DOI: 10.17469/O2106AISV000022

CLAUDIO ZMARICH, ERICA BONATO, ROBERTO BOVO,
VINCENZO GALATÀ, ALESSANDRA PINTON

A new phonological discrimination test for children aged 48-72 months[1]

This contribution is part of a wider project aiming at the creation of a phonological discrimination test for preschool subjects (48- to 72-months-old). Children with primary language impairment are usually affected by deficits in speech production and/or in the phonological representation of speech sounds causing discrimination disorders. The proposed test is designed to evaluate the ability to discriminate pairs of non-words through a "same/different" judgment. The test items combined in pairs examine all the possible contrasts' simplifications (i.e. "phonological processes") that may accompany the speech production of typical developing preschool children even if these processes are not always (and all) present during language development, and even if there is currently no consensus in the literature on which processes belong to typical or atypical development.

Key words: child language development, speech perception, non-words discrimination, phonological processes, AX testing.

1. *Introduction*

1.1 The development of speech perception and its clinical implications

We know from the literature that: i) a correct perception (and production) of the sound system of a language is the *sine qua non* condition to be able to access the other levels of the spoken language (Saffran, Werker & Werner, 2006; Werker, 2018); ii) speech and language disorders with a phonetic-phonological component are an important, if not the main, portion of the caseloads of pediatric speech language therapists (Law, Boyle, Harris, Harkness & Nye, 2000; Joffe, Pring, 2008; Eadie, Morgan, Ukoumunne, Ttofari Eecen, Wake & Reilly, 2015).

A vast body of literature has shown the role of auditory discrimination in language disorders, both in children and in adolescents (Sussman, Steinschneider, Lee & Lawson, 2015; Kujala, Leminen, 2017). Some authors hypothesize that the underlying cause to such disorders has to be sought in a deficit in the auditory elaboration of the rapid formant transitions determining the difficulty to quickly process the input (Tallal, 1980; Moore, Rosenberg & Coleman, 2005). Other authors, on the other hand, claim that these disorders are determined by a deficit in the ability to represent the phonological form in a stable and well-formed manner: the per-

[1] Authorship note: while the paper is the result of a joint collaboration and discussion between the five authors, the main research idea is to be attributed to CZ, VG and AP.

formance of these children is influenced by the degree of phonological similarity leading to significant difficulty in the discrimination of minimal pair stimuli (opposed in terms of place, manner and sonority in both a silence and noise condition), rather than by the rapid spectral change in the components of the auditory signal (Ziegler, Pech-Georgel, George & Lorenzi, 2011; Nittrouer, Shune & Lowenstein, 2011; Leybaert, Macchi, Huyse, Champoux, Bayard, Colin & Berthommier, 2014). According to others, these difficulties would be the core of specific language disorders and would represent the link to the risk of learning disorders to which they are so frequently associated (e.g. Vandewalle, Boets, Ghesquière & Zink, 2012).

According to Preston, Irwin & Turcios (2015) the perception of acoustic details is important as they are eventually mapped onto phonological and motoric representations that govern speech production. This information is also clinically relevant and many clinical remedial interventions tackling speech sound disorders exploit perception (e.g. Hodson, 2010; Bowen, 2014; Williams, McLeod & McCauley, 2010; Rvachew, Brosseau-Lapré, 2012; Kaiser, Scherer, Frey & Roberts, 2017) in order to facilitate an accurate production of speech sounds. As reported by Lof and Synan (1997), the possible simultaneous occurrence of speech perception problems is known since a quite long time in the articulation/phonology literature: as stated in early clinical writings by Van Riper (1939), "all children with speech sound production errors should routinely have their discrimination tested by having them compare the clinician's imitation of the misproduced sound to a correct production" (Lof, Synan, 1997: 63).

Although both electrophysiological (Gonçalves, Wertzner, Samelli & Matas, 2011) as well as brain imaging studies (Preston, Felsenfeld, Frost, Mencl, Fulbright, Grigorenko, Landi, Seki & Pugh, 2012) have evidenced underlying neural abnormalities in auditory and perceptual speech processing of children with phonological disorders, these techniques are clinically impractical. Hence, it is important to determine if behavioural measures of speech perception can sensitively support the identification of perceptual differences in school-age children with phonological disorders. Speech perception differences could include problems at different levels such as sound discrimination, categorical perception, and goodness judgments of phonetically acceptable and unacceptable productions of words with reference to the speaker's native language and dialect. A speech sound discrimination task typically requires children to recognize differences between phonetically similar items; a task based on categorical perception requires the child to classify synthetic speech tokens into phoneme categories; goodness judgement tasks require children to determine if a token is phonetically acceptable or unacceptable for a given category (Preston et al., 2015). Since we chose to test speech sound discrimination in 4- to 6-years-old children, we will briefly describe what is currently known about the speech perceptual capacities of children of these ages and the characteristics of a speech discrimination task.

1.2 The perceptual skills of pre-school children

The development of speech perception abilities in children up to 5 years of age is documented by a huge amount of literature (for some recent surveys the interested reader is referred to Choi, Black & Werker, 2018; Kuhl, Conboy, Coffey-Corina, Padden, Rivera-Gaxiola & Nelson, 2008; Saffran et al., 2006; Walley, 2005; Werker, 2018). We focus here on 4- to 6-years-old pre-school children because this is the age-range at which it is possible to gather reliable responses by applying adult-like testing. Starting with the ability to process the acoustic dimensions of speech, Jensen, Neff (1993) demonstrated that children tested at 4 years of age and re-tested 12-18 months later, improved speech discrimination skills beginning with variations in intensity, followed by changes in frequency and finally by changes in duration. However, at the final assessment, for many of them, discrimination in the domain of frequency and duration was still poorer than adults' discrimination. This delay in sensitivity maturation with reference to temporal information is due to both a central level processing and a working memory capacity. From a developmental point of view, the perception of consonants is, generally speaking and until 5-6 years of age, less categorical in nature and more influenced by the context with respect to adults' perception. According to Walley (2005), all these outcomes are compatible with the hypothesis that 4- to 5-years-old children are more dependent from a global and syllabic representation of speech rather than from a segmental one.

1.3 Phonological discrimination tests

In broader terms, phonological discrimination refers to that process of categorical perception through which differences that unfold along a physical continuum (of frequency, intensity, duration) are traced to discrete categories. Phonological discrimination represents an essential part of a normal speech perception development and systematically improves till 10 years of age (Edwards, Fox & Rogers, 2002), although the cornerstones for a correct discrimination are already laid down by the age of five (Tamashige, Nishizawa, Itoda, Kasai, Igawa & Fukuda, 2008). The children's normal development can fortunately be tested starting from age 4-5 by using the same methods used for adults (Polka, Jusczyk & Rvachew, 1995). Phonological discrimination tests represent an important procedure for assessing proficiency in speech acquisition, and any alteration in the ability to discriminate "similar" sounds could contribute to unveil the onset of speech and/or language disorders (Lof, Synan, 1997; Pascoe, Rossouw, Fish, Jansen, Manley, Powell & Rosen, 2016).

Phonological discrimination tests may vary with respect to both the form and the content (Vance, Rosen & Coleman, 2009). Regarding the form, i.e. the procedural paradigm used to test the phonological discrimination skills, the AX or "same/different" paradigm is to be preferred, notwithstanding a possible bias towards a "same" judgment (see Gerrits, Schouten, 2004, although their subjects were adults), because of less taxing the working-memory of the younger children in comparison to more sophisticated designs (Polka et al., 1995). Regarding the content, non-words (vs. words) stimuli are to be preferred because they are independent from previous lexical knowledge, thus engaging only the perceptual system and/or the phonological memory, but not the lexical/semantic system. Anyway, according to McAllister Byun (2015), by 5 years of age the children's discrimination skills are essentially adult-like.

It is important to emphasize the distinction between the ability to discriminate two sounds (minimal pairs) from the ability to use this contrast in a phonologically relevant way (to learn new sounds), since the two skills can have different time courses. In fact, production errors in older children who have a speech disorder may reflect either motor problems or an inadequate phonemic representation (Rvachew, Ohberg, Grawburg & Heyding, 2003; Gierut, 1998; Pascoe et al., 2016; Stackhouse, Pascoe & Gardner, 2006). At present, the question of how linguistic perception and production are interrelated is still unresolved. During development, it is possible that the child perceives speech at almost the adult level, but that he does not yet have the motor skills to achieve a certain target (McAllister Byun, Tiede, 2017). On the other hand, it is possible that the child has adequate motor skills, but still a too wide auditory-perceptive representation of the target, with the consequence of not being able to receive the error feedback that would lead him to modify his motor planning (Shiller, Rochon, 2014).

Regrettably, the understanding of the perception-production link in speech acquisition is hampered by the theoretical and historical division, since the first 70s, of the research field into two separate traditions, which Dunbar, Idsardi (2010) call as "Child Phonology", and "Infant Child Perception". The first one is embraced by the linguists' community and originated by the pioneering studies on speech production by Jakobson (1941, but first published in English in 1968), as documented by parents' diaries. The second one is embraced by most developmental psychologists and could be traced to the seminal work of Eimas, Siqueland, Jusczyk & Vigorito (1971) who shifted the focus from observational studies of production to laboratory work in perception. These two traditions elaborated different views about the primitives of phonology, the phonological features. According to the traditional linguistic theory, the distinctive features are viewed as abstract cognitive entities that characterize a certain sound in the mind of the speaker/listener (Chomsky, Halle, 1968), and they are generally be assumed to be part of universal grammar, the innate language faculty underlying chomskyan generative theory. The innateness' assumption exempted the linguists from looking for a natural history of features acquisition, but most of the developmental psychologists, together with the functional linguists, have provided serious challenges to this view, by arguing that features are learned and language specific, rather than innate and universal. In a sense, they are inherent, since they are biologically grounded as opposed to arbitrary, but as emergent from an intricate interplay among auditory-acoustic input signal, the child's developing cognitive capacity and the developing articulatory capacity: they do not stand as pre-experiential cognitive given (Menn, Vihman, 2011).

In considering the acquisition of phonological features, it is necessary to acknowledge that they perform two main functions:

- "distinctive" (Cristià, Seidl & Francis, 2011) or "lexical" (Ridouane, Clements, 2011): they are used to distinguish sounds in lexical contrast with each other (i.e. an acoustic difference can lead to a change in meaning, as shown by minimal pairs: e.g. It. /ˈpane/, Eng. "bread" ~ It. /ˈkane/, Eng. "dog");
- "classifying" (Cristià et al., 2011) or "phonological" (Ridouane, Clements, 2011): they determine the classes of sounds based on common characteristics, which may be subject to the same phonological rule. 7- to 9-months-old children quickly learn phonotactic patterns in auditory input and generalize the constraints to new sequences, although phonetic similarity is probably necessary to form a sound category (Saffran, Thiessen, 2003; Cristià et al., 2011).

One of the best evidences that features do not depend on the presence of minimal pairs in the to-be-learned child's lexicon but on the environment instead, comes from their relative acoustic salience which makes them more easily discriminable: for instance, while voiced and voiceless stops are discriminated by 1 to 4 months of age (Eimas et al., 1971), the contrast between a stop and a voiced dental fricative is still undergoing development at 10-12 months (Polka, Colantonio & Sundara, 2001). Furthermore, the fact that 14-months-old children are not able to learn minimal pairs differing in voicing (Stager, Werker, 1997) underlines the importance of distinguishing the ability to discriminate two sounds from the ability to use this contrast in a phonologically relevant manner.

We would like to conclude this paragraph by quoting the final summary by Cristià et al. (2011: 14): "experimental research in infancy does not support the hypothesis that a single construct, an abstract phonological feature set, underlies speech sound discrimination, sound pattern learning, and word learning. On the contrary, this research suggests a separation between discrimination of acoustic contrasts, the distinctive function, and the classificatory function of features [...]".

A more in-depth understanding of the relationships between perception and production in the course of development would help better understand the enormous variability of production capacity observed in children. A logical way to investigate this relationship is to provide measures of speech perception and production within the same child, and we adopted this strategy.

1.4 The need for a new phonological discrimination test

We started our endeavour in the creation of this test moving from the consideration that existing tests for Italian do not evaluate the phonological discrimination of late pre-schoolers (e.g. 48- to 72-months-old) in a satisfactory way. To be precise, there are only two norm-referenced tests that make use of non-words' pairs in an AX paradigm. These tests are proposed as a part of a battery (BVN 5-11, Tressoldi, Vio, Gugliotta, Bisiacchi & Cendron, 2005, also in Pinton, Zanettin, 1998; CMF, Marotta, Trasciani & Vicari, 2008), but they present a number of problems that can be summarised as follows:

- they do not systematically test all the phonological contrasts of Italian nor do they adopt a selection of the most significant contrasts to test the children's phonological abilities with reference to their age;
- there is no apparent attention to the phonetic context;
- the length opposition is not tested;
- it is not clear how the consonantal groups are evaluated;
- the administration procedure is neither automated nor randomized;
- the tests are not proposed in a playful way (or at least no further indication is provided on how to propose the test to the children);
- the verbal stimuli have to be pronounced anew each time by the clinician/therapist (i.e. they are not pre-recorded as they are in Pinton, Zanettin, 1998);
- the test items are written in orthography rather than in IPA.

By capitalizing on advantages and disadvantages of these previous tests and moving from a preliminary test prepared and used by Galatà and Zmarich (2011a; 2011b) to investigate the phonological discrimination of immigrant children acquiring Italian as L2, we started to elaborate a brand new test.

2. *Experimental section*

2.1 The rationale behind the new phonological discrimination test and its implementation

The proposed test development consists of two sets. The first set of stimuli is based on contrasts involving processes causing *systemic* simplifications (see, among many others: Grunwell, 1987: 221; Pinton, 2018: 105-110). These processes hold this name because they mainly consist of phones' substitution, the final effect being the reduction of the phonological inventory/system. The second set of stimuli is based on contrasts involving processes effecting *structural* simplifications (Grunwell, 1987: 212; Pinton, 2018: 105-110). These processes hold this name because they mainly consist in phones' harmony or phones' addition/deletion, the final effect being the alteration of the original phonological shape/structure. The test follows the AX paradigm (more on this later) with test items proposed in pairs. For each set, a number of control stimuli pairs have also been devised (with completely equal or completely different pair members), in order to individuate and exclude those children who are not able to accomplish the task. To this regard, a pre-test session precedes both test sets with the aim of familiarizing the children with the task.

The first set consists of 40 minimal pairs with 'VCV non-words, testing all the 10 distinctive features of the Italian phonological system (as exposed by Schmid, 1999: 134) involved in as many *systemic* processes (each process is tested with four pairs of stimuli):

1. Gliding [±consonantal]
2. Stopping/Liquid [±sonorant]
3. Stopping/Frication [±continuous]

4. Affrication/Deaffrication [±delayed released]
5. Devoicing/Voicing [±voice]
6. Nasalization/Denasalization [±nasal]
7. r/l - l/r Substitution [±lateral]
8. Fronting/Backing [±coronal]
9. Fronting/Backing [±anterior]
10. Fronting/Backing [±posterior]

Each distinctive feature is represented by two different consonant pairs for each of the two vocalic contexts (ˈaCa, ˈiCi), with each pair opposing a [+*feature*] consonant against a [–*feature*] consonant. Crucially, the two pairs make use of consonants which are different one from another but at the same time are sharing the same featural opposition, as in the case [+continuous] ~ [−continuous]. If we postulate the first consonant to be the target, and the second to be the output of a phonological process, the phonological process in the examples provided in (1) is called *stopping*:

(1) /ˈasa/~/ˈata/; /ˈisi/~/ˈiti/; /ˈava/~/ˈaba/; /ˈivi/~/ˈibi/

In this way we can be more confident that the child's response will depend on the common feature shared by the consonants rather than on the consonants *per se*.

The second set consists of 56 non-words' minimal pairs testing 14 *structural* processes (four pairs of stimuli for each process):

1. Weak syllable deletion;
2. Consonant omission;
3. Vowel omission;
4. Consonant metathesis;
5. Syllable metathesis;
6. Epenthesis;
7. Diphtong reduction;
8. Consonant harmony;
9. Vowel harmony;
10. Voiceless assimilation;
11. Degemination;
12. Homosyllabic cluster reduction (from 3 to 2 consonants);
13. Homosyllabic cluster reduction (from 2 to 1 consonant);
14. Heterosyllabic cluster reduction (from 2 to 1 consonant).

Each of the 14 processes is represented in two different pairs for each of the different vocalic contexts /a/ or /i/, with each pair opposing a target against the same target as affected by a particular process. The examples in (2) are relative to the process of homosyllabic cluster reduction (from 2 to 1 consonant):

(2) /ˈspata/~/ˈpata/; /ˈprata/~/ˈpata/; /ˈspiti/~/ˈpiti/; /ˈpriti/~/ˈpiti/

As written before, the particular system of distinctive features that we chose for describing Italian is the one presented by Schmid (1999), which adapted the theoretical framework proposed by Chomsky and Halle (1968) to Italian. Since our aim is to assess the children's perception of stimuli mirroring the typical articulatory distortions produced by late pre-schoolers, the nature of the distinctive features has to be articulatory based as in the Chomsky and Halle system.

As for the stimuli testing the *systemic* phonological processes, given that each phonological process describes a pattern of error that involves groups of phonemes sharing a critical feature (the one that defines a certain natural class, based on articulatory features), for the selection of the four consonants (two for each vocalic context) among the many potentially eligible which represent that class, we chose the consonants that:

- within each pair, are in opposition (+/–) possibly on just the articulatory feature defining the particular process, and at the same time are acoustically as similar as possible (on the basis of Jakobson's distinctive features, adapted for Italian by Muljacic, 1972, and revised by Mioni, 1983);
- do not give origin to real words;
- whenever possible, are nor marked for frequency in the language (Goslin, Galluzzi & Romani, 2014) neither for age of acquisition (Zanobini, Viterbiori & Saraceno, 2012).

The last two criteria were also used to create the stimuli testing the *structural* processes, with a supplementary criterion dictated by the particular complexity of some stimuli, as for example for the process of *weak syllable deletion* in (3):

(3) /pakaˈpata/~/kaˈpata/; /pikiˈpiti/~/kiˈpiti/; /fakaˈfata/~/kaˈfata/; /fikiˈfiti/~/kiˈfiti/

This additional criterion requires all the consonants constituting the stimuli not to be marked on a distinctive feature which is not involved in the process and which is shared by the consonants: for instance, all the consonants have to be equal for the [±voice] feature by taking the "–" (minus) value. In fact, the unvoiced (not aspirated) consonants are less marked than the voiced ones because they are more frequent in the languages of the world, less articulatory complex and learned earlier by the children.

A final criterion common to both *systemic* and *structural* processes, requires that each pair of stimuli must test a single process (i.e. the same pair cannot be used to test two different processes). This is necessary to avoid interpretation ambiguity in case of children failing the discrimination of the proposed pair.

Before moving further, we would like to clarify and address an important methodological *caveat*. We are perfectly aware that if a child does not distinguish two stimuli which are different, one cannot determine through the discrimination test alone the direction of the assimilation: for instance, confusion between [+continuous]~[–continuous] stimuli could be due to a perception of both consonants as stops (e.g. *stopping*) or fricatives (e.g. *frication*). To individuate the source of misperception, this test needs to be integrated with other tests: our project includes the use of an articulation test (see paragraph 2.2) which can offer an indication about the articulation errors in production, but in the next future we foresee the use of a forced choice word perception test, to further selectively investigate the critical features or processes evidenced by the test we propose here.

The test stimuli were recorded in a soundproof cabin and were pronounced aloud within a carrier sentence by the second author[2]. Each of the test stimuli has then been isolated and normalized for intensity by means of Praat. A list of test pairs was compiled for both sets and implemented by the fourth author by means of Praat's *ExperimentMFC* object in order to facilitate the administration and responses collection on a notebook. The stimuli pairs in each set (with the two members of each pair separated by one second silence and the target stimuli always in the same position) were automatically randomized and proposed to the children in a playful setting using two puppets from a popular story (i.e. the *Talking Cricket*, It. "il Grillo Parlante", and *Pinocchio*, see Figure 1). The experimenter presented the test to the children as follows: «Now I'll introduce you to two characters. This is the *Talking Cricket* (indicate): he is very good at saying words, especially when the word is "magic". This, instead, is *Pinocchio* (indicate): he wants to learn to speak like the *Cricket*, and to learn the magic words pronounced by the cricket. Let's see if he's good. Now the *Cricket* will say a word and *Pinocchio* will repeat it: if he says the word correctly, you will tell him *Bravo!* and you will give him a token». Alternatively, depending on the child, the answer requested after listening to the two items was one of the two options: "right/wrong" (e.g. «Was the word repeated by *Pinocchio* right or wrong?»), or "same/different" (e.g. «Did *Pinocchio* repeat the same word or a different one?»). In some cases, we also used small coloured cards, on which the features of a smiling face were drawn, as a means by which the child could express his own judgment of equality between the pair's non-words. Before starting with the experimental session, the child was asked to listen and to answer to some "easy" stimuli pairs consisting of real words in order to accustom him/her to the task, followed by some instances of non-words, exemplifying the presence of *systemic* as well as *structural* processes.

Figure 1 - *The setting of the test administration*

[2] In Gaiotto (2016) we experimentally tested and verified the usage of both synthetic and natural stimuli in a preliminary version of the proposed discrimination test. We found normal stimuli to be superior to synthetic stimuli created by a dynamically generated voice using the Mivoq Voice Synthesis Engine2 (which represents the state of the art of Italian synthesis; Tesser, Sommavilla, Paci & Cosi, 2016): children better perceive normal over synthetic stimuli.

Once the child declared to be ready, and was judged so also by the experimenter, the test started with the presentation of the experimental pairs. For each proposed pair the experimenter registered the child's answer by pushing one of two predefined keys ("same/different") on the notebook. If requested by the child, each proposed pair was played back again for no more than two times. If the child did not express any evaluation, the answer was given the "uncorrect" value, and the successive pair was proposed after a short break. After completing half of the list of item pairs, the procedure stopped for a short pause. At the end of the whole session, the experimenter saved and exported the collected responses to a text file. The whole procedure and administration setting were adapted from a previous project (see Galatà, Zmarich, 2011a, b; Galatà, Angonese & Zmarich, 2017).

2.2 Subjects, materials and procedure

The two sets of the test were administered by students graduating in speech therapy at the University of Padova to two groups of monolingual Italian children (balanced per gender) recruited and tested in various kindergarten in the Veneto region (Italy):

- the first group (56 subjects) was assessed with the first set of the test, namely the test for *systemic* processes (Bonato, 2016);
- the second group (61 subjects) was assessed with the second set of the test, namely the test for *structural* processes (Rossi, 2017; Marchetti, 2017; Degano, 2018).

According to their parents, who gave consent and compiled a questionnaire, all the children were normal under the psychophysical profile. Subsequently, the children were tested for hearing integrity through a *Starkey WRA* audiometer equipped with *Qualitone* headphones, and an illustration depicting a wooded landscape and some animals playing different instruments, attached to the instrument's flap cover. The test consisted of 9 stimuli, played to the children within a range of intensity between 20 and 60 dB with a 5 dB step for each of the following frequencies: 500, 1000, 2000 and 4000 Hz. Each child was invited to indicate when no sound was perceived anymore: the last perceived frequency was manually recorded as a threshold value. The hearing thresholds provided for exclusion from the sample were 40 dB for 500 Hz, 30 dB for 1000 Hz and 20 dB for 2000 and 4000 Hz. In a separate session all the children have also been tested with an articulation test (a modified version of Test Fonetico per la Prima Infanzia, TFPI, not published; see Zmarich, Fava, Del Monego & Bonifacio, 2012) during which they were asked to name a set of pictures. The data from the articulation test – not addressed here and used in a separate study – will be used to compare speech production and perception proficiency within each child.

The first half of each of the two groups was offered a test administration in two rounds: in the first round the audiometric test and the first part of the phonological discrimination test were performed, while in the second round the TFPI was performed – followed by the second part of the phonological discrimination test. For the second half of each of the two groups, the administration of the tests followed a reverse order: TFPI, first part of the phonological discrimination test, audiometric test and the second part of the phonological discrimination test.

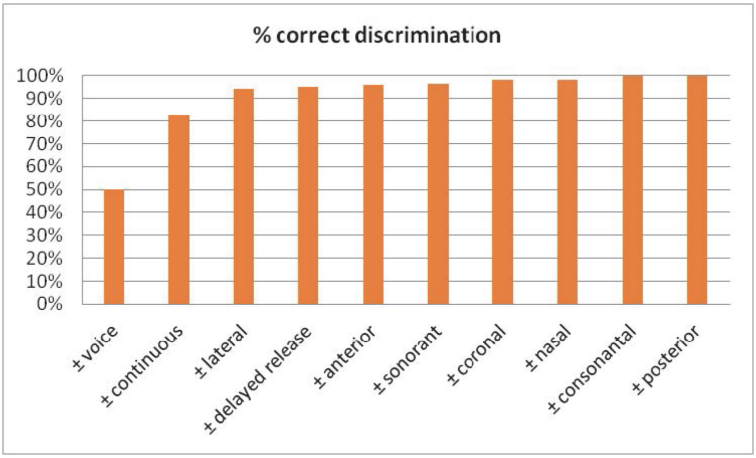
Two subjects were excluded from the first group because they did not understand the discrimination task. Three subjects were excluded for the same reason from the second group with an additional one excluded for non collaborative behavior. Moreover, a number of children exhibited some selected deficits to the audiometric test (11 for the first group, 15 for the second group). However, since none of the subjects showed deficits to both ears, nor to all frequencies, and since our study made use of stimuli in the open field, in this preliminary phase these subjects were included in the sample and coded with a special label for future analyses.

At the end, the number of children considered for the analyses were 54 subjects for the first group tested for *systemic* processes and 57 for the second group tested for *structural* processes.

2.3 Results

With reference to the analyses for the first test set (e.g. *systemic* contrasts), we considered distinctive features (ten levels, see Figure 2), age (four groups spanning six months each) and gender (male and female) as between variables and vocalic context as within variable in a repeated measures ANOVA. Percentage of correct discrimination for each feature was converted to arcsine scores (y = 2 arcsine √x) and entered as dependent variable. No significant differences were found for age group ($F_{3,80}$ = 1.859; p = .143) or gender ($F_{1,80}$ = 0.345; p = .558). Distinctive features resulted highly significant ($F_{9,80}$ = 18.687; p < .000).

Figure 2 - *Systemic phonological processes: discrimination percentages for distinctive features*



A post-hoc pairwise comparison test (with Tuckey correction for multiple comparisons) showed that [±voice] feature contrasted significantly (p < .001) with all the others. Indeed, this feature obtained only 50% of correct discrimination (see

Figure 2). The within-subject variable (vocalic context) resulted highly significant ($F_{1,80}$ = 30.793; p < .001): discrimination was almost overall better in /a/ context (93%) than /i/ context (87%). Furthermore, the vocalic context interacted significantly with the distinctive features ($F_{9,80}$ = 8.364; p < .000): a post-hoc pairwise comparison test (with Tuckey correction for multiple comparisons) showed for the continuous feature (and more specifically for /ˈava/~/ˈaba/; /ˈivi/~/ˈibi/) a reverse pattern for the vocalic context with the second pair better discriminated than the first one.

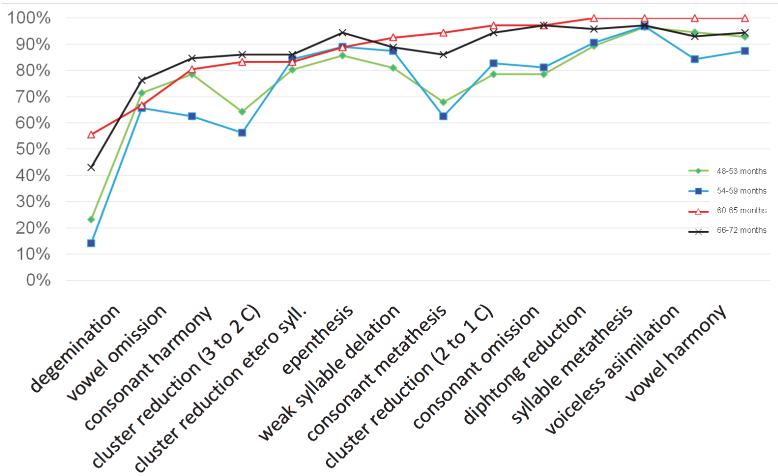
Since each distinctive feature is involved in a characteristic phonological process, a second repeated measures ANOVA was performed on the same scores as before as a dependent variable, this time considering phonological processes (seven levels) instead of features, and maintaining age (four groups spanning six months each) and gender (male and female) as between variables, with vocalic context as within variable. No significant differences were found for age group ($F_{3,104}$ = 1.890; p = .136) or for gender ($F_{1,104}$ = 0.122; p = .728). Phonological processes resulted significant ($F_{6,104}$ = 29.173; p < .001). A post-hoc pairwise comparison test (with Tuckey correction for multiple comparisons) showed that the *voicing* phonological process contrasted significantly (p < .001) with all the others. Adding to this, stopping contrasted significantly with backing (t_{104} = 3.285; p = .023) as well as with gliding (t_{104} = 3.139; p = .035). The within-subject variable (vocalic context) resulted significant ($F_{1,104}$ = 38.766; p < .001; discrimination was almost overall better in /a/ context than /i/ context), and the vocalic context interacted significantly with phonological processes ($F_{6,104}$ = 9.191; p < .000). A post-hoc pairwise comparison test (with Tuckey correction for multiple comparisons) showed that the *voicing* phonological process contrasted significantly (p < .001) with all the others in both vocalic contexts (/a/, /i/). Moreover, l/r substitution process in /a/ context contrasted significantly with the same process in /i/ context (t_{104} = 3.931; p = .011), with the /a/ stimuli better discriminated than the /i/ stimuli.

As a final exploration, we performed an ANOVA to determine whether the discrimination scores improved as a function of the number of distinctive features distinguishing the pairs' stimuli. The variables proved to be highly significant ($F_{3,316}$ = 29.483; p < .000), with the pairs having only one contrasting feature to be significantly different to all the others (p < .000, post-hoc pairwise comparison test with Tuckey correction for multiple comparisons). To this regard, the percentages of correct discrimination were 77.10% for one feature, 94.74% for two features, 100% for three features and 98.61% for four features.

With reference to the analyses for the second test set (e.g. *structural* contrasts), we factorized in an ANOVA statistical design the phonological processes (14 levels, see Figure 3), age (four groups spanning six months each) and gender (male and female) and their interactions. Percentage of correct discrimination was entered as dependent variable. Figure 3 shows the discrimination percentages for the 14 categories of *structural* phonological processes by age group.

For the *structural* contrasts tested with the second set of stimuli the following factors have been found statistically significant: phonological processes ($F_{13,686}$ = 26.299; p < .000), age ($F_{3,686}$ = 19.938; p < .000), gender by age interaction ($F_{3,686}$ = 9.148; p < .000). A Tukey's Honestly-Significant-Difference post-hoc test on phonological processes scores, using least squares means and MSE model of 0.463 with 686 *df*, allowed to discover that *degemination* scores were significantly lower than all other processes (p < .000); *vowel omission* was lower than *consonant omission* (p < .000), *diphthong reduction* (p < .000), *epenthesis* (p < .000), *syllable metathesis* (p < .000), *vowel harmony* (p < .000), *cluster reduction* (2-to-1 consonant) (p = .001) and *weak syllable deletion* (p = .003); *cluster reduction* (3-to-2 consonants) was lower than *diphthong reduction* (p < .000), *syllable metathesis* (p < .000), *voiceless assimilation* (p < .000), *vowel harmony* (p = .000), *epenthesis* (p = .020) and *consonant omission* (p = 0.021); *syllable metathesis* was higher than *consonant harmony* (p = .000), *consonant metathesis* (p < .000) and *heterosyllabic cluster reduction* (p = .011); *consonant harmony* was lower than *diphthong reduction* (p = .002), *vowel harmony* (p = .003) and *voiceless assimilation* (p = .004); *consonant metathesis* was lower than *vowel harmony* (p = .006) and *voiceless assimilation* (p = .009).

Figure 3 - *Structural phonological processes: discrimination percentages for categories by age group*



A Tukey's Honestly-Significant-Difference post-hoc test on the age variable, using least squares means and MSE model of 0.463 with 686 *df*, showed the first and the second group (respectively 48-53 months and 54-59 months) to be significantly different (p < .000) from the third and the fourth (respectively 60-65 months and 66-72 months). No significant difference was found for gender, whereas the vocalic context was not considered because not pertinent in a consistent proportion of stimuli pairs.

2.4 Discussion

Overall, considering the targeted age bands, *systemic* simplifications are managed better than *structural* ones. Comparing the performances of correct discrimination for *systemic* processes with those referred to *structural* processes in the whole sample of children, the resulting picture shows that *systemic* simplifications go beyond 90% of correctness (apart from those involving the [±voice] and [±continuous] features); analysing the *structural* simplifications, on the other hand, only four processes reach 90% of correctness (respectively *voiceless assimilation* 92.11%, *vowel harmony* 92.98%, *diphthong reduction* 93.42% and *syllable metathesis* 97.37%), with *degemination* obtaining only around 20% of correct responses for the first two age groups. The comparison of the children's performances across the different age bands (Figure 3) shows that the competences related to *structural* processes are under development given that the older children are significantly better than the younger ones. Anyway, by 5 years of age there are still a number of contrasts characterized by *degemination*, *cluster reduction (3-to-2 consonants)* and *consonant/vowel omission* that are not well discriminated by a consistent number of children.

The results from the discrimination of *systemic* processes reflect only partially what characterises production. From data on the phonetic inventory for Italian and for other languages, during typical development children seem to need more time to be able to properly master the [±voice] feature: studies on English, Canadian French and Italian show that voiceless stops, voiceless fricatives and voiceless affricates are mastered before the voiced homorganic ones (Dodd, Holm, Hua & Crosbie, 2003; McLeod, Sutton, Trudeau & Thordardottir, 2011; Zanobini et al., 2012; Viterbori, Zanobini & Cozzani, 2018; Zmarich, Bonifacio, 2005). However, perception and production don't seem to fully overlap. While voicing and devoicing processes in production are overcome by the children by the age of 3 and a half, in our sample these processes are not yet well discriminated. Affricates show the opposite case: even though they are mastered in production later with respect to other consonants' classes and the processes of affrication and deaffrication are present till older age, the discrimination of the opposition involving the [±delayed release] feature seems to be better mastered by the younger children in our sample. The question on which is the relation between perception and production remains open, e.g. whether there is a causal connection between the two or whether one of the two influences the other (McAllister Byun, 2015). A similar picture emerges if we observe the responses on the discrimination of some structural processes that can be compared to data on production in Scottish, English and Italian children (Cohen, Hodson, O'Hare, Boyle, Durrani, McCartney, Mattey, Naftalin, Watson, 2005; Dodd et al., 2003; Zanobini et al., 2012). While *cluster reduction* from 3-to-2 consonants at around 60 months of age seems to be problematic both in production and in perception (this process reaches 71.93% of correctness in our sample – ranging between 55 and 85% in the comparison across age groups – see Figure 3 – demonstrating that this process is still evolving), other processes seem to have a dissonant trend between production and perception. For example, according to the studies previously mentioned, the processes of *harmony* seem to disappear in production after 42 months of age, while in our sample children at 48 months of age (see Figure 3) show some weakness in the discrimination of contrasts involving *consonant harmony*.

Some children showed a reduced hearing threshold. However, their performance is on average fully in line with the performance of age matched peers. This demonstrates that the task we proposed to the children reflects a categorical perception: differently from auditory detection tasks, where the signal detection is achieved based upon the signal's intensity, in a discrimination task the recognition is based upon already mapped perceptual categories according to which distinctive features are detected even in noisy situations where the signal is degraded (see Ziegler et al., 2011).

3. *General discussion and conclusion*

The rationale and the choices adopted in the construction of the test can be so far be considered satisfactory allowing us to trace the path for future improvements of the test itself. In the following, we try to list a number of conclusions together with some questions still open.

The significant difference between the two vocalic contexts confirms the relevance of the vocalic context, at least for what concerns the discrimination of *systemic* contrasts. It is therefore relevant for a discrimination test to take into account such a factor.

As to the very low percentages of correctness for the *degemination* process, we can not exclude that this may be a consequence of the well known tendency to weaken the gemination contrast in production put in place by people living in the Veneto region (and therefore the children, too; see Telmon, 1997; Vietti, 2019).

Since we represented all the *systemic* and *structural* processes in a systematic way, based on the gathered data it is possible to identify those processes that better describe the children's abilities.

The structure of the proposed test was accepted by the children who fully accomplished the task (only 5 subjects have been excluded from the sample because of their scarce collaboration or non-comprehension of the proposed task): the possibility to use the test in its current form is confirmed and is in line with Polka et al. (1995) suggesting adult-like methods to test perceptual discrimination abilities in children.

However, the division of the current test in two parts, makes it a little cumbersome, long and potentially annoying the child, especially the younger ones. For this reason we are continuing working along the same lines described here to reduce the task load of the proposed test (currently about 20 + 20 minutes long) without reducing its validity and, according to preliminary results not addressed here, we are on the way to achieve a one session test lasting less than 30 minutes (Degli Agostini, 2019). Other aspects that need to be taken into consideration in future work are: i) whether the order of the target items in the pairs might have biased the results (the target items occurred always in the same position: for example, when testing the *structural* processes the "difficult" item was presented first and the "reduced" one next); ii) whether using the same voice for the stimuli could have biased the subjects' answers.

Future work is planned to further refine the proposed test as done in Degli Agostini (2019) by also increasing the number of children to be tested (including also children younger than 48 months of age and older than 72 months of age, as well as an adequate number of adults) and taking into account socioeconomic variables as well as geographical variables (e.g. regional variants of Italian) in order to be able to standardize the final and future version of the test. Additionally, we will consider the opportunity to run Mixed Effect Models rather than ANOVAs to incorporate the effect of the variability between subjects and item (random factors) in the model.

As already argued, since in case of speech errors it is not easy to ascribe them to production or perception factors, we started to investigate the correlations between the results from perception capacities (the present test) and production capacities (the phonetic test), by comparing for every child the mean percentage of correctness scores with the number of phones resulting from the phonetic inventory (Parisio, 2017; Boscolo-Nata, 2018). These results will be further addressed and proposed in future contributions.

Acknowledgments

To all the wonderful students (Alessia, Elisa, Erica, Lucia, Mariavittoria, Sabrina, Silvia M., Silvia B.N.) who graduated in Speech Therapy by using the present test and to all the children they administered it.

Bibliography

Bonato, E. (2016). La percezione fonologica in età pre-scolare. Costruzione e applicazione di un test di discriminazione uditiva. Tesi di Laurea in Logopedia, Università degli Studi di Padova.

Boscolo-Nata, S. (2018). Percezione e produzione fonetico-fonologica in età prescolare. Uno studio sperimentale. Tesi di Laurea in Logopedia, Università degli Studi di Padova.

Bowen, C. (2014). *Children's speech sound disorders*. Oxford: Wiley-Blackwell.

Choi, D., Black, A.K. & Werker, J.F. (2018). Cascading and multisensory influences on speech perception development. In *Mind, Brain, and Education*, 12(4), 212-223.

Chomsky, N., Halle, M. (1968). *The sound pattern of English*. New York: Harper & Row.

Cohen, W., Hodson, A., O'Hare, A., Boyle, J., Durrani, T., McCartney, E., Mattey, M., Naftalin, L. & Watson, J. (2005). Effects of computer-based intervention through acoustically modified speech (Fast ForWord) in severe mixed receptive—expressive language impairment: Outcomes from a randomized controlled trial. In *Journal of Speech, Language, and Hearing Research*, 48(3), 715-729.

Cristià, A., Seidl, A. & Francis, A. (2011). Phonological features in infancy. In Clements, N., Ridouane, R. (Eds.), *Where Do Phonological Features Come From? The nature and sources of phonological primitives*. Amsterdam: John Benjamins, 303-326.

Degano, A. (2018). Contrasti fonologici in età evolutiva: una prova di discriminazione uditiva. Tesi di Laurea in Logopedia, Università degli Studi di Padova.

Degli Agostini, L. (2019). Proposta di miglioramento di un nuovo test di discriminazione fonologica e sua verifica sperimentale. Tesi di Laurea in Logopedia, Università degli Studi di Padova.

Dodd, B., Holm, A., Hua, Z. & Crosbie, S. (2003). Phonological development: a normative study of British English-speaking children. In *Clinical Linguistics & Phonetics*, 17(8), 617-643.

Dunbar, E., Idsardi, W. (2012). The acquisition of phonological inventories. In Lidz J., Snyder W. & Pater J. (Eds.), *The Oxford Handbook of Developmental Linguistics.* Oxford: Oxford University Press, 7-26.

Eadie, P., Morgan, A., Ukoumunne, O.C., Ttofari Eecen, K., Wake, M. & Reilly, S. (2015). Speech sound disorder at 4 years: Prevalence, comorbidities, and predictors in a community cohort of children. In *Developmental Medicine & Child Neurology*, 57(6), 578-584.

Edwards, J., Fox, R.A. & Rogers, C.L. (2002). Final consonant discrimination in children: Effects of phonological disorder, vocabulary size, and articulatory accuracy. In *Journal of Speech, Language, and Hearing Research*, 45(2), 231-242.

Eimas, P.D., Siqueland, E.R., Jusczyk, P. & Vigorito, J. (1971). Speech perception in infants. In *Science*, 171(3968), 303-306.

Gaiotto, M. (2016). L'influenza della struttura acustica dello stimolo nella discriminazione fonologica in bambini di età prescolare. Tesi di Laurea in Logopedia, Università degli Studi di Padova.

Galatà, V., Zmarich, C. (2011a). Una proposta per valutare l'influenza fonetico-fonologica della lingua di origine dei bambini figli di immigrati sull'acquisizione dell'italiano. In Bruno, G.C., Caruso, I., Sanna, M. & Vellecco, I. (Eds.), *Percorsi migranti*. Milano: McGraw-Hill, 24, 301-317.

Galatà, V., Zmarich, C. (2011b). Le non-parole in uno studio sulla discriminazione e sulla produzione dei suoni consonantici dell'italiano da parte di bambini pre-scolari. In Gili Fivela, B., Stella, A., Garrapa, L. & Grimaldi, M. (Eds.), *Contesto comunicativo e variabilità nella produzione e percezione della lingua*. Atti del 7° convegno AISV, 26-28 Gennaio 2011, Università del Salento – Lecce. Roma: Bulzoni Editore, 118-129.

Gerrits, E., Schouten, M.E.H. (2004). Categorical perception depends on the discrimination task. In *Perception & psychophysics,* 66(3), 363-376.

Gierut, J.A. (1998). Treatment Efficacy: Functional Phonological Disorders in Children. In *Journal of Speech, Language, and Hearing Research,* 41, 85-100.

Gonçalves, I.C., Wertzner, H.F., Samelli, A.G. & Matas, C.G. (2011). Speech and non-speech processing in children with phonological disorders: an electrophysiological study. In *Clinics*, 66(2), 293-298.

Goslin, J., Galluzzi, C. & Romani, C. (2014). PhonItalia: a phonological lexicon for Italian. In *Behavior research methods*, 46(3), 872-886.

Grunwell, P. (1987). *Clinical Phonology*, 2° Ed.. London: Chapman & Hall.

Hodson, B. (2010). *Evaluating and enhancing children's phonological systems: Research and theory to practice*. Wichita, KS: Phonocomp Publishers.

Jakobson, R. (1941). *Kindersprache, Aphasie und allgemeine Lautgesetze*. Uppsala: Almqvist & Wiksell.

Jensen, J.K., Neff, D.L. (1993). Development of basic auditory discrimination in preschool children. In *Psychological Science*, 4(2), 104-107.

Joffe, V., Pring, T. (2008). Children with phonological problems: A survey of clinical practice. In *International Journal of Language & Communication Disorders*, 43(2), 154-164.

Kaiser, A.P., Scherer, N.J., Frey, J.R. & Roberts, M.Y. (2017). The effects of enhanced milieu teaching with phonological emphasis on the speech and language skills of young children with cleft palate: A pilot study. In *American journal of speech-language pathology*, 26(3), 806-818.

Kuhl, P.K., Conboy, B.T., Coffey-Corina, S., Padden, D., Rivera-Gaxiola, M. & Nelson, T. (2008). Phonetic learning as a pathway to language: new data and native language magnet theory expanded (NLM-e). In *Phil. Trans. R. Soc. B*, 363, 979-1000.

Kujala, T., Leminen, M. (2017). Low-level neural auditory discrimination dysfunctions in specific language impairment—a review on mismatch negativity findings. In *Developmental Cognitive Neuroscience*, 28, 65-75.

Law, J., Boyle, J., Harris, F., Harkness, A. & Nye, C. (2000). Prevalence and natural history of primary speech and language delay: findings from a systematic review of the literature. In *International Journal of Language and Communication Disorders*, 35, 165-188.

Leybaert, J., Macchi, L., Huyse, A., Champoux, F., Bayard, C., Colin, C. & Berthommier, F. (2014). Atypical audio-visual speech perception and McGurk effects in children with specific language impairment. In *Frontiers in psychology*, 5, 422.

Lof, G.L., Synan, S. (1997). Is there a speech discrimination/perception link to disordered articulation and phonology? A review of 80 years of literature. In *Contemporary Issues in Communication Science and Disorders*, 24(24), 63-77.

Marchetti, S. (2017). Processi fonologici in età evolutiva. Analisi della letteratura e costruzione di un test di discriminazione uditiva per l'età pre-scolare. Tesi di Laurea in Logopedia, Università degli Studi di Padova.

Marotta, L., Trasciani, M. & Vicari, S. (2008). *Test CMF. Valutazione delle competenze metafonologiche*. Trento: Erickson.

Mcallister Byun, T. (2015). Perceptual Discrimination across Contexts and Contrasts in Preschool-Aged Children. In *Lingua*, 160, 38-53.

Mcallister Byun, T., Tiede, M. (2017). Perception-Production Relations in Later Development of American English Rhotics. In *PloS one*, 12(2).

McLeod, A.A., Sutton, A., Trudeau, N. & Thordardottir, E. (2011). The acquisition of consonants in Québécois French: A cross-sectional study of pre-school aged children. In *International Journal of Speech-Language Pathology*, 13(2), 93-109.

Menn, L., Vihman, M.M. (2011). Features in child phonology: inherent, emergent, or artefacts of analysis? In Clements, N., Ridouane, R. (Eds.), *Where Do Phonological Features Come From? The nature and sources of phonological primitives*. Amsterdam: John Benjamins, 261-301.

Mioni, A. (1983). Fonologia. In Croatto, L. (Ed.), *Trattato di Foniatria e Logopedia, Vol. 2, Aspetti linguistici della comunicazione.* Padova: La Garangola, 51-87.

Moore, D.R., Rosenberg, J.F. & Coleman, J.S. (2005). Discrimination training of phonemic contrasts enhances phonological processing in mainstream school children. In *Brain and language*, 94(1), 72-85.

Muljacic Z. (1972). *Fonologia della lingua italiana*. Bologna: Il Mulino.

Nittrouer, S., Shune, S. & Lowenstein, J.H. (2011). What is the deficit in phonological processing deficits: Auditory sensitivity, masking, or category formation? In *Journal of experimental child psychology*, 108(4), 762-785.

Parisio, E. (2017), Studio sperimentale sulle relazioni tra produzione e percezione fonetico-fonologica in età pre-scolare. Tesi di Laurea in Logopedia, Università degli Studi di Padova.

Pascoe, M., Rossouw, K., Fish, L., Jansen, C., Manley, N., Powell, M. & Rosen, L. (2016). Speech processing and production in two-year-old children acquiring isiXhosa: A tale of two children. In *South African Journal of Communication Disorders*, 63(2), 1-15.

Pinton, A. (2018). *I disturbi fonetici e fonologici nell'età dello sviluppo.* Roma: Carocci.

Pinton, A., Zanettin, F. (1998). Le abilità fonetiche e fonologiche in età prescolare. Un compito di discriminazione uditiva. In Frasson, S., Lena, L. & Menin, S. (Eds.), *Procedure e metodi di trattamento nei disordini della comunicazione*. Pisa: Del Cerro, 130-142.

Polka, L., Colantonio, C. & Sundara, M. (2001). A cross-language comparison of/d/–/ð/perception: evidence for a new developmental pattern. In *The Journal of the Acoustical Society of America*, 109(5), 2190-2201.

Polka, L., Jusczyk, P.W. & Rvachew, S. (1995). Methods for studying speech perception in infants and children. In Strange, W. (Ed.), *Speech perception and linguistic experience: Theoretical and methodological issues in cross-language speech research.* Timonium (Md): York Press, 49-89.

Preston, J.L., Felsenfeld, S., Frost, S.J., Mencl, W.E., Fulbright, R.K., Grigorenko, E.L., Landi, N., Seki, A. & Pugh, K.R. (2012). Functional brain activation differences in school-age children with speech sound errors: speech and print processing. In *Journal of Speech, Language, and Hearing Research*, 55(4), 1068-1082.

Preston, J.L., Irwin, J.R. & Turcios, J. (2015). Perception of speech sounds in school-aged children with speech sound disorders. In *Seminars in speech and language*, 36(4), 224-233.

Ridouane, R., Clements, G.N. (2011). Editors' overview. In Clements, N., Ridouane, R. (Eds.), *Where Do Phonological Features Come From? The nature and sources of phonological primitives*. Amsterdam: John Benjamins, 3-11.

Rossi, S. (2017). Processi fonologici in età evolutiva. Uno studio di discriminazione uditiva in età pre-scolare. Tesi di Laurea in Logopedia, Università degli Studi di Padova.

Rvachew, S., Brosseau-Lapré, F. (2012). An input-focused intervention for children with developmental phonological disorders. In *Perspectives on Language Learning and Education*, 19(1), 31-35.

Rvachew, S., Ohberg, A., Grawburg, M. & Heyding, J. (2003). Phonological awareness and phonemic perception in 4-year-old children with delayed expressive phonology skills. In *American Journal of Speech-Language Pathology*, 12, 463-471.

Saffran, J.R., Thiessen, E.D. (2003). Pattern induction by infant language learners. In *Developmental psychology*, 39(3), 484.

Saffran, L.R., Werker, J.F. & Werner, L. (2006), The infant's auditory world: hearing, speech, and the beginnings of language. In Kuhn D., Siegler R. (Eds.), *Handbook of Child Psychology*, 6th edn, vol. 2: *Cognition, Perception, and Language*. New York: Wiley, 58-108.

Schmid, S. (1999). *Fonetica e fonologia dell'italiano*. Torino: Paravia Scriptorium.

Shiller, D.M., Rochon, M.L. (2014). Auditory-perceptual learning improves speech motor adaptation in children. In *Journal of Experimental Psychology: Human Perception and Performance*, 40(4), 1308-1315.

Stackhouse, J., Pascoe, M. & Gardner, H. (2006). Intervention for a child with persisting speech and literacy difficulties: A psycholinguistic approach. In *Advances in Speech Language Pathology*, 8(3), 231-244.

Stager, C.L., Werker, J.F. (1997). Infants listen for more phonetic detail in speech perception than in word-learning tasks. In *Nature*, 388(6640), 381.

Sussman, E., Steinschneider, M., Lee, W. & Lawson, K. (2015). Auditory scene analysis in school-aged children with developmental language disorders. In *International Journal of Psychophysiology*, 95(2), 113-124.

Tallal, P. (1980). Auditory temporal perception, phonics, and reading disabilities in children. In *Brain and language*, 9(2), 182-198.

Tamashige, E., Nishizawa, N., Itoda, H., Kasai, S., Igawa, H.H. & Fukuda, S. (2008). Development of Phonemic Distinction in Japanese Preschool Children. In *Folia Phoniatrica et Logopaedica*, 60(6), 318-322.

Telmon, T. (1997). Varietà regionali. In Sobrero, A.A. (Eds.), *Introduzione all'italiano contemporaneo, Vol. II. La variazione e gli usi.* Bari: Laterza, 93-149.

Tesser, F., Sommavilla, G., Paci, G. & Cosi, P. (2016). Automatic Creation of TTS Intelligibility Tests. In Savy, R., Alfano, I. (Eds.), *La fonetica sperimentale nell'insegnamento e nell'apprendimento delle lingue straniere.* Studi AISV 2, Milano: AISV, 289-304.

Tressoldi, P.E., Vio, C., Gugliotta, M., Bisiacchi, P.S. & Cendron, M. (2005). BVN 5-11: *Batteria di valutazione neuropsicologica per l'età evolutiva*. Trento: Erickson.

Van Riper, C. (1939). *Speech Correction: Principles and Methods*. Englewood Cliff (NJ): Prentice-Hall.

Vance, M., Rosen, S. & Coleman, M. (2009). Assessing speech perception in young children and relationships with language skills. In *International Journal of Audiology*, 48(10), 708-717.

Vandewalle, E., Boets, B., Ghesquière, P. & Zink, I. (2012). Auditory processing and speech perception in children with specific language impairment: Relations with oral language and literacy skills. In *Research in Developmental Disabilities*, 33(2), 635-644.

Vietti, A. (2019). Phonological variation and change in Italian. In *Oxford Research Encyclopedia of Linguistics*. Oxford: Oxford University Press.

Viterbori, P., Zanobini, M. & Cozzani, F. (2018). Phonological development in children with different lexical skills. In *First Language*, 38(5), 538-559.

Walley, A.C. (2005). Speech Perception in Childhood. In Pisoni D.B., Remez R.E. (Eds.), *The Handbook of Speech Perception.* UK: Blackwell Publishing, 449-468.

Werker, J.F. (2018). Perceptual beginnings to language acquisition. In *Applied Psycholinguistics*, 39(4), 703-728.

Williams, A.L., McLeod, S. & McCauley, R.J. (2010). *Interventions for Speech Sound Disorders in Children*. Baltimore, MD: Brookes Publishing Company.

Zanobini, M., Viterbori, P. & Saraceno, F. (2012). Phonology and language development in Italian children: An analysis of production and accuracy. In *Journal of Speech, Language, and Hearing Research*, 55(1), 16-31.

Ziegler, J.C., Pech-Georgel, C., George, F. & Lorenzi, C. (2011). Noise on, voicing off: Speech perception deficits in children with specific language impairment. In *Journal of experimental child psychology*, 110(3), 362-372.

Zmarich, C., Fava, I., Del Monego, G. & Bonifacio, S. (2012). Verso un "Test Fonetico per la Prima Infanzia". In Falcone, M., Paoloni, A. (Eds.), *Atti dell'8° convegno nazionale AISV*. Roma: Bulzoni Editore, 25-27.

Zmarich, C., & Bonifacio, S. (2005). Phonetic inventories in Italian children aged 18-27 months: a longitudinal study. In *Interspeech*, 757-760.