Filozofická fakulta Univerzity Palackého

Foreign Speech Sound Perception with Dyslexia

(Diplomová práce)

2017 **Eliška Spilková**

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V Olomouci dne 13.12.2017 **Eliška Spilková**

Motto *Hledejte především Boží království a jeho spravedlnost, a všechno ostatní vám bude přidáno.*

Bible, Matouš 6:33

Děkuji vedoucímu diplomové práce panu doktoru Podlipskému za pomoc a cenné rady, laskavost a trpělivost při zpracování diplomové práce. Velký dík patří mému snoubenci, rodině a přátelům za veškerou podporu. Nejvíce jsem však vděčná Bohu, který je mojí nadějí, motivací a silou.

V Olomouci dne 13.12.2017 **Eliška Spilková**

Abstract

This thesis provides a literature review on the topics of native and foreign speech perception in typically-developing population and in the population impaired with developmental dyslexia. Studies have demonstrated that because of a deviance in the speech perception development, dyslexics do not perceive sounds on the basis of phoneme categories like the typical population, but rather on the basis of allophones. In the field, there is a lack of research which would suggest implications of the phenomenon for L2 perception in individuals suffering from dyslexia. The thesis contains a research proposal, which suggests an inquiry into the cross-language categorical perception of English phonemic contrasts in dyslexic and control Czech learners of English. The aim is to evaluate the hypothesis that the less developed L1 phonemic categories allow dyslexics to access foreign- and/or second-language phones with greater fidelity than in the typically-developing learners.

Keywords

Speech perception, categorical perception, dyslexia, L2, foreign language, deficit

Anotace

Obsahem této bakalářské práce je souhrn literatury na téma vnímaní rodného a cizícho jazyka u typické populace a u lidí postižených vývojovou dyslexií. Studie ukázaly, že z důvodu deviace ve vývoji percepce řeči, nevnímají dyslektici zvuky na základě fonémů jako typická populace, ale spíše na základě alofonů. V oboru je nedostatek výzkumu, který by navrhnul důsledky tohoto jevu pro percepci cizího jazyka u jedinců s dyslexií. Práce zahrnuje návrh pro výzkum v oblasti kategorické percepce anglických fonémických kontrastů u skupiny českých dyslektiků a kontrolní skupiny, jejichž členové se učí anglicky. Cílem je zhodnotit hypotézu, že méně vyvinuté fonémické kategorie v rodném jazyce umožňují dyslektikům vnímat fóny cizího jazyka s větší přesností než typická populace.

Klíčová slova

Vnímání řeči, kategorická percepce, dyslexie, druhý jazyk, cizí jazyk, deficit

Contents

1 Perception of Native-language Speech Sounds

1.1 Language Acquisition through Speech Perception

When infants are born, their brains are not wired for learning a specific language. Instead, they exhibit a universal learning system, a set of procedures, which is applied to the language input experienced in the environment (e.g. Cutler 2012). In other words, humans can initially acquire any language as their native language.

The way a language starts being learned is through processing of the speech present in the infants' surroundings and collecting information about the individual properties of the language: prosodic speech patterns (e.g. rhythm, intonation), sound segments organizations (e.g. distributional frequencies, typical syllable structure), and the phoneme repertoire (Kuhl et al. 2008). Following from the universal nature of procedures for language acquisition, babies distinguish the universal set of phonetic contrasts (in other words, phonetic categories that are not language specific but depend on the universal quality of the speech segments), rather than a specific set of speech sounds in a single language (Werker and Tees 1984). Thus, new-born children can perceive any segmental contrast in any language (Kuhl 2007).

1.2 Speech Sounds

There is a universal foundation for speech sounds originating from the physical properties of the human organs used for producing speech, i.e. the general speech production mechanism delimits the possible speech sounds. Most of speech is produced by the passage of the airstream from the lungs through the larynx, where it is phonated by the vocal folds, after which the airflow continues through the oral or nasal cavity and is modulated by various articulatory processes created by the movements of the lips and the tongue in relation to the teeth, the roof of the mouth, and the pharynx (Ladefoged 2001).

Ladefoged (2001) estimates that there are around 600 consonants and 200 vowels in the world's languages, i.e. segments which differ in the manner of articulation, place of articulation and voicing, to which elements arising from variability can be added. On average, each language then employs approximately 40 sounds as phonemes (i.e. minimal units of speech carrying the meaning-distinguishing function) and other segments as allophones (i.e. sounds that do not carry a meaning-distinguishable function but occur systematically as variants of phonemes). However, the size of the phoneme inventory varies greatly. On one end of the range lies the Amazonian Pirahã language having a little over ten phonemes [while Maddieson and Precoda (1992) claim that 11 phonemes exist in the Pirahã language, Everett (2004) elaborates that although Pirahã men's inventory contains 10 phonemes, plus one that is debatable, that of women excludes one of them], while on the other end, the African Taa language may be considered, as it recognizes around 160 segments (Mielke 2009). It is important to clarify that a phoneme category does not consist of a single sound, but of multiple sounds which differ in various aspects while not altering the meaning in any way (Repp 1984). Still, the number of speech sounds used in any language is fairly small relative to the number of words it has.

1.3 Language-specific Categorization

Therefore, at an early stage, infants undergo a process in which they establish the phonemic categories relevant to their native language in order to recognize phonetic distinctions efficiently in their particular lingual environment. Figure 1 (from Kuhl 2008) shows the general timeline of first-language (L1)

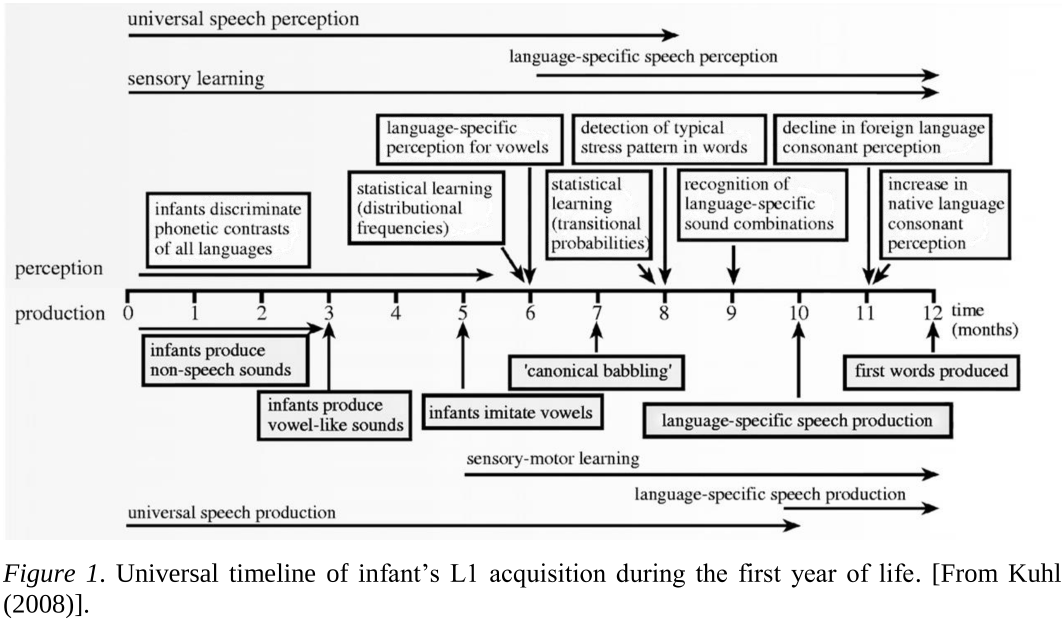

Figure 1. Universal timeline of infant's L1 acquisition during the first year of life. [From Kuhl (2008)].

acquisition. Research shows that during the first year, babies' sensitivity to the phonetic contrasts that are allophonic in the ambient language decreases and their ability to discriminate phonemic contrasts increases; specifically, infants show proficient discrimination of native vowels by the age of 6 to 8 months and of native consonants by the age of 10 to 12 months (Kuhl et al. 2006). The lower degree of attentiveness to the differences between allophones (i.e. the decreased perceptibility of within-category, subphonemic, variation) produces the so-called Categorical Perception.

1.4 Categorical Perception

Categorical perception is the phenomenon of classifying sounds of a language as specific phonemes, disregarding any intermediate sounds (Kuhl 2007). In other words, a series of stimuli continuously changing in an acoustic aspect [e.g. in voice onset time (VOT)] is perceived as discontinuous as the listener hears a sequence of discrete categories without paying attention to the changes within the category (Repp 1984). The point of the perceptual transition between the categories is called the phoneme boundary.

1.4.1 Testing Categorical Perception

Categorical perception is standardly tested in adults by the following tasks: speech sound identification (also labeling), and discrimination. In these tasks, listeners are presented (in random order and often repeatedly) with a sound or sounds (in the identification and discrimination task, respectively) drawn from a continuum spanning between two (or more) speech sounds of their langauge, which is developed by taking two sounds and smoothly changing one or more acoustic properties, that differentiates the two sounds, from the values typical for the first sound to the values typical for the second sound; and so, the intermediate value does not occur in normal speech (Cutler 2012).

The identification task consists in classifying a sound from the continuum as either of the endpoint speech sound categories, i.e. listeners are asked to decide which phoneme they heard. The outcome of such an experiment is a labeling function, which indicates the response proportion for categorization of the individual stimuli to the phoneme category (Repp 1984). The function is

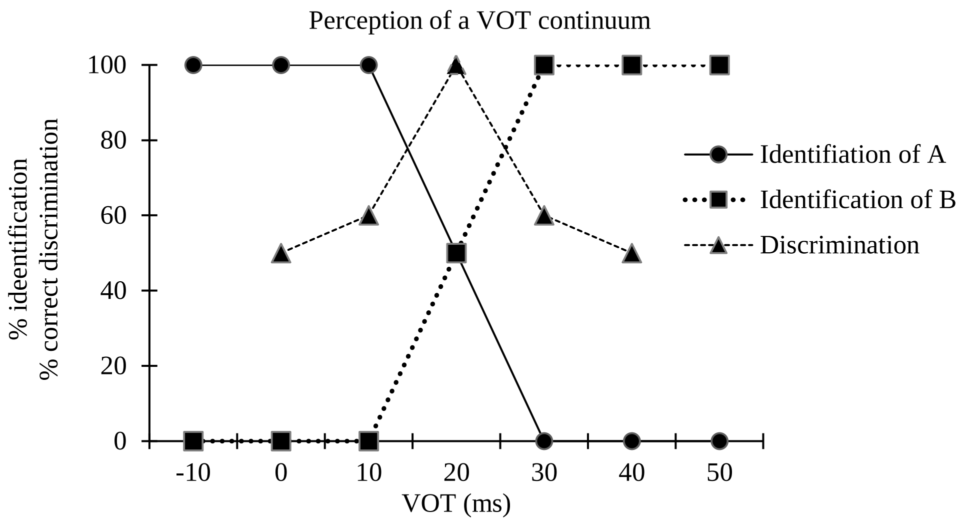

Figure 2. Graph demonstrating the appearance of the identification and discrimination functions for the perception of a VOT continuum. The identification function A shows the percentage of labeling the perceived stimuli of given VOT as phoneme A, and the identification function B corresponds to categorization as phoneme B. The discrimination function reflects the percentage of correct discrimination of two 20ms-distant stimuli from the A-B VOT continuum. [Adapted from *Categorization and discrimination curves* (2007).]

characterized by a steep slope demonstrating the decreasing (or increasing) probability of the sound being perceived as a member of the respective category (see Figure 2). The category boundary is to be found at the 50% response-rate point of the function, as it is the point where the chance that a stimulus is perceived as one category or the other is equal.

In the discrimination task, listeners are presented with sequences of stimuli of various formats, such as ABX, AXB, AX or 4IAX. In the ABX type, the sequence of stimuli takes the form of a triad: stimulus A, stimulus B, and stimulus X, which is identical to either stimulus A or B (Liberman et al. 1957); the subjects then match stimulus X to A or B. Another possible triad is AXB, which is similar to ABX with the difference that X is presented with an equal time distance to the two compared stimuli, i.e. as second in the sequence (Gerrits and Schouten 2004). The aim of the AX discrimination experiment, in which the subjects are presented with two stimuli in a trial where X is either identical to A or it is different by a certain amount, is for the subjects to decide whether the pairs of stimuli are the "same" or "different" (Gerrits and Schouten 2004). In the 4IAX discrimination task, the listener hears a sequence of two pairs: one consists of identical stimuli (AA or BB), the other of different ones (AB or BA) (Pollack and Pisoni 1971). The subjects then designate which pair was identical/different. Importantly, in all the formats, the distance between A and B (or A and X in the AX task when X is not identical to A) is constant throughout the task. Thus, the perceptibility of the same psycho-acoustic difference is tested at different locations along the continuum. The results of the discrimination task are summarized into a discrimination function (see Figure 2), which matches the measure of correct discrimination (usually in percentage rate) to the stimulus location on the continuum (Repp 1984). The function is typically near or at chance level (i.e. 50% correct discrimination for the two-alternative tasks) within a phoneme category, and reaches its peak at the phoneme boundary (Repp 1984) where discrimination is best.

Additionally, it is possible to predict the values of the discrimination function from the labeling data, assuming that the subject's response in the discrimination task corresponding to the responses the identification task, as argued by Pollack and Pisoni (1971), who propose the conversion formulae for various formats of the discrimination test.

1.4.2 An Example Study

The early experiment conducted by Liberman et al. (1957) examined the perception of the three English voiced stops, /b d g/, and focused on the correlation of the discrimination function and the labeling function. The stimuli for this research were taken from a speech-like synthetic continuum created by manipulating the second-formant onset consonant-vowel transition, which is an important acoustic cue for differentiating the three stops. In the first task, the subjects were to label 14 stimuli played in random order as either /b/, /d/, or /g/. In the second task, Liberman et al. used the ABX format for testing discrimination between the stimuli. Two groups of American subjects participated in the research: Group I consisted of five undergraduate students, who had no experience with synthetic speech; on the other hand, Group II contained four people who worked at the Haskins Laboratories[1] and were experienced in listening to synthetic speech.

[1] Haskins Laboratories is a research institute focusing on speech, language and reading.

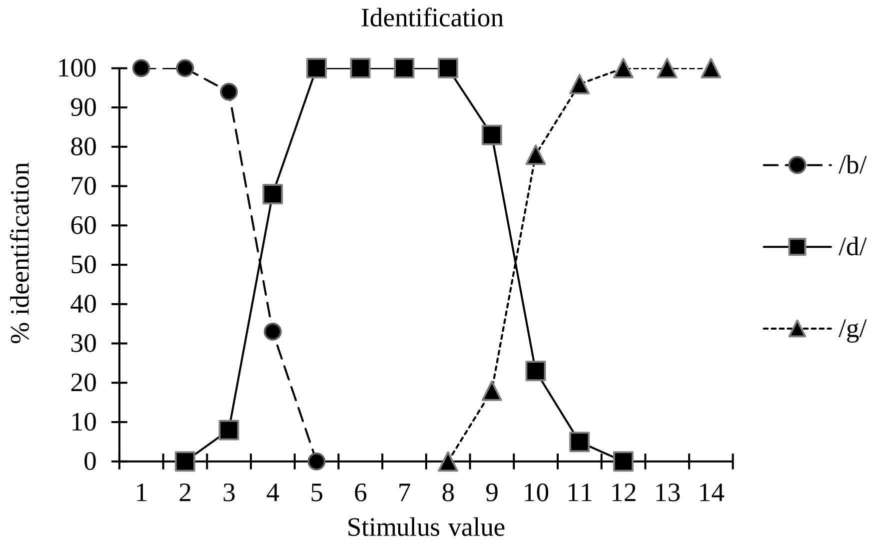

Figure 3. Graph showing labeling data for a single subject. [Adapted from Liberman et al. (1957).]

The labeling responses of most listeners suggested that the continuum is to be divided into three phoneme categories that are stable and have sharp boundaries, given that the changes of responses were abrupt. In Figure 3, which shows identification data for a single subject, it is demonstrated how the continuum is perceived as a sequence of the three discrete categories /b/, /d/, and /g/. The discrimination data shows that the discrimination of subphonemic differences was relatively poor, and more accurate when the stimuli lay close to the phoneme boundaries. When comparing the predicted discrimination functions computed from the labeling data to the actual functions, the curves were fairly accurate in predicting the high and low points of the discrimination curve, i.e. the function reached its peak in the proximity of the phoneme boundary and its lows near the stimuli lying at the center of the phoneme category. In general, however, the results of the experiment suggested better discrimination than Liberman et al. (1957) had expected.

1.4.3 The Effect of Categorical Perception on Speech Perception

To give a synopsis of how categorical perception affects speech perception, in the course of first-language acquisition, the typically-developing population partially loses sensitivity to phonetic differences in a speech that are not the basis of the language's phonemic contrasts, more so to the sounds considered allophonic (i.e. fall within the same phonemic category) than to the completely non-native, unfamiliar sounds. At the same time, their sensitivity to cross-category differences is enhanced. As demonstrated by the research by Liberman et al. (1957), in a discrimination task, typically developing individuals exhibit a discrimination peak at the point along the continuum where their native language registers a phoneme boundary. Furthermore, comparing cross-category and within-category discrimination, the former seems to be stronger, as the sensitivity to within-category differences tokens decreases in L1 development (Bogliotti et al. 2008).

1.5 Perceptual Magnet Effect

Another concept, which focuses on the internal structure of phonemic categories, is the perceptual magnet effect (Kuhl 1991, Iverson and Kuhl 1995). Its subject matter is the so-called Category Goodness of individual speech sounds, i.e. the idea that the members of a category are not perceived as equivalent. Within each category, in a particular region of the phonological space, there is an infinite number of tokens that differ in degree of how prototypical or non-prototypical they are considered by the listeners. The underlying hypothesis is that the excellent exemplars cause the tokens in their proximity seem very similar, and therefore the discrimination of these sounds is worse than that of two poor exemplars of that category. This effect is especially evident in the perception of vowel sounds.

In one of her experiments, Kuhl (1991) tested quality judgment of tokens of the vowel /i/, asking the subjects, adult speakers of English with normal hearing, to rate the stimuli on a scale from 1 ("poor") to 7 ("excellent"). Drawing on the results of a previous study that tested category goodness (Grieser and Kuhl 1989), Kuhl (1991) selected one token that had been evaluated as the best /i/, calling it the prototype (P) of that category, and another token considered a relatively poor exemplar of /i/, which she labeled as a non-prototype (NP).[2] Subsequently, Kuhl (1991) synthesized the P and NP and a set of vowels surrounding P and NP in the vowel space defined by the formant frequencies F1 and F2 (leaving the F3-F5 unchanged). The subjects then rated the goodness of the resulting 64 /i/ vowel

[2] The relatively poor token of /i/ was still easily identified as /i/, and was not confused with a different vowel.

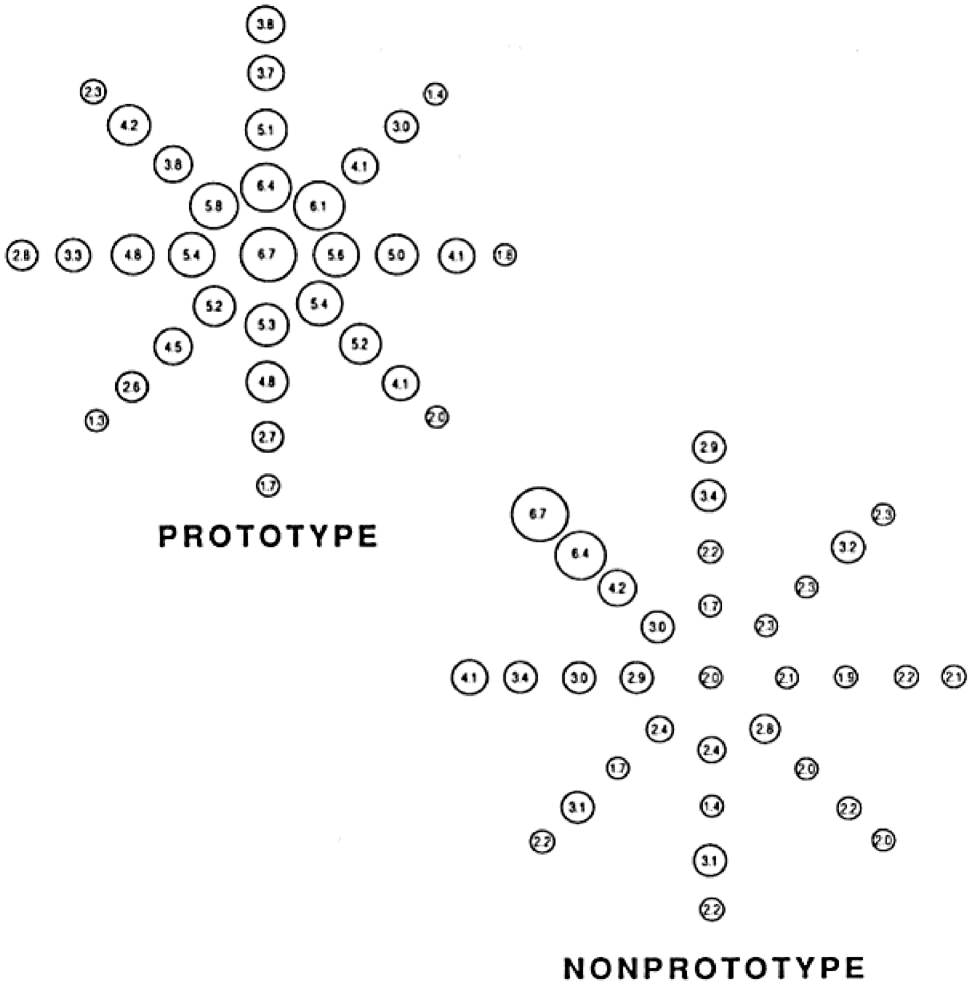

Figure 4. Diagram shows category goodness ratings for the prototypical and nonprototypical /i/, and their surrounding variants. The goodness of the stimuli was rated on a scale from 1 (a poor exemplar) to 7 (a good exemplar). The size of the circles corresponds to the degree of goodness. [From Kuhl (1991).]

stimuli, consistently giving the best (6.7) and worst (2.0) ratings to the stimuli in comparable regions of the vowel space (results in Figure 4).

In order to further examine the hypothesis of the perceptual magnet effect, the subjects were asked to participate in a discrimination task in another experiment by Kuhl (1991). The stimuli were the same as in the first experiment. One group of subjects was tested on 32 variants of the P, and the second on 32 variants surrounding the NP. The results support the hypothesis of worse discrimination of variants of Ps, as the overall score for correct discrimination of tokens of P was 78.6% and that of NP 90.5%. These findings demonstrate that the stimuli around P, i.e. typical exemplars of a category, are subjected to a greater generalization and are perceived as more similar to other tokens in the central region of the phonemic category. This ‘perceptual magnet effect’ was not present only in adults, but also in 6-month old English-acquiring infants (Kuhl 1991), suggesting that vowel categories are formed as early as that age.

Iverson and Kuhl (1995) argue that the perceptual space is distorted by losing sensitivity near the prototypical stimuli. One of Iverson and Kuhl’s (1995) experiment consisted in the mapping of warping of the perceptual space around prototypes by using the statistical method called multidimensional scaling (MDS). Based on the goodness and identification judgments collected in the preceding experiment, each token of the vowel /i/ was attributed a point in a geometric space

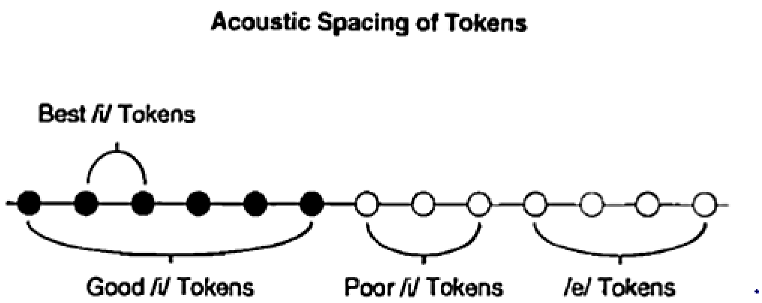

Figure 5. Diagram shows acoustic spacing of tokens. The best tokens are of average category goodness 6.1, good /i/ tokens of >5.3, and the poor tokens of <5.3. [From Iverson and Kuhl (1995).]

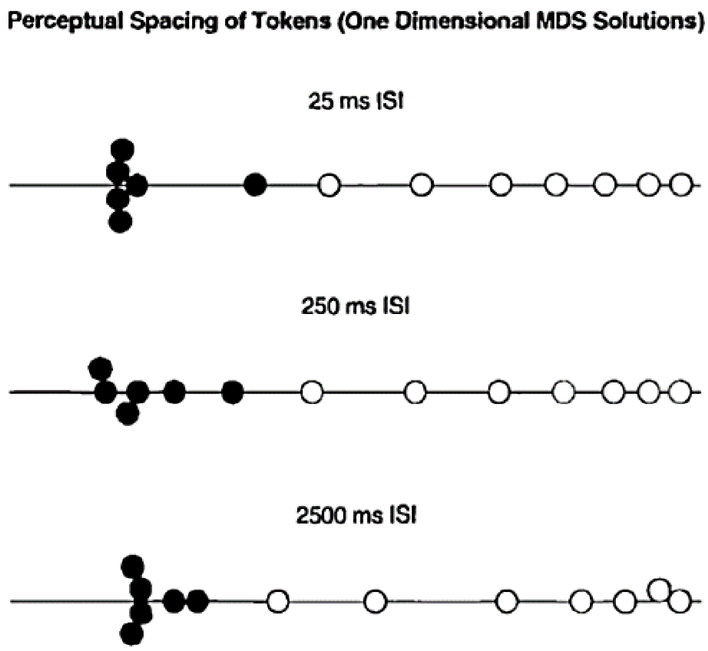

Figure 6. Diagram shows the horizontal and vertical positions of tokens in the perceptual space. Horizontal positions are equal to the values in the one-dimentional MDS solutions. [From Iverson and Kuhl (1995).]

in such a way that the distances between the tokens of the vowel sound would reflect the perceived similarity. Figure 5 shows the acoustic spacing of the stimuli. In the resulting plot (Figure 6), the perceptual distances in the region of tokens rated as “excellent” seemed to be condensed and the perceptual distances of the “poor” exemplars seemed extended, providing more evidence to the presence of a perceptual magnet effect.

2 Perception of Foreign- and Second-language Speech Sounds

As stated earlier, first-language acquisition is connected with tuning one's perception to the relevant contrasts in the native language. This chapter focuses on how this language-specific perception affects the perception of foreign speech sounds.

2.1 The Ability to Discriminate Foreign Speech Sounds

Although learning mechanisms aim to facilitate the perception of native speech sounds, it is possible that the ability to discriminate foreign phonetic contrasts is not lost, but rather the focus shifts towards pertinent phonemic contrasts, as argued by Best et al. (1988). The effect that categorical perception has on the perception of foreign sounds differs according to the nature of the foreign sound in relation to the listener's native segment inventory.

2.1.1 Non-native Sounds Not Recorded in Native Speech

The following research examined the discrimination of sounds that did not occur in the subjects' native phoneme inventory, neither did they share any primary acoustic feature. Best et al. (1988) conducted a test of English adults' discrimination of the Zulu click contrasts. The assumption was that since the click consonants are unlike any English speech sounds, the tested subjects would demonstrate good discrimination rates and the perception would not be hindered by the attuning to the native speech through categorical perception.

Nine monolingual American subjects without any experience of the Zulu language or other click languages were asked to complete phonological tasks employing stimuli taken from naturally produced minimal pairs (i.e. syllables differing only in one phoneme) containing Zulu click and the vowel /a/ segments. The experiment consisted of discriminating stimuli in the AXB format.

The subjects' responses resulted in correct discrimination of the click contrasts which were not used in their native language and therefore their perception was not affected by the phoneme bias due to the language-specific categorical perception. These findings support the hypothesis that the listeners' perception of sounds non-existent in their native language depends on the universal quality of the speech sounds and that the learning mechanisms used in first-language (L1) acquisition remain available in second-language acquisition provided L1 categories do not interfere (Flege 1995). Furthermore, the claim is that such segments which do not share any phonetic-articulatory features with native sounds are perceived rather as non-speech, and therefore pose no trouble for their discrimination (Best 1995).

2.1.2 Non-native Sounds Used in Native Speech as Allophones

When testing the discrimination of two foreign speech sounds both of wich exist in the listener’s native language, either as allophones of one phonemic category or both similar to the same native-language category along a particular phonetic dimension, the prediction is that the perception will be affected by the prior linguistic experience and the discriminability of these sounds reduced.

The cross-language experiment conducted by Miyawaki et al. (1975) examined the discrimination of /r/ and /l/ by Japanese and American native speakers. The difference between the two chosen languages is that English uses /r/ and /l/ as distinct phonemes, whereas Japanese does not and both two sounds fall within one phonemic category.

As for the participants, they were 39 American undergraduate university students and 21 Japanese university students or members of university staff. All of the Japanese participants had had at least 10 years of experience with the English language. The 13 stimuli used in the tests were taken from a synthesized /ɹa-la/ continuum. Considering the tasks themselves, both the American and the Japanese groups were tested in the discrimination task, in which the stimuli were presented in triads where two of the stimuli would be identical and one different. Therefore, the subjects had to indicate whether the odd one occurred in the first, second or third position. Subsequently, the group of Americans was given an identification task, and the subjects judged whether the segments are tokens of /ɹa/ or /la/.

In the discrimination task, the two groups responded differently. The Americans discriminated well the pairs of stimuli that belonged to different phonemic categories, i.e. that were closest to the phoneme boundary, but poorly perceived the subphonemic differences. The Japanese, on the other hand, showed no discrimination peak near the phoneme boundary; however, the discrimination of the subphonemic stimuli was comparable with that of the American listeners. Although discrimination by the Japanese subjects was relatively poor, it was generally above the chance level (33 %). In the second identification task that was given to the American subjects only, the results show close to the precise categorization of the stimuli into the two phonemic categories. When comparing the predicted discrimination rate computed from the Americans' labeling data, the obtained discrimination peak was found in the proximity of the predicted one. Nevertheless, the predicted within-category discrimination was much lower than expected.

In addition, when Miyawaki et al. (1975) asked the participants of the research to discriminate the acoustic cue for /r-l/ in isolation, no difference between the Americans and the Japanese appeared. This fact lends support to the hypothesis that categorical perception influences only the perception of speech-like intake and that speech perception is a specific mode of auditory perception.

To summarize, in comparison to the American subjects, for whom it is a native phonemic contrast, the Japanese showed a relatively poor discrimination of the non-native contrast /r-l/, which the Japanese language employs as allophones, and so the distinction is not crucial to distinguish the meaning. The findings substantiate the hypothesis that the categorical perception phenomenon influences the perception of sounds that are employed in one's language as members of one phoneme category because the sounds are assimilated into the native phoneme category (Best 1995).

2.1.3 Assimilation or Exclusion

The research carried out by Best et al. (1988), mentioned in 2.1.1, and the testing conducted by Miyawaki et al. (1975), as described in 2.1.2, demonstrate that as the speech sound perception transforms in order to become more efficient in the mother tongue, the language-specific mode of perception treats foreign sounds based on their acoustic features with regard to the native sounds' features. Phonetic segments encountered by listeners are perceived in terms of familiar phonemic categories when allowed by the proximity of generalized auditory and articulatory properties of the speech sounds, i.e. when there is sufficient similarity between the foreign and the corresponding native speech sounds.

Additionally, Best (1995) developed a model of foreign speech sound perception, the so-called Perceptual Assimilation Model, in which she takes into account the possible interpretations of non-native speech sounds in relation to one's mother tongue.

2.2 Perceptual Assimilation Model (PAM)

The PAM is a set of predictions of how a foreign speech-sound contrast will be perceived based on the assessment of the non-native segments according to the similarity or divergence from the native segments that lie nearest in the native phonological space. It is important to note that makes predictions for cross- rather than second-language speech perception, i.e. it takes into consideration naïve listeners above all who do not have learning experience of the particular foreign language.

2.2.1 Patterns for Perception of Foreign Speech Sounds

To describe a listener's perception of non-native segments, Best (1995) proposes that a non-native speech sound can be perceived in three patterns: first, the sound is assimilated to a native phoneme category when it sounds the same or similar (the latter can be perceived either as an acceptable or notably deviant exemplar); second, it is assimilated as an uncategorizable speech sound, which means that it is assimilated into the phonological space but not into a specific category; third, the sound is not assimilated into the phonological space at all and it is thus perceived as a nonspeech sound.

2.2.2 Patterns for Perception of Foreign Contrasts

In addition to these patterns, Best (1995) also records six possible assimilation patterns for cross-linguistic contrasts and their predicted levels of discrimination (i.e. tasks identifying two sounds as the "same" or "different") ranging from poor to excellent.

The first pattern is the Two-Category Assimilation in which the two phones are assimilated into different native categories, hence the anticipated discrimination of the contrast is excellent.

The second pattern is the Category-Goodness Difference and includes two phones assimilated into the same native category, but each of them is different in terms of proximity to the exemplary native sound (i.e. on the scale from acceptable to deviant), and thus the predicted discrimination can range from moderate to very good, corresponding to the sounds' extent of discrepancy from the native exemplary.

The third pattern, Single-Category Assimilation, describes a situation when both foreign sounds fall into the same native category and are on the same level of acceptability or deviancy from the model sound in the native category, resulting in poor discrimination.

The fourth possibility occurs when both sounds exist in the phonological space but are Uncategorizable into a specific native category; their discrimination varies from poor to very good, according to how close in the phonological space they are to each other and to native categories.

The fifth pattern includes one Uncategorized nonnative sound that is found within the phonological space but is not assimilated to a particular category, and one Categorized sound assimilated to a native category, resulting in very good discrimination.

The last (sixth) pattern happens when both foreign sounds are Nonassimilable, i.e. are not assimilated to speech at all, and therefore are perceived as nonspeech sounds; the discrimination of this contrast is predicted to be good to very good.

In the updated version of the PAM (Best and McRoberts 2003), Best and McRoberts propose that non-native discrimination is influenced by the articulatory organs that are involved (as follows from the direct realist view of speech perception). If the foreign contrast is produced by the same articulatory organ (/t-d/), the discrimination is poorer than that of a foreign contrast of different articulatory organs (/t-b/).

2.3 Perceptual Assimilation Model for the Second Language (PAM-L2)

In the PAM for perception of second-language (L2) contrasts, Best and Tyler (2007) focus on listeners who are in the process of acquisition of a second language. PAM-L2 demonstrates four alternatives to perceptual learning of L2 sound contrasts. To eliminate factors such as the duration of the learning process, naïve listeners starting to learn a foreign language are considered.

The first case occurs when one of the two contrasting segments is perceptually assimilated into a native phoneme category. Since the segment was perceptually categorized as a good token of the L1 category, the listener would not have trouble discriminating the contrast of the assimilated L2 segment with other L2 categories, complying with the PAM patterns Two-Category Assimilation or Uncategorized-Categorized Assimilation. Because of the easily perceived difference, perceptual learning and a shift in the perception of the contrast are not probable. Furthermore, it is likely that the listener perceives not only the L2 phonological category as identical to the corresponding L1 category but also the phonetic categories. Another option is when one L2 sound is used similarly at the phonological and phonotactic level as the L1 sound but distinctly differs in phonetic information. For instance, English speakers learning French would experience these conditions with the French /ʁ/, as opposed to the English /r/.

The second situation involves two L2 segments perceived as the same L1 phoneme, while one of them seems more deviant, which PAM describes as Category Goodness Assimilation. Good discrimination of the contrast is predicted, and even minimal lexical contrasts should not pose problems. Best and Tyler (2007) also hypothesized that eventually, the learner would shift from perceiving the deviant sound as a phonetic variant of the L1 category and create a new perceptual category; then, the learner would assimilate the better token as a member of the L1 category.

Thirdly, in the case of Single-Category Assimilation, i.e., where both segments are perceived as the same L1 category, with an equivalent degree of typicality, it is predicted that the listener will experience trouble with discriminating the contrast, at least initially. Even though it is possible that one's perception might attune to the slight perceptual difference (and therefore creating a new perceptual phonetic category), most learners might not achieve that. One of the examples of Single-Category Assimilation is the incorporation of the English phonemes /ε/ and /æ/ into a single phoneme category /ε/ by Czech learners of English, which will be further discussed in the research proposal.

The fourth possibility is that no phonological assimilation will occur between L1 and L2, both segments staying Uncategorized. In such occurrence, similarity or dissimilarity of the L2 sounds to the L1 phonological system is crucial. If the segments are distant in the learner's phonological space, two new L2 categories should be acquired and be possible to discriminate. In the context of Czech learners of English, it would be the case of the English phonemes /w/ and /ɹ/, which do not fall into any Czech phoneme category. However, if the two L2 sounds are close to each other in the L1 phonological space, and are perceived as similar to the same set of sounds, it would be challenging to discriminate them. Thus, only one L2 category is expected to be learned, incorporating both L2 segments. Such categorization would make it difficult to recognize homophonous words.

To sum up, in the course of L2 acquisition, the L1 and L2 phonological systems do not exist in separation, but interact, creating various possibilities for the perception of foreign sounds and contrasts. Some patterns of foreign speech sound perception for L2 learners might be similar to patterns occurring in naïve listeners, as described in PAM, but multiple factors, such as acquaintance with the L2 speech contrasts, exposure to authentic L2 input, or production experience, affect the way non-native speech segments are perceived by L2 listeners.

Concluding with the standard speech perception, typically-developing L1 learners form L1 categories that warp the perceptual space to enable efficient and rapid and accurate identification and discrimination of native speech sounds. However, at the same time, since these acquired categories are optimized for the L1, they may often hinder accurate perception of L2 sound contrasts, for example when two L2 sounds fall within the same L1 category (Single-Category Assimilation). Some researchers (Flege 1995) propose that this is the reason for age-related effects on L2 speech learning: younger L2 starters whose L1 categories are not yet so firmly established can acquire L2 categories faster and with greater probability than older starters. In other words, having underdeveloped L1 phonemic categories, while being a disadvantage for L1 speech perception, is an advantage for L2 speech perception and acquisition.

3 Speech Sound Perception with Dyslexia

Developmental dyslexia (DD) is a disorder which manifests itself in a problematic acquisition of reading. However, the deficit runs deeper into speech perception in general. This chapter conducts an inquiry into the definition and origin of dyslexia and its specific effects on speech sound perception.

3.1 Developmental Dyslexia

From a behavioral point of view, DD, or Specific Reading Disorder (SRD), can be characterized as a "discrepancy between reading ability and intelligence in children receiving adequate reading tuition" (Ramus et al. 2003b), provided that no sensory deficit is present. Dyslexic children exhibit low-level reading skills; in other words, they have trouble associating graphemes (smallest units of the written language, i.e. letters or groups of letters) to phonemes while decoding the written language (Serniclaes, Colet and Sprenger-Charolles 2015).

However, this traditional definition takes into consideration only of one of the symptoms of dyslexia. Individuals suffering from DD manifest abnormalities in visual as well as auditory processing. Studies have demonstrated that phonological deficits occur in the following areas: in phonological awareness, i.e. the ability to detect speech sounds (especially phonemes) and manipulate with them mentally (e.g. counting syllables in a word, creating oral rhymes, spelling nonsense words); in rapid automatic naming, which consists in recalling the phonological forms for pictures, colors, digits, or letters; and in phonological short-term memory, meaning the ability to remember phonological representations for a few seconds (e.g. repeating nonsense words) (Soroli, Szenkovits, and Ramus 2010).

3.1.1 The Origin of Developmental Dyslexia

As for the causes of DD, it is generally considered to be a genetic neurological disorder, affecting about 5-10% of the population (Serniclaes, Colet, and Sprenger-Charolles 2015). There are multiple theories trying to account for the origin of the reading impairment, five of which are considered major: the phonological theory, the rapid auditory processing theory, the visual theory, the magnocellular theory, and the cerebellar theory (Ramus et al. 2003b).

3.1.1.1 The Phonological Theory

According to the phonological theory (Liberman, Shankweiler, and Liberman 1989), dyslexia is caused by a specific impairment in the representation of speech sounds, their storage, and retrieval (Ramus et al. 2003b). The main argument of the theory is that a person who has such impairment in phoneme representation will have trouble learning grapheme-phoneme correspondences, i.e. the association of discrete letters of the alphabet to discrete speech sounds, which is a key element in being able to read an alphabetic writing system, as has already been said.

Anatomically, the deficit is to be accounted for by anomalies in the cerebral cortex, namely by a dysfunction in the temporoparietal and occipitotemporal regions, as studies suggest (Galaburda 1985, Pugh 2000, Shaywitz 1998, Shaywitz and Shaywitz 2005).

Although the nature of the phonological problems is still being discussed, it is generally accepted that phonological competence plays a key role in dyslexia. Research has evidenced that dyslexics perform poorly on phonological tasks testing phonological awareness, phonological short-term memory, and automatic naming (Soroli, Szenkovits, and Ramus 2010). However, the phonological theory is challenged by claims that dyslexia is more complex, going beyond the phonological deficits and relates to general sensory, motor or learning processes (Ramus et al. 2003b), and therefore the phonological deficit is but one of the consequences of a more profound cause. The proponents of the phonological theory typically disregard the other deficits found by certain researchers [e.g. deficit in non-verbal auditory tasks (McAnally and Stein 1996, Tallal 1980), in fast temporal processing (Stein and Walsh 1997), or in automatic skills (Nicolson, Fawcett and Dean 2001)] as a core issue and consider them only as accompanying difficulties (Snowling, Bishop and Stothard 2000). Nevertheless, the phonological theory is widely accepted among researchers in the field, as it seems to agree with the assertion based on numerous studies of dyslexic populations that the phonological deficit, especially in phoneme awareness, correlates with deficient reading in DD the most accurately (Ramus et al. 2003a, Shaywitz and Shaywitz 2005).

3.1.1.2 The Rapid Auditory Processing Theory

The rapid auditory processing theory claims that the core deficit lies in auditory processing, namely in the perception of brief or rapidly changing sensory stimuli (Tallal 2000). Research evidencing this theory observed the inferior performance of dyslexics on non-verbal auditory tasks, such as frequency discrimination (McAnally and Stein 1996), or temporal order perception (Tallal 1980). It is also hypothesized that some reading deficits could be connected to auditory impairment, as poor results in a nonsense word reading test seemed to correlate with poor results in the perception of rapidly presented auditory stimuli (Tallal 1980). Furthermore, McAnally and Stein (1996) measured neurophysiological responses to auditory stimuli and noted anomalies in dyslexics. The auditory deficit would then supposedly cause trouble in extracting acoustic cues to phonemic contrasts (Ramus et al.2003b). On the other hand, the rapid auditory processing deficit is challenged by the fact that studies have failed to confirm the presence of an auditory deficit in DD (Heath, Hogben, and Clark 1999), or have found it only in a fragment of the subjects (Adlard and Hazan 1998, Rosen and Manganari 2001, Tallal 1980); other researchers, for instance, noted a deficit in slow auditory processing, but not in rapid auditory processing (McAnally and Stein 1996, Rosen and Manganari 2001).

3.1.1.3 The Visual Theory

The visual theory states that the reason behind the reading impairment in DD, in other words behind the impeded processing of letters in a written text, is a visual deficit in binocular control (i.e. control of eye movements) and visuospatial attention (Stein and Walsh 1997). Anatomically speaking, the visual dysfunction could arise from reduced sensitivity in the magnocellular pathway of the lateral geniculate nucleus, which has been associated with DD (Livingstone et al. 1991). This theory does not overlook the deficits in dyslexics' phonological processing, but rather considers the visual defect as a primary factor in reading difficulties. Nonetheless, it is important to mention that the theory is challenged by experiments which have failed to replicate the results reflecting a visual deficit in dyslexics, or found it only in a subgroup (Amitay et al. 2002, Victor et al. 1993). Amitay et al.

(2002) have also provided data that the visual deficiency does not affect solely the perceptual tasks involving the magnocellular pathway and that the magnocellular deficit hypothesis cannot explain the reading impairment comprehensively.

3.1.1.4 The Cerebellar Theory

The proponents of the cerebellar theory argue that dyslexic individuals exhibit abnormalities in the cerebellum, for which direct neurobiological evidence has been found (Rae et al. 1998). The cerebellum is a brain center influencing motor control, skill automatization of long-practiced tasks (e.g. driving, writing, typing, reading), as well as some cognitive functions (Nicolson, Fawcett and Dean 2001). Therefore, such deficit would impact on automatization of the grapheme-phoneme correspondences and would lead to deficient reading, as registered in DD (Ramus et al. 2003b). However, this theory could be opposed by the lack of explanation for the sensory problems. Furthermore, the findings of a sensorimotor deficit show that the problems seem not to be general among dyslexic individuals (though it does occur more often in the dyslexic population than in the typical population), but a deficit present only in a subgroup of dyslexics, as suggested by the research of Ramus (2003a).

3.1.1.5 The Magnocellular Theory

Continuing in the findings of the visual theory, the magnocellular theory proposes that the dysfunction in the magnocellular layers does not affect only visual processing, but also auditory, tactile, and motor (Stein and Walsh 1997). For example, Stein (2001) stresses that dyslexics have been found to have trouble distinguishing minor changes in amplitude or frequency modulations in phoneme detection tasks (McAnally and Stein 1996). Facoetti et al. (2003) demonstrate that children with dyslexia are deficient in multimodal attention, specifically automatic auditory attention (showing a direct link to phonological impairment in dyslexia) and spatial orienting of visual attention. All in all, the magnocellular theory aims to incorporate the findings of the auditory and visual theory. Nevertheless, the magnocellular theory is undermined by various reports, some already mentioned in the sections about the rapid auditory processing and visual theory. Additionally, the research carried out by Heim et al. (2001) did not confirm the interdependency between auditory and visual temporal processing, thus opposing the multimodal deficit hypothesis.

3.2 Deficit in Categorical Perception

Developmental dyslexia is typically accompanied by a number of phonological deficits, as has been already mentioned. It seems that dyslexics' phonological processing is impaired, given that a majority of dyslexic children lag behind average readers in various phonological and phonemic tasks. One of the most striking ones is the deficit found in categorical perception, as evidenced by numerous studies (e.g. Godfrey et al. 1981, Bogliotti et al. 2008), which will now be considered in more detail.

3.2.1 Deficit Present in Dyslexic Children

Godfrey et al. (1981) carried out a study in order to identify whether the perception of the acoustic cues for speech and the categorical perception is deficient in children with DD. Furthermore, two subtypes of dyslexia, "dysphonetic" and "dyseidetic," were distinguished, so as to tap any hypothetical differences in categorical perception between the two subtypes. Godfrey et al. (1981) chose the identification and discrimination tasks typical for testing categorical perception in adults and modified them for testing children as young as 7 years old.

The experiment involved two groups of children in the range of 7 years and 3 months to 15 years and 1 month. The first group consisted of 17 dyslexic children. Godfrey et al. also divided the children diagnosed as dyslexic into two subgroups according to the nature of the prevalent errors, as suggested by Boder's diagnostic test of DD (1971, 1973): "dysphonetic dyslexics" were expected to manifest worse performance in tasks relying on auditory-phonetic processing abilities than controls; "dyseidetic dyslexics" were assumed to experience trouble with the visual form of speech, i.e. letters. The second group was composed of 17 normal readers matched in age, sex, and hand preference with the children from the first group. The intelligence of all subjects was average or above-average. The 8 stimuli used in the experiment were taken from a synthesized /da-ga/ continuum by manipulating the second and third formants. As for the tasks, the identification tests required of the subjects to identify 32 items as /ba/ or /ga/; in the discrimination task, the format AX was used, so the subjects were to judge the segments as "same" or "different".

The results evidence differences in categorical perception between dyslexics and controls, not so between the two subtypes of DD. In the identification task, the controls responses were equivalent to the typical ones tested in adults, supporting the claim that 7-year-old children are able to identify synthetic speech sounds in a comparable way as adult subjects. The controls' slope of the identification function (see Figure 7*)* reached 100% and 0% at the extremes, since the stimuli at the ends were judged unanimously, and it was steep in the area of the phoneme boundary. The dyslexics performance, on the other hand, was less consistent in labeling the stimuli. However, the majority judgment of each stimulus was the same as that of the controls, which resulted in a similarly-shaped identification curve with a smaller percentage of correct answers, and thus lesser "sharpness" of the curve. The discrimination curve (see Figure 7) following from the dyslexic children's data shows a discrimination peak at the place of the same stimulus pair as the controls, however, with less consistency in responses of the dyslexics and with the discrimination peak being much lower, giving rise to the hypothesis that dyslexics' discrimination is weaker at the phoneme boundary. On the other hand, although their responses were only around the chance level, the dyslexic children had better scores in discrimination of the subphonemic stimulus pairs than the control group,

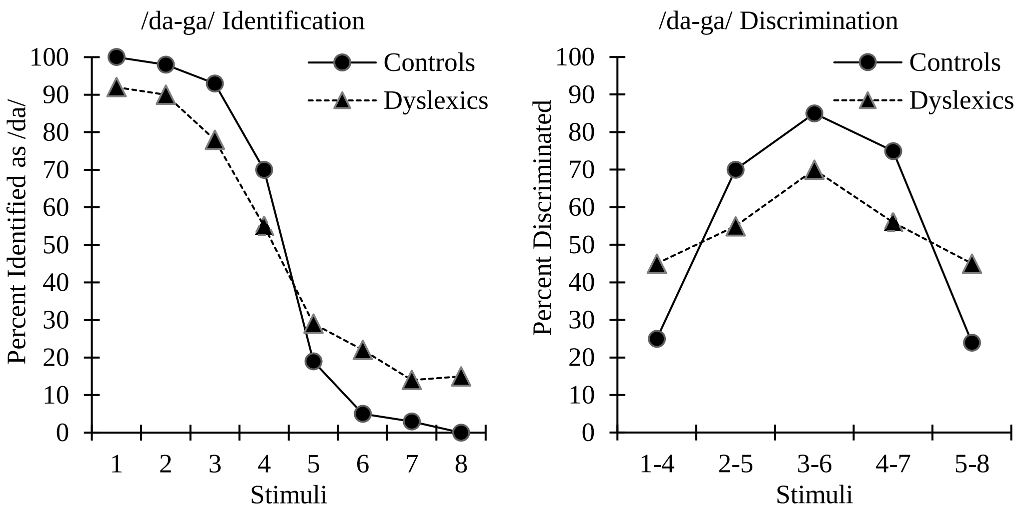

Figure 7. Discrmination and indentification functions for both groups, as observed by Godfrey et al. (1981). [Adapted from Godfrey et al. (1981).]

which leads to the supposition that dyslexics' perception of tokens from inside a phoneme category is better than that of the typically-developed population.

In conclusion, the dyslexics' overall performance on the perception tasks was worse than that of normally-developing children. Nevertheless, the dyslexic subjects were still able to judge the individual stimuli and the stimulus pairs at the category boundary correctly with percentage or the correct answers above the chance level. The occurent difference, however, is that the dyslexic children discriminate the stimuli located in between phoneme categories worse than the controls and the stimuli from within phoneme categories better than the controls, which results in the assumption that the categorical perception of dyslexics is deficient compared to typically-developing children.

3.2.2 Decreased Categorical Perception and Increased Allophonic Awareness

Research conducted by Bogliotti et al. (2008) focused on testing discrimination and identification of speech sounds on a VOT continuum in children with dyslexia in comparison to both chronological age controls and reading level controls. Assessment of both control groups was to provide evidence whether the speech perception deficiency due to dyslexia is caused by a developmental deviance or a developmental delay. In addition to replicating previous findings of speech perception deficiencies in dyslexics (notably a decreased categoricalness of perception), the study tested the hypothesis that children with dyslexia use allophonic rather than phonemic units when perceiving speech. The expectation was to observe a higher allophonic discrimination peak near the natural negative VOT boundary, which is located at -30 ms VOT. Furthermore, the individual reliability of the categorical deficits and allophonic perception in contrast with either chronological age or reading level controls was to be evaluated.

As for the participants of the research, thirty-one monolingual French children partook in the study in three separate groups: dyslexic children, children of the same chronological age, and younger children on the same reading level as dyslexics. Concerning the focal research of the study, all subjects were asked to complete two tasks: first was to discriminate same-different pairs that were combinations of sounds from the /do-to/ VOT continuum (-50 ms to +50 ms VOT), either identical or differing by 20 ms VOT, and the other task was to identify eleven stimuli as either /to/ or /do/. Stimuli were developed with natural speech combining three different French and English stimuli.

Presenting the outcomes of the research, for the control groups as well as for the dyslexics, the point on the labeling function with 50% /do-to/ responses, which corresponds to the phoneme boundary, was marked by a discrimination peak at +15 ms VOT. From the labeling data, expected discrimination functions were computed. Controls matched the expected scores for discrimination: the phonemic boundary was strongly discriminated, but the discrimination of within-category stimuli was at chance level. However, the discrimination peak for the dyslexics was much lower than expected and a second peak appeared at -20 ms VOT, which is close to the natural negative boundary at -30 ms VOT and is considered to be allophonic (Bogliotti et al. 2008), as it has already been stated. The individual functions are demonstrated in Figure 8 and Figure 9.

To summarize, the research conducted by Bogliotti et al. confirmed the previous results: they found a deficit in discrimination of speech sounds and in labeling of speech sounds in children with dyslexia. The study argues that the fact that the dyslexics displayed a reduced phonemic peak and a nonphonemic peak at -20 ms VOT supports the hypothesis that children affected by dyslexia have a mode

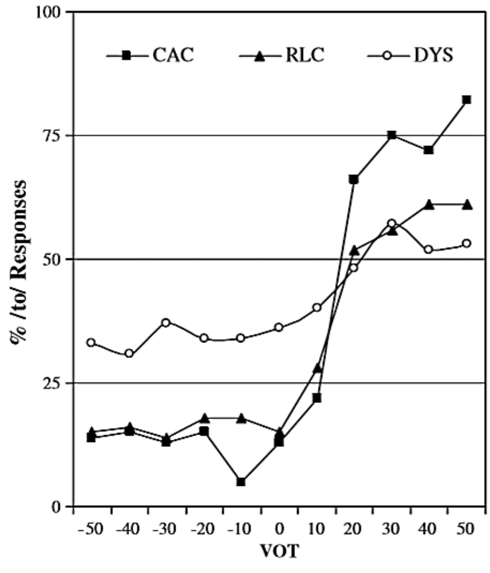

Figure 8. Graph presents the labeling functions, specifically the percentage of /to/ responses, for chronological age controls (CAC), reading level controls (RLC), and dyslexic subjects (DYS). [From Bogliotti et al. (2008).]

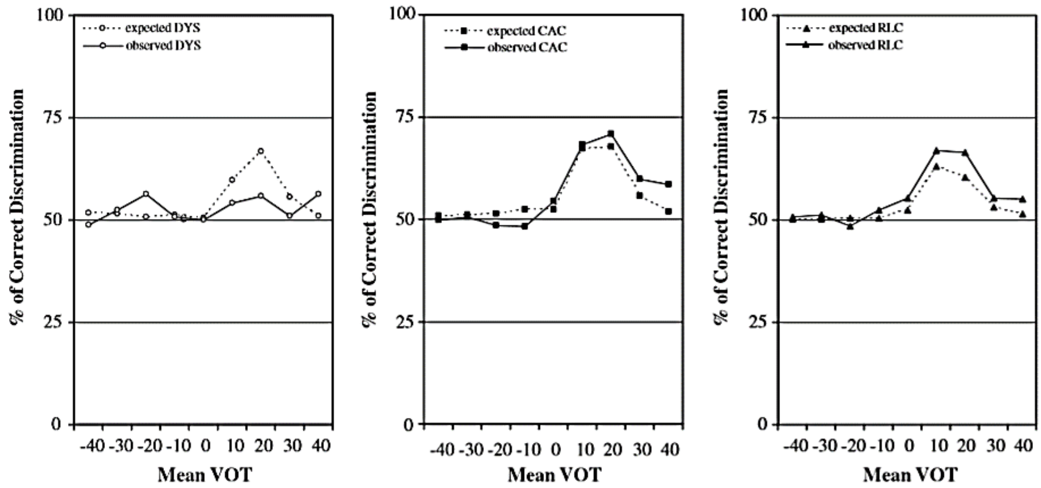

Figure 9. Graph presents the discrimination functions for chronological age controls (CAC), reading level controls (RLC), and dyslexic subjects (DYS). The percentage of correct categorization of stimuli from the /to-do/ VOT continuum. Expected scores are marked with dotted lines, and solid lines represent obtained scores. [From Bogliotti et al. (2008).]

of perception based on allophones, rather than phonemes, and thus are more sensitive to allophonic contrasts than children not suffering from dyslexia, be it chronological age controls or reading level controls.

The inclusion of both chronological age controls and reading level controls contributed to uncovering whether dyslexia is caused by a developmental deviance or a developmental delay. The fact that children with dyslexia exhibited a weaker categorical perception than children of an early age but at the same reading level, followed by an observation of an additional allophonic peak solely in the dyslexics' results, lends support to the explanation of a persistent, chronic developmental deviance rather than delay.

Additionally, looking at the individual performances, the research confirmed that categorical perception deficit and increased allophonic awareness is predominantly present in dyslexic children.

3.2.3 Origin of the Deficit in Categorical Perception

The process of perceiving a sound as a member of a phonological category can be divided into three stages: "auditory," "phonetic," and "phonological," as suggested by Serniclaes et al. (2004). First, the listener recognizes the acoustic cues, then it is followed by the transformation of the continuously-varying acoustic cues into general discrete phonetic categories, and at the end, the general phonetic categories are fused into language-specific phonological categories. The deficit in the categorical perception can be explained by the impaired processing at any of these stages.

As for the theory of the auditory deficit (for more information consult the section *3.1.1.2*), the ground was provided by Tallal's (1980) research, which consisted of tests of non-verbal auditory perception on a group of dyslexic and control children, focusing on discrimination and temporal order perception. As it was evidenced that the performance of the dyslexic children was significantly poorer in the given tasks, the results suggest that the core of the deficit in categorical perception lies in auditory processing. Nevertheless, it must be kept in mind that nonspeech perception does not necessarily have a direct correlation with speech perception (Rosen and Manganari 2001). Furthermore, Ramus et al. (2003b) raise the objection that studies do not find the auditory deficit to be consistent across individuals but to be present in only 50% of the subjects at most. Serniclaes et al. (2004) also draw attention to the fact that an auditory deficit would not impair only written language and reading but also spoken language, which does not correspond to the definition of dyslexia as a solely reading disability.

Considering whether the impaired processing leading to reading difficulties in dyslexics resides at the phonetic or at the phonological level, it is important to underline that studies have demonstrated the correspondence of graphemes (in alphabetic systems) to phonemes, not phones in general (Morais, Alegría, and Content 1987, Sprenger-Charolles 2004). In addition, multiple studies (Bogliotti et al. 2008, Serniclaes et al. 2001) evidence better within-category discrimination of acoustic differences as opposed to the cross-boundary discrimination in children with DD, which suggests that their perception is more sensitive to allophonic contrasts. Therefore, it seems that the decisive deficit hindering the categorical perception occurs at the phonological level.

3.3 Impaired Phonological Processing

Soroli, Szenkovits, and Ramus (2010) review three theories accounting for the phonological deficit in dyslexia.

The first theory taken into consideration claims that the problem lies in degraded phonological representations (Boada and Pennington 2006). It is based on the segmentation hypothesis (Fowler 1991). The claim is that atypical development of the dyslexics' phonological representations is the primary cause of the deficit, without implying the involvement of a general auditory perceptual deficit (Boada and Pennington 2006).

The second mentioned theory is the allophonic phonological system (Serniclaes et al. 2004), which says that dyslexics' speech perception is closer to the universal perception in the sense that the dyslexics' phoneme categories are not fully established and that dyslexics pay attention rather to allophones than to phonemes. In other words, it is possible that individuals suffering from DD preserve to a certain degree the ability to perceive phonetic differences falling within the phonological categories of their native languages, for instance such as the universal boundaries on the VOT continuum not coinciding with a native category boundary.

The third concept explains the phonological deficit by a core deficit in the perception of amplitude modulations of the acoustic signal, and therefore a reduced notion of speech segmentation, which facilitates learning to read, as stated by Goswami et al. (2002). It is interesting to note that unlike most other views, the focus of the beat perception deficit theory lies in the suprasegmental domain, viz. prosody, rather than in segmental phonetic properties.

Lastly, the review (Soroli, Szenkovits, and Ramus 2010) considers the idea that the phonological representations in dyslexics are in fact intact (Ramus and Szenkovits 2008), because it seems that the inferior performance in various tasks in comparison to controls, which is widely reported in the literature, could be the result of the incapacity to meet the demands of the task, such as metacognitive access, awareness skills, verbal short-term memory load, or speeded and serial access (Ramus et al. 2013, Soroli, Szenkovits, and Ramus 2010). For instance, in the experiments aiming at phonological deficits, Ramus et al. (2013) found a deficit in the phonological representations in only a third of the tested dyslexic children.

3.4 Other Phonological Deficits

Among other phonological deficits that have been found in dyslexics, tasks involving phonological awareness, phonological short-term memory, and automatic naming skills will be considered.

3.4.1 Phonological Awareness

Phonological awareness is the ability to consciously divide the input into phonemic segments and perform mental manipulations with them. One of the means to examine phonological awareness is a spoonerism task. The subjects are asked to switch the initial sounds of two words, e.g. “lazy dog” is changed to “daisy log.” There is a great amount of evidence for a deficit in this task for people with DD (Amitay et al. 2002, Messaoud-Galusi, Hazan, and Rosen 2011, Rosen and Manganari 2001, Soroli, Szenkovits, and Ramus 2010).

In phoneme monitoring, on the other hand, the subjects listen to a sequence of words/non-words, or sentences, and are asked to quickly indicate (e.g. by pressing a button) when they hear a given sound (Connine and Titone 1996).

Another possible task might include rhyme identification. The listeners are presented with a sequence of words and should indicate which words rhyme, e.g. in the sequence “sail, bloom, pale” it would be “sail” and “pale.” A deficient phonological processing in this area has been found in dyslexics (Messaoud-Galusi, Hazan, and Rosen 2011).

3.4.2 Phonological Short-term Memory

The phonological short-term memory is the ability to retain phonological representations in working memory for a brief time. The efficiency of the phonological short-term memory may be evaluated using a nonword repetition task, which consists in repeating pseudo-words, such as “tib, haplut, rubid, sepretennial.” The accuracy of repetition is expected to decrease with an increasing number of syllables. Research shows that dyslexic individuals experience lags behind the controls is this task (Snowling, Bishop, and Stothard 2000, Messaoud-Galusi, Hazan, and Rosen 2011, Rosen and Manganari 2001, Ramus et al. 2013).

3.4.3 Rapid Automatic Naming

Rapid automatic naming is the ability to rapidly retrieve familiar segments or words from long-term memory (e.g. when presented with visual stimuli like pictures or lists). The assessment of dyslexics' automatic naming skills conducted by Ramus et al. (2003b) indicated the significantly poorer performance of dyslexics compared to the controls, be it in rapid picture naming or rapid digit naming.

3.5 Suprasegmental Level

As far as it concerns dyslexics' perception of suprasegmental contrasts, the findings differ depending on the suprasegmental level. Behavioral studies have evidenced impairment in dyslexics' perception of word-level stress, and it has been suggested that individuals with DD rely on the sentence context when processing lexical stress patterns (Barry et al. 2012, Holliman, Wood, and Sheehy 2012). On the other hand, Holliman, Wood, and Sheehy's (2012) findings indicate that prosodic processing on the phrase and sentence level is intact in dyslexics. Furthermore, Männel et al. (2017) used the method of event-related brain potentials (ERPs) to measure Mismatch Negativity (MMN) responses for two contrasts: one segmental contrast (vowel length discrimination), the other suprasegmental (prosodic boundary perception). The results suggest that DD is characterized by a deficit in the segmental processing, as the dyslexics showed smaller MMN amplitudes in response to vowel changes than the controls, but that the prosodic processing in the dyslexic population is equivalent to that of the typical population. Another study (Cheung et al. 2009) explored the categorical perception of lexical tones (suprasegmental) and aspiration (segmental) in Chinese, a language with a non-alphabetic writing system, in Chinese children with dyslexia. In Chinese, both features of speech are used to distinguish meaning. Dyslexic children performed poorly on both types of contrast discrimination.

3.6 Allophonic Mode of Speech Perception

Based on the previously mentioned findings, such as the presence of an allophonic peak in a discrimination function (Bogliotti et al. 2008), or the recorded greater sensitivity to allophonic distinctions (Serniclaes et al. 2001), Serniclaes et al. (2004) developed an allophonic perceptual mode theory for dyslexia.

In the early childhood, infants are able to perceive the universal categories of speech sounds. Thereby, before the acquisition of L1 phoneme categories, the allophones correspond to the universal phonetic categories. As infants learn about the phonological information from their linguistic environment and their speech perception attunes to L1, the allophones that are used in the L1 (although not phonemically) become incorporated into the relevant phoneme categories. For example, until the age of 6 months, babies distinguish three voicing categories on the VOT continuum (Serniclaes et al. 2004), but later on their sensitivity to the irrelevant boundaries decreases (Werker and Tees 1984). However, dyslexics maintain the sensitivity to allophonic contrasts beyond this age irrespective of their L1 categories to some extent and their categorical perception is not fully developed. Therefore, it seems that the dyslexic population perceives speech sounds as members of allophonic categories, whereas the typical population perceives sounds on the basis of phoneme categories (Serniclaes et al. 2004).

The hypothesis of the allophonic mode of speech perception in dyslexia states that the perception based on allophones would pose problems for learning to decode the written language, specifically to establish the phoneme-grapheme relations crucial for reading acquisition. In contrast, such perception would not affect the oral language to a great extent, because the speech perception would generally remain categorical, though relying on allophonic categories instead of the phonemic units.

Nevertheless, the allophonic perception would require a more difficult processing in order to access the mental lexicon, which could be the explanation of several phonological impairments. The deficit in phonological short-term memory (Snowling, Bishop, and Stothard 2000) might be one of the consequences of the hypothesized allophonic perception because the dyslexics operate with a larger categorical inventory, which could affect the memory load. Another impairment, which arises in phoneme awareness, suggests that individuals suffering from DD perform poorly on phoneme awareness tasks (Morais, Alegría, and Content 1987, Ramus et al. 2003b) because the occurrence of allophones is variable according to the context unlike than of phonemes.

The research conducted by Serniclaes et al. (2004) aimed to confirm the dyslexics' deficit in categorical perception and to test the allophonic deficit hypothesis in dyslexics in the first place. In addition, they tried to replicate previous findings that the categorical perception of average reading children is not as developed as that of adults. Lastly, their objective was to compare the allophonic perception in average reading children and adults.

Three groups participated in the research: 18 dyslexic children (mean age of 9 years, more than 18-month reading delay), 23 average reading children (similar mean age), and 12 adults. All subjects were monolingual native speakers of French. As for the stimuli, four VOT continua were employed: sinewave /ba-pa/ and /ga-ka/ (the formants were replaced by pure tones), modulated /ba-pa/ (created by discarding high frequencies and keeping the lower ones on the sinewave continuum), and a natural /ga-ka/ continuum. There were 6 stimuli which differed in voice onset time, ranging from -60 ms to +60 ms and 20 ms apart. The mean phoneme boundaries for the four continua was determined at +10 ms. Concerning the discrimination task, the stimuli were presented in pairs in the AX arrangement.

As for the results, the phoneme boundary was confirmed at the location +10 ms VOT, which was the same for all three participant groups. However, in the dyslexics' function, as the second allophonic peak of a comparable size appeared at -30 ms VOT (natural voicing boundary), in line with the findings by Bogliotti et al. (2008). Looking at the difference between the performance of the average reading children and adults, it seemed that adults indeed display stronger categorical perception and weaker allophonic perception, but not all differences were statistically significant.

To sum up, the testing related the theory of the allophonic mode of perception evidenced the categorical perception deficit in comparison to controls and lent support to the existence of allophonic perception in children with dyslexia. The study also found a tendency towards differences in the strength of categorical perception and allophonic perception of typically-developed children and adults.

4 Foreign Speech Sound Perception with Dyslexia

It has been demonstrated in chapter 2 that L2 perception is affected by one's L1, specifically by the characteristics of the phoneme inventory and the nature of suprasegmental features. This chapter concentrates on the manifestation of dyslexia in cross-linguistic perception and how it differs from foreign speech sound perception of the normally-developed population.

4.1 Predictions for Cross-Language Perception in Developmental Dyslexia

As there are numerous theories trying to account for which underlying deficit causes the specific phonological problems associated with DD, as described in section 3.3, Soroli, Szenkovits, and Ramus (2010) inquire into the predictions for L2 perception derived from four of the theories and conduct research in order to lend support to the hypotheses or to demonstrate their shortcomings.

The first theory of degraded phonological representations (Boada and Pennington 2006) allows predicting that such deficit would affect the specification of native sounds in the first place and of foreign sounds even more distinctly.

In regard to the theory of allophonic phonological system, Serniclaes et al. (2004) hypothesize that in second-language acquisition, dyslexics could discriminate and label L2 phoneme categories that do not occur in their L1 but cross the universal phonetic boundaries better than typically-developed age-matched individuals.

The prediction for L2 following from the theory that dyslexics' have a reduced notion of speech segmentation (Goswami et al. 2002) is that the deficit occurs because dyslexics are not able to cope with increased task demands is that DD would primarily give rise to an impediment in the perception and acquisition of prosodic contrasts.

Lastly, the prediction made for L2 speech sound perception based on the supposition that the deficit arises as a result of an inability to meet the task demands could be that the dyslexic individuals would generally experience similar difficulties as controls, but would perform more poorly with the growing task demands.

4.2 Discrimination of a Non-native Segmental / Suprasegmental Contrast

The study itself (Soroli, Szenkovits, and Ramus 2010) examined dyslexics' perception and production of two non-native contrasts: Korean stop consonant voicing (viz. segmental contrast) and Korean stop consonant voicing (viz. prosodic contrast). The research also included a native phonemic contrast to provide a reference point. Furthermore, the sequences in the tasks were of three different lengths in order to examine the performance in tasks demanding contrasting short-term memory loads. The participants of the tests were 15 dyslexic and 15 control adults; all were native, monolingual speakers of French with similar non-verbal IQ, age, and level of achieved education. Prior to each experiment, the subjects were familiarized with the stimuli and the difference between the Korean bilabial plosives in training.

The first experiment testing the discrimination of native segments employed two CVCV pseudo-words /kupi-kuti/ and /mipa-mita/, arranging them into 16 two-element sequences and 16 three-element sequences in the AX and ABX formats respectively. In the second experiment, the subjects discriminated the voicing contrast on Korean bilabial plosives: /p'/ (tense), /p/ (plain), and /p_h/ (aspirated), which were organized into the pairs /p'-p/ and /p-p_h/. In contrast to the Korean language, French has two voicing categories on bilabial plosives, and that is voiced /b/ and unvoiced /p/. It was predicted (at least in the case of controls) that the pair /p'-p/ would be harder to discriminate than the pair /p-p_h/, even though /p_h/ is recorded in French as a token of /p/ because of its strong aspiration cues. The discrimination tasks employed naturally produced pseudo-words CVCV with the voiced bilabial consonant in the initial position (e.g. /p'ada, pada, $p_h$ada/ or p'eda, peda, $p_h$eda/). Each pair of the contrasts (/p'-p/ or /p-p_h/) were presented in sequences of different length: 36 trials of one-element sequences (i.e. half same, half different) in the AX format, 16 trials of two-element sequences in the AX scheme as well, and 16 trials of three-element sequences in the ABX scheme. The third part comprised of producing words in isolation (9 different pseudowords) or in a pair (18 different pairs), which was recorded on a hard disc and subsequently judged as pronounced correctly or incorrectly by two Korean native speakers. For the next task on discrimination of lexical stress, 6 minimal pairs of CVCV pseudowords differing in syllable stress, such as /pàku-paku/, were used. The "same" / "different" tasks included 24 sequences of one (half same, half different), 16 sequences of two, and 16 sequences of three pseudo-words in the AX or ABX arrangement. The last experiment was the production of lexical stress, in which the subjects were to repeat three different pseudo-words played in isolation in 18 trials and 18 pairs of the same pseudo-words.

Looking at the results, the discrimination of the first control contrast was similar for both groups as it is an easy contrast for French speakers; however, the score was better for two-word sequences, which held true for all participants. The results of the second experiment suggest that there was no statistically significant difference between the group of dyslexics and controls in discrimination of the Korean bilabials (see Table 1 for the results at each length). As expected, /p-p_h/ was better discriminated than /p'-p/ in both groups. Furthermore, shorter sequences generally led to better scores than longer ones. Nevertheless, the individual data does suggest that length 3 was better discriminated than length 2 (though not significantly), which could be explained by a training effect, or by a random quirk in the data. Both groups recorded poor results with Korean plosives since they coincide with French phoneme categories, which caused a close-to-floor score in discrimination at greater length. Considering the production of Korean plosives task, /p_h/ was produced with a greater accuracy than /p'/, or /p/, and no statistically significant differences between the two groups of participants arose. Additionally, the subjects were more successful with single pseudo-words than with pairs of pseudo-words. As for the discrimination of lexical stress, it is possible to mark a significant difference between the dyslexic and control subjects, as the former

Table 1. Discrimination of Korean bilabial plosives. The table shows scores for the overall performance (averaged across the two pairs) and for each of the pair of plosives at each length. Scores are mean *A'* values.

Group	Length 1			Length 2			Length 3		
	Overall	/p'-p/	/p-ph/	Overall	/p'-p/	/p-p$_h$/	Overall	/p'-p/	/p-p$_h$/
Controls	0.83	0.83	0.82	0.54	0.50	0.56	0.59	-	-
Dyslexics	0.80	0.81	0.79	0.54	0.46	0.61	0.63	-	-

Table 2. Discrimination of lexical stress. The table shows mean *A'* scores for the discrimination task at each length of the pseudo-words.

Group	Length 1	Length 2	Length 3
Controls	0.95	0.90	0.83
Dyslexics	0.89	0.79	0.68

achieved worse results than the latter at every length of the discriminated stimuli. Again, the length factor was significant in this task. Looking at the last experiment, controls were marginally better at the repetition of lexical stress than dyslexic individuals. Furthermore, even though the length of the produced pseudo-words was consequential for both groups, it seems that lexical stress might pose notable difficulties for French dyslexics.

Conducting a general linear model analysis, these results of the research show that relative to controls, the performance of the dyslexic subjects was not significantly different, though still slightly worse overall, in the experiments of segment discrimination, be it a native or non-native contrast. In fact, the pattern of how numerous factors affected their performance was more or less equal: they were better at native contrasts, at shorter sequences, and at perception (as opposed to production). Nevertheless, the factor that did play a role in the dyslexics' achievements was segmental versus suprasegmental contrast, as the values of discrimination of lexical stress were notably lower than those of the control group.

With a purpose to evaluate the previously suggested hypotheses in light of the results from the experiments, the theory of degraded phonological representations seems not to be coherent with the fact that dyslexics performed relatively normally on French and Korean segmental contrasts, but not so on Korean prosodic contrast. Considering the allophonic perception theory, it is not possible to make a definite conclusion, since the theory concerns only VOT. Indeed, the variable in the Korean plosives was voicing, spanning over at least one universal voicing boundary, but potentially also other acoustic cues. In other words, it cannot be determined with certainty that the dyslexic and control subjects responded based on the perception of identical acoustic cues. With regard to the beat perception theory, although it seemingly made correct predictions for the deficit in the perception of lexical stress, it is important to consider that apart from amplitude rise time indicating stress, there are also other cues for lexical stress, such as duration and pitch, which could possibly enable the impaired to overcome the deficit in amplitude perception. The next hypothesis that phonological representations in DD are not degraded at all, but that their retrieval is hindered due to task constraints, could not explain the fact that the length factor, and therefore varying short-term memory load, had an impact on dyslexics' perception and repetition in a similar manner as on controls.

In conclusion, the research conducted by Soroli, Szenkovits, and Ramus (2010) found evidence that individuals impaired with dyslexia experience trouble in discriminating lexical stress (specifically in tasks including the cues of amplitude, pitch, and duration), but do not differ significantly in the discrimination of voicing (in the possible presence of other acoustic cues) on the segmental level. Furthermore, the findings do not demonstrate any degradation in phonological representations in dyslexics' speech perception, as hypothesized by Ramus and Szenkovits (2008). According to the researchers (Soroli, Szenkovits, and Ramus 2010), it is possible that the deficits in phonological awareness and short-term memory found in individuals with DD could account for the trouble with foreign speech sounds by themselves. Reviewing all the considered theories and their implications for foreign speech sound perception, the data did not provide direct support to any hypothesis in its current formulation. Finally, the authors emphasize the need for further studies on L2 perception with dyslexia, employing a wider range of phonological segments.

5 Research Proposal

The research proposal, which is a subject of this thesis, inquires into foreign speech sound perception with developmental dyslexia.

In the review of the literature, it has been described that the typical population perceives speech sounds in terms of phoneme categories, which consequently affects foreign speech perception. However, the categorical perception of dyslexic individuals is not fully developed and they have maintained a certain level of sensitivity to allophonic categories. It has also been discussed how the deficit in categorical perception and phonological processing influences the perception of foreign speech. Nevertheless, the existing research in this area is not conclusive as there are numerous theories and hypotheses on the origin of the deficit and on its implications on non-native language perception, which cannot fully account for the phonological impairment and its manifestations. Numerous researchers accentuate the need for more data in the domain of dyslexics' perception of foreign speech.

In order to investigate the perception of foreign speech sounds in people suffering from developmental dyslexia, the methodology for future research presented here suggests the examination of how Czech dyslexic children discriminate an English segmental contrast. Education in the English language is mandatory from an early age in the Czech schooling system, namely from the first grade in elementary school, which typically corresponds to the age of 6 or 7 years. Therefore, Czech children have the linguistic experience of the perception and production of oral and written English from a relatively early age. This implies that the English contrast is not completely unknown to them as it is to naïve listeners, but also that the study has to be approached as a second-language inquiry.

Whereas the implications of the categorical deficit present in individuals with developmental dyslexia for the native language have been formulated in numerous theories, the effects on second-language categorical perception have not been described sufficiently.

The research question concerns the cross-language categorical perception of English contrasts in dyslexic and control Czech learners of English.

5.1 Methodology

5.1.1 Experiments

The proposed research consists of three experiments:

Experiment 1 tests the identification and discrimination of a Czech phonemic contrast. The use of the Czech segments has two main reasons: first, the aim is to replicate the previous findings of a deficit in categorical perception in dyslexics' native language (Bogliotti et al. 2008, Godfrey et al. 1981, Serniclaes et al. 2004), and the second objective is to provide a diagnosis of the participants. It is apparent that the experiment may not provide a sufficient diagnosis of dyslexia since it is a more complex impairment and is normally measured in multiple cognitive and phonological tasks. Nevertheless, the comparison of the dyslexics' and the controls' perception of a native contrast may provide an additional part of the diagnosis of developmental dyslexia and a useful reference point.

Experiment 2 examines the identification and discrimination of an English phonemic contrast. Being an integral part of the research, the results of this experiment could relate evidence to a hypothesis existing in the literature, or provide ground for a new theory. Therefore, it is important to correctly and explicitly report all possible factors connected to the spectrum of participants, or to the character of the tested stimuli and of the task.

Experiment 3 is conceived as an opportunity to teach the subjects an English contrast and to observe the occurent learning effect. The experiment includes three subparts: a pre-test, feedback, and a post-test. The pre-test involves an identification task, labeling the individual English stimuli. Then, the subjects would be asked to perform the identification of a different set of stimuli. The subsequent post-test is identical to the pre-test so that it would be possible to measure the learning effect. The aim of the learning task is to help the participants of the research learn to perceive a difference in a meaning-distinguishing English contrast with which Czech learners of English often have problems and to contribute to their language acquisition in that way.

5.1.2 Tasks

The phenomenon examined in the research proposal is the categorical perception. It demonstrates itself when a listener is presented with a set of stimuli that continually change in an acoustic property. Such continuum is then perceived as a sequence of discrete categories, and the listener disregards the changes within the category (Repp 1984). Categorical perception is often tested in the identification and discrimination task.

5.1.2.1 Stimuli

In order to create a continuum, two or more segments that differ in an acoustic cue are taken and the specific value is continuously changed from one extreme to the other. Afterward, a series of stimuli with equal steps between them is employed in the tasks concerning the categorical perception. The individual stimuli are played in a random order and can be repeated multiple times.

5.1.2.2 Identification

In the identification task, the subjects listen to the stimuli chosen for the experiment and decide whether it belongs to the phoneme category A or B. The results are summarized by two identification functions, one for phoneme A and one for phoneme B, which indicate the percentage of the responses that labeled the stimuli as a token of the specific phoneme.

Furthermore, it is possible to compute the expected discrimination curves from the labeling data by using a conversion formula (Pollack and Pisoni 1971).

5.1.2.3 Discrimination

For the discrimination task, the stimuli A and B are organized into pairs or triads. There are various formats, like AX or ABX, where X is identical either to A or B. The role of the subjects in these particular sequences is to determine whether they categorize the sound X as the phoneme A or B. A discrimination function is computed from the obtained data. One axis usually corresponds to the measure of correct discrimination (usually in percentage), and the other indicates the stimulus value on the continuum.

Given that this study would focus on testing kids, it seems appropriate to use the AX format. In a more complex scheme, such as ABX, the subject needs to retain A and B in short-term memory for comparison with X. That would make the task harder for the dyslexics than for the controls, and therefore it would exaggerate the difference.

5.1.3 Contrasts

This section suggests what segment contrasts could be possibly used in the individual experiments. Each section provides some phonetic information about the phonemes and the findings of various researchers.

5.1.3.1 Experiment 1

In the tasks involving the Czech phonemes, the possibility of the /s-ʃ/ contrast and /s-f/ is suggested.

In terms of phonetic characteristics, all three consonants belong to the category of fricatives. They are produced by the "approximation of two articulators so that the airstream is partially obstructed and turbulent airflow is produced" (Ladefoged and Johnson 2011). The fricative sounds are accompanied by a hiss, which is sharp with the Czech /s/, /ʃ/, and /ʒ/, and continual with /f/, /v/, and /z/ (Pálková 1994). In English, however, the hissing sound is considered sharp with only /s/ and /z/, being continual with the remaining fricatives (Pálková 1994). It is possible to make the consonant longer, as opposed to stop consonants (Pálková 1994). With regard to the place of articulation, /s/ is alveolar, /ʃ/ is postalveolar, and /f/ is labio-dental. The three phonemes are also voiceless.

A study carried out by Skarnitzl, Šturm, and Pavel Machač (2013) focused on the voicing mechanism in Czech alveolar/postalveolar fricatives and their articulation. They argue that in the Czech language there is a strong link between the phonological voicing (i.e. specified in the language system) and the phonetic voicing (i.e. the presence or absence of vocal fold vibration). The research used the method of electropalatography (EPG) to measure the contact of the tongue and the palate during the articulation of the target fricatives (/s/, /z/, /ʃ/, and /ʒ/) in normal, phonated speech, and whispered speech. The results showed an interesting occurrence in the way the tongue touched the palate in voiced and voiceless alveolar/postalveolar fricatives. In the production of the voiced fricatives /z/ and /ʒ/, there was a greater degree of contact than in the voiceless fricatives /s/ and /ʃ/. However, only phonated speech produced a significant difference compared to whispered speech. To conclude, a variability in the articulation of Czech alveolar/postalveolar fricatives, specifically in relation to the tongue position, was found.

The voiced counterparts to the consonants /s/, /ʃ/, and /f/ are /z/, /ʒ/, and /v/, respectively. When the voiced fricatives occur in word-final position, they are replaced by the voiceless fricatives in the Czech language. On the contrary, the word-final voiced fricatives remain voiced in English.

As for the categorical perception, Kronrod, Coppess, and Feldman (2016) claim that the degree of categorical effects varies based on the stimuli. In consonants, they seem very strong, as opposed to nearly continuous perception in vowels. Their findings on the effects in fricatives have not been consistent, as some found them to be weak in fricatives, others strong (Kronrod, Coppess, and Feldman (2016). Thus, the categorical effects still remain a matter of further research.

5.1.3.2 Experiment 2

For the English contrast, it is proposed to use the /w- ɹ/ contrast, for example in way-ray. As for the phonetic properties, /w/ is a voiced labio-velar approximant, and /ɹ/ is a postalveolar approximant. Approximants are produced while the two articulators are in proximity but there is no flow of turbulent airstream involved (Ladefoged and Johnson 2011). The phoneme /w/ can also be called a semivowel, because it is to them similar phonetically, but are not syllabic like vowels.

The distinction between the two phonemes can be characterized in terms of formant transitions. Looking at a spectrogram of the two phonemes, there is an evident difference in the third formant transition slope (Ladefoged and Johnson 2011). In /ɹ/, the F3 starts at an extremely low position and rises sharply. The second and third formant of /w/ also start low, but the sharp rise occurs in F2.

Regarding the contrast itself, it is used to created minimal pairs, i.e. a pair of words that differ in meaning and exactly one segmental information. Minimal pairs like wage-rage or went-rent may be considered. However, it seems better to use nonsense words in order to eliminate the influence of the learning experience in English and to minimize the impact of the individuals‘ level of English.

As a non-native contrast, it is possible to analyze the predicted perception of /w-ɹ/. Both categories are relatively new to Czech listeners. Neither the phoneme /ɹ/ nor /w/ is present in Czech. According to Best's PAM (1995), the typically-developed naïve Czech listener would perceive both sounds as Uncategorizable into a phoneme category but both sounds would still fall into the phonological space. The listener would not experience any biased listening and would be close to a universal perceiver. However, as it has been already stated, the Czech participants would probably have linguistic experience with English. Therefore, consulting the PAM for L2 (Best and Tyler 2007), the following option is possible. Both segments would be perceived as Uncategorizable. In this case, the discrimination of the contrast would not be difficult for Czechs and two new L2 categories would be established.

Nevertheless, the grapheme representing the postalveolar approximant in English is the same as for the Czech trill /r/, which may affect the learning of the sound to some extent. For example, it is not uncommon for Czech learners of English to pronounce the English grapheme *r* as the Czech trill /r/.

5.1.3.3 Experiment 3

Concerning the experiment including feedback in the labeling task, the idea is to use a contrast that poses problems for Czech people so as to help the subjects learn the distinction. One of the possible contrasts is the vowel contrast /ɛ-æ/.

Phonetically, /ɛ/ is an open-mid near-front vowel, and /æ/ is a near-open near-front vowel. In terms of formant frequencies, /ɛ/ exhibits a lower F1 and a higher F2 but the third formant is equivalent for the two vowels.

As for the interaction of the contrast with the Czech language, the English vowels /ɛ/ than to /æ/ would fall into the Czech vowel /ɛ/, therefore causing Single-Category Assimilation (Šimáčková 2003). The findings from Šimáčková's (2003) research also show that Czech learners rely on duration cue in identifying the vowels /ɛ/ or /æ/ rather than on their height and other properties.

5.1.4 Participants

Two groups would be expected to participate in the research: a group of dyslexics and a group of age-matched controls. All subjects should be monolingual speakers of Czech without any additional impairment.

As for the age of the participants, it seems fitting to involve children who are in their first year or in the second year of high school. Typically, the age would be 15 or 16. The reason for the age preference is that it would be easier for these participants to comprehend the task and to maintain their attention throughout the whole testing, as opposed to younger children. Nevertheless, the inclusion of younger children may be helpful because they are not likely to have an extensive knowledge of English, and therefore they would be on a similar level of English.

Prior to the experiments examining the categorical perception, it could be beneficial to assess the subjects' L2 skills in order to be able to compare the test results with the obtained categorical perception.

5.1.5 Diagnosis of Developmental Dyslexia

To diagnose the children as dyslexic, it is possible to use one of the batteries of tests. The Palacký University Psychology Department has a test of reading skills "Zkouška čtení" by Zdeněk Matějček, which are intended for diagnosis of dyslexia in children who are between the first and sixth grade of elementary school.

Another possibility is that the dyslexics have already been diagnosed, and therefore possess certificates written out by psychologists.

5.1.6 Procedure

The research is proposed to be conducted on computers, using headphones for a clearer presentation of the stimuli. The environment should be quiet so as not to create biases situations, and distractions should be eliminated.

Concerning the testing itself, the subjects would be looking into a computer program, where they would click on the option that they have determined is correct. In the third experiment, the task including the feedback could show pictures as a response to the answers, e.g. a smiley face or a thumbs-up in case of the correct identification of the stimuli, and a thumbs-down for the incorrect labeling, in order to motivate the subjects, and make it more entertaining.

In addition, all subjects taking part in the research should be familiarized with the character of the study and of the way personal data is going to be processed. The participants should sign an informed consent (see Appendix), or bring it signed by their parents in the cases of minors.

5.2 Hypotheses

Hypothesis 1. Previous findings of a categorical perception deficit in children with dyslexia will be replicated. It is expected that the dyslexics will exhibit a poorer performance in Experiment 1, which tests the categorical perception of a native contrast.

Hypothesis 2. The data obtained from the dyslexics' responses in Experiment 1 may show additional allophonic peaks in discrimination along the continuum.

Hypothesis 3. In the discrimination of the English contrast /w-ɹ/ in Experiment 2, it is hypothesized that the dyslexics may display an additional peak or peaks on the continuum.

Hypothesis 4. The dyslexics will encounter similar challenges with the non-native contrast like controls (Soroli, Szenkovits, and Ramus 2010).

Hypothesis 5. Alternatively, the dyslexics will be helped be the allophonic perception in discriminating the non-native contrasts (Serniclaes et al. 2004).

Hypothesis 6. It is presumed that the typically-developed children will experience a greater learning effect in Experiment 3 since they are better at speech sounds.

Hypothesis 7. Alternatively, the dyslexics will show a better learning effect since they have better access to within-L1-category phonetic detail.

6 Conclusion

The theoretical work consisted of a literature review concerning various aspects of speech perception. The first chapter provided an account of the language development during an early childhood as a basis for a language-specific speech perception, which is demonstrated especially in the phenomenon of the categorical perception. The second chapter demonstrated how native speech perception affects the perception of non-native speech sounds. Also, the predictions for the perception of foreign contrasts were introduced in the summary of the Perceptual Assimilation Model. The subject of the third chapter was developmental dyslexia, its definitions, and its theories. Furthermore, the deficits associated with dyslexia were discussed, namely impairment in the tasks involving the categorical perception and phonological abilities. The last chapter described predictions of second-language perception in dyslexia, which were contrasted with the research outcomes. Finally, a study on dyslexic learners' cross-language perception was proposed as a ground for further research.

7 Résumé

Obsahem této bakalářské práce je souhrn literatury na téma vnímaní rodného a cizího jazyka u typické populace a u lidí postižených vývojovou dyslexií. V průběhu jazykového vývoje v raném dětství dochází k přeměně z univerzálního vnímání řeči na percepci zaměřenou na mateřský jazyk jedince. Z inventáře kategorií batolete tak v průběhu prvního roku života mizí zvuky, které nejsou v daném jazyce relevantní. Následovně se utváří kategorická percepce, která zjednodušuje vnímání mateřského jazyka tím, že se sníží sensitivita při rozlišování subfonemických kontrastů. Studie ukázaly, že z důvodu deviace ve vývoji percepce řeči, nevnímají dyslektici zvuky na základě fonémů jako typická populace, ale spíše na základě alofonů. V literatuře je navržený model pro vnímání cizích kontrastů, tzv. Model percepční asimilace. Pro developmentální dyslexii však tyto predikce chybí a v oboru je nedostatek výzkumu, zaměřeného na percepci cizího jazyka u jedinců s dyslexií. Bakalářská práce proto zahrnuje návrh pro výzkum v oblasti kategorické percepce anglických fonémických kontrastů u skupiny českých dyslektiků a kontrolní skupiny, jejichž členové se učí anglicky. Cílem je zhodnotit hypotézu, že méně vyvinuté fonémické kategorie v rodném jazyce umožňují dyslektikům vnímat fóny cizího jazyka s větší přesností než typická populace.

8 Appendix

Účast ve výzkumu

Vážení rodiče a studenti,
chtěla bych Vás požádat o spolupráci na výzkumu, který je předmětem pro výzkum v oblasti vnímání zvuků cizí řeči s dyslexií. Dyslexie je specifická porucha čtení, která se mimo jiné vyznačuje deficitem ve vývoji kategorické percepce, tj. vnímání zvuků jazyka jako členů určitých kategorií, např. v češtině se znělé /ch/ (ve slově *chobot*) i neznělé /ch/ (ve slově *rampouch*) řadí do stejné kategorie /ch/, protože nemění význam slov. Protože dyslektici nemají kategorie zvuků plně vyvinuté, jejich vnímání řeči se odlišuje od typické populace, jehož důsledkem je lepší rozlišování zvuků v rámci jedné kategorie než běžná populace. Hypotézou výzkumu tedy je, zda může dyslektikům nedostatek v kategorické percepci pomoci při rozlišování zvuků v cizím jazyce a zda může prospět při studiu cizích jazyků.

…………………………………………………………………………………….……………..

Informovaný souhlas zákonného zástupce se vstupem do výzkumu

Výzkum se zabývá vnímáním jazyka u dyslektiků v porovnání s typickou populací a jeho hlavní součástí je testování rozpoznání a rozlišení zvuků českého a anglického jazyka.

Přístup k osobním údajům Vašich dětí je umožněn pouze výzkumníkovi, který je povinen zajišťovat a zachovávat důvěrnost Vašich údajů. S Vašimi údaji bude nakládáno jako s přísně důvěrnými v souladu s právními předpisy České republiky, a to zejména zákonem č.101/2000 Sb. o ochraně osobních údajů a o změně některých zákonů v platném znění. Máte právo nahlížet do záznamů vedených o Vaší osobě a případně požádat o odstranění zjištěných nedostatků při jejich zpracování v souladu s výše zmíněným zákonem. Výsledky výzkumu, které budou použity, budou anonymizovány a všechna jména budou pozměněna. Účast ve studii je dobrovolná. Účastník může odmítnout pokračování v testování bez udání jakýchkoliv důvodů nebo odmítnout účast ve studii, a to bez jakýchkoliv postihů. Máte právo se i zpětně zeptat na cokoliv, co se týká této studie.

Souhlas zákonného zástupce:

Já………………………………..…………………... jsem si přečetl/a výše uvedené informace, těmto informacím rozumím a dobrovolně souhlasím s účastí své dcery/ svého syna ………………………………..…………………... ve studii „Vnímání zvuků cizí řeči s dyslexií“. Rozumím, že mohu souhlas odmítnout, případně svobodně a moje dcera/ můj syn může bez udání důvodu ze studie kdykoliv odstoupit a zároveň souhlasím s tím, že data sebrané z výzkumu budou použita pro vědecké účely v anonymizované podobě.

V…………..……Dne……………. Podpis zákonného zástupce: ……………………….

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9.2 Digital Image

Categorization and discrimination curves [Categorization-and-Discrimination-Curves.png]. 2007. *Wikimedia Commons*. https://commons.wikimedia.org/wiki/File:Categorization-and-discrimination-curves.png.