood each word, said each word, and an adjusted understood measure derived from subtracting the number of children who said a word from the number of children who understood the word. Pearson and Spearman correlations are given in the upper and lower quadrants of Table 5, respectively. These two types of correlations gave very similar results. As already mentioned, words said significantly correlated with words understood and with the adjusted measure of words understood. Log parental input frequency did not correlate with the number of children who said or understood the words. As can also be seen in the table, higher parental input frequencies were negatively correlated with difficulty of articulation. Most importantly, for distinguishing among the three theories, difficulty of articulation was negatively correlated with words said but not with the adjusted measure of words understood. This is true even though words said remains positively correlated with our adjusted measure of words understood. This result provides some evidence that different processes might be involved in production than in perception so that difficulty of articulation is more of an influence in production than in perception.

To better assess the contribution of difficulty of articulation independently of log parental input frequency, we carried out partial correlations shown in Table 6. Difficulty of articulation remains correlated with words said when parental input frequency was partialed out. In contrast, difficulty of articulation did not correlate with the adjusted measure of words understood when parental input frequency was partialed out.

Table 5. Correlations among difficulty of articulation, log parental input frequency, words said, words understood, and the adjusted words understood for the complete data set of 386 words. Pearson correlations are given in the upper right quadrant and Spearman correlations are given in the lower left quadrant. (Note * = p < .05; ** = p < .001).

	Difficulty of Articulation	Log Parental Input Frequency	Said Words	Understood Words	Adjusted Understood Words
Difficulty of Articulation		-.293**	-.245**	-.142*	-.045
Log Parental Input Frequency	-,283**		-.032	.018	.044
Said Words	-.208**	-.039		.748**	.412**
Understood Words	-.123*	.047	.757**		.913**
Adjusted Understood Words	-.056	.083	.576**	.952**	

Table 6. Partial correlations of difficulty of articulation with words said, words understood, and the adjusted words understood when log parental input frequency is partialed out. (Note * = p < .05; ** = p < .001).

	Difficulty of Articulation (Log Parental Input Frequency Partialed Out)
Said	-.271**
Understood	-.142*
Adjusted Understood	.031

To assess the validity of our Difficulty of Articulation measure, we compared it to a measure given by Shriberg (1993) who categorized 24 speech

segments into early, middle, and late acquisition classes with 8 segments per class.
Early 8: /m, b, j, n, w, d, p, h/
Middle 8: /t, ŋ, k, g, f, v, tʃ, dʒ /
Late 8: /ʃ, ʒ, s, z, θ, ð, l, r/
These measures have found some validity in research and applications (Goldstein and Fabiano, 2010; Shriberg et al., 1997). Across the 386 words, the Shriberg measure given in Table 4 correlated .91 with our Difficulty of Articulation measure and gave identical statistical outcomes.

Table 7. Partial correlations of Log Parental Input Frequency with words said, words understood, and the adjusted words understood when Difficulty of Articulation is partialed out. (Note * = p < .05; ** = p < .001).

	Log Parental Input Frequency (Difficulty of Articulation Partialed Out)
Said	-.113*
Understood	-.025
Adjusted Understood	.033

Table 7 gives the partial correlations between log parental input frequency and our three dependent measures. With the exception of the log parental input frequency and said words, log parental input frequency had very little influence on words understood or our difference measure when difficulty of

Table 8. Correlations among difficulty of articulation, log parental input frequency, words said, words understood, and the adjusted words understood for the set of 202 nouns. Pearson correlations are given in the upper right quadrant and Spearman correlations are given in the lower left quadrant. (Note * = p < .05; ** = p < .001).

	Difficulty of Articulation	Log Parental Input Frequency	Said Words	Understood Words	Adjusted Understood Words
Difficulty of Articulation		-.255**	-.293**	-.161*	-.044
Log Parental Input Frequency	-.221*		.313**	.263**	.178*
Said Words	-.280**	.311**		.810**	.525**

Understood Words	-.136*	.251**	.783**		.924**
Adjusted Understood Words	-.053	.207*	.640**	.971**	

articulation is partialed out. This result should not be too surprising since Goodman et al. (2008) found no overall effect of log parental input frequency in a similar data set. However, they found some significant effects of log parental input frequency when they carried out the analyses within some of the data set's different lexical categories. We therefore carried out correlation analyses on subsets of our data sample. First, we created a noun category that had 202 nouns from our data sample. Table 8 gives the Pearson correlations among difficulty of articulation, parental input frequency, number of children that understood each word, said each word, and the adjusted understood measure for the subset of 202 nouns. The results shown in Table 8 replicate the differential influence on said and understood words. Difficulty of articulation correlated significantly with said words (-.293, $p < .001$) but not with the adjusted measure of words understood. Replicating Goodman et al.'s findings, log parental input frequency correlated significantly with our three dependent measures.

Table 9 gives the partial correlations between Difficulty of Articulation and our three dependent measures for the 202 nouns. The influence of Difficulty of Articulation holds up when the analysis is limited to just the noun category. The partial correlation of difficulty of articulation with said words was significant even when the contribution of parental input frequency was partialed out. Similarly, difficulty of articulation did not correlate with understood words or the adjusted measure of understood words. This significant correlation of difficulty of articulation with said words but not with understood words casts doubt on both the motor theory that posits similar processes in perceiving and producing words and the theory assuming equivalent representations for perception and production.

Table 9. Partial correlations of difficulty of articulation with words said, words understood, and the adjusted words understood when log parental input frequency are partialed out for 202 nouns. (Note * = $p < .05$; ** = $p < .001$).

	Difficulty of Articulation (Log Parental Input Frequency Partialed Out)
Said	-.237**
Understood	-.104
Adjusted Understood	.000

Table 10 gives the partial correlations between parental input frequency and our three dependent measures for the class of 202 nouns. When the analysis is restricted to the class of nouns, log parental input frequency has the expected effect that children are more likely to have vocabulary corresponding to what they hear.

Table 10. Partial correlations of Log Parental Input Frequency with words said, words understood, and the adjusted words understood when Difficulty of Articulation is partialed out for the 202 nouns category. (Note * = p < .05; ** = p < .001).

	Log Parental Input Frequency (Difficulty of Articulation Partialed Out)
Said	.257**
Understood	.232**
Adjusted Understood	.172*

We repeated the partial correlations on the 51 action words, the 32 descriptive words, and the 42 prepositions, quantifiers, question, and words about words. The same results were found as for the subset of 202 nouns.

3.2.3 Correlations with Imagery and Concreteness

Ma et al. (2009) found that the acquisition of both nouns and verbs in Chinese and English was correlated with the imageability ratings of adults. McDonough et al. (2011) replicated these results in English and found that both parental input frequency and form class correlated with vocabulary acquisition, as measured by the CDI. The imagery ratings were taken from Masterson and Druks (1998). Given the possible differential influence of imagery and concreteness on comprehension and production, we found 133 nouns that had concreteness and imagery ratings in the MRC psycholinguistic database and replicated our analysis with these items. We found very little influence of concreteness and imagery. As expected, concreteness and imagery correlated with one another, $r = .569$, $p < .001$. However, the only significant correlation was that higher concreteness was positively correlated with words said, $r = .194$, $p < .05$.

There is a very small range of concreteness and imageability within this class of nouns, which probably accounts for the failure to find robust effects of concreteness and imagery within the class of nouns. To expand the range of concreteness and imageability ratings in our analysis, we found 269 words in our complete database of 386 words that had concreteness and imagery ratings in the MRC psycholinguistic database and replicated our analysis with these items. These correlations are shown in Table 11. As can be seen in the table, Imagery was positively correlated with Difficulty of Articulation and inversely correlated with Log Parental Input frequency. Imagery was positively correlated with said but not with understood words.

To assess whether imagery, log parental input frequency, and Difficulty of Articulation independently contributed to vocabulary development, partial correlations were carried out. Table 12 gives the partial correlations and shows that all three variables made significant independent contributions to vocabulary development.

Table 11. Correlations among difficulty of articulation, parental input frequency, words said, words understood, and the adjusted words understood for the subset of 269 words with imagery concrete ratings. Pearson correlations are given in the upper right quadrant and Spearman correlations are given in the lower left quadrant. (Note * = p < .05; ** = p < .001).

	Difficulty of Articulation	Log Parental Input Frequency	Imagery	Said Words	Understood Words	Adjusted Understood Words
Difficulty of Articulation		-.293**	.206**	-.245**	-.142*	
Log Parental Input Frequency	-.283**		-.642*	-.032	.018	-.045
Imagery	.188*	-.443**		.193**	.130*	.044
Said Words	-.208**	-.039	.305**		.748**	.081
Understood Words	-.123*	.047	.092	.757**		.412**
Adjusted Understood Words	-.056	.083	.036	.576**	.952**	.913**

Table 12. Partial correlations of Log Parental Input Frequency with words said, words understood, and the adjusted words understood when Difficulty of Articulation is partialed out for the 202 nouns category. (Note * = p < .05; ** = p < .001).

	Imagery (Difficulty of Articulation and Log Parental Input Frequency Partialed Out)	Difficulty of Articulation (Log Parental Input Frequency and Imagery Partialed Out)	Log Parental Input Frequency (Difficulty of Articulation and Imagery Partialed Out)
Said	.367**	-.253**	.232**
Understood	.269**	-.143*	.182*

Adjusted Understood	.183*	-.072*	.133*

To assess whether imagery, log parental input frequency, and Difficulty of Articulation independently contributed to vocabulary development, partial correlations were carried out. Table 12 gives the partial correlations and shows that all three variables made significant independent contributions to vocabulary development.

A multiple regression analysis was carried out and revealed that all three variables accounted for about 18%, 9% and 4% of the variance of said, understood, and adjusted understood words, respectively.

3.2.4 Correlations with Word Length, Segment Probability, and Neighbors

We also investigated the influence of several other possible influences: namely word length, segment probability, and number of neighbors. The number of phonemes in each word was used as a measure of word length. The positional segment frequency was computed for each sound in the target word by iterating over every entry in the corpus that is long enough to have any sound in the corresponding position (counted from the left edge of the word without respect to syllable structure) and by checking for matches against each sound in the target word. A position-sensitive sum and a biphone sum were computed for each words based on a child and adult corpus, respectively (Storkel, 2013, 2014). This measure is defined as the sum of the log frequencies of all of the words in the corpus that contain the given segment in a specific word position, divided by the sum of the log frequencies of all of the words in the corpus that contain any segment in that word position (see, Storkel, 2004b). Basically, these latter two measures give the uniqueness of a segment occurrence in a word relative to its occurrence in all of the words in the corpus. Finally, the number of neighbors was defined in the traditional manner in which neighbors were counted as any words that differed from the target word by just one phoneme (Storkel, , 2013, 2014; Storkel & Hoover, 2010).

To assess these variables, we carried out an analysis on 198 nouns that had these measures. The only significant correlation was that length was inversely correlated with said words.

We also computed these measures for 346 words from our full database from the measures given by Vaden (2009). These measures are identically defined as just described except that the segment probabilities are computed on the basis of frequency of occurrence in the Kucera-Francis database. These measures gave very little predictive value for the acquisition of either receptive or expressive language.

4. Conclusions and Discussion

The correlation analyses with all words overall and the lexical classes nouns and action words show a somewhat more robust correlation of difficulty of articulation with words said than with words understood. This result is particularly impressive because the range of understood words was larger than that of said words so that ceteris paribus a larger correlation with understood words would be expected. This result points to different processes involved in speech perception and production and their acquisition. Future work should be extended to new and more elaborate databases.

4.1 Previous Literature

We might expect that input frequency might positively correlate with vocabulary acquisition. Goodman, Dale, and Li (2008) examined the influence of the frequency of occurrence on vocabulary acquisition as revealed by perception/comprehension and production. They used two valuable databases: The MacArthur-Bates Communicative Development Inventory which provides norming data on age of acquisition for 562 individual words collected from the parents of children aged 0;8 to 2;6, and the CHILDES database which provides estimates of frequency with which parents use these words with their children (age: 0;7–7;5; mean age: 36 months). Age of usage was defined as the age when 50% of the children in the MacArthur-Bates database used the word in comprehension or production, respectively. They computed Pearson correlations between the age of usage of words (for comprehension and for production) and the frequency of occurrence of those words in parents' child directed speech.

There were no overall effects of frequency so Goodman et al. (2008) carried out the analyses within different lexical categories: common nouns, people words, verbs, adjectives, closed class, and a default category. This partitioning is not commonly carried out in the adult literature because most experiments studying frequency effects use just a single class of items such as nouns. The expected correlations of frequency were now observed within some lexical categories but they were much larger for production than for comprehension. Parental input frequency was significantly correlated with all six categories of words for production but with only the category nouns for perception.

Goodman et al. (2012) explained these differences between comprehension and production in terms of the expected smaller number of experienced occurrences required to learn to comprehend a word versus the number required to produce that word. If learning is probabilistic in both cases, a variable with the smaller number of occurrences will necessarily give a smaller correlation than a variable with a larger number of occurrences. If production lags comprehension, it follows that a larger number of occurrences is needed for production than for comprehension and, therefore, more extreme correlations should be expected for production than comprehension.

An analogous explanation might explain the differences of the influence of difficulty of articulation on receptive and expressive language. If additional occurrences are required to learn to produce a word than to understand a word, then the influence of difficulty of articulation would be magnified for production relative to perception. If this explanation is valid, it adds further support for the idea that comprehending a word occurs much earlier in language acquisition than producing that word, as observed in the

MacArthur-Bates database and by Roy's (2011) observations. In addition, it adds to the broad range of results that indicate that the same representation is unlikely to be used in both receptive and expressive language, as assumed by the motor theory and the McMurray et al. (2012) formal common-representation model.

One possibility, not considered by Goodman et al. (2008), however, was that there were fewer items in the correlation analysis for the comprehension condition than for the production condition. The comprehension measures were not available for the age group 1;6 to 2;6 (the scoring for these items asked whether the word was both understood and produced). Our current study overcomes this potential confounding because we have equivalent data sets for perception and production.

Some children are extremely late talkers but seem to show normal comprehension of speech. This result would not be expected if indeed speech production processes necessarily mediated speech comprehension. Sowell (2001) gives a number of examples of late talking children. These children begin talking late in their development after ages two or three but seem to have no delay in cognitive development or even the comprehension of language. Leslie, a young girl had an IQ of 139 but she did not talk until age 2. Leslie was like many other children who talk late but have no trouble understanding what other people are saying. While Leslie repeatedly had difficulty in producing words to express her meanings and relied heavily on multi-purpose words, her passive vocabulary was in the 99th percentile, as evidenced by her score on the Peabody picture vocabulary test. Sowell concludes, "Yet another fact consistent with this hypothesis is that many bright children who have not yet begun talking have no difficulty understanding what other people are saying to them and may even follow complex instructions better than most other children their age" (Sowell, 2001. p. 95). Temple Grandin did not talk until she was four.

There is some recent evidence, however, that late talkers might be somewhat delayed in comprehension also. Weismer, Venker, Evans, and Moyleb (2013) carried out a fast mapping vocabulary learning task with late-talking (LT) toddlers and toddlers with normal language (NL) on both novel object labels and familiar words. The LT group revealed poorer learning than the NL group on both the comprehension and production of novel words and the production of familiar words. The authors suggested "that late talkers' limitations in expressive language do not just stem from lexical retrieval problems, but appear to be related to more fragile phonological, lexical and semantic representations that are reflected in subtle comprehension difficulties that, in turn, result in more substantive deficits in vocabulary production." (p. 10).

Goodman et al (2012) uncovered a potentially damaging result for motor theory. They found that closed-class words are not produced at age 2;6 even though they occur frequently in the child's parental input speech. (The closed-class words consisted of pronouns, words about time, articles, quantifiers, prepositions, and question words.) There is evidence that children by this same age do comprehend many of these words, which is additional evidence against motor theory. Toddlers (13-15 month-olds) have only a few words in their productive vocabulary but can understand the relations among words in a spoken sentence (Hirsh-Pasek & Golinkoff, 1996). One alternative explanation that we do not accept is that children might be using telegraphic speech and intentionally omitting these words in their production even though they are perfectly capable of doing so.

The dissociation between expressive and receptive language is not limited to an advantage of receptive language. There are cases in which a correct use of expressive language can precede receptive language. As reviewed by Hendriks (2014), preschool English-speaking children correctly produce pronouns such as me or him and a reflexive such as myself or himself. On the other hand, these same children and even children a few years older misinterpret these pronouns in sentence contexts. They will often interpret an object pronoun as a reflexive. So, for example, they understand "Ernie washed him" as "Ernie washed himself." Hendriks (2014) describes several other aspects of grammar in which expressive language precedes receptive language.

4.2 Theories Revisited

As recently observed by Hickok (2009), motor theories have a long history in behavioral science. Over 100 years ago, Walter B. Pillsbury (1911) said, "The [motor] theory is so simple and so easy to present that every one is glad to believe it. The only question that anyone cares to raise is how much of it will the known facts permit one to accept" (p. 84). It is sobering how little has changed during the intervening century in that few, in any, motor theorists would be swayed by Pillsbury's caveat.

What is most disappointing about motor theory is that its advocates do not offer specific testable hypotheses about how it accomplishes speech perception. Most of the explanations have taken the form of analysis by synthesis models. Given a speech event, the perceiver benefits from selecting and synthesizing potential alternatives during their processing of the speech input and somehow determining which of these possibilities is the best match. To accomplish this selection, however, the perceiver still requires access to the speech signal so we have regressed back to the original challenge of understanding how the speech signal is processed.

Brain traumas have helped scientists uncover specific areas of the brain responsible for comprehension and production of sign language (Hickok, 2009). Traditionally, brain researchers and practitioners have distinguished between Broca's area (discovered by Paul Broca in 1861) responsible for speech production and Wernicke's area (discovered by Carl Wernicke in 1874) responsible for speech comprehension. Both of these areas are in the left hemisphere and are close neighbors of the auditory cortex. Damage to either of these areas appears to compromise only one of these two abilities and leave the other ability mostly intact. (Damage to the right hemisphere leaves speech perception and comprehension more or less intact but has grave consequences for visual-spatial behavior.) For example, persons with Broca's aphasia can perceive and understand speech but have difficulty producing it.

Dodd (1975) provides interesting although somewhat indirect evidence that perception and production are dependent on separate processes. She recorded three-year-old children when they named a large set of pictures. They then listened to this recording of them saying the names as well as adults saying the names. They were asked to identify what was being named for each word they heard. They could accurately recognize only 48% of the words they uttered in contrast to their 94% accuracy in recognizing the adults' words for these same objects. If production mediated perception, as assumed by motor theory, then the children should have recognized their own words at least as well as the adult words.

Successful perception requires a reasonable invariant relationship between the things being recognized and their corresponding categories. To date, there appears to be no invariant correspondence between a phoneme and its acoustic occurrence in the speech signal. Motor theory was advocated in part because it appeared to solve the lack of invariance in the speech signal. However, this finding alone does not justify a motor theory and there is now some evidence that there may be more invariance in the acoustic consequences of articulation than in the articulation itself. Vocal tract imaging and tracking techniques indicate that American speakers produce /r/ with many different tongue shapes, and yet all of these are perceived as /r/ (Nieto-Castanon, Guenther, Perkell, & Curtin, 2005). What appears to be critical for a /r/ to be perceived as such is that its acoustic stimulus must have a very low third formant (F3), although we know that many other characteristics of the spectrum are influential (such as the direction of the formant transitions). There is other evidence that talkers use what they hear to guide their speech production. If the auditory feedback given a talker is modified, then the talker will actually modify their articulation based on what they heard rather than their articulatory movements (Guenther, Hampson, & Johnson, 1998).

Mefford and Green (2010) assessed the degree to which articulatory and acoustic information specified a phonetic category and the variability within the category. They had typical talkers utter a sentence in typical speech or slower or louder than normal. These different utterance conditions naturally create articulatory and acoustic variability. For our purposes concerning sensory versus motor sources of information in speech perception, a question is whether the acoustic or the articulatory source is more informative. A source is defined as more informative to the extent it distinguishes among different phonemes and has low variability within a phoneme class. Based on their measurements of tongue movements and first and second formant transitions, the authors concluded that the acoustic input was more informative than the articulatory information.

Vihman (2002) describes how motor processes might work in speech acquisition in one of the few explicit accounts of the putative role of motor processes in speech perception. Infants practice canonical babbling and produce consonant-vowel (CV) sequences at 6-8 months of age. This practice in production sensitizes them to similar speech that is received from their caregivers. Having uttered CV sequences allows these CVs to be more easily recognized from their caregiver's speech because their familiarity from babbling allows them to pop out of the acoustic stream. Vihman and her colleagues have demonstrated an effect of infants' familiarity with their own production patterns on attention to isolated-word lists (DePaolis, Vihman, & Nakai, 2013; Majorano, Vihman, & DePaolis, 2013) and to words embedded in passages (DePaolis, Vihman, & Keren-Portnoy, 2011). They interpret these results that their vocal practice "bring into particular focus elements of what is perceived (Thelen & Smith, 1994; Vihman, 1991, 1996)". In another study, they showed that accuracy in speech production was correlated with the quality of speech perception. They tracked the recordings of 59 infants weekly from 9 months, to identify the age at which they had two well-practiced consonants in their speech. The authors then recorded looking times to words likely to be known or unknown to the infants. They found that those infants with two well-practiced consonants in their speech revealed a sharper differentiation between the known and unknown words. The results were interpreted as an interaction between productive and receptive knowledge in development.

However, the impressive series of results by Vihlman and her colleagues do not necessarily mean that production processes are necessarily involved in speech perception. Although the babbling patterns would become familiar with practice and this increase in familiarity might facilitate perception, it does not mean that the motor processes involved in babbling were actually functional during the infant's speech perception. We can expect that both perception and production would be modified as the child experiences more language, even though they operate independently of one another (e.g., Westerman & Miranda, 2004). It is also possible that perception of a segment or word is mastered first and that improvement in production comes later. Production might allow an infant to better learn a speech category without necessarily requiring that production processes be involved in the infant's perception. Furthermore, infants at 6-8 months quickly learn arbitrary statistical properties of segments occurring in continuous speech, which cannot be easily explained by canonical babbling (Saffran, 2003).

If perception precedes production in a child's language development, then the possibility of perception-based phonological development might be worth studying (Werker et al, 2012). As described earlier, one of the basic assumptions of the FLMP is that there are multiple sources of information in the speech signal and these cues are not equally informative, they are learned at different stages, and individuals differ greatly in terms of when and the degree to which they are learned. This framework is similar to Werker and Curtin's (2005) PRIMIR model (a developmental framework for Processing Rich Information from Multi-dimensional Interactive Representations). Curtin, Byers-Heinlein, & Werker (2010) have extended their model to give an account of bilingual language development. As observed by Soderstom et al. (2009), "infants pursue multiple analyses of many input properties, letting a thousand flowers bloom."

We have made the theoretical and empirical arguments for an independence of perception and production processes. The significant correlation of difficulty of articulation with said words but not with understood words casts doubt on the motor theory that posits similar processes in perceiving and producing words and a theory assuming equivalent representations for perception and production. Our new results run counter to the motor theory of speech perception and to the assumption that there is a common

representation used in both perceiving and producing speech. This same evidence argues in favor of separate processes for speech comprehension and speech production.
Given that empirical and theoretical results have weakened the claims of motor theory, there have been several softer versions of the theory.

4.2.1 Modified Motor Theory: Ambiguity Backup.
In this version of motor theory, the recognition system recruits the motor representations only when there is an ambiguity in the input stream such that speech perception does not succeed based on typical sensory processing (e.g., Moulin-Frier & Arbib, 2013). In some cases, there may be a degraded speech signal so that no single alternative can be chosen from a number of similar candidate words. It should be kept in mind, however, that for typical cases when the sensory representations are sufficient for pattern recognition the motor representations are never consulted. When ambiguity persists after prototypical pattern recognition processes have been engaged, however, it might seem reasonable to consult an auxiliary source of information such as a motor representation.
More recently, Moulin-Frier & Arbib (2013) acknowledge that there is good evidence that much of speech perception can occur without any intervention of motor processes but speculate that, in some cases, motor processes can make a positive contribution. One example would be speech perception of challenging input such as the speech of a non-native speaker of the language. In this case, production processes might be instantiated that would provide a set of alternative candidates for understanding, as in traditional analysis-by-synthesis models.
Although the ambiguity backup model is attractive primarily because it allows for motor processes but does not make them mandatory, it will not be easy to test. Utilizing motor processes when the direct route to perception fails might necessarily imply that perception would be slower when the motor route is engaged than when it is not. Thus, the overall distribution of reaction times (RTs) to a successful perceptual identification should be a composite of two underlying distributions rather than just one. If indeed perception followed this dual route model, it is surprising that no one has observed a bivariate distribution of RTs in spoken word recognition.
Like the original motor theory, it is still troublesome to understand how a motor representation might help. The fallback explanation is usually the instantiation of an analysis by synthesis process. The motor system generates likely alternatives that somehow allow a comparison process that might aid in perception of the word. We believe our tests that falsify the standard motor theory are equally relevant to the Ambiguity Backup version.

4.2.2 Modified Motor Theory: Limited Influence.
We know that there are multiple influences in speech perception and it is possible that motor processes might have a small influence. Hickok, et al. (2011) are swayed by recent findings that suggest a limited and modulatory role for the motor system in speech perception. This evidence comes from neurological measurements that show activation of the motor system during

speech perception with no explicit motor task. These results, of course, could simply reflect associated activation with no functional role in speech perception.

Other evidence indicates some success with interfering with speech perception by stimulating premotor cortex, and facilitating or interfering with speech perception by stimulating motor or lip or tongue areas. It is important to note, however, that motor theory necessarily predicts that the sensory information must be more accurately resolved independently of any contribution of additional sources of information that prediction provides. It's processing cannot be simply biased in the direction of one alternative or another based on an additional source of information. None of these studies that show some role for the motor system has partialed out these two types of influence. Hickok et al. (2011) admit that all of these findings might simply reflect a non-perceptual bias rather than perceptual sensitivity (Massaro & Cowan, 1993).

Roy (2011) documents about 70 instances in which his son attempted to pronounce "water" before he was able to pronounce it correctly. Many of these instances illustrate that he was able to perceive and understand the spoken word but simply unable to produce it. In addition, Roy's child successive attempts at producing the word water did not appear to be a continuous embellishment of a single impoverished representation but rather included significantly different forms. This scientific observation revives the anecdotal one in which a father is mimicking his son's mispronunciation of the word "rabbit". His son says, "No dad, not wabbit, but wabbit." The son clearly could perceive the difference between "rabbit" and "wabbit" even though he wasn't able to accurately produce the difference.

4.2.3 Common Representation for Word Perception and Production.

This thesis of equivalent representations (Figure 2) might explain the comprehension advantage by assuming that an infant's word's representation is sketchy. This adumbrated representation is sometimes sufficient for comprehension but not for speech production. The difference between comprehension and production is simply the number of viable competitors in the task. The results from individual children, on the other hand, show that a child's good perception performance of a variety of words but little or no production contradicts the common representation explanation (see Tables 2 and 3 and corresponding explanation).

4.2.4 Pattern Recognition: Different Processing for Perception and Production

Although the three theories we have considered are still very much in contention, we favor the view that understanding speech is a prototypical pattern recognition situation. Multiple sources of information are used to make sense of the input conveying some meaningful event. This framework has been successful in describing many different speech perception experiments with both adults and children (Massaro, 1975; 1998; Movellan & McClelland, 2001). In addition to this behavioral model, the dual-route model with ventral and dorsal processing streams provides a neural level of description (Hickok, 2008). We look forward to new results and theories to illuminate further how language is learned and used.

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The acquisition of the passive structure in European Portuguese

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Abstract
This study aims at the description of the acquisition of passives in European Portuguese. Many studies show that this construction is acquired late in different languages. In this paper we contribute to the study of the acquisition of passives with the results of two experiments run with 3-5 year-old European Portuguese speaking children, using a Picture Selection Test and a Truth-Value Judgment Test. The results show that in Portuguese, only at the age of four, children can interpret syntactic passive sentences with actional verbs. The acquisition of non-actional verbs happens later.

Keywords acquisition, passive construction, actional verbs, non-actional verbs, by-phrase

1. Introduction

The present study investigates whether the European Portuguese (EP) 3-5 year-old speaking children understand passives or not. Our goal is to explore the comprehension of passives and whether the type of verb matters. In most languages and in EP, in particular, the passive construction has the following characteristics: the patient argument is highlighted, while the agent argument is not; the phrase presents a non-canonical word order; there is specific verbal morphology and a reduction of an argument (agent) by making it oblique. The example 1 is an active phrase in EP and the example 2 is the correspondent passive phrase:

1. A Alice abraça o Henrique.
   (Alice embraces Henry)

2. O Henrique é abraçado pela Alice.
   (Henry is embraced by Alice)

The example 2 is a long passive (with a *by-phrase*), while example 3 is a short passive (without a by-phrase):

3. O Henrique é abraçado.
   (Henry is embraced)

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We can also find passives with actional verbs (like 2) and passives with non-actional ("mental" verbs) like *ver* (to see), *amar* (to love), *pensar* (to think) etc., as example 4 illustrates:

4. A Alice é amada pelo Henrique.
   (Alice is loved by Henry)

Passives of verbs that take the roles of agent and patient are known as actional passives, whereas passives of verbs that take experiencer and theme theta roles are known as non-actional passives.
The reversibility of the verb is also important when it comes to passives. Examples 2 and 4 constitute reversible passives, while example 5 is a non-reversible passive, as the noun phrases *Os livros* e *o Henrique* cannot be interchanged and result in a sentence that is considered semantically appropriate, as it happens in example 6.

5. Os livros são amados pelo Henrique.
   (Books are loved by Henry)

6. *O Henrique é amado pelos livros.
   (Henry is loved by books)

It is argued that non-reversible passive sentences are less challenging since the identification of the agent and patient is explicit and is supported by world knowledge, while the interpretation of the passive in reversible sentences requires grammatical knowledge. In our experiments we only used reversible passives.
Presented these general aspects of passive that are important to our own work, we can now move to studies about the acquisition of this structure. If the literature on acquisition of passive constructions in EP is rare, it is very large with respect to other languages. Noteworthy are some studies for the following languages: English (Borer & Wexler, 1987; Crawford, 2012; Fox & Grodzinsky, 1998; Maratsos et al, 1985; Orfitelli, 2012,); Mandarin (Chang, 1986); Spanish (Pierce, 1992), Japanese (Sugisaki, 1999), Brazilian-Portuguese (Gabriel, 2001; Rubin, 2009); Greek (Terzi & Wexler, 2002), among others.
We will shortly refer to some of these studies, in order to contextualize our own specific experimental studies. First, we provide, on the one hand, data from languages in which problems were encountered in the acquisition of this structure, and on the other hand, data from other languages that show precisely the opposite. We also present previous studies on the acquisition of syntactic passive in EP.
Maratsos et al. (1985) developed a study to test the understanding of passive with actional verbs (eg. biting) and passive with non-actional verbs (eg. see). As in many other studies, the results point to a better understanding of passives with actional verbs than non-actional verbs. However, the same children comprehend active sentences with both types of verbs in the same way, which shows, according to the authors, that the problem is specifically

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related to passives and not to processing difficulties coupled with non-actional verbs.
Gordon and Chafetz (1990) also found that non-actional passives were comprehended more poorly than actional passives. This verb type effect was true also for short passives. The authors found that although children performed slightly better on short passives, their performance was not significantly different from long passives. Gordon and Chafetz (1990) found that increasing the input of a particular type of passive has an equalizing effect. They argue that in the novel verb studies that investigate children's knowledge of actional and non-actional passives, the effect of verb type on children's production of passives is nullified. According to the authors, this suggests that passive acquisition is somehow related to input. Children hear more actional verbs than non-actional verbs in passive sentences, precisely because the former are more frequent. As such, it is not the nature of the semantic verb classes that restricts acquisition, but the strength of the input.
Two studies that were distinguished by the impact they got were those of Borer and Wexler (1987) and Fox and Grodzinsky (1998). The first authors advocate the Maturation Hypothesis as an explanation for the delay in verbal passive production. By this hypothesis, children's late acquisition of full verbal passives is related to biological maturation. The authors further argue that children's early short passives are "lexical or adjectival expressions" which do not have the same grammatical status as the passives used by adults. Assuming the Universal Grammar (UG) is innate, they argue that young children do not yet understand A-chains, which mature later. Thus, the child is unable to assign the Theta role non-locally to the subject NP, and misinterprets the passive sentence. Borer and Wexler argue that children do not acquire verbal passives until their ability to form A-chains matures. Therefore, they claim that children do well in interpreting the passive whenever it can be interpreted as adjectival.
More recently, Wexler (2004) and Orfitelli (2012) bring forward the Universal Phase Requirement and the Argument Intervention Hypothesis, respectively. These authors claim that children do not have the capacity to overcome a locality constraint that applies in verbal passives. Accordingly, the ability to deal with this movement develops later. It is important to clarify that the question here is not related to an inadequate input, but with the fact that children cannot make use of the input they receive because their universal grammar is biologically constrained.
Therefore, the authors bring about the idea that children are using adjectival passive syntax because these passives do not entail the object to subject movement that verbal passives do. We also have to consider that verbal passives have an intervening subject argument (Hyams & Snyder, 2005), while adjectival passives don't.
Fox and Grodzinsky (1998) argue that children do not have problems with a-chains, but with the transmission of the theta roles to the by-phrase. They claim that children would have problems with long non-actional passives when the theta role transmitted to the by-phrase is an experiencer role instead of the typical agent role. Fox and Grodzinsky predict the inexistence

of problems with short passives of actional or non-actional verbs. They also claim that children will not have problems with long actional passives, because the theta role transmitted to the by-phrase is a canonical agent.
The authors show that children aged 3;6-5;5 comprehend sentences with A-chains: long get-passives, long actional be-passives with reversible verbs and non-actional truncated be-passives. They concluded that children fully control all aspects of passives except for the ability to transmit the external theta-role of the VP to the by-phrase. Children do well on reversible passives, because by assigns agent as its inherent θ-role. The difficulty with theta-role transmission arises in the non-actional passive where the inherent Theta role of the by-phrase (agent) conflicts with the theta role of the external argument of non-actional verbs (experiencer).
As we have seen, many authors described difficulties in the acquisition of passive and try to advance explanations for such delays. In parallel, several studies show that the delay is not transversal to all languages, disagreeing with the universality of this delay. One example is that of Demuth (1990), which points to the absence of difficulties in the acquisition of passives in Sesotho, a language of the Bantu group. The author justifies this sucess with the high frequency of passives in the input and the specific morphology of this construction in sesotho.
Also Allen and Grago (1996) report the productive use of passive by the two year-old children in Inuktitut, a language spoken in northern Canada. The justification provided is related to specific factors of this language, either structural or functional.
Armon-Lotem et al. (2015) studied the acquisition of passives in eleven languages, as part of a larger European project - COST ACTION A33 - and they concluded, in most languages, the long passive is more difficult than the short passive and there is a certain preference for the canonical word order as a strategy when the children can not interpret passive. Furthermore, they found that the difficulties with long passives are not due to the by-phrase or to the low frequency of the construction in input. Above all, the exposure to morphologically and syntactically similar constructions was found to be important. They state that the variability in word order and the experience with the mapping between argumental reduction and passive morphology in the impersonal passive, and resultatives and inacusatives in various languages can help understand children's success in the interpretation of short passive.
If, on the one hand, there are authors who have developed their approaches pointing to the universality of delays, on the other hand, there are those that show the relevance of interlingual variability in the acquisition of this structure, highlighting the role of input. In fact, what we see is the persistence of dissimilar results in different languages, which makes the task of assigning an explanation to the seemingly late acquisition of the passive structure more arduous. Even if we think in a same language, English for instance, we notice some differences in terms of results, which are justified, for example, through methodological issues.
In our point of view, it is precisely this apparent disparity of results that legitimizes the need for more experimental studies in this particular area. We

think that the analysis of data from EP also raises interesting questions in this regard.
The study that Sim-Sim (2006) carried out with four, six and nine year-old children distinguished between the comprehension of reversible (ex. The cat was bitten by the dog *vs*. The dog was bitten by the cat) and non-reversible (ex. The bone was bitten by the dog vs. The dog was bitten by the bone) passives and the results pointed out to the fact that children with six years still had difficulties in understanding reversible passives. Just nine year-old children had an adult level performance, with a 77% of correctness. Non-reversible passive were understood by four year-old children, with 94% of correct answers. Contrary to Sim-Sim (2006), our own results show that four year-old children had good results when they had to show their understanding of reversible passive with agentive verbs, with 77% of correctness. We will see these results in detail in the next section.
Another study, by Correia (2003), confirms that, on the one hand, the syntactic complexity of passive constructions will play an important role in the way children understand and produce this structure; on the other, it is possible to establish a relationship between the process of understanding and producing of passive constructions" and the age and level of education of the participants.
In what concerns Brazilian Portuguese, Rubin (2009) carried out a study on the comprehension of passives. Her results show that, if we take into account individual performance, the assumption that it is a late process does not hold. She also concludes that while the group results point to difficulties in the acquisition of passive, individual results suggest that, for some children, there is no delay. Thus, to state that there is a universal delay is too narrow, since there are individual differences in language acquisition strategies.
Because there is still no consensus regarding the factors that may be causing the delay that apparently occurs in several languages, the study of the acquisition of passive in EP is justified. It is precisely this matter that is the focus of this paper. In section 2, we get to know the two experimental studies that we conducted in order to assess any difficulties in the interpretation of passive by children from three to five years old. In section 3, we discuss the results in order to bring some light into this topic and draw some conclusions. We finalize with a few notes defending the relevance of new studies on the passive structure.

2. Experimental Studies in European Portuguese

In what concerns EP, we intent to verify if there is a late acquisition of the construction in analysis and, if so, try to identify the factors that justify this delay. Our goal is to investigate the comprehension of long and short passives, and whether the type of verb (actional *vs.* non-actional verbs) matters.
Given the theoretical developments presented in the previous section, we should now display the two working hypotheses that underlie our study, making the fundamental assumptions clear.

Hypothesis 1: Understanding long passive is more difficult than understanding short passive.
This hypothesis relates to the idea that short passives will be easier for children, in an initial phase. The ability to deal with movement (required in long passives) develops later.

Hypothesis 2: Understanding passives with non-actional verbs is more difficult than understanding passives with actional verbs.
This hypothesis relates to the idea that children's performance on passive comprehension tasks is significantly better when they are presented with passive sentences containing an actional verb as opposed to a non-actional, mental verb.
With these two hypotheses, we aim at understanding how children acquire passives, using different methodologies. With the first experiment, we study how children behave with actional passives, through a Picture Selection Test and, with the second experiment, we analyse the acquisition of non-actional passives, through a Truth-Value Judgment Test.

2.1 Passives with actional verbs

In the first study, the experimental design explored the ability to comprehend two types of passive constructions (short and long passives) with actional verbs and active constructions. Both correct responses as well as error types will be analysed in order to provide insight into why passives seem to be acquired relatively late. We will try to answer the two following questions:

i) Do children understand both short and long passives by the same age?
ii) Are long passives harder to learn than short ones?

2.1.1 Participants

In the first study, 72 children were tested on their comprehension of short and long passives with actional verbs. In the table below, we present their ages and mean age:

Table 1. Participants' age and gender on the first experiment

Age Group	Male	Female	Total	Mean Age
3;1.5-3;11.23	14	10	24	3;7.15
4;0.23-4;11.27	13	11	24	4;7.16
5;0.18-5;11.10	11	13	24	5;6.14

Children were selected taking into account their age and the mother tongue. All had Portuguese as their mother tongue, were monolingual and were not diagnosed with any disorder that might disturb their performance in the test.

2.1.2. Experiment

Our experiment was developed from the project COST ACTION A33, Crosslinguistically Robust Stages of Children's Linguistic Performance, which designed a comparative study of the acquisition of various linguistic structures for 5 year-old children, from several European countries (Armon-Lotem et al., 2015). We have adapted the experiment, originally designed in English, and extended the age group, including children from three to five years old.

The experiment consisted of a series of picture-choice tasks. All the participants were expected to choose the picture (from a set of four) that matched the sentence in the presentation of a given set of pictures. For instance, for the verb *fotografar* (to photograph), three sentences were tested:

7. O rapaz fotografa o avô. (ACTIVE)
   (The boy photographes the grandfather)

8. O avô é fotografado pelo rapaz. (LONG PASSIVE)
   (The grandfather is photographed by the boy)

9. O avô é fotografado. (SHORT PASSIVE)
   (The grandfather is photographed by the boy)

Every sentence (active or passive) was paired with a picture depicting the action and three mismatched pictures. All pictures for one verb depicted three people from a set of four interveners: two were directly involved in the action and one was a neutral observer. The three mismatched pictures depicted the following events; a) role reversal of the protagonists, b) replacement of the agent or patient by a third person c) no action at all (Armon-Lotem at al., 2015).

Picture 1. Example of a slide with 1 match picture and 3 mismatch pictures

The four pictures used in each sentence were presented simultaneously on a single slide; the organization of the four pictures on a slide was pseudorandom for each picture types for each item. Active sentences were of the same length across both tasks while the passive sentences differed in length reflecting the type of the passive that was tested, short or long. The first two sentences of the experiment were active to verify that the child understood the task. Sentences were pre-recorded by a male native speaker with neutral intonation giving no additional cues for sentence interpretation.
In this experiment, verbs tested were chosen taking into account the test developed under the project referred before in this section.
All sentences tested were semantically reversible and contained actional verbs, which are more easily depicted in pictures. We used a set of transitive, non-reflexive verbs. There was a total of 22 verbs tested, which are available in the table below.

Table 2. EP actional verbs tested in the first experiment

empurrar (to push)	abraçar (to hug)
examinar (to examine)	secar (to wipe)
beijar (to kiss)	tapar (to cover)
alimentar (to feed)	carregar (to carry)
lavar (to wash)	puxar (to pull)
perseguir (to chase)	barbear (to shave)
coçar (to scratch)	fotografar (to photograph)
pentear (to comb)	pintar (to make-up)
desenhar (to draw)	divertir (to tickle)
sujar (to dirty)	magoar (to hit)
Acariciar (to stroke)	morder (to bite)

Children were tested individually in their preschools rooms. The experimenter began the testing session by introducing the protagonists, in the computer, as a big family that enjoys doing things together. Then the child was told that he/she was going to see the family picture album. The children were then introduced to each character and asked to identify each of the protagonists (e.g. “This is the little brother, this is the big brother”). The child received help in identifying the characters until the experimenter was sure that he/she knew each protagonist.
Then the experimenter explained the procedure, saying to the child that he/she would see the family picture album and that the child would have to listen carefully and choose the picture which matches what the family has recorded. The child had to identify the target picture by pointing to the appropriate picture on the screen. All test stimuli (pictures and pre-recorded sentences) were presented via a Power Point presentation.

2.1.3. Results

The results for the first experimental study show that the interpretation of the active sentences is not a problem for children, as we expected, but passives with actional verbs are only comprehended by 4 year-old children, as we can see in the table below:

Table 3. Results for the interpretation of active and passive sentences with actional verbs

Age(years)	Active sentence	Passive sentence	P-value
3	0.86	0.64	<0.0001
4	0.91	0.77	0.0001
5	0.93	0.90	0.0662

Table 3 also shows that the difference between the interpretation of the active sentence and the passive setence with actional verbs is statistically significant at three and four years, but not at five years old, as shown by the p-values. Assuming a 5% significance level, it was considered that the difference between the proportions is statistically significant when the p-value is <0.05. Thus we see that the interpretation of either the active or the passive evolves according to the age progression.

With respect to the results for the interpretation of the long and short passive sentences, we find that the difference is not significant in any of the age groups. In this sense, we can say that children have the same level of performance with the short passive and long passive, with actional verbs. This is seen in the data below:

Table 4. Results for the interpretation of long and short passive sentences with actional verbs

Age(years)	Short passive	Long passive	P-value
3	0.636	0.545	0.0761
4	0.773	0.818	0.5894
5	0.909	0.955	0.1944

This data shows that long passives are not harder to learn than short ones. Indeed, the agent phrase does not seem to be a major source of difficulty for European Portuguese speaking children, who are able to assign the patient thematic role to the subject position. Contrarily, in other languages, full passive poses a further challenge for 5 year-old children, which is precisely the interpretation of the by-phrase (Armon-Lotem et al., 2015).

As it is known, the passive involves a change in word order, with the patient assuming the subject position. Besides, the passive operation can also result

in an argument reduction (short passives). In Portuguese, we can find different word order as SVO (canonical), OVS and others. This flexibility of word order can be understood as a property that may facilitate children's comprehension of passives. Also the fact that Portuguese has an impersonal passive provides the children with further possibility for exposure to argument reduction.
Following Armon-Lotem et al. (2015), we can argue that, given the relevant linguistic input in what concerns flexibility in word order and experience with argument reduction, Portuguese speaking children at the age of four are capable of comprehending both the short and the full passive.

2.2 Passives with non-actional verbs

In the second study, the experimental design explores the ability to comprehend passive constructions with actional and non-actional verbs and active constructions. Non-actional verbs are those that cause a change or transition from one mental state to another mental state (*frighten*), or express the state after a mental process has taken place (*fear*). Another way to distinguish between actional and non-actional verbs is that actional verbs are verbs with agent subjects, whereas non-actional verbs are essentially verbs with experiencer subjects, or cause subjects.
We will try to answer the two following questions:

i) Are passives with non-actional verbs more difficult than the ones with actional verbs?
ii) Are long passives with non-actional verbs harder to learn than short ones?

2.2.1 Participants

In the second study, 75 children were tested on their comprehension of short and long passives with actional and non-actional verbs. In the table below, we present their ages and mean age:

Table 5. Participants' age and gender on the second experiment

Age group	Male	Female	Total	Mean age
3;1.25-3;10.28	16	9	25	3;7.16
4;0.04-4;11.16	14	11	25	4;5.18
5;0.27-5;11.19	12	13	25	5;6.15

2.2.2. Experiment

With the second experiment, actional and non-actional verbs were used. Children were tested for the comprehension of passives with actional and non-actional verbs, using a truth-value judgment test.
The experimental design involved the presentation of an image to the child, who was sought after to indicate whether the spoken sentence corresponded

or not to the presented image. The investigator described the image generally, without any reference to the verbs under analysis. All drawings presented two animated characters, which could be human or non-human.
Before the test took place, there was a period of familiarization with the task, the characters and the images. This familiarization becomes necessary to facilitate the child's performance on the one hand, and to confirm that she/he realizes the context on the other. Thus, it is ensured that the performance is not compromised.
The verbs tested are presented in the table below. Again, important aspects, such as the semantic reversibility of the arguments, the plausibility of being part of the children's world knowledge and the possibility of representation through images, were taken into account.

Table 6. Actional and non-actional verbs tested in the second experiment

Actional verbs	Non-actional verbs
empurrar (to push)	avistar (to sight)
lavar (to wash)	odiar (to hate)
pentear (to comb)	ver (to see)
abraçar (to hug)	adorar (to adore)
pintar (to paint)	ouvir (to listen)
tapar (to cover)	detestar (to hate)
fotografar (to photograph)	amar (to love)

In the selection of non-actional verbs, we elected as the only criterion that the subject of the active sentence does not receive the thematic role of agent, in the relevant context, so it is easy to identify other aspects that differentiate the selected verbs.

2.2.3. The results

Within the second experimental study, table 7 shows that, three year-old children respond at chance level (just like in the previous experiment), but at age four cildren perform as adults, with 79% correct answers in what concerns actional passives. With non-actional passives, the results are poor. Five year-old children have 64% of target responses. The difference between the interpretation of actional passives and non-actional passives is statistically significant from the age four ($p = 0.00014$).

Table 7. Results for the interpretation of actional and non-actional passives

Age (years)	Actional passive	Non-actional passive	P-value
3	0.50	0.50	0.909
4	0.79	0.50	0.00014
5	0.93	0.64	<0.001

We also made an analysis that aimed at comparing children performance in understanding actional and non-actional long passives and actional and non-actional short passives:

Table 8. Results for the interpretation of actional and non-actional long and short passives

Age group (years)	Short actional passive	Short non-actional passive	P-value	Long actional passive	Long non-actional passive	P-value
3	0.43	0.57	0.961	0.43	0.43	0.8075
4	0.86	0.57	<0.0001	0.86	0.43	0.0003037
5	1	0.71	<0.0001	1	0.57	<0.0001

Table 8 shows that, at three, children interpret at chance level long and short actional passive, reaching much better results at age four: 86%. In what concerns the long and short non-actional passive, in any of the age groups results above 71% are achieved. The results point out that there are significant differences in the interpretation of actional and non-actional passives at four and five years old.

With actional passives, children behave the same way, whether we have short or long passives. But when we have non-actional passives, the results are slightly better when the agent is not presented. This difference is not statistically significant.

Children's performance with active phrases with non-actional verbs is also more problematic than with actional verbs, contrary to the data pointed out by Maratsos et al. (1985), as we can see in table 9:

Table 9. Results for the interpretation of actional and non-actional active phrases

Age (years)	Actional active phrase	Non-actional active phrase	P-value	Non-actional passive phrase
3	1	0.71	0.002508	0.50
4	1	0.71	<0.0001	0.50
5	1	0.86	0.00012	0.64

Our data differ from those displayed by Maratsos et al. (1985), since, even the active phrases with non-actional verbs involve lower levels of performance. When the construction has non-actional verbs, children reveal more difficulties, not only in passive sentences, but also in actives.
Moreover, the agentivity of the verb seems to be a very important issue that is sometimes ignored. So it is fundamental to study the role of agentivity in constructions as actives, passives and others.
To sum up, our study shows that there is a delay in the acquisition of passives in European Portuguese, when compared with the acquisition of active sentences. Only with four years old, children show their ability to interpret passives with actional-verbs, with 79% of correct answers.

3. Conclusions and discussion

Previous in this paper, we outlined two prominent analyses in this topic. The linguistic maturation hypothesis (initially proposed by Borer & Wexler, 1987) asserts that certain linguistic constructions made available by Universal Grammar (including those involving A-chains, such as the passive) are not immediately accessible to children, but must rather mature over time. Before maturation, constructions involving A-chains are ungrammatical for the child. And so, utterances involving them will not appear in spontaneous speech. Consequently, they argue that children succeed in interpreting the passive whenever it can be interpreted as an adjectival passive (as short passives can) and fail when they cannot.
If we remember our first hypothesis, it should be more dificult for children to understand long passives than short passives. Nevertheless, the results of all our experiments show that children have the same performace whether they are dealing with long or short passives. So we have to reject our first hypothesis. Indeed, not all types of A-movement are problematic. Since we can not see a statistically significant difference between short and long passives, we cannot assume, as intended Borer and Wexler (1987), that children only have success in short passives, because they give them an adjectival reading.
Also the explanation based on the difficulty in interpretating the by-phrase, proposed by Fox and Grodzinsky (1998), is inadequate, according to our

data, which shows no significant differences between the interpretation of short and long passives. The authors predicted that only the long passive with actional verbs would be interpreted by children. What is certain is that passive with non-actional verbs are problematic in general, whether they are long or short.

If in EP children had the same performance with short and long passives, Armon-Lotem et al. (2015) show that in all eleven languages tested in their study, the majority of children were at least 80% accurate on short passives comprehension test, while with long passives the variation seen across the different languages was notorious. For EP, we can argue that, given the relevant linguistic input in what concerns flexibility in word order and experience with argument reduction, 4 year-old children will have no problems interpreting long and short passives.

Our second hypothesis states that understanding passives with non-actional verbs is more difficult than understanding passives with actional verbs. This hypothesis suggests that children's performance on passive comprehension tasks is better when we have an actional verb as opposed to a non-actional.

In fact, the results of experiment 2 show that passives with non-actional verbs are more difficult to children. Therefore, is the second hypothesis presented that is supported by our data. However, contrary to what Fox and Grodzinsky (1998) claim, the problem does not disappear with short non-actional passives. The interpretation of these passives should be significantly easier, given the absence of the by-phrase. Nevertheless, table 8 shows, as we have seen, that children perform better in interpreting short than long non-actional passive, although this difference is not statistically significant. Also five year-old children can't understand short or long non-actional passives.

Passivization of non-actional verbs is known to be comprehended later that actional passives in diferent languages (Gordon & Chafetz 90; Pinker, Lebeaux & Frost 1987). So, this problem is not unique to Portuguese. Given the results, it seems that the presence of the by-phrase is not a determining factor for the interpretation of the passive, but the existence of non-actional verbs is. In addition, it should be recalled that children also have difficulties with actives sentences with non-actional verbs. It is important to point out, then, the cumulative effect that occurs. For children, the passive structures are more difficult than the active, and non-actional verbs are more demanding than actional verbs. The results we obtained show that putting these two elements together (passive structure and non-actional verbs) becomes more problematic for children.

In conclusion, our data confirm some difficulties with syntactic passives at an early stage. It is important to say that four year-old children can understand passives, but only with actional verbs. In a large amount of studies, these difficulties have been explained by several factors: the rarity of the construction in the input, the optionality of the by-phrase, the predicate agentivity. Some authors claim the universality of this delay, while others refute this universality given the interlinguistics variability. The truth is that the interlinguistic work is fundamental to the discovery of the nature of children's language. Moreover, with the development of new techniques and theories, our understanding can change and that's why we think that it's necessary to continue developing studies that deslindem how children deal with the passive.

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Is apparent regression an indicator of linguistic progress?

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Abstract

The phenomenon of apparent regression in syntactic development as a consequence of progress has been reported by earlier researchers. Considering these reports of regression of certain grammatical features during the developmental stages of language, the current investigation was taken up to study the signs of regression of various grammatical components in Hindi speaking children as shown by the performance on a screening test of syntactic development in Hindi. A total of 160 participants were categorized under eight age groups studied in the present analysis. The data available in the study was cross-sectional. The late errors were identified in terms of the stages of acquisition the different age groups were in. Differences were also noted in the performance of males and females. The late errors were seen for various grammatical categories both in comprehension and expression skills.

Keywords Late errors, language development, grammatical categories

1. Introduction

The way a child acquires his/her first language has perplexed researchers for decades. There have been many studies and theories as well as arguments on this subject, but this question keeps fascinating the researchers even today. On the basis of conclusions drawn from various studies, it can be said that children really do not just imitate what they hear but that they try to construct their own simplified grammatical (syntactic) rules which they use to form sentences. These rules get modified as the child grows; the child's increasing vocabulary and intellectual processes also play an important role in this process. This allows the children to gradually start using more and more complex structures until the language they use is syntactically similar to adult speech. Thus, syntax of a language plays a very crucial role in providing the necessary structure to the language that the child acquires in his/her early years.

There have been various studies on the acquisition of syntax across various languages over the past (English language: Klima & Bellugi, 1966; Bellugi, 1967; Carrow, 1973; Gazdar, 1981; Bloom, Merkin, and Wooten, 1982; Haas and Owens, 1985; Tomasello, 1987; Duncan and Gibbs, 1987; Crystal, Fletcher and Garman, 1989; Bloom, 1991; Drozd, 1995; Stromswold, 1995; O'Grady, 1997; Blackwell, 1998; Wexler & Hershberger, 1998; Seymour & Roeper, 1999; Goffman & Leonard, 2000; Befi-Lopes, Rodrigues, Puglisi,

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2009; Rispoli, Hadley and Holt, 2009; Mandarin, Cantonese and Korean languages: Lee, 1970; Choi and Gopnik, 1995; Tam and Stokes, 2001; Spanish language: Lust, 1999; Felix-Brasdefer and Cesar, 2006; Italian language: Guasti, 1993; German language: Poeppel & Wexler, 1993; Tamil language: Murthy, 1981; Kannada language: Sreedevi, 1976; Prema, 1979; Roopa, 1980; Vijayalakshmi, 1981; Hindi language: Basavaraj, Goswami, & Priyadarshi, 2010). These studies have succeeded to provide with the essential information regarding the development pattern of various aspects of syntax of the particular language.

Language development has been considered as a straightforward process of expansion and improvement. A child's vocabulary keeps on expanding with the addition of new lexical items and their use is gradually brought into conformity with adult conventions. The child starts using one-word utterances by one year which further gets shaped into short sentences consisting of content words. These lengthen a bit and articles, prepositions, inflections, and other "little words" that were omitted earlier, are included. Previous researchers have discussed about the U shaped phenomena that is observed in language development. Initially there is an increase in the usage of language and around 3 years a dip in the performance is noticed. Further, the language development continues in an increasing trend. "Sometimes….progress involves apparent regression on the child's part, i.e., his commission of errors in aspects of language that he seemed to control at an earlier time" (Bowerman, 1976). The onset of these errors in the domains of language that the child has already mastered is called as late errors. These are errors which do not set in until after a period of correct usage. Specifically, language acquisition being a rather extended process, it continues long after fully adequate communication has been achieved with respect to a given form, and it sometimes involves underlying shifts in the way children organize linguistic information and other parts of their developing grammar (Bowerman, 1983). The phenomenon of apparent regression in syntactic development as a consequence of progress has been reported by earlier researchers (Bever, 1970; Cromer, 1970; Palermo and Molfese, 1972; Brown, 1973; Bowerman, 1974; and Maratsos, 1974). Bowerman (1976) looked at certain late errors in the child's spontaneous speech and interpreted them as signs that the child had arrived at a deeper appreciation of underlying relationships and regularities in the structure of language than she/he had achieved before. The late errors that she observed were the (1) causative verb errors (2) nouns used as verbs and (3) relating and contrasting semantically similar word.

Considering the above facts and findings, the present study aimed at looking for late errors, if any, in the developmental acquisition of grammatical categories in Hindi speaking children in the age range of 1-5 years.

2. Methodology

2.1. Participants

A total of 160 participants (80 males and 80 females) in the age range of 1.0 years to 5.0 years were included in the study. A total of eight age groups, comprising of 20 participants in each; were formed within a range of six months. The groups were divided as follows:

Group	Age range	Group	Age range
I	1.0-1.6 years	V	3.1-3.6 years
II	1.7-2.0 years	VI	3.7-4.0 years
III	2.1-2.6 years	VII	4.1-4.6 years
IV	2.7-3.0 years	VIII	4.7-5.0 years

All the participants had Hindi as their first language and belonged to middle socio-economic status. It was also ensured that they neither had any speech and language deficits or delayed milestones, nor any past/present history of neurological, psychological and sensory deficits.

2.2. Procedure

2.2.1. Test material

The test material comprised of a total of 89 test items divided into 17 sections which were based on Screening Test for the Acquisition of Syntax in Hindi (STASH): An adaptation of Screening Test for the Acquisition of Syntax in Hindi (STASK) (Basavaraj, Goswami and Priyadarshi, 2010). The 17 sub-sections were further classified as comprehension and expression sections. The details of the number of items in each sub-section are given below in Table 1. A set of pictures and toys were used as stimuli to obtain data from the participants.

Table 1. Number of items in various sub-sections

Section	Comprehension	Expression
Simple sentences	3	3
Person	2	3
Case markers	2	3
Adjectives	3	3
Post-positions	2	2
Definite-determiner	3	2
Tense markers	3	3
Number markers	3	3
Wh-questions	2	2
Yes-no questions	3	3
Negatives	3	3
Embedded sentences	3	3
Co-ordinated sentences	3	3
Gender	2	2
Transitives/Intransitives	2	2
Causatives	2	2
Total	41	42
Narration	6	
Total	89	

2.2.2. Test administration

The caregivers of the children were explained the purpose and procedures of the study, and an informed verbal and/ or written consent was taken. Both, experimenter and participant sat on mat or chair-table setup, facing each other. Before starting the experiment, the participants were oriented to get familiarized with the toys and pictures to be used for the experiment. For assessment of the comprehension task, participants were asked to point at one of the toys or picture; for the expression task, the participants were asked to name the attributes. Each of the attribute was tested thrice, if at least two trials were correct, the attribute was scored as correct response. An adequate time (up to two minutes) for each of the trials was provided. The question was repeated, if the participant did not respond within the stipulated time. Only after obtaining the response of previous one, next set of stimuli were presented. The experiment was performed in a quiet room at home setting and responses were audio/video recorded.

2.2.3. Scoring

For comprehension, a score of 2 was given for a correct response (CR) and a score of 0 was given for an incorrect (IR) or no response (NR). A score of 2 was given for CR and 0 for an incorrect (IR) or no response (NR), to objectify the scores for expression. A score of 1 was given for an incomplete response. Thus, the maximum score for comprehension was 82 (41 items x 2) and for expression was 84 (42 items x 2). The maximum score in the narration section was 6. The grand total maximum score for the test was 162.

2.2.4. Test-retest reliability

Sixteen participants were requested to take part in the replication of the test in order to establish the test-retest reliability of the developed tool.

2.3. Data analysis

The data was initially subjected to item analysis and further statistical analysis was performed. The results were analyzed using appropriate statistical tools (Descriptive statistics, Independent samples t test, ANOVA and MANOVA) in order to obtain the developmental pattern of grammatical structures, normative scores for comprehension and expression for the morpho-syntactic forms, gender differences, if any and age wise comparisons, if any.

3. Findings and discussion

As the study aimed at looking for late errors, if any, in the developmental acquisition of grammatical categories in Hindi speaking children in the age range of 1-5 years, the late errors were identified in terms of the stages of acquisition the different age groups were in. Some late errors were observed in the present study. Differences were also noted in the performance of males and females. The late errors seen for each grammatical category have been summarized in the tables below for comprehension and expression tasks:

Table 2. Age group and the details of grammatical structures which showed regression in males and females for comprehension task

Males			Females		
Grammatical structure	Percentage score in previous group	Percentage score acquired in group where regression occurred	Grammatical structure	Percentage score in previous group	Percentage score acquired in group where regression occurred
Person	VI (100)	VII (95)	Adjectives	V (95)	VI (69.99)
Post positions	V (100)	VI (80)	Tense	IV (90)	V (50)
Tense	VI (90)	VII (50)	Coordinated sentences	VI (100)	VIII (66.66)
Yes-no	V (100)	VI (90)	Number	VI (83.33)	VII (70)
Transitive/ Intransitive verbs	V (100)	VI (90)	Wh questions	IV (90)	V (75)
Determiner	V (80)	was completely absent in group VI	Causatives	V (100)	VI (80)

Table 3. Age group and the details of grammatical structures which showed regression in males and females for expression task

Adjectives	V (85)	VI (66.66)	Simple sentences	IV (100)	V (59.99)
Post-positions	V (100)	VI and VII completely absent	Person	IV (100)	V (79.99)
Tense markers	V (100)	VI (85)	Tense markers	VI (95)	VII (86.66)
Wh questions	V (90)	VI (65)	Yes-no questions	VI (55)	absent in VII
Negatives	V (100)	VI (90)	Gender	V (90)	VI (85)
Coordinated sentences	V (90)	absent in group VI			
Gender	VI (100)	VIII (82.50)			
Causatives	VI (100)	VIII (80)			

Table 2 and Table 3 show the age groups and the particular grammatical structures where the regression occurred. The numbers in the parentheses indicate the mean percentage score obtained by the group.
The appearance of late errors is an indication that children have not fully mastered the conventional meanings of words. According to Bowerman (1982b), children apparently use error free forms for as much as a year or two, and then start to produce occasional errors. These errors arise as children analyze the meanings of the relevant forms in a greater detail. They start reorganizing their parts of lexicon and a concrete concept is formed. From the findings of the present study, it can be inferred that the process of assimilation and accommodation takes place in the young child. So, one has

to be careful not to attribute full adult like knowledge of word and construction of meanings to children too soon. Appropriate use in one context does not necessarily suggest mastery of the adult meaning. But a consistent adult like use across a range of contexts is a stronger indication of acquisition.

4. Conclusions

The present study brings out the fact that apparent regression is a normal phenomenon in the process of language acquisition of any neuro-typical child by pointing out at some late errors during the developmental acquisition of grammatical categories in Hindi speaking children in the age range of 1-5 years. The findings of the study suggest that interpretation of result of tests during preschool period should be carried out with caution. It could be a normal process of in the development of language acquisition rather than a developmental delay.

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