Analysis of the language environment in Brazilian toddlers with hearing impairment

Pre-validation of the LENA system in Brazilian Portuguese

Miriam da Silva Ferreira

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Master of Philosophy in Special Needs Education
Department of Special Needs Education
Faculty of Educational Sciences

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Miriam da Silva Ferreira

http://www.duo.uio.no/

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Abstract

The Language ENvironment Analysis system (LENA) is a tool used for investigating the audio and language environment of families of young children. To date, its normative data is in American English (Gilkerson, & Richards, 2008) despite a number of studies testing the feasibility of this system to other languages (Aragon & Yoshinaga-Itano, 2012; Gilkerson et al. 2015; Da Prato, 2016; Ganek & Eriks-Brophy, 2017; Canault et al., 2016). The objective of the present study was to investigate the characteristics of the natural language environment of Brazilian Portuguese speaking environments of children with normal hearing (NH) (n=7). A comparative analysis was also conducted with a cohort of children with hearing impairment (HI) (n=7). The LENA system was used for collecting data. The number of child vocalizations and adult words correlated well with human counts. Increase in sample size would generate a stronger correlation between the automated and the human counts. The natural language environment of the two groups was similar. Significant gender differences were observed regarding the number of words spoken near the children by the participating female caregivers in relation to male caregivers. Differences in language performance among children with HI was associated with the age of fitting of hearing technology.

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1 Introduction

Hearing impairment (HI) affects about 0.2% of the newborn population in Brazil (IBGE, 2015). However, a great number of these children still do not have their HI diagnosed and remediated within the timeframe suggested by the Early Hearing Detection and Intervention (EHDI) guidelines (Joint Committee on Infant Hearing, 2007). Therefore, it is necessary to speed up this process and find more options for supporting the families with relevant strategies for stimulation of the language and auditory development in these children. By supporting families with individualized and more specific strategies, it could be possible to minimize the possible negative impact of the HI on the early language acquisition process in children with HI, due to auditory deprivation. Consequently, children with HI could then develop better cognitive, emotional, and social development. Also in the group of children with NH there is a variation of language development that can be related to their home environment and factors like socioeconomical status (SES).

This master thesis is paper-based. It means that this study was prepared to be published in a renowned academic journal (cf. appendix IX).

1.1 Definition of hearing impairment

Kirk, Gallager, Anastasiow, and Coleman (2011) defined hearing loss as an individual's hindered ability to perceive sounds from the environment and thereby unable to communicate by listening. The different types of hearing loss were defined based on the age of onset and the severity of impairment (Kirk et al., 2011). In this section, a brief explanation of the different types of hearing loss in relation to the age of onset and its severity was provided.

The language development of a child with HI is understood based on the age of onset of the hearing loss. If the inability to process auditory information starts prior to the onset of spoken language development, it is called pre-linguistic deafness. Cases of pre-linguistic deafness have either e.g. genetic-like non-syndromic cause, connexin 26, or Usher's syndrome. Hearing loss can also be acquired at birth or shortly thereafter due to congenital causes, like congenital cytomegalovirus (CMV) infection, X-linked HL, and prenatal infections. Post-linguistic deafness is an acquired form of HI due to i.e. trauma, meningitis or virus infections, which happen after a child has acquired some speech and language (Kirk et al., 2011). Often the cause of deafness/HI is unclear and unknown.

The severity of an individual's ability to perceive sound is measured in decibels (dB), which is the measurement scale used by the World Health Organization (WHO, 2018 May 17). According to Kirk et al. (2011), hearing losses is an umbrella term used for referring to the various levels of severity a person's hearing skills are hindered. It includes the following terms: deafness or HI, hearing loss, and hard of hearing. The terms HI or deafness refer to an individual's moderate to severe-profound (56-90+ dB HL) inability to process linguistic information through hearing and listening. The term mild-moderate hearing loss (26-55 dB HL) refers to a temporary or permanent difficulty in processing linguistic information through hearing. Lastly, the term hard of hearing refers to all other categories of auditory loss (Kirk et al., 2011). Yet, the WHO (2018 March 15) referred to disabling hearing loss as being greater than 30 dB[1] in the better hearing ear in children between 0 and 14 years.

A number of different terminologies have been used to refer to individuals with reduced hearing abilities, i.e. deaf, hard of hearing, hearing loss, and HI. In order to avoid any mislabeling, the term HI is used for referring to this population in the current thesis.

1.2 The Early Hearing detection and intervention

The Early Hearing Detection and Intervention (EHDI) guidelines, also known as the 1-3-6 policy, were established in the United States to urge the diagnosis and the treatment of HI in young children (Joint Committee on Infant Hearing, 2007; Muse, Harrison, Yoshinaga-Itano, Grimes, Brookhouser, Epstein, & Martin, 2013). These guidelines suggested that children should have their hearing screening by 1 month, diagnosis of hearing loss by 3 months and intervention by 6 months (Joint Committee on Infant Hearing, 2007; Muse et al., 2013). Following these guidelines would minimize the impact of the HI on children's language development (Fulcher, Purchell, Baker, & Munro, 2012; Wake, Ching, Wirth, Poulakis, Mensah, Gold, & Rickards, 2016; Yoshinaga-Itano, Sedey, Wiggin, & Chung, 2017).

Evidence from research has supported the importance of following the EHDI guidelines (Fulcher et al. 2012; Wake et al., 2016; Yoshinaga-Itano et al., 2017). To this regard, Fulcher

[1] Disabling hearing loss: deaf, hard of hearing, hearing loss (mild to profound).

et al. (2012) observed that children with HI who met the 1-3-6 policy had were matched with their peers with NH on measures of speech and language at the age of three and achieved typical language development by the age of five. Yoshinaga-Itano et al. (2017) observed that children with HI that have met the 1-3-6 policy have higher vocabulary quotient regardless of processing factors that may hinder expressive language development. Wake et al. (2016) suggested that children diagnosed with HI with the universal screening test were better at receptive and expressive language and receptive vocabulary at school age entry.

1.3 Hearing impairment in Brazil

Hearing impairment is a type of disability of high prevalence in Brazil. As of the Brazilian Demographic Census 2010 (IBGE, census 2010), about 8.7 millions of Brazilians have some degree of HI, which represents about 5.1% of the country total population. Data from the Brazilian Ministry of Health[2] (Brasil, 2012) suggested that HI occurs in a ratio of 6:1000 newborns and between 1:100 and 4:100 preterm babies. Altogether, it is estimated that about 10% of the infants born in Brazil display some degree of HI. According to the Brazilian National Health Research[3] 2013 (IBGE, 2015), individuals with severe levels of HI represented 20.6% of the population although only 8.4% of the total population with HI received rehabilitation services.

The early diagnosis of HI in Brazilian children has been possible since August 2010 due to the implementation of the Federal Law #12303. The text of this law demanded that every hospital and maternity clinic should offer the Otoacoustic Emissions test (OAE) free of charge to every family of a newborn. Aiming at improving the quality of life of individuals with HI, the Brazilian Integrated Health System (*Sistema Único de Saúde* – SUS) is the responsible agency for providing individuals with HI adequate hearing health services. The provided services consist of the complete diagnosis of HI, which includes the OAE test and the Auditory Brain Response (ABR). After the diagnosis, the SUS provides HA, referral to cochlear implantation (CI) investigation, pre- and post-chirurgical support (*SUS oferece reabilitação*…, Portal Brasil, 2015).

[2] *Ministério da Saúde*
[3] *Pesquisa Nacional de Saúde*

Concerned with the high ratio of prevalence of HI among infants, the Brazilian Ministry of Health elaborated the Neonatal Auditory Screening Program (Brasil, 2012). The guidelines of this program include (1) support to multidisciplinary groups of professionals working with child hearing health, (2) child auditory screening, (3) follow-up on infants' hearing and language development, (4) diagnostic, and (5) rehabilitation services.

The purpose of the Neonatal Auditory Screening program is to identify the HI among infants as early as possible. The Ministry of Health suggests the screening to be conducted preferably within the first 48 hours of life, but no later than the first month of life. The auditory screening consists of test and retest of infants' hearing with physiological and electrophysiological measures. The two tests available are the OAE and the ABR. If the result was not adequate, the test should be conducted again between 15 to 30 days later. The infant should be referred to a center of hearing health service in case of unsatisfactory results.

Ideally, the diagnosis of HI should be confirmed within the infant's third month of life. The fitting of hearing aids (HA) should be done within a month of the diagnosis. If the HI is confirmed, the intervention should begin before the infant becomes six months old. Due to the plasticity of the central nervous system, early intervention favors the development of the auditory and language functions of the infant with HI. Thus, it supports learning, improves quality of life, and the inclusion of these individuals in society (Brazil, 2012).

All infants, regardless if they are at-risk or not, should have their auditory development monitored monthly throughout their first year of life. Children at-risk of HI should be referred to formal diagnosis, be fitted with adequate HA/CI, and receive speech therapy as established on the decree MS / GM #835, 25 April 2012.

Despite the implementation of the above-mentioned decrees, reducing the number of people with HI who do not receive rehabilitation services is a rather challenging task. For this reason, it is of paramount importance to start with the young ones. Diagnosing HI among the newborn population following the 1-3-6 policy, and supporting them with rehabilitation services from early on would minimize the consequences of the language delay due to the HI. It would enable them to achieve age adequate oral language skills. Consequently, the positive impact of such practice would linger throughout these children's whole lives.

1.4 The structure of Brazilian families

In the traditional structure of Brazilian families, fathers are the family providers whilst mothers are in charge of the house duties and the childcare. However, this structure has been challenged by the increasing insertion of women in the workforce since the 90's (De Brito & Dessen, 2010; Dessen, 2010). Data from the last demographic census, which was conducted in 2010, have demonstrated the increasing participation of Brazilian women in the workforce since 2016 (IBGE, 2012; Mulheres ganham espaço…, 2017). The numbers varied from 43% in 2003, 41% in 2007, 45% in 2011, and 44% in 2016. Even though men have been co-operating more in-house duties and childcare, women are still the family member in charge of the family affairs in many households (Dessen, 2010).

The above-mentioned on-going process of both women and men being at work has challenged the traditional structure of the Brazilian family. It has to do with who is going to be in charge of childcare while both parents are at work. Wagner, Vieira, & Maciel (2017) suggested that parents have been finding it difficult to cope with childcare due to their work, and therefore, they need external assistance. Martins Filho (2012) brought up the idea of *criança terceirizada* (Eng.: 'outsourced child'). This term refers to children being looked after by third parts while parents are at work. According to the author, children are more and more often taken care by an aunt, grandparents, nannies, daycare centers from very early age (Martins Filho, 2012).

This scenery changes again when the families find out they have a child with special needs, such as HI. Having a young child diagnosed with HI leads families to adapt their structure and routines in order to accommodate to the child's needs and to support her language development (De Paula Teixeira, Silva, & Lima, 2015). A common example of changes in the family is structure regards the parents working situation. In such situation, one of the parents, often the mother decides to reduce her workload or even quit her job to have more time to take care of the child with HI.

All of the necessary adaptations in the family organization and choices they had to make to best support their child's upbringing has an impact on the emotional state of family members. Tenor & Deliberato (2015) raised the attention to the high expectation parents have on their child's language development, especially after CI. According to the authors, the CI promotes auditory stimuli, which supports oral communication skills of the cochlear implanted child.

However, parents expect that the CI child is going to start talking in no time (Tenor & Deliberato, 2015). Actually, the development of listening and language skills of a child with HI depends on factors like auditory memory capacity, adequate stimulation in the family environment, and early speech therapy intervention (Tenor & Deliberato, 2015).

1.5 The LENA System

The Language Environment Analysis (LENA) system (www.lena.org) is an advanced speech streaming technology developed by Terrance and Judith Paul in the U.S.A. in 2008. This technology was developed to measure and to analyze samples of auditory and linguistic information recorded in the home environment of children age between zero and 48 months. Therefore, it has been used by researchers and clinicians with the purpose (1) to evaluate the listening and language development of the child, (2) to demonstrate parents the importance of early language input by tracking the amount of talk between i.e. parents and their children (Canault et al., 2016), and (3) to contribute to the development of family-centered intervention programs aiming at enhancing parent-child daily close interaction.

This software relies on statistical algorithms that turn voice and sound recordings into measurable data. The basic LENA measures are numbers of adult words (AW), parent-child conversational turns (CT) and child vocalizations (CV) uttered per hour. In addition, the software identifies and measures the audio environment during the day measured in percentage of silence, electronic sounds (TV, iPad), and exposure to meaningful language (spoken language presented on close distance to the key child) and distant language (spoken language presented on distance or overlap of speech). All data are presented in four different composites, namely monthly, daily, hourly, and 5-minute view.

As an advanced speech streaming technology, the LENA system is known for being a non-invasive instrument for data collection. This system enables the researcher to collect a larger amount of high-quality audio recordings collected in a naturalistic fashion. It is also known for facilitating the data analysis because all of the recordings are processed within a matter of minutes by the LENA software for analyzing linguistic and acoustic information. Therefore, the LENA system allows researcher to conduct large-scale research and to collect 12-hour long naturalistic samples of linguistic and auditory information of small children's home environment.

The normative data of the LENA system is in American English (Gilkerson, & Richards, 2008; Gilkerson, Coulter & Richards, 2008). Results of this longitudinal study suggested that the amount of AW spoken to a child between the ages of zero and three is a predictor of the child language achievement by the end of that period (Hart & Risley, 1995). The main goal of the LENA foundation is to strengthen and increase interactive talk in children between zero and four years of age, for it is considered the critical period of brain development (cf. chapter 2, p. 10). Growing up in a rich language environment positively impacts on children's social, emotional, and cognitive development. A number of studies have been conducted for validating the system to other languages due to the importance of this tool for empowering families to stimulate and strengthening their young children's development (cf. section 3.3, p. 16).

1.6 The Brazilian pre-validation study

The LENA system has sparked the interested of researchers around the world because it is able to explore measures of child-parent interaction patterns in a naturalistic environment. (Aragon & Yoshinaga-Itano, 2012; Gilkerson & Richards, 2009). As of the author knowledge, the LENA system has not been tested in Brazilian settings, yet. This master thesis represents the first step to testing the feasibility of the LENA system in BP-speaking environments.

The present study is part of the international and longitudinal research program 'Words make difference', which is led by Associate Prof. Ulrika Löfkvist from the University of Oslo (Norway) and Karolinska Institutet (Sweden). The objective of this research program is to explore the influence of the listening and language environmental factors for the linguistic and socio-emotional development of young children with HI. The performance of children with HI is assessed by using the LENA system and then compared to the performance of age-matched children with NH by using the LENA system.

The investigation of the language and listening environment of Brazilian children of the 'Words make difference' research program was conducted in cooperation with Associate Prof. Cilmara Levy from the College of Medical Sciences Santa Casa and the Santa Casa Hospital (São Paulo, Brazil). The Santa Casa Hospital is a philanthropic health care unit and center of reference for CI in São Paulo. This hospital provides health services and CI to children from low-income families with the support of the Brazilian Integrated Health

System. Due to the level of expertise of the professionals working there, its services are also sought by middle- to high-income families of children with HI. Currently, the Santa Casa Hospital has agreements with some health insurance companies, so children from middle- to high-income are also cochlear implanted by its professionals in its facilities.

1.7 Research objectives

The LENA system normative data is in American English (Gilkerson, & Richards, 2008). Although a number of studies have tested the LENA system in foreign languages, no known study has so far been conducted in Brazilian Portuguese (BP) context. Because the LENA system has already been validated in syllable-timed languages (cf. section 3.3, p. 16), it was therefore hypothesized that this software would be a valid tool for evaluating and monitoring language development in BP.

The main objective (1) of this master thesis was to pre-validate the LENA system to BP. In order to do that, it was necessary to investigate the listening and language environment of Brazilian children with NH with focus on AW and CV. Therefore, it would answer the question whether The LENA algorithms would generate reliable AW and CV estimates for BP or not.

The second objective (2) of this study was to explore the language and listening environment of Brazilian children with NH and with HI measured with LENA system. The comparison focused on group performance on the language assessment and on characteristics of their language and listening environment. Gender differences in parent-child interaction were also taken into consideration. More specifically, this comparative analysis sought to investigate the involvement of male and female caregivers on childcare and difference in the interaction of adults with male and female children. Based on aspects of Brazilian culture, it was hypothesized that female caregivers have more influence on child development.

The third objective (3) of this study was to investigate if there was any correlation among the LENA system's variables to children's age, performance on the selected expressive and receptive language assessment tests, the amount of exposure to significant linguistic input, and the level of parental education. Such investigation would provide a clearer picture of how environmental factors impact on children's receptive and expressive vocabulary and listening development. It was expected that older chronological age, early age of fitting HA, and amount of exposure to AW and parent-child CT would positively impact on children's language development.

For achieving the third objective, the following questions were asked. Would the number of CT, CV, and AW increase as children get older? Would an increase in exposure to significant linguistic input (spoken language uttered close to the child) positively correlate with the language environmental factors and children's language performance? What are the characteristics of language and listening environment of children with NH and their counterparts with HI according to the SES of their families?

1.8 Importance of this study

To date, normative data of the LENA system are from English-speaking homes (Gilkerson, & Richards, 2008; Gilkerson et al., 2008). Pre-validating the LENA system for BP is of scientific relevance, for it could contribute to the work being developed by the LENA Foundation by expanding the use of the LENA system to other languages.

Second, having the LENA system pre-validated to BP would regard it as a reliable tool for data collection. In other words, it would provide an understanding of the characteristics of language and audio environment of Brazilian families from an ecological perspective.

Understanding the existing need of supporting Brazilian families with strategies for stimulating the language acquisition of their infants and toddlers with HI, the LENA system could be used as a key component of family-centered programs for accelerating language development of at-risk children, i.e. children with HI, in Brazilian settings.

1.9 Structure of this thesis

This master thesis consists of five chapters, which are organized as follows. Chapter 1 presents the background, the purpose, and the importance of this study. Chapter 2 presents the theoretical background that provided the ground knowledge for pursuing this research. Chapter 3 presents the research design and method. Chapter 4 presents and discuss the results. Chapter 5 provides a summary of the main findings and recommendations for future studies.

2 Theoretical background

2.1 The nativist theory for language acquisition

The nativist theory for language acquisition claims that the human brain is pre-programmed with the innate ability to acquire language in the same way as any other biological function (Chomsky, 1988 & 2011). Chomsky argued that the human brain is endowed with a language acquisition device (LAD). The LAD enables children to perceive, understand, and organize the basic elements of a language in any linguistic context. The basic elements of a language are common features shared by all languages, such as nouns and verbs. These features are genetic components of the language faculty, which Chomsky called universal grammar (UG). It means that individuals can independently understand and generate rules of grammar from the languages to which they are exposed in the environment.

Under the nativist premises, the LAD is activated as soon as children have access to samples of natural language. Children acquire a language by combining their innate knowledge of the principles of the UG to the particular structures of the language in the environment. To this matter, Chomsky (2011) claimed that each individual has an internal language (I-language) and that a child's I-language enables her to generate an infinite combination of linguistic expressions.

The nativist theory has a strong biological basis. It suggests that virtually all children can successfully learn a language just by being exposed to limited samples of language. It means that they learn their mother language in a rather natural fashion, without receiving any formal instructions. However, the LAD only works successfully if stimulated within a specific period of time. In other words, children's innate ability for language acquisition happens within the critical period, which arguably lasts until about the age of four or five (Cipollone, Keiser, & Vasishth, 1998; Kirk et al., 2011; Lennenberg, 1967). After this period, this innate ability gradually fades away (Cipollone et al., 1998; Kirk et al., 2011). That is because the LAD specializes in the mother language and becomes unable to detect sounds and grammar from other languages.

2.1.1 First language acquisition and the hearing impaired child

The nativist theory postulate that virtually every child has the innate ability to acquire language, which lasts for the first five years of her life (Cipollone et al., 1998; Chomsky, 1988 and 2011; Kirk et al., 2011; Lennenberg, 1967). This affirmative applies to children not facing any cognitive and atypical developmental challenges. Thus, it raises the question of how children with HI develop their language skills in the light of the nativist theory for language acquisition.

Kirk et al. (2011) explained that most children with HI have normal cognitive abilities and that they have the same mechanisms for language learning as their age-matched peers with NH. Because HI is a silent disability, it only becomes apparent when a child faces audio-verbal demands. From this point in life, the developmental pathways of children with HI and NH begin to diverge (Caskey & Vohr, 2013; Kirk et al. 2011). For this reason, specialized support becomes necessary to close this developmental gap. If a child with HI receives specialized support for developing their oral language skills within the critical period, this child will achieve the expected language milestones with ease (Kirk et al. 2011).

The EHDI guidelines are in line with the principals of the nativist theory for language acquisition (cf. section 1.2, p. 2). Researchers have observed that children whose HI was early identified (1 month), with early fitting of hearing technology, and followed by an specialized early family-centered intervention program before the age of 6 months develop better oral and sign language skills than those who were identified later in life (Joint Committee on Infant Hearing, 2007; Muse et al., 2013). Thus, the earlier in life a child's HI is identified and an intervention program is initiated, the better is the prognosis for an optimal language development (Aragon & Yoshinaga-Itano, 2012; Gilkerson & Richards, 2009; Hart & Risley, 1995; Kirk et al. 2011; Van Dam, Oller, Ambrose, Gray, Richards, Xu, ... & Moeller, 2015).

The main goal of intervention programs is to expose children with HI in a rich language environment for stimulating their language acquisition process within the critical period, when the brain is most plastic. It has been argued that early intervention begins in the home environment, and above all, it relies on the active involvement of parents (Gilkerson & Richards, 2009; Hart & Risley, 1995; Kirk et al., 2011). Therefore, parents have a significant role in cooperating with the child with HI to attain better communication skills.

2.2 The theory of ecological systems

The theory of ecological systems was developed by Urie Bronfenbrenner (1917-2005) in 1979. This theory focus on the evolving interaction between the developing person (child) and the environment. In other words, the theory represents a relevant approach in relation to the use of the LENA system. This theory can explain how the environment and social relationships may affect a child's development in a wider and ecological context.

On his work, he defined development as 'a lasting change in the way a person perceives and deals with her environment' (Bronfenbrenner: 1979, p. 3). That is because individuals develop in multiple environmental contexts, and these diverse environmental contexts influence their development either directly or indirectly.

Bronfenbrenner (1979) talked about the dyadic interaction between two people, also called two-person system. It means that a pair of individuals undergoes a process of development in consequence of their two-way interaction. For instance, parents who get involved in reciprocal interaction with their child not only end up supporting the child's language development, but they also learn something from or about their child.

According to Bronfenbrenner (1979), reciprocal relationships may also involve more than two persons or a larger group. Dyadic interactions are determined by the existence and the nature of social interconnection between settings, i.e. the amount of information in each setting about the other (Bronfenbrenner, 1979). Under this view, a person's development is affected by the environment events happening in the immediate surroundings. It means that a person may either be engaged in the activity or simply be present in the environment where a given activity undergoes so that the learning process can take place.

Being present in the environment where an activity takes place works as an inspiration for the developing person to undertake similar activities on her own. For example, children learn to talk by listening to others talking directly to her or him in their nearby surroundings, such as when one of the parents reads a story for the child while the other does the housework. Beginning to talk constitutes an evidence that they have learned from environmental events and join-interaction. This is what Bronfenbrenner (1979) called as a molar activity. Involvement in molecular activities is a sign of both internal mechanisms and external manifestation of psychological growth.

Bronfenbrenner (1979) was concerned with the validity of the results of research conducted in a laboratory. He argued that the change in environment plays an impact on the behavior of the developing person. Thus, the possible impact of the research location on its results should be accounted. For this reason, Bronfenbrenner (1979) proposed a research model that could expand and converge the theoretical conceptions of environment present both in naturalistic and experimental approaches to scientific research. This is the idea of ecological validity.

The idea of ecological validity should be pursued and approached even though Bronfenbrenner (1979) considered it unachievable. Pursuing and approaching the ecological validity during an investigation promotes scientific understanding of the interaction between the growing person and aspects of the physical and social environment (phenomenological validity). The changes in the behavior of the developing person are consequent of changes in the environment and may be observed across time and space (developmental validity).

Therefore, development should be investigated in context, so the investigation could yield valid conclusions (Bronfenbrenner, 1979). The investigation of development-in-context should be carried out under two places and circumstances to be ecologically valid. These places are (1) the subject's natural setting because it involves the objects and the activities of the daily life, and (2) a setting, which contains the properties of the real-live environment expected by the investigator.

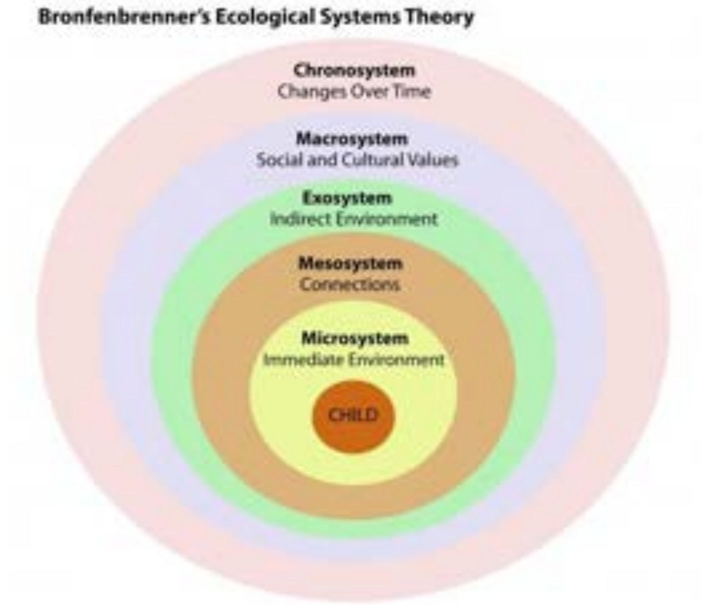
Bronfenbrenner (1979) organized a person's environment in five systems as described below.

1. The **microsystem** involves mutual interaction between the developing person and the people that he or she is directly related to and interacts with daily, such as parents, siblings, and teachers.
2. The **mesosystem** consists of the interaction between the different parts of the developing person's microsystem and the way their interaction affects her or him. It reshapes and expands due to these interactions, such as the interaction between the parents and the speech-language pathologist.
3. The **exosystem** involves the settings that do not include the developing person as an active participant. However, the decisions made in these settings somehow affect that person in diverse areas of development, i.e. change in the workload or unemployment of a family member.

4. The **macrosystem** refers to the cultural environment in which the person lives as well as all the other systems. It includes the economic situation, the law, the cultural values, and the political system.
5. The **chronosystem** refers to the dimension of time in relation to a person's development. Time tracks the events during a person's development.

These systems were organized in a spherical model as presented below.

Figure 1: The theory of Ecological systems



Note: Retrieved from: <u>*https://www.psychologynoteshq.com/bronfenbrenner-ecological-theory/*</u>*, on 12 May 2018.*

3 Literature review

3.1 The LENA system and hearing impairment

Ambrose, Walker, Unflat-Berry, Oleson, & Moeller (2015) examined the quantity and quality of caregiver talk in caregiver-child interactions in laboratory settings. They investigated caregiver-child interactions with a group of children with NH and another group of children with HI at 18 and at 36 months. Research results suggested that at the 18-month visit, the two groups of children (NH and HI) were exposed to a similar amount of utterances and words, but children with HI were more exposed to directing utterances. At the 36-month visit, both groups of children were exposed to a similar proportion of utterances, but children with HI were exposed to fewer proportions of words and lower quality of input.

Research findings (Ambrose et al., 2015) have also suggested that the quantity of language input provided to children with HI at the 18-month visit was related to the family's Socioeconomic Status (SES) level and strong language abilities. The quality of language input (directing utterances) at 18 months was related to child language abilities at 36 months. Ambrose et al. (2015) suggested that caregivers provided a higher quality of linguistic input to children with HI overtime. Differences in the quality of language input received by a child with NH and with HI suggest that caregivers of children with HI need a specific and additional support to provide their children with a more effective language-learning environment.

Aragon & Yoshinaga-Itano (2012) conducted an intervention study with the aim to also investigate the feasibility of the LENA^{TM} system in Spanish-speaking household of children with HI. The objective was to investigate the possible differences of LENA^{TM} variables between English- and Spanish- speaking children with HI in comparison to English- and Spanish-speaking typically developing children with NH. However, the results indicated a relationship between the HI and NH groups regardless of linguistic background were comparable to the LENA^{TM} normative English-speaking data (Gilkerson, & Richards, 2008). The relationship was visible in the amount and type of language to which the cohort of children with HI was exposed to in their home environment. More specifically, the group of children with HI performed better than the English norms for AW, and their performance was equivalent on CT. In comparison to their TD Spanish-speaking peers, they performed below average in CV, but above average on AW. Aragon & Yoshinaga-Itano (2012) argued that the children with HI needed a higher amount of language input to develop language levels comparable to NH peers.

Da Prato (2016) was interested in pre-validating LENA in Italian. The objective of this study was twofold. First, it aimed to investigate the listening and language environment of monolingual, Italian speaking children with NH. Second, the study explored the language and listening environment of each child with NH and with HI and related it to environmental factors measured with LENA. Da Prato (2016) tested the accuracy of LENA estimated by comparing it to human counts of CV and AW of a 15-min sample of conversation with high parent-child CT. Research results suggested that there was a correspondence between hearing and linguistic stimulation and spoken language development (Da Prato, 2016).

3.2 The LENA system and SES

Children's language performance based on CV, AW, and CT measures have previously been been associated to their family's SES (Aragon & Yoshinaga-Itano, 2012; Nilsson & Olsson, 2015; Suskind, Leffel, Graf, Hernandez, Gunderson, Sapolich, & Levine, 2015; Weisleder & Fernald, 2013; Wood, Diehm, Callender, 2016). It has been suggested that increasing the amount of child-directed speech directed to infants of families of low SES level would boost children's vocabulary outcomes and real-time language processing skills (Weisleder & Fernald, 2013). In time, it is important to have a cohort representative of the whole population in order to achieve more population-based and valid results. In the Swedish validation study (Nilsson & Olsson, 2015), the number of parents between the ages of 25-44 who had a high school diploma was of 25% of the sample whereas the distribution based on the Census 2012 was of 52.5% of the population.

3.3 Validation studies of the LENA system in other languages

The LENA^{TM} normative data are from English-speaking homes (Gilkerson, & Richards, 2008; Gilkerson, Coulter, & Richards, 2008). Currently, the biggest challenge being faced by its designers is to refine the system acoustic parameters for word counting taking linguistic diversity into consideration. Interested in this challenge, researchers have explored its accuracy in the analysis of the language environment in Spanish (Aragon & Yoshinaga-Itano, 2012), European French (Canault, Normand, Foudil, Loundon, & Thai-Van., 2016), Chinese (Gilkerson, Zhang, Xu, Richards, Xu, Jiang, ... & Topping, 2015), Italian (Da Prato, 2016), Vietnamese (Ganek & Eriks-Brophy, 2017), Korean (Pae, Yoon, Seol, Gilkerson, Richards, Ma, & Topping, 2016), and in Swedish-speaking families (Nilsson & Olsson, 2015; Schwarz, Botros, Lord, Marcusson, Tidelius, & Marklund, 2017). A summary of the above-mentioned research is presented below.

Canault et al. (2016) conducted a reliability study aiming to investigate the accuracy of the LENA™ in European French-speaking homes. Data from this study resulted in the following results. Considering the phonetic and acoustic features differences between English and French, the authors observed a significant correlation between the automated and the human counts of AW (r_s=.64, $p< .001$) and CV (r_s= .71, $p< .001$) (p.1114). Although the AW and CV were underestimated in comparison to the human counts, it did not prevent the LENA system good reliability between the LENA automated and the human count for French.

Canault et al.'s (2016) research also demonstrated that analyzing 1-hour recording (6 chunks of 10 min) for correlating the automated and the human counts were enough for obtaining a reliable sample for both estimates when controlling for random effects of participants and of recordings (Canault et al., 2016). Therefore, the reliability of the data strengthened with a greater volume of data. Finally, it was observed that the LENA™ counts were not affected by noise-related factors, such as overlapping near noise. However, the human counting method was more effective in the presence of substantial noise.

Gilkerson et al. (2015) were interested in the performance of the LENA™ system for Chinese and Mandarin. Their main concern was whether this automated, algorithm-driven system was sensitive to differences in geographically, linguistically and culturally diverse environments. The authors hypothesized that the LENA™ system is not language dependent because it measures speech segmentation of the audio stream by identifying the sound sources. Research results suggested that the LENA™ system was sensitive in identifying adult and child voice patterns although it mixed up mothers to key child voice due to the rise in pitch associated with motherese voice.

Gilkerson et al. (2015) also observed that there was a strong correlation in (1) CT (r= .72, $p<$ .001) and AW (r= .73, $p< .001$) between LENA and human counts for Chinese (2) the reliability measure for the Chinese sample was comparable to the American-English one, and (3) AW and CT performance was in accordance with child age. Despite the small sample and other limitations of this study, Gilkerson et al. (2015) suggested that the LENA^{TM} is a promising tool for investigating the language environment regardless of acoustic differences among languages.

Research findings on children language acquisition suggested that child-directed speech in early infancy is directly related to vocabulary development and IQ level (Hart & Risley, 1995). Based on that, Ganek & Eriks-Brophy (2017) claimed that parent-child interaction is essential to children's language development, especially language production. For this reason, Ganek & Eriks-Brophy (2017) aimed at devising a coding protocol to validate the LENA system (CT counts) in Vietnamese. In their study, two Vietnamese speakers were invited to transcribe the selected audio files and correlated their CT counts to the estimated counts provided by the LENA automated estimates (2017). The research question was whether a concise protocol could generate valid, relevant information to validate the LENA system in Vietnamese.

Ganek & Eriks-Brophy (2017) observed that the statistical analysis showed a strong correlation (r_s (18) = .70, p<.001). No significant difference between the human and the automated counts (U= 143, p= .12) were found despite their small sample, which comprised of ten families. Such result discards the need for a larger sample analysis. Findings also showed no significant difference between CT of children with NH and with HI. To this regard, Ganek & Eriks-Brophy (2017) suggested that parents of children with HI might have been instructed by a speech-language pathologist in how to engage in a meaningful conversation with their child in order to use more CT and stimulate language development.

A pilot intervention study conducted by Pae et al. (2016) verified the validity of the LENA system for Korean. Their aim was to verify if the LENA system would measure reliable estimates that demonstrated the changes in the natural language environment of Korean families. A total of 99 children aged 4-16 months participated and half of them received individual feedback about language strategies (experimental group vs. control group). Children in the experimental group were recorded every week whereas those in the control group were recorded at the baseline, middle, and in the end of the 6-month research study.

Pae et al. (2016) compared and correlated LENA measures to human transcriptions. LENA and human estimates on AW and CV were significantly correlated at baseline (r= .72, p= <.001 and r= .67, p=.001, respectively). Due to the frequent amount of whining noises and overlapping speech, CT was not interpreted so cautiously by transcribers and outliers were excluded. Yet, interrater reliability reached an agreement rate of 98.5% for AW and 95% for CT. Therefore, AW and CT were regarded to be a reliable measure for the Korean language (2016).

Nilsson & Olsson (2015) used the LENA system for investigating the listening and language environment of a group of Swedish toddlers. Results of the reliability study estimated 80% agreement for CV and 75% agreement for AW between human and automated counts, which deemed the LENA system sensitive to the acoustic features of Swedish. These researchers were interested in investigating whether the number of CT and AW could be predictors of the amount of CV. A correlational analysis suggested that the amount CT was a strong predictor of the amount of CV (r= .79, p=.01) than the amount of AW (r= .33, p=.29).

In the same study, Nilsson & Olsson (2015) also observed a moderate correlation between the Swedish CDI and the number of AW (r= .62, p= .05). A weak correlation was found between the DevSnap and the Swedish CDI at the vocabulary level (r= .51, p= .11) and at the pragmatic level (r= .56, p= .07). It suggested that the DevSnap should be adapted to Swedish and tested in larger samples. These findings suggested that the amount of parent-child directed talk stimulated children to talk more, which also led to improvements in their language skills (Nilsson & Olsson, 2015; Hart & Risley, 1995). Nilsson & Olsson (2015) claimed that knowledge of language development may encourage parents to talk more to their children. For this reason, intervention should focus on parent-child interaction.

The purpose of the pilot study conducted by Schwarz et al. (2017) was to evaluate the reliability of the LENA system for Swedish. Evidence from research has shown that child-directed adult speech directly influences on child vocabulary development (Weisleder & Fernald, 2013). For this reason, Schwarz et al. (2017) decided to verify the LENA AW estimates against human counts. Two measures were taken for the transcription, namely number of orthographic words and number of vowels. Pearson's correlations coefficient indicated (1) high interrater reliability for AW (r= .95, p< .01) and for vowel counts (r= .93, p<.01) and (2) moderate correlation with the LENA AW (r= .67, p< .05) and vowel counts (r= 66, p< .01). Schwarz et al. (2017) conducted a preliminary study for validation of the

LENA system in Swedish. However, one conclusion was that further studies should be conducted testing the reliability of the LENA estimated for CV and CT before the LENA system can be used in Swedish clinical settings.

3.4 The reliability and validity of a novel instrument

In development studies, new instruments to assess the concepts of a theory under investigation are constantly being evaluated (LoBiondo-Wood, & Haber, 2014). In using a new measurement instrument, researchers should be concerned in finding out if the results obtained from a sample represented true, consistent measures of behavior. For this reason, issues like reliability and validity of these instruments are of major concern. Therefore, it was here necessary to understand the concepts of reliability and validity.

In psychometrics, reliability has to do with the internal consistency and stability an instrument, like the LENA system, and if it measures the attributes of a variable (Colman, 2015; LoBiondo-Wood, & Haber, 2014). Reliability is also concerned with predictability, precision, and equivalence. In other words, a reliable measuring instrument is capable of yielding the same results in repeated administrations by using the same scale to measure a given set of behaviors (LoBiondo-Wood, & Haber, 2014).

The reliability coefficient ranges from 0 to 1. For an instrument be considered reliable, the reliability coefficient should be equal or above to .70 (LoBiondo-Wood, & Haber, 2014). Due to the nature of the LENA system, the interrater reliability test was used to calculate the reliability coefficient of this instrument. It gives the degree of consensus and consistency on the ratings given by raters on a certain stimulus (Colman, 2015; LoBiondo-Wood, & Haber, 2014). Thus, it is used to determine if an instrument is appropriate to measure a variable. Interrater reliability can be calculated by statistical measures such as intra-class and interrater correlation.

Validity refers to the degree of accuracy to which a measurement or an instrument corresponds to the real world (Colman, 2015; LoBiondo-Wood, & Haber, 2014). Testing the validity of an instrument means verifying the extent the interpretation of the tests score satisfies the postulates of a theoretical construct. LoBiondo-Wood & Haber (2014) mentioned that the validity of an instrument is dependent on its reliability. Being so, the percentage of confidence a tool is considered valid depends on the level of reliability coefficient.

The LENA system was the instrument for measuring data evaluated in this research. For it was the first time the LENA system was used in a BP-speaking environment, its reliability (consistency) and validity (accuracy) had to be tested, so adequate conclusions could be drawn. Demonstrating the validity and the reliability of the LENA system to BP was critical ‘for assessing the strength and the quality of evidence provided by the design and findings of a study and its applicability to practice’ (LoBiondo-Wood, & Haber: 290, 2014).

4 Methods

4.1 Participants

Twelve families and fifteen children participated in this study. The families of children with HI were recruited from the network of patients of two centers for speech pathology and audiology in São Paulo, Brazil, namely the Santa Casa Hospital and the Centro Especializado Paulista. The families of children with NH were recruited from the network of speech-language pathologists of the above-mentioned centers. These families lived either in the city of São Paulo or in its Metro area. They were all monolingual speakers of BP. This group of families was relatively homogeneous regarding their SES-level concerning formal parent education. A total of 79% (22) of the participating parents had a college degree.

One family faced difficulties in handling the DLP. Consequently, only two hours of their day were recorded. Due to incomplete recording, their child with HI had to be excluded from the research due to insufficient data.

- **Clinical group:** Seven children aged around 20 to 43-month-old with HI (M= 34 mo, SD=10 mo). This group consisted of four boys and three girls. The causes of HI varied. In this cohort, there was one case with congenital CMV infection, two cases with genetic causes (siblings), one preterm, one caused by Waardenburg syndrome, and two cases of unknown cause. Their degree of HI ranged from moderate to profound. All of them had been fitted with hearing technology (one bilateral CIs, four bimodal[4], and one regular HA), and their hearing age (time with hearing technology) ranged from 4 to 34-months (M= 17 mo, SD= 11 mo). These children were used to listen to spoken Portuguese as their primary means of communication, both at home and at school. However, two of them also learned sign language at school, four of them attended regular inclusive school, and one child stayed at home with mom.
- **Control group:** Seven children aged between 11 to 29-months with NH (M= 21 mo, SD= 6 mo). This group consisted of four boys and three girls. Among these children, there were two sets of twins - one set of twin boys and one set of twin girls. These children came from monolingual BP-speaking families. Yet, there were three children

[4] The term bimodal means that the child with HI uses a combination of HA and CI.

in the group who were exposed to English as a foreign language either at school or at home. Exposure to English has been introduced in their education as a pedagogical activity rather than a natural language for communication.

- Parents and other caregivers of both groups of children (NH and HI), ten mothers, two fathers, two grandmothers, and one grandfather. The parents of one child with NH could not make it to the interview, so the child's grandmother represented them.

Children were also matched by gender even though results from previous studies have demonstrated that gender does not affect results on LENA (Aragon and Yoshinaga-Itano, 2012; Canault et al., 2016; Gilkerson et al., 2015). A total number of four boys and three girls participated in the NH and respectively in the HI group as described previously.

4.2 Materials

The LENA system comprises of the following items.

- LENA™ Software for analyzing linguistic information (PC compatible)
- LENA™ DLP, which is a small recording device able to capture up to 16 hours of a child's natural audio environment (cf. figure 2, p. 23)
- Specialized LENA™ Clothing for placing the DLP (cf. figure 2, p. 23)

Figure 2: The DLP and the Specialized LENA clothing for placing it in.

Note: The specialized vest was especially designed to fit the DLP in. The noise of the friction between the vest and the DLP is minimized and does not affect the quality of the recordings.

LENA software organizes the data into a report list, which are displayed in three different diagrams.

1. **LENA composite view** consists of a comprehensive analysis of the acoustic and linguistic elements recorded in the environment displayed in four categories (a-d). The report for each composite is displayed by month, day, hour, or 5-minute view (cf. appendix VIII).
   - **a. Audio environment report (AE)** reveals the amount of meaningful speech (amount of language spoken within two meters from the child) and distant speech (amount of language presented more than two meters from the child), TV and electronic sounds, noise (non-detectable sounds, scream, cry, and overlapping speech), silence and background sounds within the child's language environment (for a detailed description of these components, see LENA Pro user guide, p. 34-5).
   - b. **Child vocalizations report (CV)** estimates the number of continuous speech-like utterances the key child produces during a time segment followed by a pause greater than 300 milliseconds. The CV report discards vegetative sounds and other non-speech signals (User guide LENA Pro, p. 33).
   - c. **Conversational turns report (CT)** provides the number of conversational interactions between the key child and an adult. Conversational turn is here understood as speaker's verbal initiative and interlocutor's response within 5 seconds. CT does not estimate overlapping speech and vegetative sounds such as cry and cough. The CT report also tracks for possible language delays, which means that the key child falls 1 ½ standard deviations (SD) below the mean for her age (User guide LENA Pro, p. 30).
   - d. **Adult words report** (AW) indicates the number of AW that the key child is exposed to in the home environment as estimated by the software. More specifically, the software estimates the number of AW spoken to and near the child during the recording period. (User guide LENA Pro, p. 29).
2. **Developmental snapshot (DevSnap)** is a parental checklist. This parental checklist consists of 52 questions for assessing a child's expressive and receptive language abilities (cf. appendix VIII). Its results are demonstrated in standard scores. This measure also estimates a child's developmental age in relation to language abilities, which is represented as advanced, within normal limits and at risk (User guide LENA

Pro, p. 29). Reports are provided as DevSnap standard score and age. LENA calculates neither the DevSnap standard score nor the developmental age for children older than 36 months.

For the purpose of this study, I translated the DevSnap to BP taking in consideration both linguistic and cultural differences. For this reason, the examples from the AE version of the DevSnap were adapted to the specificities of BP and the Brazilian culture. Professor Levy guided me on this process.

3. **Automatic vocalization assessment (AVA)** is an assessment tool for measuring a child's expressive language (cf. appendix VIII). The LENA system uses automatic speech recognition technology for measuring the child's expressive ability. In other words, it estimates the use of consonant and vowel sounds a child vocalizes. Thus, the acoustic information is statistically analyzed, and the analysis of a child's expressive language development is reported as AVA standard score and percentile. AVA standard scores are bounded between 65 and 135, and results outside this range are displayed as <65 and >135. AVA standard score is not provided for children over 48 months of age**.** AVA standard score has demonstrated statistical reliability in correlation to other standard expressive language assessment such as REEL-3 and PLS-4 (User guide LENA Pro, p. 27).

In addition to the LENA system, we used the materials listed below.

- **McArthur-Bates Communicative Development Inventories** (CDI): The CDI is a parental checklist for investigating children communicative development (Fenson, Marchman, Thal, Dale, & Reznick, 2007). This checklist assisted in screening and developing a prognosis of children with HI, for it measure data on children's early signs of comprehension, nonverbal gestural signals, early vocabulary, and grammar. It covers the language skills of children age range 8-36 months, but it may also be used with older children with developmental delays. The following components of the CDI were used: Words and Gestures, for children age 8-16 months, and Words and Sentences, for children 18-36 months. For the purpose of this study, the corresponding adaptation of the MacArthur-Bates CDI to BP[5] was used (Padovani & Teixeira, 2004).

[5] The adaptation of the CDI to BP is yet in process of normalization. For this reason, a copy of the CDI-BP was not provided in the appendix. Any further inquiry regarding the CDI-BP should be directed to Professor Elizabeth R. Teixeira. Her contact information can be found on https://mb-cdi.stanford.edu/adaptations.html (Web. 21 May 2018).

The forms were completed mostly by the mothers in the current study, but in two cases in cooperation with one of the grandparents.

- The parental formulary Words Make Difference gathered demographic information about the key child health condition, parents working situation, parental educational level, number of siblings, and the family's language backgrounds (appendix V).
- Daily activity log allowed parents to keep a record of the activities the key child was involved in throughout the day by hour and who was in the environment with the child (appendix VI).
- A 15-min transcription of the recordings for human AW and CV (under the family consent) was used to compare the automated counting done by the software, further described on section 4.3.2 (page 28).
- An information sheet, which explains how to use the DLP (cf. appendix VII).

4.3 Research design

This study was organized in four parts so that its objectives could be achieved. Its structure consisted of a meeting with the parents or other caregivers, a pre-validating study, a correlation study, and an age-matched comparison study (NH vs. HI). A full description of the procedures is presented below.

4.3.1 Meeting with the parents and caregivers

.The meetings with the recruited families were arranged between 28 and 31 of August 2017. The meeting took place in three places and at the time that best suited each family, namely the Center for Speech therapy and Audiology of the Santa Casa Hospital, at Centro Especializado Paulista, and at the working place of two mothers. All of the respondents in charge of the children with NH were met within their working hours. The reason for that was that they were recruited from the network of speech pathologists of the above-mentioned centers. The caregivers of the children with HI were seen at Santa Casa or at Centro Especializado Paulista. The meetings were held while their children were at the speech therapy session. Four meetings were held in the middle of the afternoon and two other cases early in the evening.

The purpose of the meeting was to provide families with information regarding the research purpose and the research ethics. Every family was informed that they had the right to have the recording deleted immediately upon request. In case the family wished to continue to participate in the study, an extra day was scheduled for recording the child's language environment. All the recruited families decided to participate in the study. For this reason, they were asked to sign a letter of consent[6] accepting the terms of the research.

After they had accepted to participate in the research, they completed the Developmental Snapshot (DevSnap), WMD forms, and the MacArthur-Bates CDI adapted to BP either as an interview or on their own. Regarding the completion of the DevSnap and the CDI, the respondents, caregivers of children with HI completed the DevSnap as an interview, but they were given time to complete the CDI on their own. Whereas, caregivers of children with NH were certified speech-language pathologist and psychologists who are experienced users of similar forms. For this reason, they had the option to fill in both forms at home as they were expected to have little or no difficulty in filling in the forms. All the material handed to each family was collected within a week after the recording was conducted. Considerations about the conversation with the families were made in the discussion section (p. 56).

In order to agree upon finding a suitable day for recording, we asked the participants about their family weekly routine aiming to find out when each child spent most part of the day with their family members. Two important aspects were observed among the participating families. First, we observed that for most families, except one, Saturdays and Sundays were suitable days for doing the recording. This is because in most cases both parents work (85.7% of the cohort), and the child spends their days in kindergarten and/or being taken care by a relative or a nanny. A second aspect common among these families was that they were all involved in social activities on weekends, such as birthday parties, family gatherings, and religious services. It meant that the children were often immersed in a rather noisy environment.

Then, they received a LENA vest for placing the device and they were taught how to operate the DLP for conducting the recording**.** The recording took place on the weekend after our meeting. The families were advised that children would wear the LENA vest with the DLP in it for at least 12 hours. It was estimated to collect about 180 hours of total recording time. Such procedure helped us to collect naturalistic linguistic data. Every family was asked to also keep a written log of the activities the child took part in during the recording day and with whom they were together with during the all-day recording.

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[6] Termo de Consentimento Livre e Esclarecido (TCLE). Cf. appendix III.

Once the data collection was completed, the recorded data were transferred, analyzed and processed automatically by the LENA™ software for the DLP. Data from the recordings were estimated by the LENA software through the use of advanced algorithms and statistical models for speech segmentation and sound recognition. These estimates were grouped in the categories described in section 5.2 (p. 36).

4.3.2 Pre-validation study

The purpose of this preliminary study was to verify the accuracy of the LENA system compared to human counts for BP. In this study, the focus was on AW and CV estimates, for they have shown a high degree of accuracy in American English as demonstrated in previous studies (Oetting, Hartfield, & Pruitt, 2009; Xu, Yapanel, & Gray, 2009). The AW and CV of a child with NH had to be manually counted and compared to the LENA automated counts.

Because it was the first known study testing the sensitiveness of the LENA system in BP, the pre-validation study was conducted in two parts. The first part consisted of devising a coding protocol for the human coders and checking for the inter-rater reliability using a five-minute sample of recording of a randomly selected child with NH. The second part consisted of an agreement study. It relied on the use the protocol for transcribing fifteen-minute recording samples of seven children with NH and for conducting inter-rater reliability tests based on the human and the LENA automated counts. The whole pre-validating study is described below.

Part one: Training protocol for human coders

The main goal of the training protocol for human coders was to establish the criteria for manually transcribing and counting the AW and CV to be applied on future pre-validation studies. To assess the reliability of the LENA system, for BP, the manual transcriptions were conducted by two native speakers and linguists in BP, namely myself and a friend with competence within Linguistics. The work of a second transcriber was of relevance, for it would increase the reliability of this study.

Because it was the first known study that investigated the validity of the LENA system in BP, which is a syllable-timed Latin language, it was decided to adapt the coding protocol from the study conducted in European French (Canault et al., 2016). A video conference between the two linguists was arranged, so they could agree upon and refine the criteria protocol for conducting the transcription and counting AW and CV. By making the protocol available below, it turned the research process transparent and fostered discussion for coding the LENA data in BP (Ganek & Erikcs-Brophy, 2017).

1. Every speech-like babbling and vocalizations within a child's utterance cluster was counted. For instance, vocalizations such as 'ba' or 'bababababa' were counted as 1 vocalization each, but 'bababa#ba' was counted as 2 vocalizations.
2. Cases of children in the single-word period or in the two-to-three-word combinations, each word was counted as 1 vocalization. For example, if a child said 'papai#carro#rua' (Daddy#car#street), it was counted as 3 vocalizations.
3. Every word with at least 1 syllable was considered as meaningful speech, and therefore, counted as a word. For example: 'sim' (yes), 'não' (no).
4. Formal spelling of Portuguese was used except when there was a difference in number of syllables between spoken and written form, i.e. 'tá' as short for 'está' (he/she/it is), 'tô' as short for 'estou' (I am) 'dá' (give), and 'cê' or 'ocê' as short for 'você' (you) (Schwartz et al, 2017).
5. Free morphemes, such as determiners (o, a, os, as, um, uma, uns, umas), prepositions (para, pra, após, antes), and pronouns (ele, ela, eu, você/ocê/cê, a gente) were counted as 1 word each.
6. Bound morphemes, such as prefixes and suffixes, were not counted independently. For example, desempregado (unemployed) was counted as 1 word.
7. Compound words with clear boundaries (with or without a hyphen) like pé-de-moleque (brittle) were counted as 3 words, and matéria-prima (raw material) were counted as 2 words.
8. Apócopes such as 'caldi-cana' instead of 'caldo-de-cana' (sugar-cane syrup) were counted as 2 words instead of 3 and mal-humorado (bad mood) was counted as 1 word because it is pronounced as 'maumorado'.
9. Elipses, such as 'copo d'água' instead of 'copo de água' (glass of water), 'casa d'Alice' instead of 'casa da Alice' (Alice's house) were counted as 2 words instead of 3.
10. Onomatopeias were counted as 1 word each. For example: 'auau' (dog), 'cocó' (chicken), 'miau' (cat), and 'oinc-oinc' (pork).
11. Vegetative sounds (burping) and fixed signals (scream and cry) were not counted even though labeled as other sounds (OS)

When the protocol was established, we proceeded with the transcription of a 5-min sample of recording of a randomly selected child with NH. This 5-min sample was extracted from the LENA composite view – 5-minute according to the following criteria. First, the hour of the day with the highest number of CT was identified as indicated on the LENA composite view – hourly. Then, the 5-min region with the highest CT observed within the selected hour of the day was extracted from the LENA composite view – 5-minute. Next, we discussed issues identified in the protocol and redefined it.

Each linguist produced their own transcription of the selected extract following the protocol. The following labels were used in the transcription: female adult voice (FV), male adult voice (MV), key child (KC), other child (OC), and other sounds (OS). Because the LENA software uses statistical algorithms for estimating the number of AW, the number of meaningful speech segments spoken by FV and MV were all added up and reported as AW whereas KC and OC were counted separately.

In a pilot study for validating LENA for Chinese, Gilkerson et al. (2015) observed that LENA showed good sensitivity in recognizing child and adult voice. However, they observed that 30% of what LENA estimated as child segments were counted as AW by the human rater. They hypothesized that the rise in pitch associated with motherese talk might have misled the software to count such segments as CV. For this reason, each adult voice present in the recording was first identified, counted separatedly, and then they were added up in order to avoid AW being labeled as CV. Therefore, it would be possible to verify any discrepancies between the human and the automated counts.

In this study, there were three sets of siblings. Each set was recorded at the same time and place. In addition, some of these children had other siblings present in the environment even though they were not participating in the study. For this reason, it was decided to label them as KC and OC and count them separately. This measure would answer any discrepant counts between LENA and human coders by controlling for random effects of other children in the environment. Differentiating KC from OC avoids mismatches and aligns the coding protocol for human coders to LENA software (Ganek & Eriks-Brophy, 2017).

Measures

Three simple statistical measures, namely distance in metric, distribution of differences, and percentage of matching, were applied for verifying interrater reliability. Interrater reliability was deemed strong if matching between raters was equal or above 80% (LoBiondo-Wood, & Haber, 2014).

Part two: The inter-rater procedures

This agreement part of the study attempted to pre-validate LENA automated estimates to BP by testing its accuracy. The accuracy of automated counts was therefore compared to the estimates of two human coders. Research questions sought to investigate (1) how well ratings reflected the true number of AW and CV, (2) what the consistency of ratings between human and automated counts was, and (3) what the proportion of times human and automated counts agreed on CV and AW. Because it is the first time LENA is being used for investigating BP language environments, only participants with NH were selected to take part in this study.

This study procedures consisted of the transcription of 15 min of the recording (3 chunks of 5 minutes each) of 7 children with NH, being 4 boys and 3 girls between 11 and 29 months. These recordings were selected based on an analysis of the LENA composite view – hourly. Having identified the time of the day in which the software indicated as having the highest number of CT, it was necessary to identify and select the 5-min region which had the highest CT counts within that hour as indicated by the LENA composite view – 5-minute. Then, the two subsequent 5-min regions were selected regardless of the number of CT.

A total of 105 minutes of recording was transcribed by two expert linguists and native speakers of BP, according to the guidelines presented on page 29. The raters worked independently. Their counts were compared to each other using statistical measures for reliability and correlation purposes. Just as in the study of Gilkerson et al. (2015), it was here hypothesized that American English based LENA algorithms would generate reliable estimates for AW and CV for BP. For this reason, the accuracy of LENA automated estimates for AW and CV was tested in comparison to means of human rater counts. Measures for reliability and correlation between the automated and the human counts were applied.

Measures

The reliability and validity of LENA AW and CV for BP-speaking families were both tested for correlation with human raters' estimates. Statistical analyses were performed in SPSS 24 (IBM Corp, 2016) to obtain descriptive statistics, percentage agreement, Pearson correlation coefficient (Person's r), intra-class correlation coefficient (ICC), and means comparisons by paired-samples *t*-tests, and Spearman rho.

4.3.3 Comparative pilot study

The children with NH and their peers with HI were compared according to their age, gender, language development (CDI, DevSnap, and AVA scores), language (CV, CT, AW, MAN, and FAN) and audio environment (silence, noise, TV/radio, close and distant language). The Mann-Whitney U nonparametric test was used to compare the medians between these two groups aiming to identify any significant differences between them. Paired sample t-test was used for calculating the difference in the amount of exposure to FAN and MAN words to which children were exposed.

4.3.4 Correlational analysis

With the purpose of investigating whether an increase in the LENA variables correlates with an increase in child age, the Spearman's rank correlation was calculated. The analysis had its focus on (1) children's age (chronological, developmental, and hearing age) in relation to children's language environment, (2) chronological age and children's language performance, and (3) language environment and children's language performance.

The correlational analysis was conducted in three parts. First, it was conducted considering only the data of the cohort of children with NH. Next, it took into consideration the data of children with HI, including the hearing age as another factor. Then, the correlational analysis was conducted including the data of both children with NH and with HI.

5 Results

5.1 Meeting with the parents and other caregivers

Parents working situation and educational background

Their educational background was relatively high as 79% (22) of them had a college degree. The level of education among the participating families was rather high. It was reported that 100% of the parents of children with NH had a college degree. Among parents of children with HI, 69% (10) of them had a college degree. This was a rather homogeneous group. However, it was not representative of the level of education of the Brazilian families, which was 27% of the head of the families, regardless of their gender, had between eleven and fourteen years of education (IBGE, 2001-2011).

Regarding the working situation of the parents in the participating families, it was observed that 86% (22) of the total population was employed, and 14% (2) of them were for some reason out of the workforce. Among the families of children with NH, all parents were full-time employed. However, the situation was slightly different among parents of children with HI. Among the six participating families of children with HI, five fathers were full time employed and one was unemployed at the time of the data collection. Among the six mothers who were interviewed, a total of 81% (4) of the participating mothers were employed and 19% (2) of them were full-time stay-home mothers. One mother of the children with HI worked full-time, two were staying-home moms, three worked part-time, and one worked from home. This suggests the increasing participation of women joining the workforce, which is in line with the data of the Demographic census 2010 (IBGE, 2010).

Parents’ participation in childcare

It was observed among the eleven participating families that mothers represented 100% of the main respondents of the parental checklists and the forms used for collecting data. Among the families of children with NH, only the female caregivers actively co-operated with this research. In time, it should be taken into consideration that all of them were visited at their workplace during working hours. Perhaps, the scenery would have been different under other circumstances. Future research should investigate this factor.

Among the six participating families of children with HI, mothers were the main respondent. However, two fathers collaborated in the data collection. The two fathers who were present at the interview provided relevant comments and examples about their offspring's language and listening development. They complemented their wives input, usually in accordance with what they said.

Considering that in most of the participating families both mothers and fathers worked, it was observed the dominance of women in charge of childcare, which is in line with Dessen's study (2010). However, all of the mothers reported that their spouses were seriously committed to their child's listening and language development at home, regardless of the child's hearing condition.

Outsourced children

Of the group of fourteen children, thirteen of them were enrolled at a daycare center/kindergarten unity, one of them was watched full time by the mother, and one of them was taken care by a nanny. When not at the daycare/kindergarten, it was reported that three of these children were at the mother care, five of them with both parents, two of them with their mother and the help of a nanny, and one with a nanny. This result is in line with earlier studies which suggested that parents have the need to rely the care their child on third parties while they are at work (Martins Filho, 2012; Wagner et al., 2017).

In this study, three grandparents were reported to take care of their grandchildren a few hours a week. Two of these grandparents (one male and one female) actively participated in the interview. They reported feeling very comfortable talking about their grandchildren because they spend time with their grandchild regularly. During the interview, these grandparents acted as secondary respondents often nodding their head in agreement to what the child's mother said. However, they would immediately speak up when they disagreed with their daughters regarding their grandchild's level of language development and communication skills. Because they were not with their grandchild on a daily basis, they could notice subtle changes in the process and ability to communicate that the child's mother could not. This leads to an important subject for discussion, namely the mothers' expectations on their child's achievements despite the biological aspects of language development.

The diagnostic of HI and its impact on the family structure and emotions

Having a young child diagnosed with HI leads to changes in the family structure. These changes are made to accommodate the child's needs and to support her language development (De Paula Teixeira, Silva, & Lima, 2015). Among the respondents of this study, some mothers reported having reduced their workload or even quit their jobs, so they could concentrate on their child's hearing and language development. Therefore, they have high expectations on their child's outcomes.

Regarding mothers expectations on the development of their child with HI, it was observed among the interviewed mothers that some of them had a more critical view about their child's language development. In one case, the mother reported overlooking her child's attempts at communicating through vocalizations because she always expected more from the child since she was engaged in the child's speech therapy. In some cases, mothers were more critical because they were so close to the child that they seemed to be blind to subtle advances in the process. For this reason, they had hard time to accept a relevant and correct word that was not pronounced clearly. In some other cases, mothers expected their child to achieve higher milestones within a short period of time due to their effort in supporting their child. Some of them said they felt responsible to make their child achieve age-level language skills, because they had either reduced their workload or had quit their jobs to take care of their child. What was common among all of them was their willingness to support their child as much as possible, and a believe the language and development outcomes would depend solely on their effort to see their child succeed.

Parents', especially mothers', too high, and somewhat unrealistic expectations of their child's language development could cause a feeling of frustration and helplessness (Oliveira, Cúnico, Cunha, Kruel, & Tochetto, 2013). That is because they believe that they are the only one responsible for their child's success. What they do not realize is that language acquisition is a capacity innate to an individual (Chomsky, 1988). It evolves gradually and in due time even though it is also influenced by the environment (Ramírez-Esparza, García-Sierra, & Kuhl, 2014). Because these children are HI, their acquisition of oral language began after they were fitted with HA. These children hearing age is therefore lower than their chronological age.

5.2 Pre-validation study

5.2.1 Part one: Training protocol for human coders

The percentage of matching between raters suggested high interrater reliability for both measures (AW= 98% and CV=84%), as shown on table 1.

Table 1: Pilot study devised for assessing protocol. Interrater reliability tests.

Rater	AW	CV
R1	269	165
R2	274	196
M	272	181
Matching %	98	84
Difference	-5	-31
SD	3	16

Note: Rater 2 overestimated rater 1 for AW and for CV.

The same measures were used for comparing the means of human counts to the LENA automated ones (table 2). The percentage of matching was found to be weak to moderate (CV= 41% and AW=64%).

Table 2: Pilot study for assessing protocol. Reliability tests between human and automated counts

Rater	AW	CV
Human rater	272	181
LENA	426	74
M	349	128
Matching %	64	41
Difference	**-154**	107
SD	77	54

Note: The LENA automated counts overestimated the human counts for AW, but it was underestimated for CV.

5.2.2 Part 2: the inter-rater and agreement study

Reliability analysis between the counts of human raters

A simple reliability analysis demonstrated good interrater consistency for both AW and CV (α= .993 and α= .842 > .70). ICC estimates and their 95% confidence intervals were calculated based on a mean-rating (k= 2), consistency, 2-way-random-effects model. Average measures for ICC were ICC (2, 4) = .993 for AW and ICC (2, 4) = .997 for CV (cf. table 3). Therefore, we found 99.3% and 99.7% consistency in the means of the raters, which demonstrated high interrater reliability (cf. tables 4 and 5).

Table 3: Cronbach's Alpha reliability between human and automated AW and CV estimates respectively

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
,967	,967	2

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
,842	,965	2

Table 4: ICC of interrater reliability - AW

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	,985[a]	,917	,997	133,661	6	6	,000
Average Measures	,993[c]	,956	,999	133,661	6	6	,000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Table 5: ICC of interrater reliability - CV

Intraclass Correlation Coefficient

	Intraclass Correlation[b]	95% Confidence Interval		F Test with True Value 0			
		Lower Bound	Upper Bound	Value	df1	df2	Sig
Single Measures	,994[a]	,963	,999	310,297	6	6	,000
Average Measures	,997[c]	,981	,999	310,297	6	6	,000

Two-way mixed effects model where people effects are random and measures effects are fixed.

a. The estimator is the same, whether the interaction effect is present or not.

b. Type C intraclass correlation coefficients using a consistency definition. The between-measure variance is excluded from the denominator variance.

c. This estimate is computed assuming the interaction effect is absent, because it is not estimable otherwise.

Tables 6 and 7 (p. 38) show the reliability between the two transcribers for AW and CV. Mean matching percentage is 92% for AW and 85% for CV, which is rather strong (LoBiondo-Wood, & Haber, 2014).

Table 6: Human and automated estimates for AW.

ID	Gender	Chronological age (mo)	AW			
			Rater 1	Rater 2	Matching %	Average value
C2	F	25	605	586	97	596
C6	M	21	643	605	94	624
C7	M	11	1031	1035	100	1033
C9	M	21	829	841	99	835
C11	F	19	379	303	80	341
C12	F	19	529	443	84	486
C15	M	29	335	363	92	349
M		21	622	597	92	609
Min-Max		19-29	335-1031	303-1035	80-100	341-1033
SD		5	227	244	7	235

Table 7: Human and automated estimates for CV

ID	Gender	Chronological age (mo)	CV			
			Rater 1	Rater 2	Matching %	Average value
C2	F	25	317	366	87	342
C6	M	21	123	160	77	142
C7	M	11	43	50	86	47
C9	M	21	77	85	91	81
C11	F	19	85	92	92	89
C12	F	19	35	54	65	45
C15	M	29	392	406	97	399
M		21	153	173	85	163
Min-Max		19-29	35-392	50-406	65-97	45-399
SD		5	142	150	10	146

Correlation analysis between human raters counts

A Pearson's correlation analysis was computed to assess the relationship between rater 1 and 2 for AW and CV for each participant family. Statistical analysis indicated a strong, positive correlation between rater 1 and rater 2 for both AW and CV (r= .988, n= 7, p= .000 and r= .995, n= 7, p= .000, respectively) as shown on figure 8 (p. 39). It was therefore observed strong, positive correlation between raters for both measures.

Table 8: Pearson correlation coefficient for human raters counts of AW and CV

Correlations

		Rater1_AWC	Rater2_AWC
Rater1_AWC	Pearson Correlation	1	,988**
	Sig. (2-tailed)		,000
	N	7	7
Rater2_AWC	Pearson Correlation	,988**	1
	Sig. (2-tailed)	,000	
	N	7	7

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations

		Rater1_CVC	Rater2_CVC
Rater1_CVC	Pearson Correlation	1	,995**
	Sig. (2-tailed)		,000
	N	7	7
Rater2_CVC	Pearson Correlation	,995**	1
	Sig. (2-tailed)	,000	
	N	7	7

**. Correlation is significant at the 0.01 level (2-tailed).

Note: Manual trancription of samples of 15 minutes of the recordings of each participating child with NH (n=7)

Reliability analysis between the automated and the human counts

Table 9 shows the reliability between the means of human counts and the LENA automated ones for AW and CV. Mean percentage of matching was 84% for AW, which is rather strong (LoBiondo-Wood, & Haber, 2014). However, the percentage of matching between the human and the automated counts was 66% for CV, which was regarded as moderate (LoBiondo-Wood, & Haber, 2014).

Table 9: Reliability between Human transcribers and LENA for AW *and* CV.

ID	Gender	Chronological age	AW				CV			
			Human average	LENA	Words Difference [a]	matching %	Human average	LENA	Words Difference [a]	matching %
C2	F	25	596	655	**-59**	91	342	150	**192**	44
C6	M	21	624	700	**-76**	89	142	58	**84**	41
C7	M	11	1033	1021	12	99	46	49	-3	94
C9	M	21	835	1054	**-219**	79	81	50	31	62
C11	F	19	341	372	**-31**	92	89	86	**3**	97
C12	F	19	486	640	**-154**	76	45	67	-22	67
C15	M	29	349	557	**-208**	63	399	237	**162**	60
M		21	610	714	**-104**	84	163	99,5	**64**	66
Min-Max		19-29	341-1033	372-1054	12-219	63-99	45-399	49-237	3-192	41-97
SD		5	254	245	83	11	146	70	78	20

Note: Words difference [a] values reflect rater- minus LENA-based counts. (n= 7 – NH).

Correlation tests between the automated and the human counts

The average agreement for each participant was measured and compared to LENA automated estimates for AW and CV. Pearson's correlation analysis generated strong, positive correlation between these variables for both AW and CV (r= .936, and r= .932, n= 7, *p*= .002). Results were reported in **figure # (p. #).** Overall, there was a strong, positive correlation between the LENA automated estimates and the human counts. Increases in the sample size would generate a stronger correlation between the automated and the human counts.

Table 10: Pearson correlation LENA vs. Human AW *and* CV

Correlations

		Human_CountsAWC	LENA_AWC
Human_CountsAWC	Pearson Correlation	1	,936**
	Sig. (2-tailed)		,002
	N	7	7
LENA_AWC	Pearson Correlation	,936**	1
	Sig. (2-tailed)	,002	
	N	7	7

**. Correlation is significant at the 0.01 level (2-tailed).

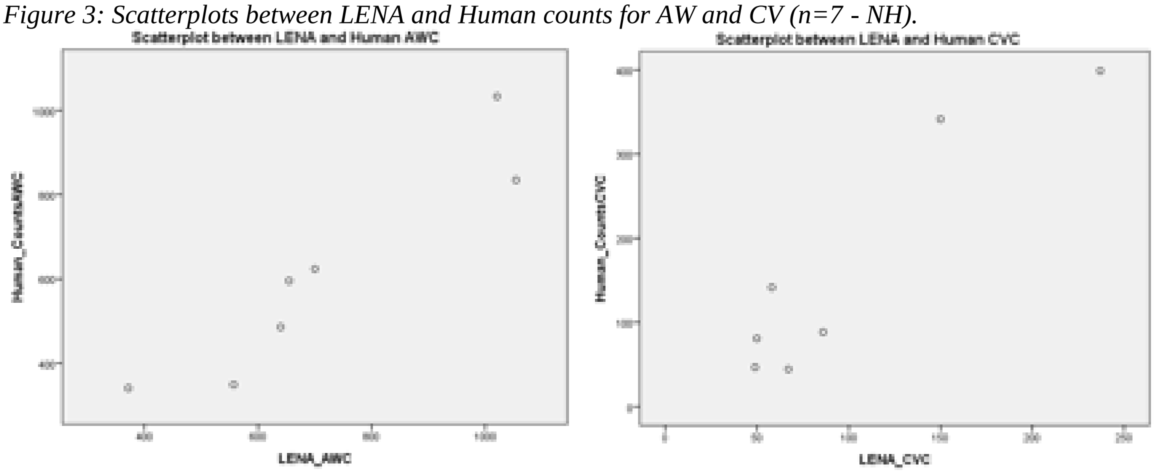
Correlations

		Human_CountsCVC	LENA_CVC
Human_CountsCVC	Pearson Correlation	1	,932**
	Sig. (2-tailed)		,002
	N	7	7
LENA_CVC	Pearson Correlation	,932**	1
	Sig. (2-tailed)	,002	
	N	7	7

**. Correlation is significant at the 0.01 level (2-tailed).

A scatterplot summarizes the results (cf. figure 3).

Figure 3: Scatterplots between LENA and Human counts for AW and CV (n=7 - NH).



5.3 Comparative pilot study

5.3.1 Results produced by the language assessment tools

Tables 11 and 12 (p. 41-2) show the results for 11 participating families who responded on the DevSnap regarding the performance of the 14 participating children (NH=7 and HI=7). Great variability was observed on the level of language development among children regardless of their hearing condition.

The group of children with HI varied much with regards to their chronological, hearing, and developmental age. Yet, two children (C15 NH, and C4 HI) could not have their developmental age calculated, for their developmental performance was above to what the software could calculate (max. 36-month).

These tables also show the AVA scores (Table 11 and 12, p. 41-2) of the participating children. The AVA assesses children expressive language development as recorded. The LENA automated counts suggested that one child with NH could be at-risk of experiencing delay on expressive language development, namely C11. Among the participants with HI, three children were reported as at-risk of expressive language delays, namely C1, C8, and C13.

The DevSnap is an assessment tool used for investigating children's expressive and receptive language development based on parental report. As for the group of children with NH, the DevSnap score and percentile varied greatly (Table 11 and 12, p. 41-2). Among the participants with NH, two of them were reported to be at-risk of experiencing developmental delays (C11 and C12). Due to the advanced age of three children with HI, the DevSnap standard score and its percentile could not be calculated (C3, C4, and C8). Among the participants with HI, three children were reported as at-risk of language delays, namely C1, C8, and C13.

Due to the incomplete normalization process of the CDI for Brazilian Portuguese, the raw score for each participating child was here presented without its assigned standardized score and percentile value. Hopefully making these data available would contribute to the completion of the work done by Padovani & Teixeira (2004).

*Table 11: Children with NH (n= 7): CDI, DevSnap, and AVA scores. *CDI Words and gestures. **Children at risk of language delay.*

ID/NH	Gender	Chrono. age	DS dev. age	DS std. score	AVA std. score	CDI
C2	F	25	33	116	122	373
C6	M	21	16	83	84	20
C7**	M	11	11	109	71	98*
C9	M	21	16	80	90	19
C11**	F	19	11	74	92	51
C12**	F	19	11	74	114	64
C15	M	29	36+	123	112	587
M		21	16	94	98	186
Min-Max		11-29	11-36+	74-123	71-122	19-587
SD		6	9	21	18	238

Note: C7, C11, C12 were referred as being at-risk of language development.

Table 12: Children with HI: CDI, DevSnap, and AVA scores. *Children at risk of language delay. **n=4.

ID/HI	Gender	C. age	H. age	Age fitting HA	DS dev. age	DS std. Score**	AVA std. score	CDI
C1*	M	37	8	29	12	<65	71	2
C3	F	43	27	16	32	N/A	92	223
C4	F	38	34	4	36+	N/A	114	459
C5	M	41	23	18	30	87	101	268
C8*	F	42	12	30	6	N/A	78	8
C10	M	19	13	6	17	93	87	54
C13*	M	20	4	16	14	81	68	3
M		34	17		19	82	34	145
Min-Max		19-43	4-34		6-36+	<65-93	68-114	2-459
SD		10	11		10	12	5	177

Note: The DevSnap is sensitive up to the expressive and receptive language of children up to 36 months. The developmental age of C4 was estimated over 36 months. For this reason, it could not be calculated. The DevSnap standard score was equal or below <65, which is the minimum calculated by the DevSnap. The DevSnap standard score could not be calculated for C3, C4, and C8 due to their chronological age be above 36 months.

Group differences

A Mann-Whitney U test was conducted for comparing the results of the language assessment tools between the two groups of participants. The results suggested that there was no significant differences on chronological age (Md= 23 mo, U= 40, p= .53), developmental age (Md= 16 mo, U= 28, p= .71), CDI (Md= 54, U= 16, p= .53), AVA standard score (Md= 91, U= 17, p= .38), or DevSnap (Md= 83, U= 11, p= .65).

Gender differences

To investigat possible gender differences on children's language performance was also an objective of this thesis. There were no significant differences between male and female participants for chronological age (Md= 23 mo, U= 31, p= .41), developmental age (Md= 16 mo, U= 23, p= .85), CDI (Md= 54, U= 28, p= .37), AVA standard score (Md= 91, U= 39, p= .59), and DevSnap (Md= 83, U= 9, p= .63), regardless of children's hearing condition.

5.3.2 Comparative analysis of the language environment

The total recording time, the age of each child, and the number of CV, CT, AW, MAN and FAN words measured by the LENA system composite view are presented in tables 13 and 14 (p. 43-4). The data were gathered according to the child hearing condition. The Mann-Whitney U test was conducted for verifying any significant difference between-group performances. Differences within groups regarding children's exposure to FAN and MAN words was measured with paired samples tests.

The total recording time of the participating children varied between 10 hours 53 minutes and 15 hours 14 minutes (M= 12:47). For this reason, the total number of CV, CT, and AW needed to be evenly distributed within the period of 12 hours. Being so, the total recording time of each participant was counted in minutes. Then, the total number of CV, CT, and AW was divided by the number of minutes to find the number of CV, CT, and AW per minute. Subsequently, those numbers were multiplied by 60 min to find out the number of CV, CT, and AW per hour. Then, those numbers were multiplied by 12 hours as shown in tables 13 and 14 (p. 43-4). Similar procedure was followed by Nilsson and Olsson (2015).

Table 13: Total number of CV, CT, and AW divided by 12 hours for each child with NH (n= 7)

ID/NH	Total recording time	C. age	CV per hour x 12h	CT per hour x 12h	AW per hour x 12h	FAN Word	MAN Word
C2	12:56	25	2676	840	16608	16331	4374
C6	15:14	21	2256	372	9936	11080	1537
C7	12:58	11	660	300	19476	14658	6398
C9	13:01	21	1944	372	6876	9832	2407
C11	13:00	19	1068	240	7152	5861	1889
C12	12:49	19	1728	396	10392	8723	2380
C15	11:43	29	4128	1248	15864	9500	6903
M	13:05	21	2066	538	12329	10855	3698
Min-Max	11:43-15:14	11-29	660-4128	240-1248	6876-19476	5861-16331	1537-6903
SD	01:02	6	1137	369	4965	3579	2212

Table 14: Total number of CV, CT, and AW divided by 12 hours for each child with HI (n= 7)

ID/HI	Total recording time	C. age	CV per hour x 12h	CT per hour x 12h	AW per hour x 12h	FAN Word	MAN Word
C1	12:27	37	384	144	13668	7541	6644
C3	11:38	43	2244	648	15888	11348	5967
C4	14:29	38	4565	852	14100	11710	5311
C5	10:53	41	3528	1548	30252	20733	6709
C8	13:23	42	636	180	10068	8224	3820
C10	11:03	19	1752	564	22176	14926	3741
C13	13:35	20	852	204	10848	7898	5899
M	12:29	34	1994	591	16714	11769	5442
Min-Max	10:53-14:29	19-43	384-4565	144-1548	10068-30252	7541-20733	3741-6709
SD	1:22	10	1572	501	7170	4759	1230

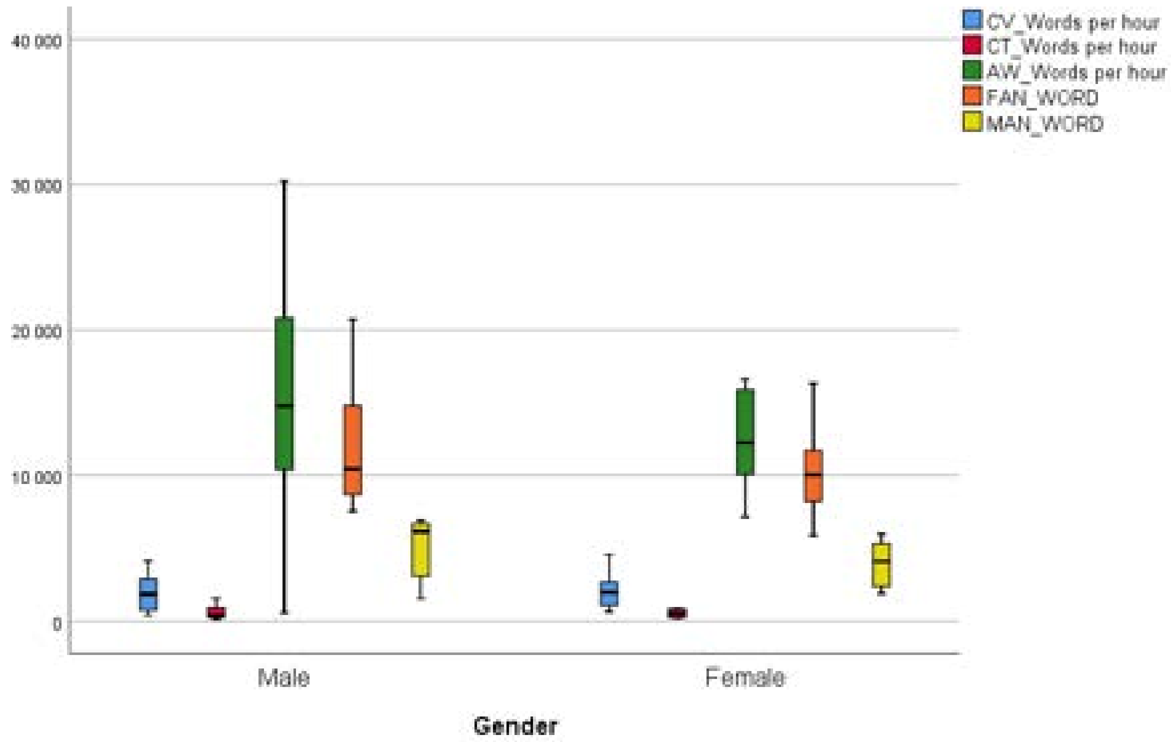
Group differences

Results of the Mann-Whitney U test showed no significant difference between groups regarding the characteristics of their language environment (Cf. table 13 and 14, p. 43-4). It means that the amount of CV (Md= 1848, U=21, *p*= .71), CT (Md= 384, U= 23, *p*= .90), AW (Md= 13884, U= 34, *p*= .25), FAN (Md= 10456, U=26, *p*= .90) and MAN (Md= 4843, U=35, *p*= .20) words were similar regardless of the children's hearing condition.

Gender differences

As for the whole cohort (cf. figure 4, p. 45) , no significant difference the median was found for CV (Md= 1848, U= 26, *p*= .86), CT (Md= 384, U= 26, *p*= .86), AW (Md= 13884, U= 19, *p*= .57), FAN (Md= 10456, U=21, *p*= .75), and MAN (Md= 4843, U=15, *p*= .28) regarding the gender of the participating children regardless of their hearing condition (n= 14).

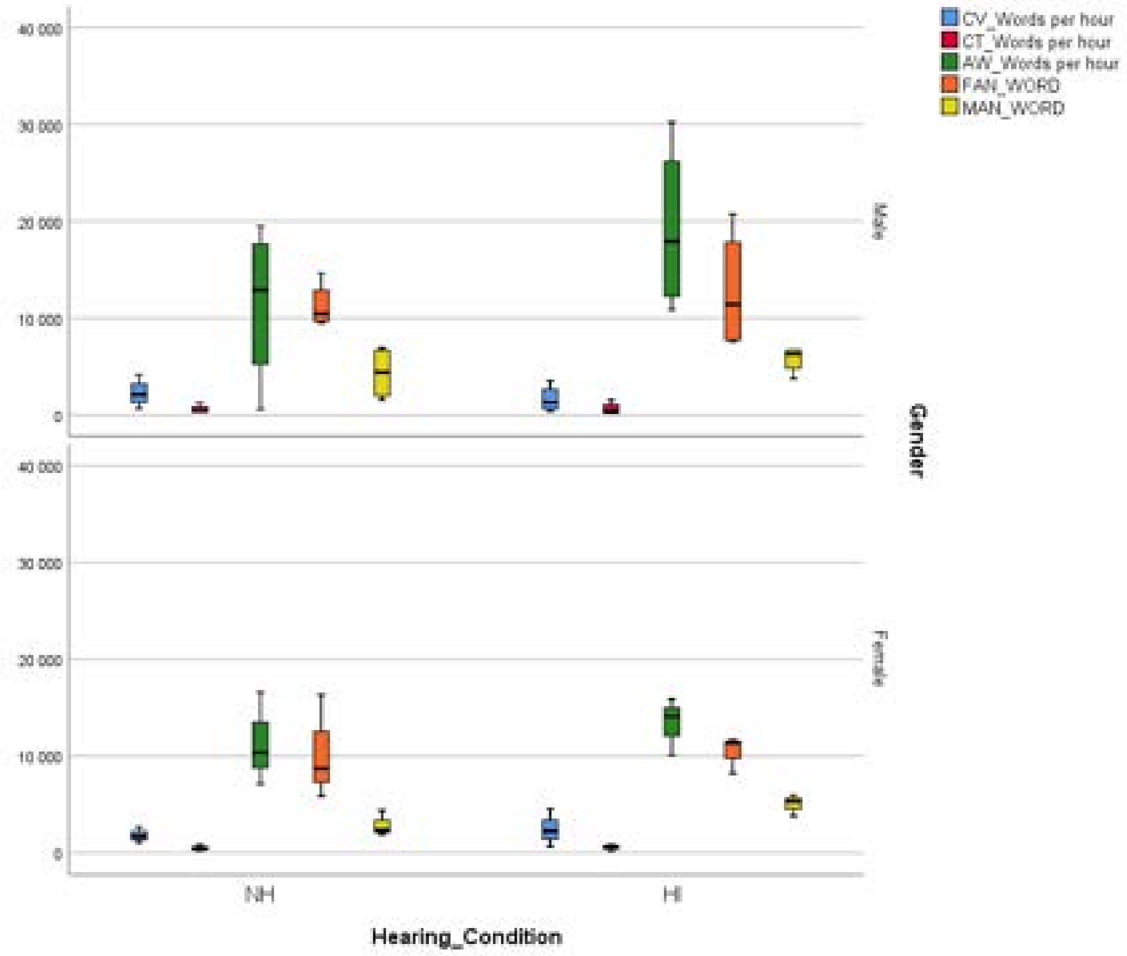
Figure 4: Gender differences observed on the language environment of the participating children, whole cohort (n= 14).



No difference in the median of CV (Md= 1944, U= 5, *p*= .86), CT (Md= 372, U= 6, *p*= 1.0), AW (Md=12238, U= 3, *p*= .40), FAN (Md= 9831, U= 4, *p*= .63, and MAN (Md= 2406, U= 4.0, *p*= .63) was found between gender among the participants with NH (n= 7).

Regarding the analysis of the language environment of children with HI (n= 7), no significant difference was observed in the medians of CV (Md= 1752, U= 8.0, *p*= .63), CT (Md= 564, U= 7.0, *p*= 1.0), AW (Md= 14100, U= 4.0, *p*= .63), FAN (Md= 11348, U= 6.0, *p*= 1.0), and MAN (Md= 5898, U= 4.0, *p*= .63) words between male and female participants. Figure 4 (p. 45) shows the characteristics of the participating children's language environment based on their gender.

Figure 5: Distribution of the CV, CT, AW, FAN, and MAN words between-groups and gender. Clinical group (n= 7), control group (n= 7).



Note: Subgroups differences on the language environment (gender differences). There was a total of four boys and three girls in each group.

The role of gender on childcare

Paired samples tests suggested that children with NH were significantly more exposed to FAN words (M=10855, SD= 3579) than to MAN words (M=3968, SD= 2212); t(6)= 5.9, *p*= .001. Significant difference in means was also observed among children with HI. They were significantly more exposed to FAN words (M= 11769, SD= 4759) than to MAN words (M=5442, SD= 1230); t (6) = 3.5, *p*=.013 (Cf. figures 4 and 5, p. 45-6). Such results confirmed the hypothesis that Brazilian mothers or female caregivers talk more to their child than fathers or male caregivers do.

5.3.3 Comparative analysis of the audio environment

LENA system analyzed the AE of the participant families under the following categories: silence, noise, TV/radio, distant, and meaningful language. Tables 15 and 16 show the descriptive statistics and the estimates of the AE variables provided in percentage for each group of participants.

Table 15: Audio environment – control group (n= 7)

ID/NH	Gender	Age	Silence	Noise	TV	Distant	Meaningful
C2	F	25	50	3	4	22	21
C6	M	21	42	4	1	34	19
C7	M	11	29	3	2	48	18
C9	M	21	32	3	2	41	22
C11	F	19	54	3	11	19	13
C12	F	19	46	2	18	18	16
C15	M	29	55	2	1	19	23
M			44	3	6	29	19
Min-max			29-55	2-4	1-18	18-48	13-23
Range			26	2	17	30	10
SD			10	1	7	12	4
Median			46	3	2	22	19

Table 16: Audio environment – Clinical group (n= 7)

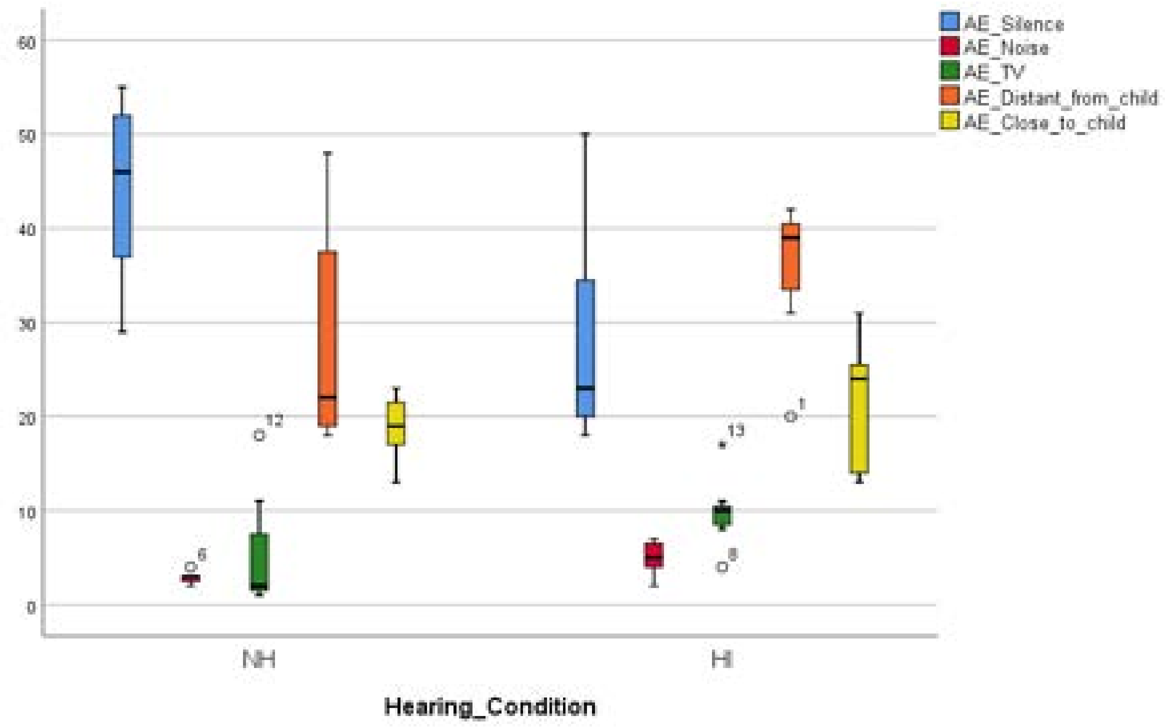
ID/HI	Gender	Age	Silence	Noise	TV	Distant	Meaningful
C1	M	37	50	7	9	20	14
C3	F	43	23	4	8	41	24
C4	F	38	20	2	11	40	27
C5	M	41	18	5	10	36	31
C8	F	42	46	6	4	31	13
C10	M	19	20	4	10	42	24
C13	M	20	23	7	17	39	14
M			29	5	10	36	21
Min-max			18-50	2-7	4-17	20-42	13-31
Range			32	5	13	22	18
SD			13	2	4	8	7
Median			23	5	10	39	24

Group differences

A Mann-Whitney comparative analysis of the audio environment of the participating children have suggested that children in both groups were exposed to a similar amount of time of TV/radio (Md= 9%, U= 36, *p*= .17) exposure to language spoken close to the child (Md= 20%, U= 31, *p*= .46) and distant from them (Md= 35%, U= 34, *p*= .26).

However, their environment diverged in relation to their time of exposure silence (Md= 37%, U= 8, *p*= .04) and noise in the environment (Md= 4%, U= 42, *p*= .03) as shown on **figure XX (p. XX)**.

Figure 6: Characteristics of the audio environment of children with NH in comparison to the audio environment of children with HI.



Gender differences

No significant differences in the audio environment of the participating children were observed based on their gender as shown below.

Table 17: Gender differences in the audio environment of the participating children (n= 14).

Mann-Whitney U test			
	Md	U	p-value
AE_Close to	20%	20	.57
AE_distant from	35%	15	.28
AE_TV/radio	9%	34	.23
AE_noise	4%	15	.28
AE_silence	37%	30	.49

5.4 Correlational analysis

5.4.1 Child age vs. language environment variables

The results of the Spearman correlation analysis for child age (chronological, developmental and hearing age) and the language environment variables (CV, CT, AW, FAN, and MAN) was presented below.

Control group

As for the group of children with NH (n=7), children's chronological age strongly correlated with number of CV (r_s= .98, *p*= .04), and with the amount of CT (r_s= .79, *p*= .04), and to the amount of language spoken close to the child (r_s= .82, *p*= .02). Chronological age strongly correlated with child developmental age (r_s= .97, *p*= .00). No correlation was found between child age and the amount of AW, FAN, and MAN words recorded.

Considering these children developmental age, similar results were found. Statistical analysis indicated that developmental age strongly correlated with the amount of language spoken close to the child (r_s= .89, *p*= .01), with the amount of CV (r_s= .95, *p*= .00), and with the amount of CT (r_s= .77, *p*= .04). No correlation was found between child age and the amount of AW, FAN, and MAN words recorded.

Clinical group

When taking into consideration children's longer hearing age, a positive, strong correlation was found with higher number of CV (r_s= .86, *p*= .01), and with the number of CT (r_s= .79, *p*= .04). A strong, positive correlation was found between child developmental age and the amount of language that was spoken close to the child (r_s= .86, *p*= .01), with the number of CV (r_s= .93, *p*= .00), and with the number of CT (r_s= .86, *p*= .01). No correlation was found between the chronological age and any of variables related to the language environment as for children with HI, and no correlation was found between child age (chronological, developmental, and hearing age) and the number of AW, FAN, and MAN words recorded.

Whole cohort

A strong, positive correlation was found between children's developmental age and the amount of language spoken close to them (r_s= .83, *p*=.00), with the number of CV (r_s= .88, *p*= .00), with the number of CT (r_s= .83, p= .00). A positive, moderate correlation was found between children developmental age and the number of FAN words they heard (r_s= .56, *p*= .04). No correlation was found between the chronological age and any of variables related to the language environment as for whole cohort or between child age and the number of AW and MAN words recorded (n=14).

5.4.2 Child age vs. language performance

The results of the Spearman correlation analysis for child age (chronological, developmental and hearing age) and the language performance (CDI, AVA, and DevSnap) was presented below.

Control group

The correlational analysis between child age their level of language performance yielded the following results for the control group (n= 7). A very strong, positive correlation was found between children's chronological age and developmental age (r_s= .97, *p*= .00). A strong, positive correlation was found between children's developmental age and DevSnap standard score (r_s= .77, *p*= .04). No correlation was found between child age and CDI, and child age and AVA standard score.

Clinical group

The Spearman correlational analysis between child age and child language performance for children with HI (n= 7) took in consideration their chronological age, developmental age, and hearing age. A very strong correlation was observed between hearing developmental age (r_s= .86, *p*= .01). No correlation was found between chronological age and CDI, AVA, and DevSnap standard score. As of hearing age, very strong correlation was found with children's performance on CDI (r_s= .93, *p*= .00), and with AVA standard score (r_s= .96, *p*= .00). No correlation was found between hearing age and DevSnap standard score. Children developmental age strongly correlated with CDI (r_s= .86, *p*= .01) and with AVA (r_s= .82, *p*= .02). No correlation was found between developmental age and DevSnap standard score.

Whole group

The language performance of all participants (n= 14) was analyzed in relation to their chronological and developmental age. No correlation was found between child chronological age and CDI, AVA, and DevSnap standard score. A strong correlation was found between developmental age and CDI (r_s= .78, *p*= .00). A moderate correlation was observed between child developmental age and AVA (r_s= .57, *p*= .04) and DevSnap (r_s= .68, *p*= .02).

5.4.3 Language environment vs language performance

The results of the Spearman correlation analysis between language performance (CDI, AVA, and DevSnap) and the language environment variables (the language spoken close to the child, CV, CT, AW, FAN, and MAN) was presented below.

Control group

The results of the correlational analysis indicated a strong to a very strong correlation between the CDI and the number of CT (r_s= .81, *p*= .05) and the number of AW (r_s= .89, *p*= .02). No correlation was found among any of the other variables.

Clinical group

It was observed on the results of the correlational analysis that children's performance on CDI strongly correlated with CV (r_s= .96, *p*= .00), CT (r_s= .93, *p*= .00), and FAN words (r_s= .82, *p*= .02). The CDI neither correlated with AW nor with MAN words.

Children's expressive language (AVA score) strongly correlated with CV (r_s= .89, *p*= .01), CT (r_s= .86, *p*= .01), and FAN words (r_s= .79, *p*= .03). No correlation was found with AW or with MAN words. The DevSnap did not correlate with any of the language environment variables.

Whole group

Data of the whole cohort (n= 14) suggested a very strong correlation between the CDI and the number of CV (r_s= .87, *p*= .00) and CT (r_s= .94, *p*= .00). A moderate correlation was observed between the CDI and the number of AW (r_s= .57, *p*= .04) and FAN words (r_s= .63, *p*= .02). No correlation was found between the CDI and the amount of MAN words.

The AVA standard score strongly correlated with the amount of CV (r_s= .73, *p*= .00) and with the amount of CT (r_s= .77, *p*= .00). The AVA standard score did not correlate with AW, FAN, and MAN words.

The DevSnap moderately correlated with CT (r_s= .66, *p*= .03), AW (r_s= .61, *p*= .05), and FAN words (r_s= .69, *p*= .02). No correlation was found between DevSnap and CV and between DevSnap and MAN word.

5.4.4 Language spoken close to the child

Control group

The results of the correlational analysis indicated a strong correlation between the number of words spoken close to the child and the number of CV (rs= .79, *p*= .04). As for the control group, the number of words spoken close to the child did not correlate with any of the other variables related to children's language performance and the characteristics of their language environment.

Clinical group

The number of words spoken close to the child strongly correlated with the CDI (r_s= .84, *p*= .02) and to the AVA scores (r_s= .84, *p*= .02). It was also found strong correlation to CV (r_s= .89, *p*= .01), CT (r_s= .93, *p*= .00), AW (r_s= .87, *p*= .10), and FAN word (r_s= .82, *p*= .02). No correlation was found between the amount of words spoken close to the child and MAN word and DevSnap.

Whole group

A correlational analysis including the data of the whole cohort indicated moderate to strong correlation among the variables taken into consideration. The amount of language spoken close to the child moderately correlated with the results of the CDI (r_s= .69, *p*= .01), the DevSnap (r_s= .64, *p*= .03), and the amount of AW (r_s= .60, *p*= .02). A strong correlation was found between the amount of language spoken close to the child and CV (r_s= .81, *p*= .00), CT (r_s= .87, *p*= .00), and FAN words (r_s= .79, *p*= .00). The amount of language spoken close to the child neither correlated with the AVA standard score nor to the amount of MAN words.

5.4.5 Parental education

Control group

The group of children with NH was rather homogeneous in regards to the level of parental education, for all of the participating parents had a college degree. The Spearman correlational analysis could not compute the correlation between the level of parental education and children's language performance on the selected assessment tools. Likewise, the correlation analysis yielded no results for the level of parental education in correlation to the number of words spoken close to the child and to the amount of AW directed to the child. Clinical group

As presented in section 4.1 (p. 22), 69% of the participating parents had a college degree and 31% of them had a high school diploma. The correlational analysis yielded no result at a significant level for the correlation between the level of parental education and any other variable.

Whole group

Taking in the whole cohort, the correlational analysis between the level of parental education and all the other variables did not yield significant results.

6 Discussion

6.1 Theoretical background

The LENA system allows researchers to gather more knowledge about the interactions between the developing children and their parents in their home environment. It provides relevant data for supporting our understanding of how much parent-child interaction in their home environment has contributed to a child's language development by the recording day. Bronfenbrenner's (1979) and Chomsky's (1998 and 2011) theories were relevant for this study because it provided the theoretical background for understanding how parent-child interactions and the home settings influenced on the child's level of language development in relation to their chronological, developmental, and hearing age as of the recording day.

The theory of ecological system (Bronfenbrenner, 1979) and the nativist theory for language acquisition (Chomsky, 1998 and 2011) provided grounds for urging Brazilian authorities to strengthen public policies for supporting individuals with HI soon after birth. The existing policies focuses on the early identification of HI and on providing adequate support for the families and the developing child with HI pre- and post- fitting of HA/CI (cf. section 1.3, p. 3). However, these services have been provided to only 8.4% of the population with HI (IBGE 2015). Strengthening these policies should increase the number of children receiving adequate support, reduce the period the child spends in silence, support their language development, and improve their quality of life.

6.2 Pre-validation study

The LENA system is a speech streaming technology developed in the USA for primarily measuring the characteristics of the listening and language environment of toddlers. This system has so far been deemed sensitive to the acoustic features of seven other languages as discussed in section 3.2 (p. 16). The current study was the known first study devised for testing and pre-validating the LENA system to BP. As part of the pre-validation process, it was necessary to devise a coding protocol for manually transcribing samples of 15-min recording of the participants with NH. The devised protocol was adapted from coding protocol for European French (Canault et al., 2016).

An intraclass correlation coefficient was calculated for measuring the degree of agreement between the human raters' counts. High interrater agreement for the AW and CV counts were very high (α= .993 and α= .842 > .70) and showed a consistency value of 99.3% for and 99.7% for AW and CV, respectively. Thus, research findings were in line with Canault et al. (2016) and suggested that the devised protocol was valid and should be used in the pre-validation study.

The reliability analysis between the LENA and the means of human raters' estimates for AW and CV yielded a moderate to strong mean percentage of matching (84% and 66%, respectively). Contrary to the French reliability study (Canault et al., 2016), the LENA system tended to overestimate the human count for AW, but underestimate it for CV for BP. Such result suggests a type of labeling error that should be further investigated. However, it did not compromise the good reliability between the LENA automated and human counts for BP.

The above-mentioned differences were not observed on the correlation analysis between the automated and human counts for both variables (r= .936, *p*= .002 and r= .932, *p*= .002, AW and CV respectively). The correlation between the LENA automated and the human counts for AW and CV found in this study were stronger than the results from previous studies (cf. section 3.2, p. 16). Despite the small sample (n=7 and 105 min samples), the very strong, positive correlation found between the LENA automated and the human counts suggested that the LENA system was sensitive to the acoustic features of BP, and therefore, it generated reliable counts of AW and CV (Canault et al., 2016).

6.3 Comparative study

No significant difference was observed on chronological and developmental age between the children in the children with NH and in the clinical group (HI). For this reason, the comparative analysis of the language performance, the language and the listening environment between the two groups could be conducted without major restrictions. A Mann-Whitney analysis of the group performance on the language assessment tests yielded no significant differences between groups (cf. section 5.3.1, p. 40).

It was observed that children's performance on the language assessment tests (DevSnap, CDI, and AVA) varied greatly within groups regardless of children's hearing condition. The age of the fitting of HA/CI accounted for the language performance in children with HI. Those who were fitted with HA/CI at younger age displayed better language skills than their peers older age at fitting. This result was in line with Ambrose et al. (2015) who observed that the amount linguistic input provided by parents to children with HI increases as child age. As of the performance of the participants in the control group, the varied level of language skills was associated with the very young age of three of the participants (11 to 19 months). Investigating subgroups differences in language skills and language environment was not within the scope of this study. Yet, it should be further investigated in future studies.

Although it was not the objective of the study, it was observed a difference in the language performance of children with moderate to profound HI. Among the children with HI, those with moderate HI (C4, C5, and C10) presented better language skills than the ones with profound HI (C1, C8, and C13)[7]. Subgroup differences in language performance and environment should be further investigated in a future study.

No significant difference was observed in the language environment between the two groups. It suggested that children with HI were exposed to a similar number of AW, got involved in a similar number of CT, and produced a comparable number of CV. They have also been exposed to a similar number of FAN and MAN words. The present results suggested that children with HI need a higher amount of input to develop language level comparable to children with NH (Aragon & Yoshinaga-Itano, 2012). The similarities of the language environment in the participating families is possibly a consequence of the fact that parents of children with HI have been oriented by their child's speech therapist on how to interact with their child with HI (Ganek & Eriks-Brophy, 2017).

As of the characteristics of the audio environment, between-groups comparison analysis suggested that the audio environment of the participating children was similar with regards to the amount of exposure to TV/radio, and language spoken close to and distant from them. Yet, it was observed that children with NH spent relatively more time in a silent environment than their counterparts with HI. Conversely, it was observed that children with HI spent significantly more time in a noisy environment than their peers with NH. These differences could be explained by the fact that the group of children with NH was slightly younger than their counterparts with HI even though this was not a significant difference. Being so, the

[7] C3 was the only child with profound HI whose language skills were within the expected range for her chronological age. Her adequate language performance as associated with the early age of fitting HA.

children with NH spent more time in silence because they napped in the afternoon whilst the slightly older children with HI did not.

Regarding gender differences, no difference in language performance was observed between boys and girls despite their hearing condition. Similarly, the characteristics of the language and listening environment of male and female children were comparable. It suggests that Brazilian parents provided the same language and developmental opportunities to their male and female offspring. However, it was observed a significant difference on the number of words male and female caregivers directed to their child. Female caregivers spoke significantly more to their child than their male partners. Such result is in line with previous studies suggesting that Brazilian women are still the caregiver in charge of childcare (Dessen, 2010; IBGE, 2012) and the LENA studies in the USA (Gilkerson, & Richards, 2008; Johnson, Caskey, Rand, Tucker, & Vohr, 2014).

6.4 Correlation study

Control group

Evidence from previous studies has suggested that the number of CT and AW would be predictors of the number of CV (Gilkerson et al., 2015; Nilsson & Olsson, 2015). Gilkerson et al.'s (2015) observed in their validation study for Chinese that the number of AW correlated with child age. Contrary to Gilkerson et al.'s (2015) study, no correlation was found between child age and the number of AW in the present study. However, correlation analysis suggested that the number of words spoken close to the child, CV and CT was in accordance with child chronological and developmental age **(cf. unit 5.4.1, p. XX)**. Evidence from research suggested that increase in child age leads to increase on the exposure to linguistic input, on the number of involvement in parent-child interaction, and consequently on the number of vocalizations (Ganek & Eriks-Brophy, 2017).

The amount of language spoken close to the child with NH strongly correlated to the number of vocalizations produced. It suggested that the amount of linguistic input directed to the child stimulated the child to produce more vocalizations. A strong, positive correlation was also found between CT and CV for the group of children with NH, but no correlation was found between AW and CV and between AW and CT. These findings suggested that the number of parent-child interaction was a predictor of child language performance rather than number of AW heard by the child (Nilsson & Olsson, 2015). Thus, the more conversational turns and interactions between caregivers and children, the better will the child develop language in relation to the chronological age (Romeo, Leonard, Robinson, West, Mackey, Rowe, & Gabrieli, 2018).

A strong correlation between child performance on the CDI and the number of CV and AW was observed. It suggested that child language performance is in line with the number of CV, but also the number of AW directed to the child. The present results were in line with Nilsson & Olsson's study (2015). These findings suggested that the amount of parent-child directed talk stimulated children to talk more, which led to improvements in their language skills (Nilsson & Olsson, 2015; Hart & Risley, 1995).

Clinical group

Contrary to the participants in the control group (n= 7), no correlation was found between chronological age and any of the language environment and performance variables among the children with HI (n= 7). The LENA system was able to capture the correlation between the language environment performance and child age after the fitting of the HA. The correlational analysis between hearing age and the language environment variables indicated that the number of CT and CV was in accordance with their hearing age. Child expressive language and communicative development were also in line with children's hearing age.

Children hearing age strongly correlated with their developmental age. The developmental age strongly correlated with the same measures as the hearing age did. However, the child developmental age has also correlated with the amount of language spoken close to the child. Similar results were observed among children with NH. These findings stressed the importance of the role of parent-child interaction on children language development.

Just as for the children with NH, the number of CV was dependent on the amount of parent-child interaction and not the number of AW to which they were exposed. Yet, child exposure to linguistic input produced close to them have also influenced on their language production, which was in accordance with their developmental age. Children performance on the CDI and the AVA was also in accordance with their developmental age. These results suggested that children language production were at the expected level for their developmental age.

It was observed that child communicative and expressive language development correlated with their exposure to linguistic input produced close to them, the number of CV, CT, and FAN words. This result suggested that both the amount of exposure to linguistic input and parent-child interaction played a role in the amount of language production of the participating children with HI.

The number of words spoken by male caregiver did not correlate with any variable. In line with studies on the role of women in child care in Brazilian context (Dessen, 2010; IBGE, 2010; IBGE, 2012), the present data indicated the influence of female caregivers on their child language development. Further study should investigate the reason why the number of MAN words did not influence on child language development in a similar way. Considering that having the recordings conducted on a weekend, when all the family members were at home, would it be the case that fathers felt uncomfortable in being recorded? Or would it be a sign of imbalance in the division of childcare chores? Further investigation is needed.

Whole group

The results of the correlation analysis including all of the participants (n= 14) suggested that the developmental age of the child was a more appropriate measure for investigating child language development and language and audio environment. The developmental age was believed to place all of the participating children on the same grounds. The correlational analysis indicated that not only the amount of exposure to language input close to the child but also the number of parent-child interaction contributed to achieve age-related levels of language development.

The children's performance on the language assessment tests correlated well with the factors of their language environments. Both the number of AW and CT were in accordance with their level of language development. Again, the focus should be given to the role of interaction with female caregivers to children language development. The results of the present research challenged the results of earlier studies suggesting the influence of the number of AW on children's language performance (Nilsson & Olsson, 2015; Hart & Risley, 1995). Childrens' language acquisition involves the child's own active role and more than just listening to adults talking. Seemingly it relies most on the constant dyadic interaction between caregivers and the child (Romeo et al., 2018; Nilsson & Olsson, 2015).

Language assessment tools

As of the correlation among the CDI, the AVA, and the DevSnap scores, no significant results were observed among the children with NH. Regarding the data of the cohort of children with HI, no correlation was found between the DevSnap and any other variable. Yet, the CDI correlated with AVA scores. The correlation analysis gathering the data of both children with NH and children with HI, the CDI strongly correlated with the AVA and the DevSnap. This correlation suggested that the CDI would be a sensitive tool for assessing child communicative development in BP. Future study should investigate the correlation between the CDI to the DevSnap adapted to BP with a larger sample. Finding a positive correlation between these three assessment tests would strengthen the validity of the DevSnap as a language assessment tool to BP (Nilsson & Olsson, 2015).

Child language and parental education

Previous research has suggested a correlation between children level of language development to the level of parental education (Ambrose et al., 2015; & Hart & Risley, 1995). Ambrose et al. (2015) argued that the highly educated parents would use good quantity and quality of speech in interaction to their children. Results from previous research suggested that children from low SES families received fewer stimuli for developing their language skills whilst children from higher SES families received more support for developing language (Yoshinaga-Itano, 2012; Nilsson & Olsson, 2015; Weisleder & Fernald, 2013; Wood et al., 2016).

In this study, nine out of 11 participating families came from middle to high SES. The level of parental education was very high, for 86% (22) of them hold a college degree. It resulted in a rather homogeneous cohort despite the diverse language environment of these families. However, no correlation was found between language environment and the level of parental education/SES. It was observed that both child language performance and adult input varied greatly between both groups of participants regardless of the level of parental education. Consequently, the profile of language profile of Brazilian children from low SES families is still unknown. A similar pattern was observed in Pae et al. (2016). Thus, future study should further investigate the SES of the participating families in relation to their children language skills.

7 Conclusion

The present research results suggested that LENA system is a reliable tool for investigating the language environment of Brazilian families, monolingual speakers of BP. The present results were in line with earlier studies testing the LENA system for other languages (Aragon & Yoshinaga-Itano, 2012; Canault et al., 2016; Da Prato, 2016; Gilkerson et al. 2015). Replicating this study with a larger cohort would provide us a more consistent and detailed insight of the audio and language environment in Brazilian families, and preferable in a cohort that consists of all levels of SES.

The correlation between early age of fitting HA/CI and child language development stressed the need to diagnose and take care of HI soon after birth. Therefore, it would minimize the negative impact of the period that deaf children spent in silence during early years when their language development is emerging (Chomsky, 1998 & 2011, Heart & Risley, 1995). The present findings strengthened the importance of parent-child interaction on child language development. Children learn the language from the environment they are immersed by interacting with competent speakers of that language (Romeo et al., 2018).

The current findings highlight the need for creating public policies to support validation and implementation of the LENA system in a Brazilian context. The investigation of the natural language environment of Brazilian children in a large scale would generate the normative data of the LENA system to BP. If so, it would allow researchers and clinicians (1) to understand what a typical language environment of Brazilian families looks like, (2) identify children at-risk of language delay, (3) to elaborate personalized, family-centered intervention for the developing child, and (4) to support parents to stimulate their child with HI at home, based on their family routines and with a more ecological assessment tool that can measure the progress of both the children and families. Consequently, the impact of language delay on the child, i.e. due to HI, would be diminished whilst stimulating their communicative, cognitive, and social development.

Reference list

Ambrose, S. E., Walker, E. A., Unflat-Berry, L. M., Oleson, J. J., & Moeller, M. P. (2015). Quantity and quality of caregivers' linguistic input to 18-month and 3-year-old children who are hard of hearing. *Ear and hearing*, *36*(0 1), 48S.

Aragon, M., & Yoshinaga-Itano, C. (2012, November). *Using Language Environment Analysis to improve outcomes for children who are deaf or hard of hearing*. In Seminars in speech and language (Vol. 33, No. 04, pp. 340-353). Thieme Medical Publishers.

Brasil. Lei no. 12.303, de 2 de agosto de 2010. Dispõe sobre a obrigatoriedade de realização do exame denominado Emissões Otoacústicas Evocadas, from http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/lei/l12303.htm.

Brasil. Ministério da Saúde (MS). Portaria nº 835, de 25 de abril de 2012b. Institui incentivos financeiros de investimento e de custeio para o Componente Atenção Especializada da Rede de Cuidados à Pessoa com Deficiência no âmbito do Sistema Único de Saúde (Web). Retrieved on 31 August 2018. From: http://bvsms.saude.gov.br/bvs/saudelegis/gm/2012/prt0835_25_04_2012.html

Brasil. Ministério da Saúde. Secretaria de Atenção à Saúde. Departamento de Ações Programáticas Estratégicas. Diretrizes de Atenção da Triagem Auditiva Neonatal / Ministério da Saúde, Secretaria de Atenção à Saúde, Departamento de Ações Programáticas Estratégicas e Departamento de Atenção Especializada. – Brasília: Ministério da Saúde, 2012. 32 p.: il. ISBN 978-85-334-1980-3

Bronfenbrenner, U. (1979). The ecology of human development Cambridge. *MA: Harvard*.

Canault, M., Le Normand, M. T., Foudil, S., Loundon, N., & Thai-Van, H. (2016). Reliability of the Language ENvironment Analysis system (LENA™) in European French. *Behavior research methods*, *48*(3), 1109-1124.

Caskey, M., & Vohr, B. (2013). *Assessing language and language environment of high-risk infants and children: a new approach*. Acta Paediatrica, *102*(5), 451-461.

Chomsky, N. (1988). *Current issues in linguistic theory* (Vol. 38). Walter de Gruyter.

Chomsky, N. (2011). Language and other cognitive systems. What is special about language? *Language learning and development*, *7*(4), 263-278.

Cipollone, N., Keiser, S. H., & Vasishth, S. (Eds.). (1998). *Language files: materials for an introduction to language & linguistics*. Ohio State University Press.

Colman, A. (2015). A Dictionary of Psychology. : Oxford University Press. Retrieved 17 Feb. 2018, from http://www.oxfordreference.com/view/10.1093/acref/9780199657681.001.0001/acref-9780199657681.

Da Prato, I. (2016). *The application of LENA Method to a sample group of Italian children* (Master's thesis). University of Pisa, Italy.

De Brito, A. M. W., & Dessen, M. A. (2000). *Crianças surdas e suas famílias: um panorama geral*. Red Psicología Reflexão e Crítica.

De Oliveira, C. T., Cúnico, S. D., da Cunha, L. G., Kruel, C. S., & Tochetto, T. M. (2013). O impacto do diagnóstico de surdez infantil e suas repercussões na vida da criança e de seus familiares. *Disciplinarum Scientia| Ciências Humanas*, *14*(1), 81-94.

De Paula Teixeira, G., de Paiva, A. B., & Lima, M. C. M. P. (2015). Concepção sobre surdez na perspectiva de mães de crianças surdas. *Saúde (Santa Maria)*, *41*(1), 93-104.

Dessen, M. (2010). Estudando a família em desenvolvimento: desafios conceituais e teóricos. *Psicologia Ciência e Profissão*, 30 (Esp.). 202-2019. Retrieved February 7, 2018, from http://www.redalyc.org/html/2820/282021786009/

Fenson, L., Marchman, V. A., Thal, D. J., Dale, P. S., & Reznick, J. S. (2007). *MacArthur-Bates communicative development inventories: User's guide and technical manual*. Baltimore, MD: Brookes.

Fulcher, A., Purcell, A. A., Baker, E., & Munro, N. (2012). Listen up: children with early identified hearing loss achieve age-appropriate speech/language outcomes by 3 years-of-age. *International journal of pediatric otorhinolaryngology*, *76*(12), 1785-1794.

Ganek, H. V., & Eriks-Brophy, A. (2017). A Concise Protocol for the Validation of Language ENvironment Analysis (LENA) Conversational Turn Counts in Vietnamese. *Communication Disorders Quarterly*, 1525740117705094.

Gilkerson, J., Coulter, K. K., & Richards, J. A. (2008). Transcriptional analyses of the LENA natural language corpus. *Boulder, CO: LENA Foundation. Retrieved January*, *12*, 2013.

Gilkerson, J., & Richards, J. A. (2008). The LENA natural language study. *Boulder, CO: LENA Foundation. Retrieved March*, *3*, 2009.

Gilkerson, J., & Richards, J. A. (2009). The power of talk: Impact of adult talk, conversational turns, and TV during the critical 0-4 years of child development. *Boulder, CO: LENA Research Foundation*.

Gilkerson, J., Zhang, Y., Xu, D., Richards, J. A., Xu, X., Jiang, F. ... & Topping, K. (2015). Evaluating Language Environment Analysis system performance for Chinese: A pilot study in Shanghai. *Journal of Speech, Language, and Hearing Research*, *58*(2), 445-452.

Hart, B., & Risley, T. R. (1995). *Meaningful differences in the everyday experience of young American children*. Paul H Brookes Publishing.

IBM Corp. Released 2016. IBM SPSS Statistics for Windows, Version 24.0. Armonk, NY: IBM Corp.

Instituto Brasileiro de Geografia e Estatística (IBGE), Pesquisa Nacional por Amostra de Domicílios 2001-2011. Retrieved May 1, 2018, from: https://seriesestatisticas.ibge.gov.br/series.aspx?no=6andop=0andvcodigo=PD284andt=pessoas-referencia-familia-anos-estudo

IBGE, Censo Demográfico 2010 (Web). Retrieved 31 August 2018. from: http://www.censo2010.ibge.gov.br/apps/mapa/

IBGE (2012). Pesquisa Mensal de Emprego: mulher no mercado de trabalho. Retrieved February 7, 2018, from https://ww2.ibge.gov.br/home/estatistica/indicadores/trabalhoerendimento/pme_nova/Mulher_Mercado_Trabalho_Perg_Resp_2012.pdf

IBGE (2014). Pesquisa Nacional de Saúde 2013: percepção do estado de saúde, estilos de vida e doenças crônicas, from biblioteca.ibge.gov.br/visualizacao/livros/liv94522.pdf

Joint Committee on Infant Hearing. (2007). Year 2007 position statement: Principles and guidelines for early hearing detection and intervention programs. *Pediatrics*, *120*(4), 898-921.

Kirk, S., Gallagher, J. J., Coleman, M. R., & Anastasiow, N. J. (2011). *Educating exceptional children*. Cengage Learning.

LENA Foundation: https://www.lena.org/

LENA Research Foundation. (2015). *User Guide LENA Pro* [Brochure]. Author.

Lenneberg, E. H. (1967). The biological foundations of language. *Hospital Practice*, *2*(12), 59-67.

LoBiondo-Wood, G., & Haber, J. (2014). Reliability and validity. *Nursing research-ebook: Methods and critical appraisal for evidence-based practice. Missouri: Elsevier Mosby*, 289-309.

Martins Filho, J. (2012). *Criança Terceirizada (a)*. Papirus Editora.

Mulheres ganham espaço no mercado de trabalho. (2017, March 9). In *Governo do Brasil*. Retrieved February 7, 2018, from http://www.brasil.gov.br/economia-e-emprego/2017/03/mulheres-ganham-espaco-no-mercado-de-trabalho

Muse, C., Harrison, J., Yoshinaga-Itano, C., Grimes, A., Brookhouser, P. E., Epstein, S. ... & Martin, P. (2013). Supplement to the JCIH 2007 position statement: Principles and guidelines for early intervention after confirmation that a child is deaf or hard of hearing. *Pediatrics*, *131*(4), e1324-e1349.

Nilsson, C., & Olsson, L. (2015). LENA-En stegmätare för ord: Lyssnings-och talspråksmiljö hos en grupp svenska barn vid 18-24 månaders ålder mätt med Language Environment Analysis.

Oetting, J. B., Hartfield, L. R., & Pruitt, S. L. (2009). Exploring LENA as a tool for researchers and clinicians. *The ASHA Leader*, *14*(6), 20-22.

Padovani, C. M., & Teixeira, E. R. (2004). Using the Macarthur Communicative Development Inventories (CDI'S) to assess the lexical development of cochlear implanted children. *Pro-fono: revista de atualizacao cientifica*, *16*(2), 217-224.

Pae, S., Yoon, H., Seol, A., Gilkerson, J., Richards, J. A., Ma, L., & Topping, K. (2016). Effects of feedback on parent–child language with infants and toddlers in Korea. *First Language*, *36*(6), 549-569.

Ramírez-Esparza, N., García-Sierra, A., & Kuhl, P. K. (2014). Look who's talking: speech style and social context in language input to infants are linked to concurrent and future speech development. *Developmental science*, *17*(6), 880-891.

Romeo, R. R., Leonard, J. A., Robinson, S. T., West, M. R., Mackey, A. P., Rowe, M. L., & Gabrieli, J. D. (2018). Beyond the 30-Million-Word Gap: Children's Conversational Exposure Is Associated With Language-Related Brain Function. *Psychological science*, *29*(5), 700-710.

Schwarz, I. C., Botros, N., Lord, A., Marcusson, A., Tidelius, H., & Marklund, E. (2017). The LENA^{TM} system applied to Swedish: Reliability of the Adult Word Count estimate. *In:* Proceedings of the 18th Annual Conference of the International Speech Communication Association (INTERSPEECH 2017) / [ed] Marcin Wlodarczak, STockholm: The International Speech Communication Association (ISCA), 2017, p. 2088-2092, article id 1287 Conference paper (Refereed).

Suskind, D. L., Leffel, K. R., Graf, E., Hernandez, M. W., Gunderson, E. A., Sapolich, S. G., ... & Levine, S. C. (2015). A parent-directed language intervention for children of low socioeconomic status: A randomized controlled pilot study. *Journal of Child Language*. Advance online publication. doi: 10.1017/S0305000915000033

SUS oferece reabilitação para pessoas com deficiência auditiva. (2015, November 10). In *Portal Brasil*. Retrieved April 12, 2017, from http://www.brasil.gov.br/saude/2015/11/sus-fornece-reabilitacao-para-pessoas-com-deficiencia-auditiva

Tenor, A. C., & Deliberato, D. (2015). Expectativas de comunicação dos pais de crianças surdas. *Ensino e Aprendizagem na Educação Básica: desafios curriculares*, 1528.

Van Dam, M., Oller, D. K., Ambrose, S. E., Gray, S., Richards, J. A., Xu, D., ... & Moeller, M. P. (2015). *Automated vocal analysis of children with hearing loss and their typical and atypical peers*. Ear and hearing, *36*(4), e146.

Johnson, K., Caskey, M., Rand, K., Tucker, R., & Vohr, B. (2014). Gender differences in adult-infant communication in the first months of life. *Pediatrics*, *134*(6), e1603-e1610.

Wagner, L. C., Vieira, G. P., & Maciel, V. E. M. (2017). A terceirização dos cuidados infantis: um fenômeno histórico. *Revista de EDUCAÇÃO do Cogeime*, *26*(51), 77-92.

Wake, M., Ching, T. Y., Wirth, K., Poulakis, Z., Mensah, F. K., Gold, L., ... & Rickards, F. (2016). Population outcomes of three approaches to detection of congenital hearing loss. *Pediatrics*, *137*(1), e20151722.

Weisleder, A., & Fernald, A. (2013). Talking to children matters: Early language experience strengthens processing and builds vocabulary. *Psychological science*, *24*(11), 2143-2152.

Wood, C., Diehm, E. A., & Callender, M. F. (2016). An investigation of language environment analysis measures for Spanish–English bilingual preschoolers from migrant low-socioeconomic-status backgrounds. *Language, speech, and hearing services in schools*, *47*(2), 123-134.

World Health Organization (2018, March 15). Deafness and hearing loss. Retrieved May 31, 2018, from http://www.who.int/news-room/fact-sheets/detail/deafness-and-hearing-loss

WHO (2018, May 17). Prevention of blindness and deafness - Estimates. Retrieved May 31, 2018, from http://www.who.int/pbd/deafness/estimates/en/

Xu, D., Yapanel, U., & Gray, S. (2009). *Reliability of the LENA Language Environment Analysis System in young children's natural home environment*. Retrieved online July, 27, 2009.

Yoshinaga-Itano, C., Sedey, A. L., Wiggin, M., & Chung, W. (2017). *Early hearing detection and vocabulary of children with hearing loss*. Pediatrics, e20162964.

Appendix

Appendix I – Approval from the committee on ethics in research

REK
REGIONALE KOMITEER FOR MEDISINSK OG HELSEFAGLIG FORSKNINGSETIKK

Region:	Saksbehandler:	Telefon:	Vår dato:	Vår referanse:
REK sør-øst	Mariann Glenna Davidsen	22845526	23.06.2017	2016/2235/REK sør-øst B
			Deres dato:	**Deres referanse:**
			20.06.2017	

Vår referanse må oppgis ved alle henvendelser

Ulrika Löfkvist
Institutt för spesialpedagogikk

2016/2235 Ord gjøre en forskjell - lytting og muntlig språkmiljø hos små barn med og uten nedsatt hørsel

Forskningsansvarlig: Universitetet i Oslo
Prosjektleder: Ulrika Löfkvist

Vi viser til søknad om prosjektendring datert 20.06.2017 for ovennevnte forskningsprosjekt. Søknaden er behandlet av leder for REK sør-øst på fullmakt, med hjemmel i helseforskningsloven § 11.

De omsøkte endringene er beskrevet i skjema for prosjektendringer og gjengis her (uthevet i kursiv):

Ny prosjektmedarbeider:
Miriam Ferreira, student, institutt for spesialpedagogikk

Økning i antall forskningsdeltakere
Brasiliansk pilotstudie (masteruppsats) i Ord gjør forskjell. Ytterligare 20 barn och deras foreldrer bjuds in; 10 barn med hørselsnedsættselse og 10 barn med normalt hørsel i aldern 18-30 månader boende i Sau Paolo, Brasilia. Nye analyser av innsamlete prosjektdata Redegjør nærmere for de nye analysene.
Något færre tester och analyser genomførs i denna pilotstudien jmf med norsk studie. I den planerade brasilianska studien ingår en LENA-mæning inklusive developmental snapshot (øversatt foreldreformulær om generell utveckling) samt portuguisisk MacArthur-Bates Communicative Development Inventory (CDI)-formulær som anvænds før att undersøka ordførråd (föräldraformulär). Insamling sker för övrigt enligt samma procedur som i norska studien. Norska formulæren som ges till forældrarna om hur LENA fungerar og dagboksanteckningsblad har øversatts ordagrant till portugisiska av masterstudent i samråd med forskare i Sao Paulo.

Ny/endret forespørsel om deltakelse og samtykkeerklæring
Pilotstudie (norskt masterprojekt) med i princip samma upplægg som i den norska Ord gjør forskjell-studie ska genomføras. Data samlas in i Sao Paulo i Brasilia under børjan av høsten 2017 och redovisas i en norsk masteroppgave vid Institutt for spesialpedagogikk, UiO, på internationala masterprogrammet (se separat bifogad projektplan) samt senare i vetenskapliga artiklar. Etiskt godkænnade søks parallellt æven via en samarbetspartner på Universitetet i Sao Paulo (professor Cilmara Levy, Faculdade de Ciências Médicas da Santa Casa de São Paulo at FCMSCSP). Norsk utstyr (LENA) anvænds før datainsamling och analyseras via analysprogram på UiO och lagres sedan på samma sætt som tidigare beskrivits gællande norsk data (se bifogad projektbeskrivelse).

Komiteens vurdering
Komiteen har ingen innvendinger til de omsøkte endringene, men setter vilkår om at det må foreligge en godkjenning fra tilsvarende instans i Brasil før prosjektet igangsettes. Kopi av denne må oversendes REK.

Besøksadresse:
Gullhaugveien 1-3, 0484 Oslo

Telefon: 22845511
E-post: post@helseforskning.etikkom.no
Web: http://helseforskning.etikkom.no/

All post og e-post som inngår i saksbehandlingen, bes adressert til REK sør-øst og ikke til enkelte personer

Kindly address all mail and e-mails to the Regional Ethics Committee, REK sør-øst, not to individual staff

Vedtak
Komiteen har vurdert endringsmeldingen. Når ovennevnte vilkår er oppfyllt godkjennes endringen slik det nå foreligger med hjemmel i helseforskningsloven § 11.

Godkjenningen er gitt under forutsetning av at prosjektet gjennomføres slik det er beskrevet i endringsmeldingen.

Komiteens vedtak kan påklages til Den nasjonale forskningsetiske komité for medisin og helsefag, jf. Forvaltningslovens § 28 flg. Eventuell klage sendes til REK Sør-øst. Klagefristen er tre uker fra mottak av dette brevet.

Vi ber om at alle henvendelser sendes inn via vår saksportal: http://helseforskning.etikkom.no eller på e-post til post@helseforskning.etikkom.no.

Vennligst oppgi vårt referansenummer i korrespondansen.

Med vennlig hilsen

Grete Dyb
professor, dr. med.
leder REK sør-øst B

Mariann Glenna Davidsen
rådgiver

Kopi til:
- Universitetet i Oslo ved øverste administrative ledelse

Appendix II – Approval from the committee on ethics in research Santa Casa Hospital

SANTA CASA DE MISERICÓRDIA DE SÃO

S

Plataforma Brasil

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: Análise do ambiente linguístico de crianças brasileiras com deficiência auditiva

Pesquisador: cilmara cristina alves da costa levy

Área Temática:

Versão: 1

CAAE: 72198817.1.0000.5479

Instituição Proponente: IRMANDADE DA SANTA CASA DE MISERICORDIA DE SAO PAULO

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 2.216.543

Apresentação do Projeto:

Projeto de pesquisa prospectiva comparativa entre o ambiente auditivo linguístico de crianças de 18 a 30 meses de idade com deficiência auditiva e de audição normal.

Farão parte deste estudo 10 crianças dentro da faixa etária e deficiência auditiva recrutado pelo hospital da ISCMSP. Será usado um sistema denominado LENAtm que é um programa para medir e analisar gravações do idioma utilizado no ambiente doméstico de crianças entre 0 e 4 anos.

Objetivo da Pesquisa:

Analisar o ambiente auditivo e linguístico de crianças entre 18 e 30 meses de idade com deficiência auditiva em comparação com o ambiente de linguagem dos controles de audição normal combinados em idade no contexto brasileiro. Serão coletados e analisados pelos Sistema LENAtm as vocalizações infantis, palavras de adultos e turnos conversacionais.

Avaliação dos Riscos e Benefícios:

Riscos leves, sem intervenção no participante

benefícios: Fornecer maiores dados sobre o ambiente linguístico da criança brasileira, possivelmente auxiliar no uso do sistema na língua portuguesa. Com base no conhecimento adquirido, possibilitar a melhora na qualidade de vida, inclusão social e desenvolvimento da criança com deficiência auditiva.

Endereço: SANTA ISABEL
Bairro: VILA BUARQUE **CEP:** 01.221-010
UF: SP **Município:** SAO PAULO
Telefone: (11)2176-7689 **Fax:** (11)2176-7688 **E-mail:** cepsc@santacasasp.org.br

Comentários e Considerações sobre a Pesquisa:

Esclarecimentos dos questionamentos apontados anteriormente foram realizados, os questionários foram apresentados, mas não anexados no projeto. Verificadas as mudanças quanto aos critérios de inclusão que contemplam os dois grupos.

Considerações sobre os Termos de apresentação obrigatória:

Corrigidos e apresentados, porém o TCLE apresenta erros de digitação e espaçamento. Sugiro correção.

Recomendações:

Corrigir TCLE

Conclusões ou Pendências e Lista de Inadequações:

Aprovado. Os apontamentos para correção de erros de digitação e espaçamento no TCLE não impedem a aprovação.

Considerações Finais a critério do CEP:

Aprovado com recomendações.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_954527.pdf	28/08/2017 13:35:55		Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	TCLE.pdf	28/08/2017 13:34:53	cilmara cristina alves da costa levy	Aceito
Outros	ParecerconsubstanciadodoCEP.docx	28/08/2017 10:08:12	cilmara cristina alves da costa levy	Aceito
Outros	inventarioanexo1.pdf	28/08/2017 10:07:16	cilmara cristina alves da costa levy	Aceito
Outros	LittlEars.pdf	28/08/2017 10:06:14	cilmara cristina alves da costa levy	Aceito
Projeto Detalhado / Brochura Investigador	ProjetodepesquisacomLena.docx	28/08/2017 10:04:37	cilmara cristina alves da costa levy	Aceito
Declaração de Instituição e Infraestrutura	Of_ACPC_1912017.pdf	31/07/2017 11:25:33	Edgar Vieira Rodrigues	Aceito
Declaração de Instituição e	Digitalizacaoautorizacao.pdf	22/07/2017 18:46:20	cilmara cristina alves da costa levy	Aceito

Endereço: SANTA ISABEL
Bairro: VILA BUARQUE **CEP:** 01.221-010
UF: SP **Município:** SAO PAULO
Telefone: (11)2176-7689 **Fax:** (11)2176-7686 **E-mail:** cepsc@santacasasp.org.br

Infraestrutura	Digitalizacaoautorizacao.pdf	22/07/2017 18:46:20	cilmara cristina alves da costa levy	Aceito
Declaração de Pesquisadores	Digitalizacaocompromisso.pdf	22/07/2017 18:45:33	cilmara cristina alves da costa levy	Aceito
Folha de Rosto	Digitalizacaofolhaderostoassinada.pdf	22/07/2017 18:44:13	cilmara cristina alves da costa levy	Aceito
Cronograma	Cronograma.docx	14/07/2017 21:15:50	cilmara cristina alves da costa levy	Aceito
Orçamento	orcamento.pdf	14/07/2017 21:03:36	cilmara cristina alves da costa levy	Aceito
Declaração de Instituição e Infraestrutura	autorizacaodepartamento.pdf	14/07/2017 21:02:53	cilmara cristina alves da costa levy	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

SAO PAULO, 11 de Setembro de 2017

Assinado por:
Pollyana Oliveira Lira
(Coordenador)

Endereço: SANTA ISABEL
Bairro: VILA BUARQUE CEP: 01.221-010
UF: SP Município: SAO PAULO
Telefone: (11)2176-7689 Fax: (11)2176-7688 E-mail: cepsc@santacasasp.org.br

Appendix III - Term of Consent to parents/caregivers

UiO : Universitetet i Oslo   SANTA CASA de São Paulo   LENA™ Every Word Counts

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

Eu Miriam da Silva Ferreira, portadora do RG 13054652-2, graduanda do programa de Mestrado em Educação Especial da Universidade de Oslo, sob orientação da Prof. Dra. Ulrika Löfkvist, professora adjunta do programa de pós-graducação em Educação Especial da Universidade de Oslo, e Prof. Dra. Cilmara Cristina Alves Costa Levy, portadora do RG 15549522-7, coordenadora do Curso de Especialização *Lato Sensu* em Audiologia da FCMSCSP, venho convida-lo para participar da minha pesquisa intitulada Análise do ambiente linguístico de crianças brasileiras com deficiência auditiva.

O objetivo da pesquisa é analisar o ambiente auditivo e linguístico de crianças de 18 a 30 meses de idade com deficiência auditiva em comparação com o ambiente de linguagem dos controles de crianças com audição normal, combinados em idade no contexto brasileiro. Para alcançar esse objetivo, o sistema LENA™ será usado para coletar, analisar e classificar os dados com base em três variáveis: (1) **vocalizações infantis**, (2) **palavras de adultos** e (3) **turnos conversacionais**.

O sistema automático LENA™ é um programa de computador desenvolvido para medir e analisar as gravações do idioma utilizado no ambiente doméstico de crianças entre 0-4 anos. Será realizado gravações durante um dia inteiro (cerca de 12 horas) feitas com a metodologia LENA™.

Os pais receberão gratuitamente os coletes contendo um mini-gravador-PLD (**processador de linguagem digital)** que irá identificar e medir o ambiente de audição durante o dia de acordo com a porcentagem de silêncio, sons eletrônicos (TV, IPad), fala significativa (conversas a distância próxima à criança chave) e distante (conversas à distância ou sobreposição da fala) e, as devidas orientações de manuseio.

Os documentos não serão utilizados para qualquer outro fim senão o proposto por essa pesquisa, sendo que somente a pesquisadora do trabalho terá acesso às respostas, preservando desta forma a identidade do participante.

O participante não terá despesa, remuneração ou ajuda financeira referente à sua participação e o mesmo tem a liberdade de, em qualquer momento, retirar seu consentimento e deixar de participar da pesquisa sem nenhum prejuízo no atendimento realizado na Instituição.

A pesquisadora acima citada pode ser encontrada no Setor de Fonoaudiologia da Irmandade de misericórdia da Santa Casa de São Paulo, situado a Rua Jaguaibe,355, Vila Buarque/SP, CEP: 01221-020, Telefone 11 217675939 ou 11 999884927. Podendo esclarecer dúvidas no Comitê de Ética em Pesquisa da Irmandade da Santa Casa de Misericórdia de São Paulo, situado a Rua Santa Isabel, 305, 4° andar, Santa Cecilia/SP, CEP: 01221-010, Telefone (11) 2176-7689.

Eu, ____,portador do RG número ____________________, declaro que fui devidamente informado (a) sobre os procedimentos que deverei realizar e autorizo a utilização dos materiais contendo meus dados para a realização deste estudo.

São Paulo, ______de ________________de 20___.

________________________   ________________________

Assinatura do Participante   Assinatura do Pesquisador

Appendix IV - Developmental Snapshot checklist

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"Palavras fazem a diferença" - questionário para os pais

Nome da criança: ______________________________ **Número do DLP:** __________

Data de Nascimento: __/__/__ **Gênero:** Masculino (__) Feminino (__) Data do implante: __/__/__

1. Quando você conversa com seu filho (a), ele (a) procura primeiro por um contato visual e depois pela sua voz? *Ex. Você toca no seu (a) filho (a) para que ele (a) olhe para você?*	Sim Ainda não ☐ ☐
2. Quando você ri para seu (a) filho (a) ou o chama em voz alta, ele (a) normalmente responde ao seu chamado?	Sim Ainda não ☐ ☐
3. O (a) seu (a) filho (a) se comporta de maneiras diferentes dependendo do que ele (a) quer? *Ex.: O seu (a) filho (a) faz sons diferentes quando está com fome ou casado (a)?*	Sim Ainda não ☐ ☐
4. O (a) seu (a) filho (a) demonstra estar satisfeito ou insatisfeito com sons que não seja grito ou riso? *Ex. O seu fillho (a) pode fazer sons que demonstrem satisfação ou frustração?*	Sim Ainda não ☐ ☐
5. O (a) seu (a) filho (a) costuma colocar brinquedos ou outros objetos na boca?	Sim Ainda não ☐ ☐
6. O (a) seu (a) filho (a) costuma rir?	Sim Ainda não ☐ ☐
7. O (a) seu (a) filho (a) costuma brincar com sua voz fazendo sons diferentes? *Ex.:* O (a) seu (a) filho (a) *produz sons leves (sons de alta frequência), sons baixos/surdos e estala os lábios como se estivesse mandando um beijo?*	Sim Ainda não ☐ ☐
8. O (a) seu (a) filho (a) fala mais de duas vogais, ex. /a/ ou /e/?	Sim Ainda não ☐ ☐
9. O (a) seu (a) filho (a) reconhece o próprio nome ou apelido? *Ex.: Quando você fala o nome do* seu (a) filho (a), *ele (a) as vezes para o que está fazendo para te olhar?*	Sim Ainda não ☐ ☐
10. O (a) seu (a) filho (a) produz sons/fala ou grita para chamar sua atenção?	Sim Ainda não

	☐ ☐
11. O (a) seu (a) filho (a) pode imitar os sons que você ou outra pessoa produz?	Sim Ainda não ☐ ☐
12. O (a) seu (a) filho (a) pode falar sílabas como 'bababa' ou 'dadada'?	Sim Ainda não ☐ ☐
13. Quando você diz para o (a) seu (a) filho (a) coisas como 'você quer colo' ou 'oi', ele (a) levanta os braços ou da tchauzinho?	Sim Ainda não ☐ ☐
14. O (a) seu (a) filho (a) consegue combinar sons diferentes quando está balbuciando? *Ex.: ele (a) fala 'ba-da-ba', 'pa-ta-be', variando os sons das consoantes e das vogais?*	Sim Ainda não ☐ ☐
15. O (a) seu (a) filho (a) usa a voz e gesticula para comunicar o que ele quer? Ex.: O (a) seu (a) filho (a) *toca ou se move em direção ao objeto desejado enquanto* **usando a voz**?	Sim Ainda não ☐ ☐
16. O (a) seu (a) filho (a) fala outras palavras além de "mamãe", "papai"? Ex.: O (a) seu (a) filho (a) *fala 'aua' ou 'aga' tentando dizer 'água'.*	Sim Ainda não ☐ ☐
17. Se você perguntar o (a) seu (a) filho (a) por um objeto, ele (a) consegue entender o que você quer? Ex.: O (a) seu (a) filho (a) *entende quando você pergunta 'cadê a bola' ou pede 'me dá seu sapato'?*	Sim Ainda não ☐ ☐
18. O (a) seu (a) filho (a) entende um pedido simples? *Ex.: Como quando você diz 'pegue os seus sapatos'.*	Sim Ainda não ☐ ☐
19. O (a) seu (a) filho (a) aponta para o objeto correto quando você pergunta 'cadê a bola' ou 'você viu o caminhão' ou faz perguntas parecidas?	Sim Ainda não ☐ ☐
20. Você consegue perceber na intonação da voz do (a) seu (a) filho (a) quando ele (a) faz uma pergunta?	Sim Ainda não ☐ ☐
21. O (a) seu (a) filho (a) sabe apontar para as partes do corpo quando solicitado (a)? *Ex.: Ele (a) sabe apontar para os olhos, nariz, dedos, cabelo, etc.*	Sim Ainda não ☐ ☐
22. O (a) seu (a) filho (a) sabe dizer pelo menos 10 palavras que você consegue entender?	Sim Ainda não

Ex.: A pronúncia não precisa ser perfeita. Se seu filho (a) sempre fala 'ca' para se referir a palavra 'casa', 'ca' é considerado uma palavra.	☐ ☐
23. O (a) seu (a) filho (a) aponta para objetos na página de um livro enquanto você lê a história? *Ex.: Quando você lê um livro junto com seu filho (a) e pergunta 'onde está o gato', o seu filho (a) consegue apontar para a foto do gato?*	Sim Ainda não ☐ ☐
24. O (a) seu (a) filho (a) costuma imitar palavras que ele escutou em uma conversa?	Sim Ainda não ☐ ☐
25. O (a) seu (a) filho (a) consegue seguir instruções complexas? *Ex.: 'Pegue os seus sapatos e coloque-os na mesa' ou 'pegue seu casaco e entregue-o para a vovó'.*	Sim Ainda não ☐ ☐
26. O seu filho (a) entende pelo menos 4 verbos mesmo se você não gesticular ao mesmo tempo? *Ex. O seu filho (a) entende palavras como 'pula', 'joga', e 'dorme' mesmo quando você não dá nenhuma indicação do significado destas palavras?*	Sim Ainda não ☐ ☐
27. O seu filho (a) entende perguntas com 'o que', 'quem' e 'onde'?	Sim Ainda não ☐ ☐
28. Você consegue identificar os objetos aos quais seu (a) filho (a) se refere? *Ex.: Ele (a) tenta dizer palavras como 'vidro', 'colher' e 'fralda'.*	Sim Ainda não ☐ ☐
29. Quando você aponta para fotos de pessoas e objetos, seu (a) filho (a) tentar nomear o que ele vê?	Sim Ainda não ☐ ☐
30. O seu (a) filho (a) consegue entender a diferença entre **'dentro', 'fora', 'sobre', 'em cima', 'em baixo'**?	Sim Ainda não ☐ ☐
31. O (a) seu (a) filho (a) consegue formar frases simples com duas palavras? *Ex.: 'dá bola' ou 'senta mamãe'*	Sim Ainda não ☐ ☐
32. Seu (a) filho (a) sabe falar pelo menos 50 palavras?	Sim Ainda não ☐ ☐
33. O (a) seu (a) filho (a) entende a diference entre um/a, uns/umas, o/a?	Sim Ainda não

Ex.: se você apontar para um número de peças do tipo Lego® e disser 'eu quero UMA pecinha', o(a) seu(a) filho(a) consegue entender a tarefa?	☐ ☐
34. O seu filho consegue prestar atenção em instruções sem se distrair? *Ex.: 'Vai no seu quarto, pegue o carrinho e traz ele para mim'*	Sim Ainda não ☐ ☐
35. O (a) seu (a) filho (a) usa as palavras 'eu', 'mim' e 'você'?	Sim Ainda não ☐ ☐
36. Seu (a) filho (a) sabe o nome das cores? *Ex.: seu (a) filho aponta para o objeto vermelho quando você diz 'cadê o vermelho'?*	Sim Ainda não ☐ ☐
37. O (a) seu (a) filho (a) já sabe usar palavras para se referir ao tamanho dos objetos? *Ex.: Ele (a) diz palavras como 'grande' e 'pequeno'?*	Sim Ainda não ☐ ☐
38. Seu (a) filho (a) já fala frases com 4 palavras?	Sim Ainda não ☐ ☐
39. Seu (a) filho (a) já sabe usar palavras para se referir a mais de um objeto do mesmo tipo? Ele (a) sabe usar as palavras no plural? *Ex.: Ele (a) fala 'gatos' quando vê mais de um gato?*	Sim Ainda não ☐ ☐
40. Seu filho (a) sabe dizer o que fazer com objetos diferentes? *Ex.: Isto é uma escova de dentes. O que você faz com ela?*	Sim Ainda não ☐ ☐
41. Seu (a) filho (a) sabe conjugar os verbos? Ex. 'eu pulo' ou 'ela pula'	Sim Ainda não ☐ ☐
42. O (a) seu (a) filho (a) sabe diferenciar entre o/a quando usa os artigos? *Ex.: 'a cama', 'o chapéu', ou 'as bolas'.*	Sim Ainda não ☐ ☐
43. O (a) seu (a) filho (a) sabe identificar o formato de um triângulo, círculo, quadrado e estrela?	Sim Ainda não ☐ ☐
44. O (a) seu (a) filho (a) usa/entende os conceitos 'menos', 'mais' e 'primeiro'?	Sim Ainda não ☐ ☐

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45. O (a) seu (a) filho (a) usa/entende os conceitos como 'longo', 'curto', 'alto', 'baixo'?	Sim Ainda não ☐ ☐
46. O (a) seu (a) filho (a) usa/entende os pronomes, como 'eu', 'você', 'a gente'?	Sim Ainda não ☐ ☐
47. O (a) seu (a) filho (a) usa/entende os verbos no passado? *Ex.: ele (a) usa palavras com 'acabou', 'caiu', etc.*	Sim Ainda não ☐ ☐
48. O (a) seu (a) filho (a) faz espontaneamente frases com mais de 10 palavras?	Sim Ainda não ☐ ☐
49. Seu (a) filho (a) sabe identificar a categoria de objetos? *Ex.: Ele (a) entende quando você diz 'diga 3 frutas' ou ' dê exemplos de 3 animais'?*	Sim Ainda não ☐ ☐
50. Seu (a) filho (a) sabe contar uma história com começo, meio e fim? *Ex.: Você entende a história que ele (a) conta do começo ao fim?*	Sim Ainda não ☐ ☐
51. Se você disser um objeto, o (a) seu (a) filho (a) conhece duas palavras para descrever este objeto? *Ex.: seu (a) filho (a) conhece duas palavras que descrevem uma bicicleta,*	Sim Ainda não ☐ ☐
52. Seu (a) filho (a) pergunta o significado de uma palavra e depois a usa em uma frase?	Sim Ainda não ☐ ☐

Appendix V – Words make difference Parental Questionnaire

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”Palavras fazem a diferença”
Formulário dos pais

Nome da criança: ____

Nome da mãe: ____

Nome do pai: ____

Data de nascimento da criança: ___/___/___   Data do implante: ___/___/___

Gênero da criança: masculino (__) feminino (__)   Data: ___/___/___

	Sim, qual?	**Não**
Seu (a) filho (a) tem algum problema de saúde?		
Se sim, por favor indique a idade da criança quando o problema foi identificado.		

Grau de escolaridade?		
	Mãe	**Pai**
Educação básica		
Ensino fundamental		
Ensino médio ou profissionalizante		
Nível superior		

	Mãe	**Pai**
Em que país você nasceu?		
Se você não nasceu no Brasil, em que idade você veio para o Brasil?		

Que idioma você fala principalmente com seu (a) filho (a)?		
	Mãe	**Pai**
Sozinho (a) com a criança		
Junto com o outro responsável (pai ou mãe)		

Appendix VI – Words make difference - Daily Activities log

UiO : Universitetet i Oslo   SANTA CASA de São Paulo   LENA™ Every Word Counts

”Palavras fazem a diferença”
Relatório de atividades diárias

Nome da criança: ____
Data de Nascimento da criança: ___/___/___   Data de implante: ___/___/___
Data: ___/___/___

Hora	Presentes no ambiente (Ex.: irmãos, pais, etc.)	Atividade contínua, o que acontece?
06:00-07:00		
07:00-08:00		
08:00-09:00		
09:00-10:00		
10:00-11:00		
11:00-12:00		
12:00-13:00		
13:00-14:00		
14:00-15:00		
15:00-16:00		
16:00-17:00		
17:00-18:00		
18:00-19:00		
19:00-20:00		
20:00-21:00		
21:00-22:00		

Appendix VII – Instruction sheet - Recording with LENA^{tm}

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”Palavras fazem a diferença” –

Gravação com o LENA

Durante a gravação: verifique se o equipamento está funcionando adequadamente ao longo do dia. Gravar de 12 à 16 horas, isto é, o dia inteiro.

Assim é o gravador LENA:

Para gravar:

1. Ligue o LENA pressionando o botão **POWER**. Segure o botão por alguns segundos.
2. Esperar até que apareça a palavra **SLEEPING** (dormindo) na tela.

3. Pressione o botão **REC** por 4 segundos até que apareca a palavra **RECORDING (gravando)** na tela. A gravação terá então iniciado.

O colete

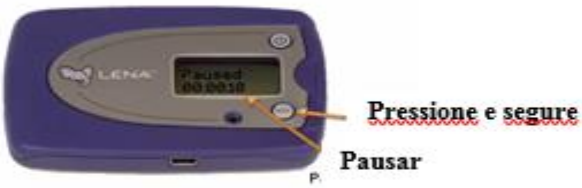
Para gravar com o LENA, você precisará usar um colete para armazenar o gravador. Certifique-se de iniciar a gravação antes de inserir o gravador no colete.

O gravador deve sempre ser inserido no bolso do colete com a figura do elefante de cabeça para cima e o microfone virado para a frente, antes de vestir o colete na criança! O colete deve ser colocado na criança de forma que o gravador fique na altura do seu **peito ou da sua barriga.**

O elefante deve ser inserido primeiro!

Pausa

Pressione **REC** para pausar a gravação. Inicie a gravação apretando **REC** novamente.



Parar a gravação

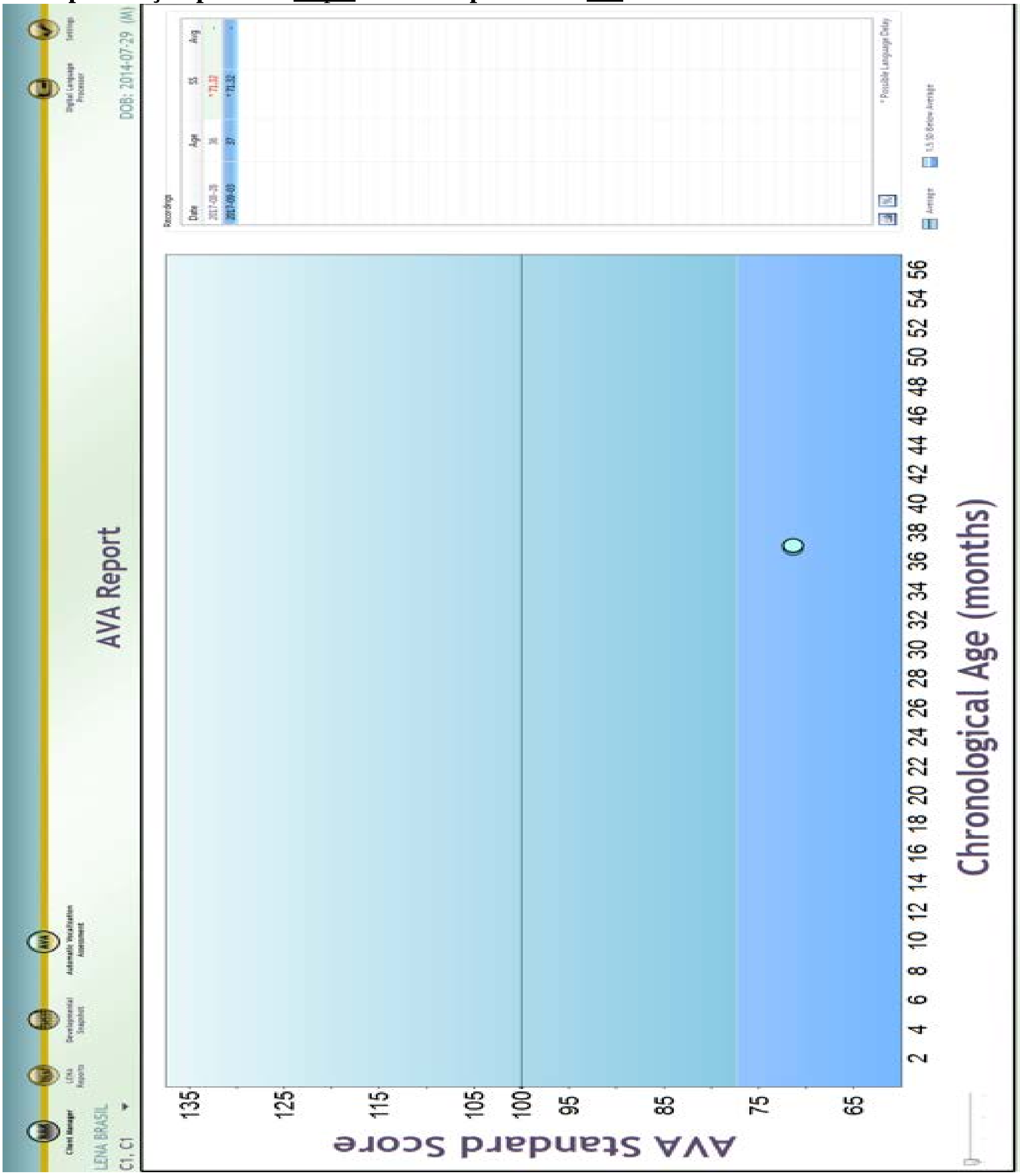
Ao fim do dia, foram registrados de 12 à 16 horas de gravação. Desligue o gravador **pressionando o botão POWER.** Segure o botão por alguns segundos.

Appendix VIII - LENA Composite Review, AVA Report, and Developmental Snapshot by case

Nome da criança: C1 **Gênero:** Masculino
Nome da Mãe: XXX
Data de nascimento: 07/2014 **Idade no dia da gravação:** 37 meses
Data do implante: 11/2016 **Idade auditiva:** 8-9 meses

Relatório da avaliação automática de vocalização

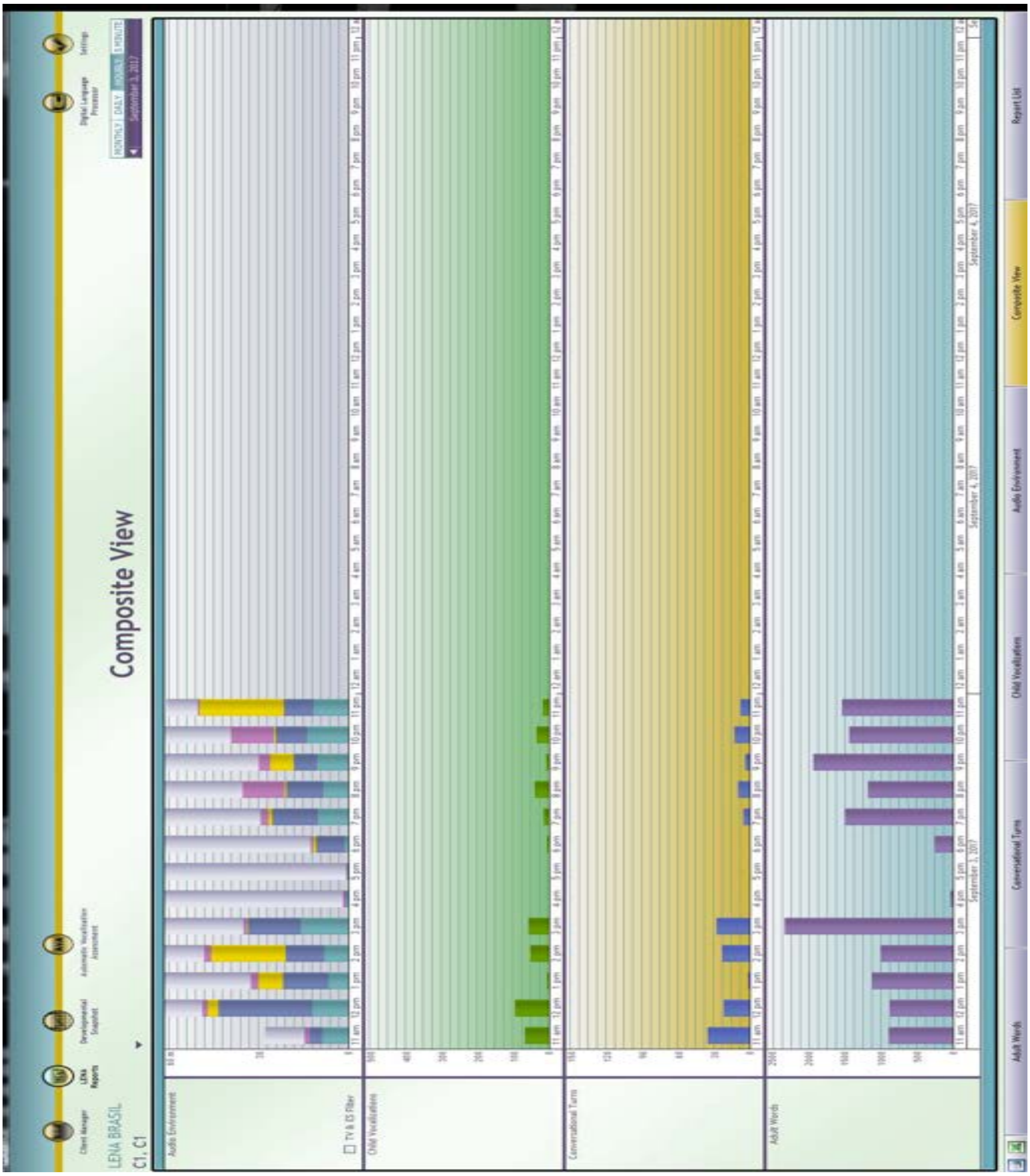
AVA pontuação padrão: 71pts **AVA percentil**: 2%



Nome da criança: C1 **Gênero:** Masculino
Nome da Mãe: XXX
Data de nascimento: 07/2014 **Idade no dia da gravação:** 37 meses
Data do implante: 11/2016 **Idade auditiva:** 8-9 meses

Áreas de avalição

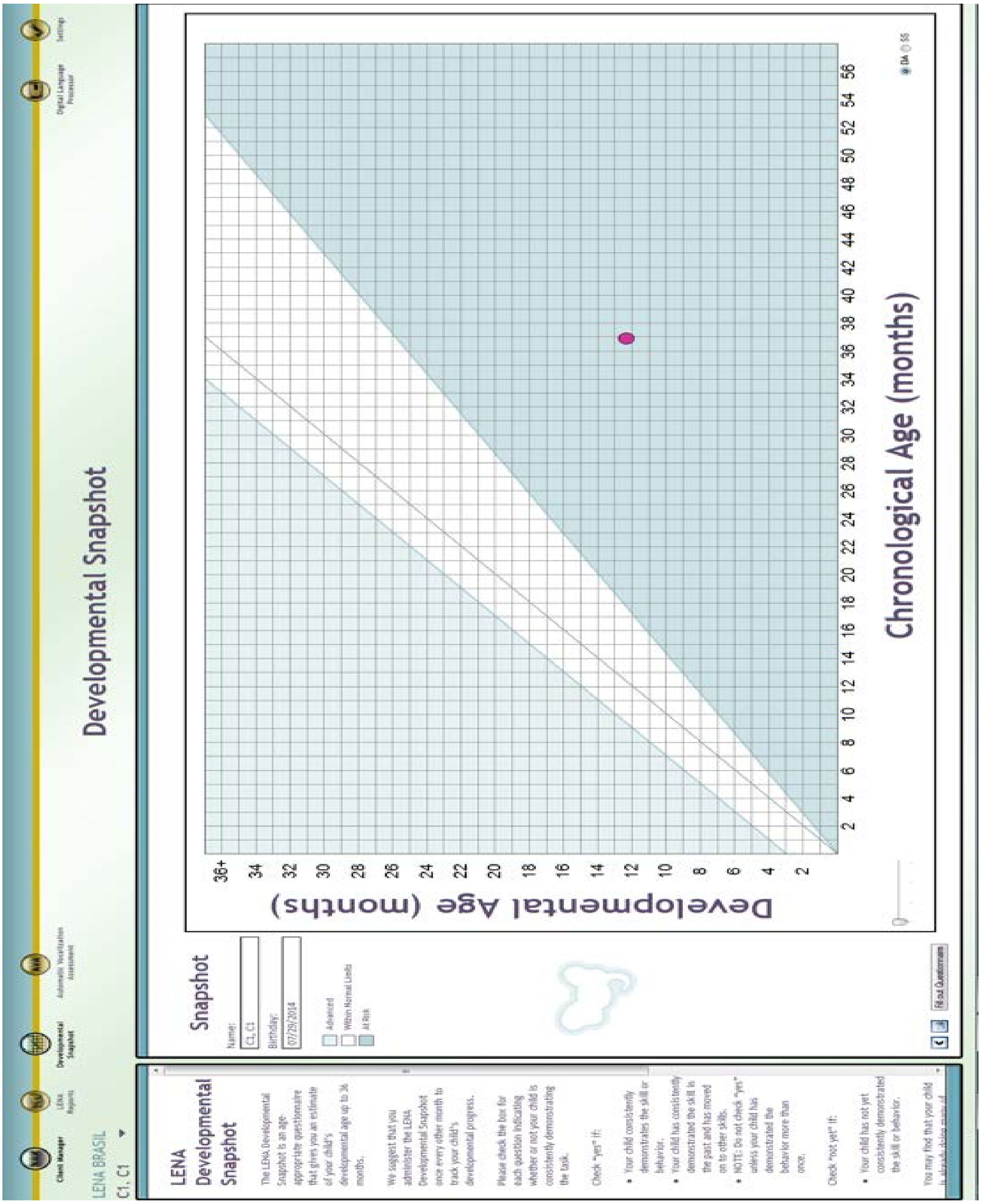
Ambiente sonoro (%)		Tempo total de gravação: 12h27m Vocalizações infantis: 384 Turnos conversacionais:144 Palavras enunciadas por adultos: 13668
Silêncio: 50% Barulho: 7% TV/rádio/eletrônicos: 9%	Fala distante: 20% Fala significativa: 14%	



Nome da criança: C1 **Gênero:** Masculino
Nome da Mãe: XXX
Data de nascimento: 07/2014 **Idade no dia da gravação:** 37 meses
Data do implante: 11/2016 **Idade auditiva:** 8-9 meses

Ponto de desenvolvimento

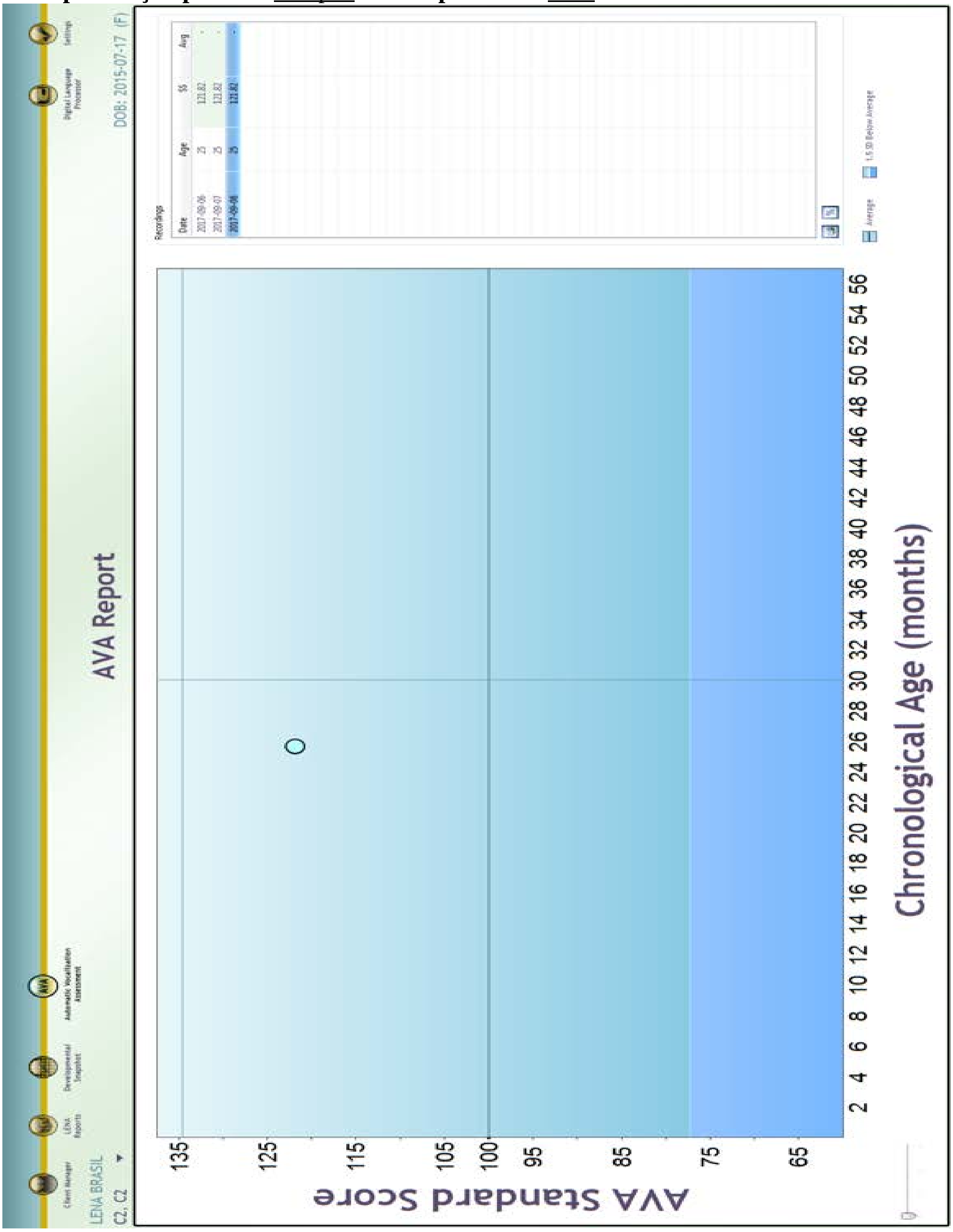
Idade de desenvolvimento: 12 meses – *risco de atraso no desenvolvimento*
DevSnap pontuação padrão: <65 pts **DevSnap percentil:** 1%



Nome da criança: C2 **Gênero:** Feminino
Nome da Mãe: XXX
Data de nascimento: 07/2015 **Idade no dia da gravação:** 25 meses

Relatório da avaliação automática de vocalização

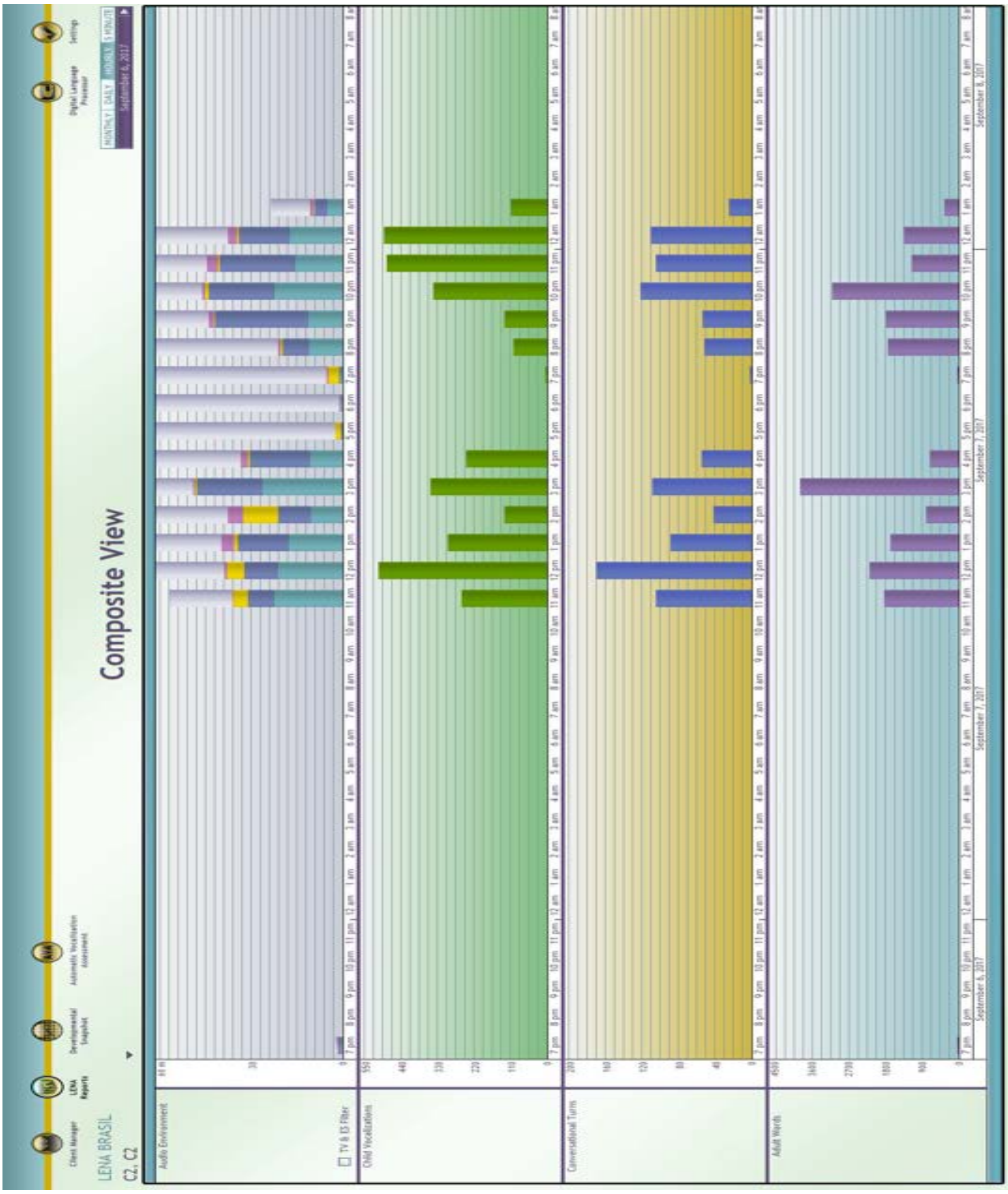
AVA pontuação padrão: 122 pts. **AVA percentil**: 92%



Nome da criança: C2 **Gênero:** Feminino
Nome da Mãe: XXX
Data de nascimento: 07/2015 **Idade no dia da gravação:** 25 meses

Áreas de avalição

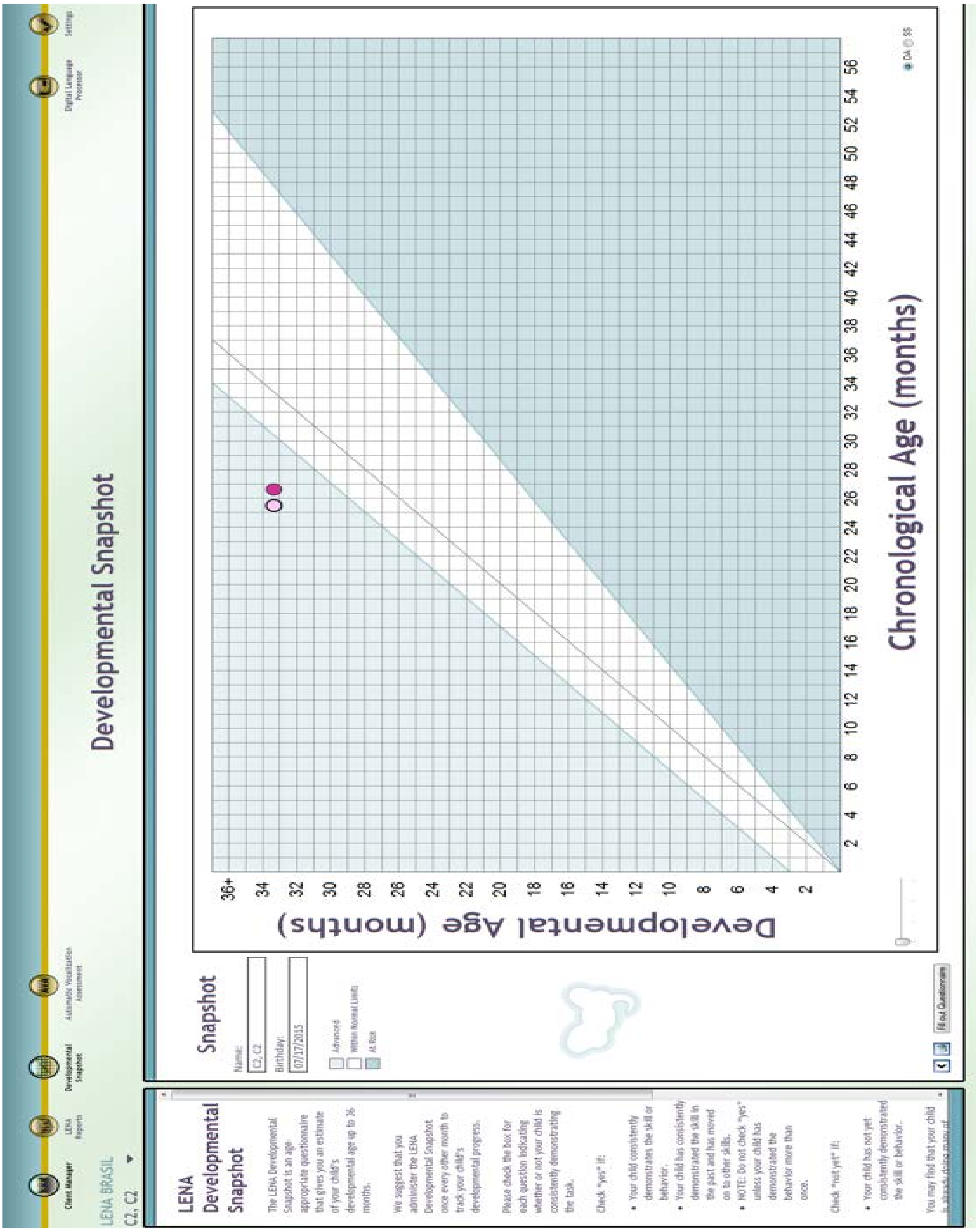
Ambiente sonoro (%)		Tempo total de gravação: 12h 56m
Silêncio: 50% Barulho: 3% TV/rádio/eletrônicos: 4%	Fala distante: 22% Fala significativa: 21%	Vocalizações infantis: 2676 Turnos conversacionais: 840 Palavras enunciadas por adultos: 16608



Nome da criança: C2 **Gênero:** Feminino
Nome da Mãe: XXX
Data de nascimento: 07/2015 **Idade no dia da gravação:** 25 meses

Ponto de desenvolvimento

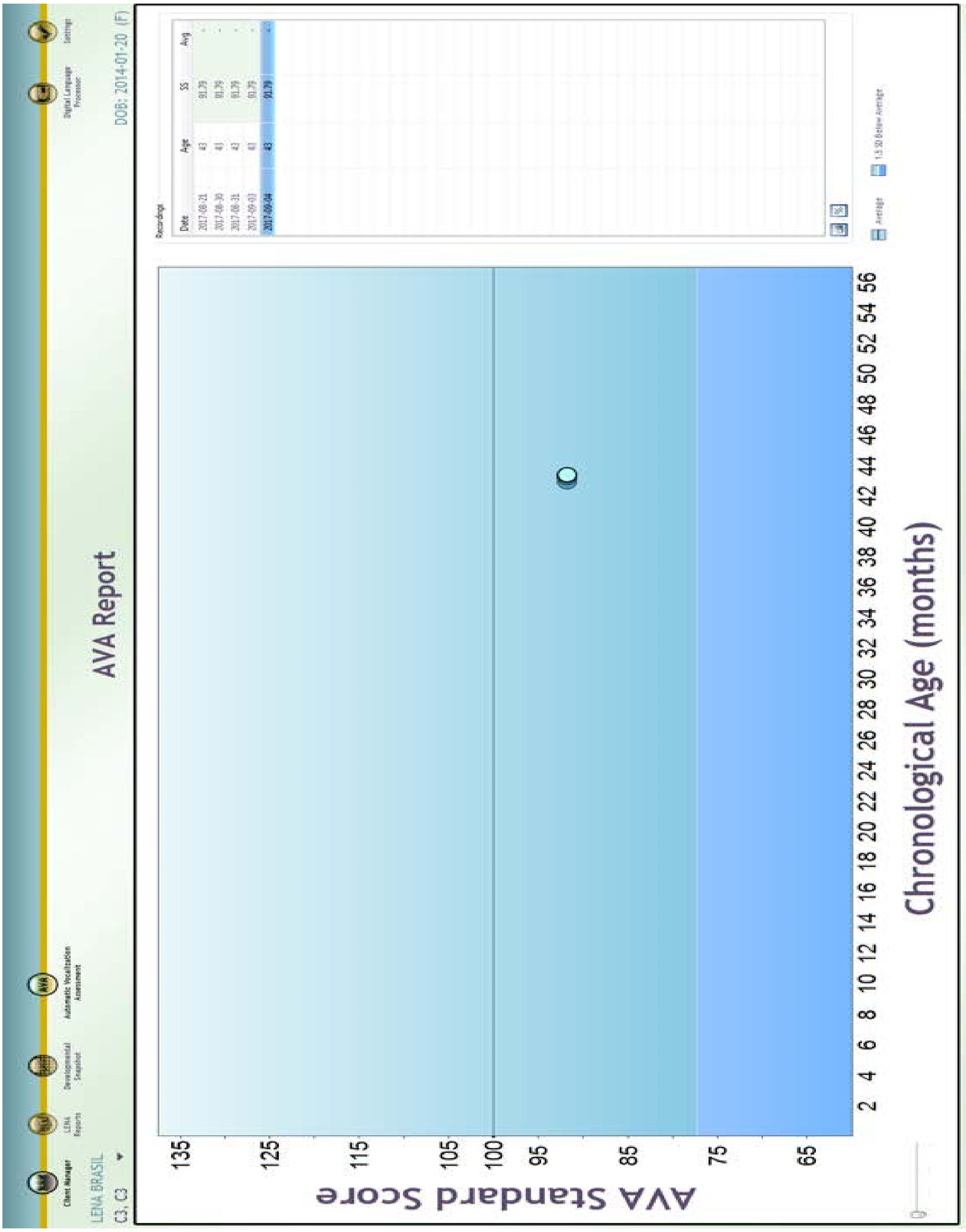
Idade de desenvolvimento: 33 meses – *desenvolvimento avançado*
DevSnap pontuação padrão: 116 pts **DevSnap percentil:** 86%



Nome da criança: C3 **Gênero:** Feminino
Nome da Mãe: XXX
Data de nascimento: 01/2014 **Idade no dia da gravação:** 43 meses
Data do implante: 05/2015 **Idade auditiva:** 27 meses

Relatório da avaliação automática de vocalização

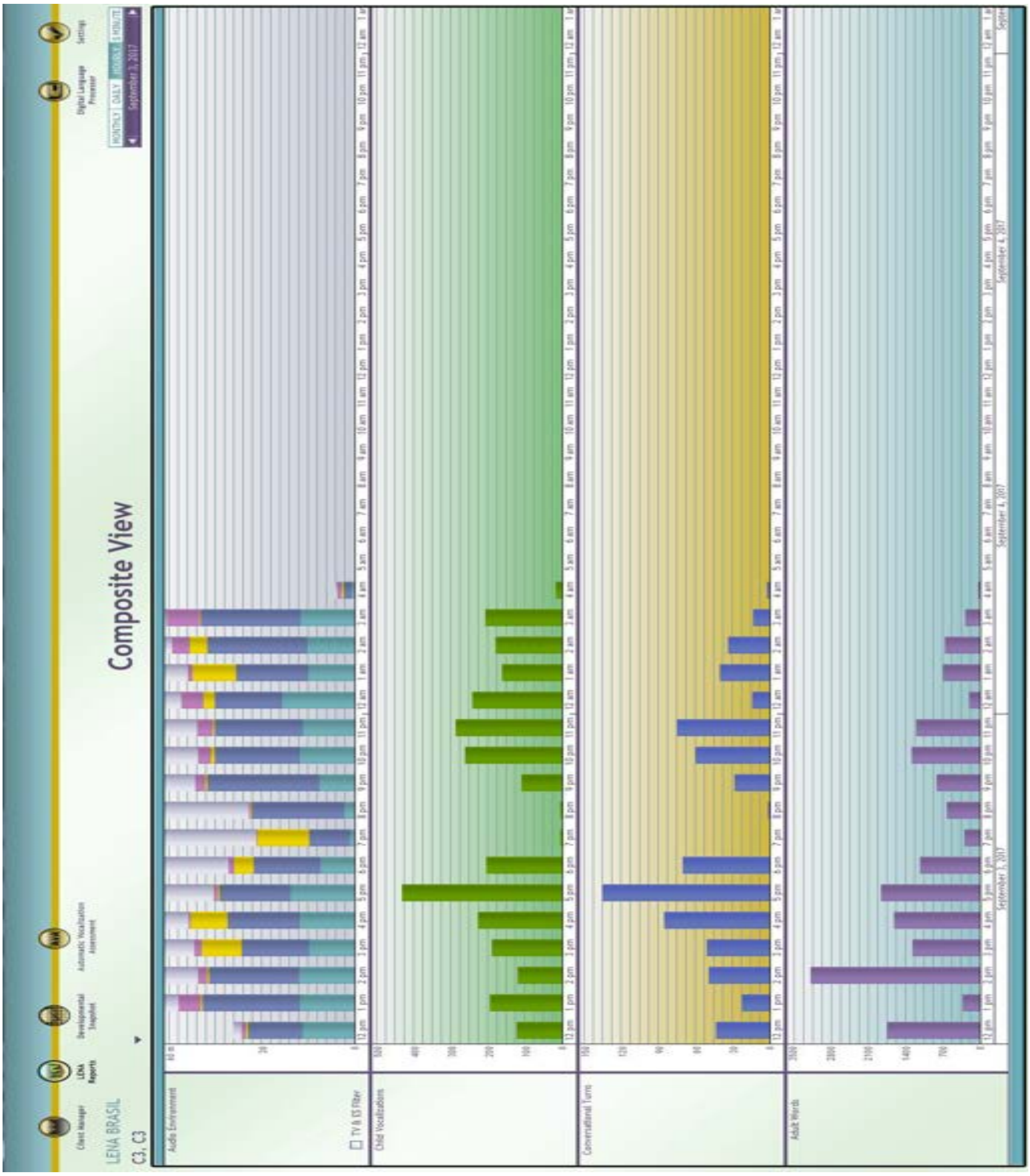
AVA pontuação padrão: 92 pts **AVA percentil**: 29%



Nome da criança: C3 **Gênero:** Feminino
Nome da Mãe: XXX
Data de nascimento: 01/2014 **Idade no dia da gravação:** 43 meses
Data do implante: 05/2015 **Idade auditiva:** 27 meses

Áreas de avalição

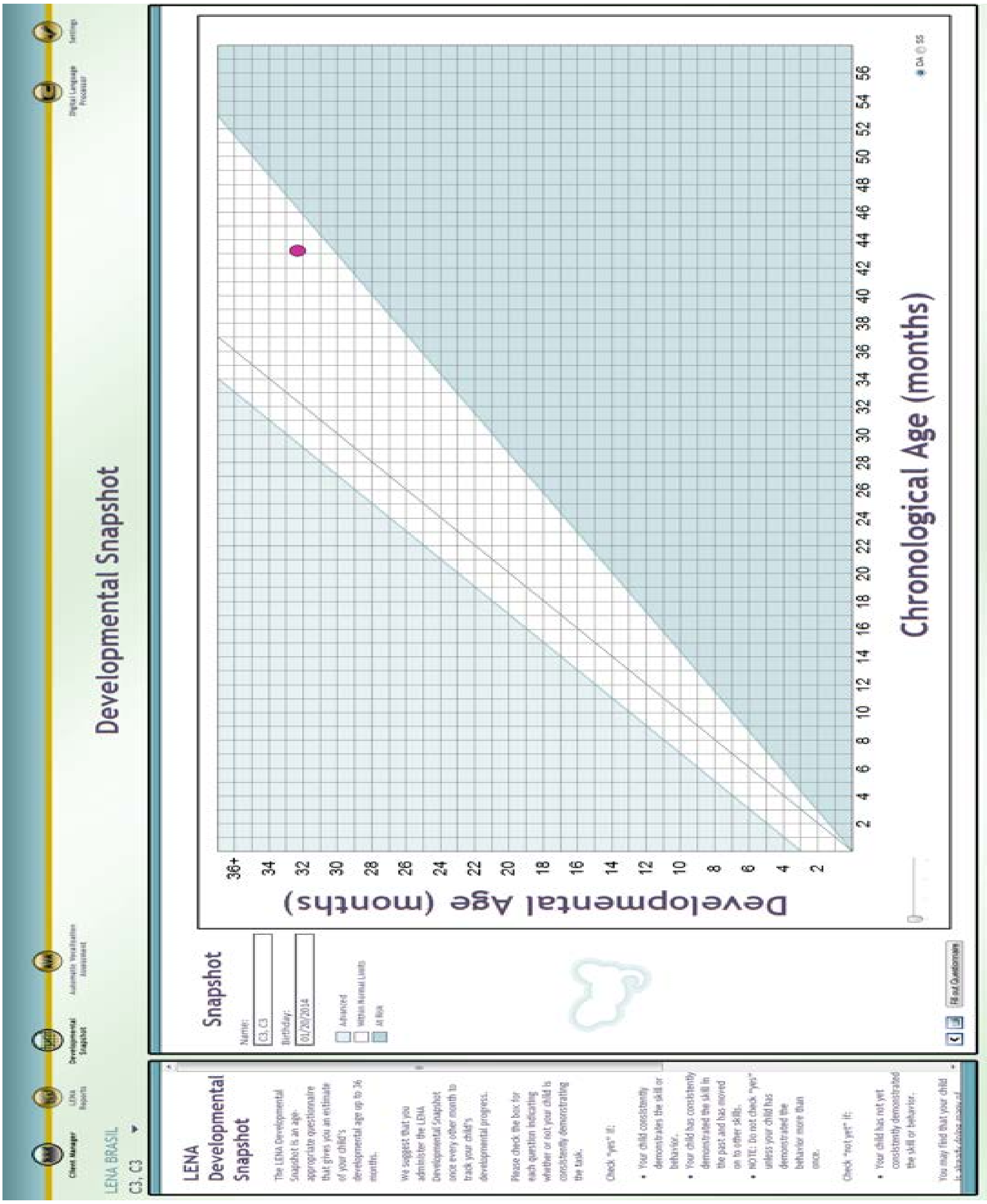
Ambiente sonoro (%)		Tempo total de gravação: 11h 38m Vocalizações infantis: 2244 Turnos conversacionais: 648 Palavras enunciadas por adultos: 15888
Silêncio: 23% Barulho: 4% TV/rádio/eletrônicos: 8%	Fala distante: 41% Fala significativa: 24%	



Nome da criança: C3 **Gênero:** Feminino
Nome da Mãe: XXX
Data de nascimento: 01/2014 **Idade no dia da gravação:** 43 meses
Data do implante: 05/2015 **Idade auditiva:** 27 meses

Ponto de desenvolvimento

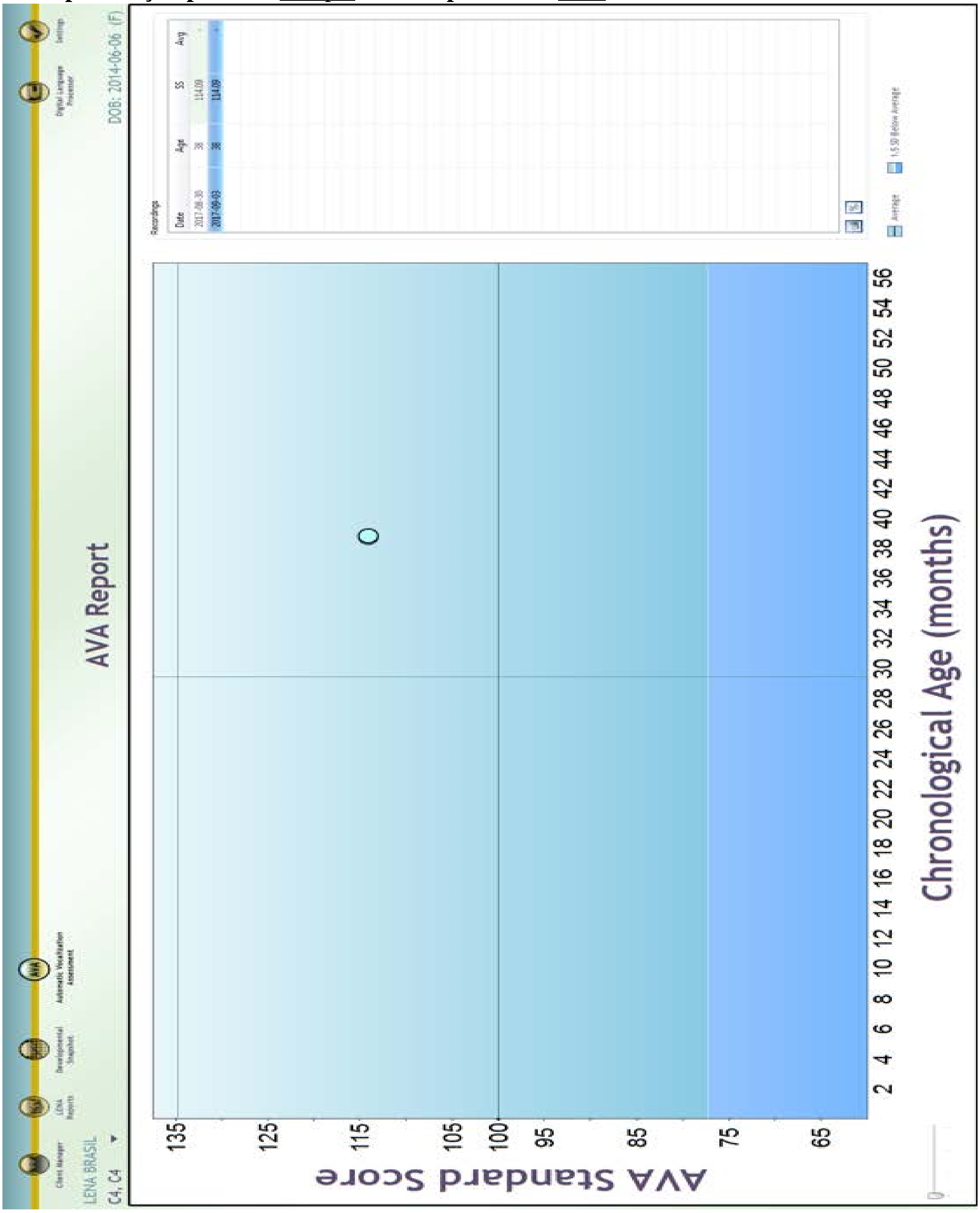
Idade de desenvolvimento: 32 meses – *desenvolvimento dentro do esperado*
DevSnap pontuação padrão: idade > 36 meses **DevSnap percentil:** não calculado



Nome da criança: C4 **Gênero:** Feminino
Nome da Mãe: XXX
Data de nascimento: 06/2014 **Idade no dia da gravação:** 38 meses
Data do implante: ___/___/___ **Idade auditiva:** 34 meses

Relatório da avaliação automática de vocalização

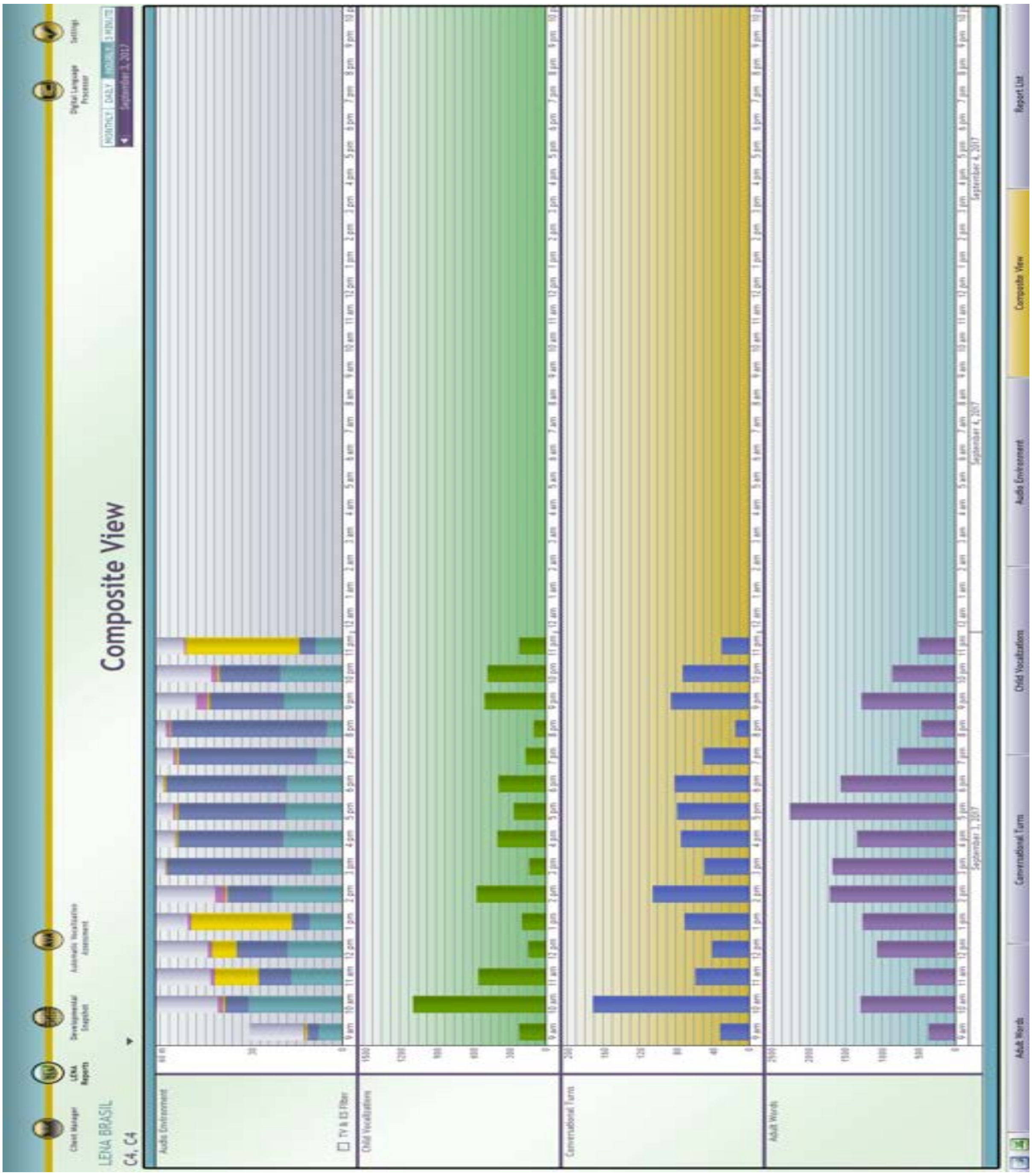
AVA pontuação padrão: 114 pts **AVA percentil**: 82%



Nome da criança: C4 **Gênero:** Feminino
Nome da Mãe: XXX
Data de nascimento: 06/2014 **Idade no dia da gravação:** 38 meses
Data do implante: ___/___/___ **Idade auditiva:** 34 meses

Áreas de avalição

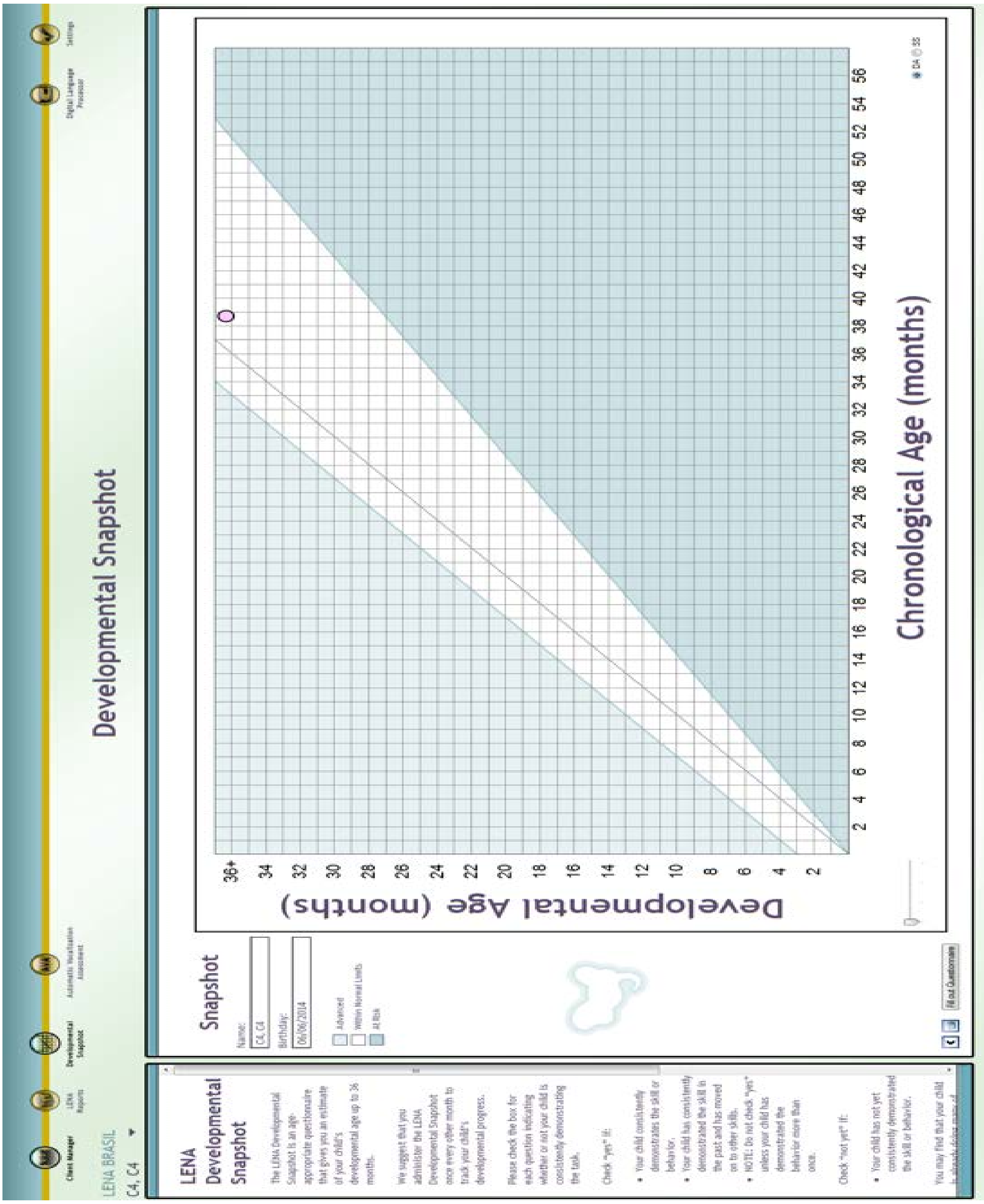
Ambiente sonoro (%)		Tempo total de gravação: 14h 29m Vocalizações infantis: 4565 Turnos conversacionais: 852 Palavras enunciadas por adultos: 14100
Silêncio: 20% Barulho: 2% TV/rádio/eletrônicos: 11%	Fala distante: 40% Fala significativa: 27%	



Nome da criança: C4 **Gênero:** Feminino
Nome da Mãe: XXX
Data de nascimento: 06/2014 **Idade no dia da gravação:** 38 meses
Data do implante: ___/___/___ **Idade auditiva:** 34 meses

Ponto de desenvolvimento

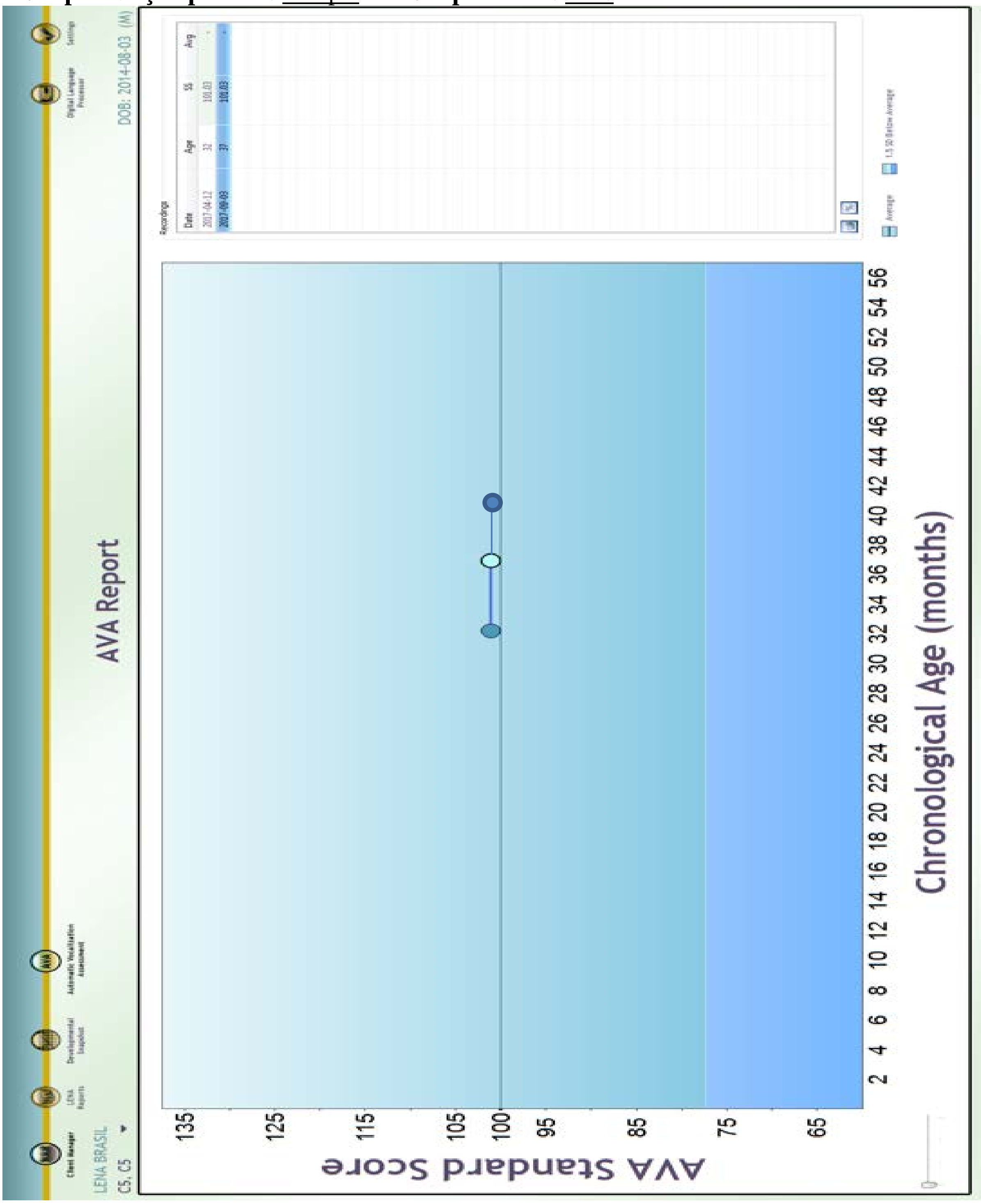
Idade de desenvolvimento: +36 meses – *desenvolvimento dentro do esperado*
DevSnap pontuação padrão: idade > 36 meses **DevSnap percentil:** não calculado



Nome da criança: C5 **Gênero:** Masculino
Nome da Mãe: XXX
Data de nascimento: 08/2014 **Idade no dia da gravação:** 41 meses
Data do implante: ___/___/___ **Idade auditiva:** 23 meses

Relatório da avaliação automática de vocalização

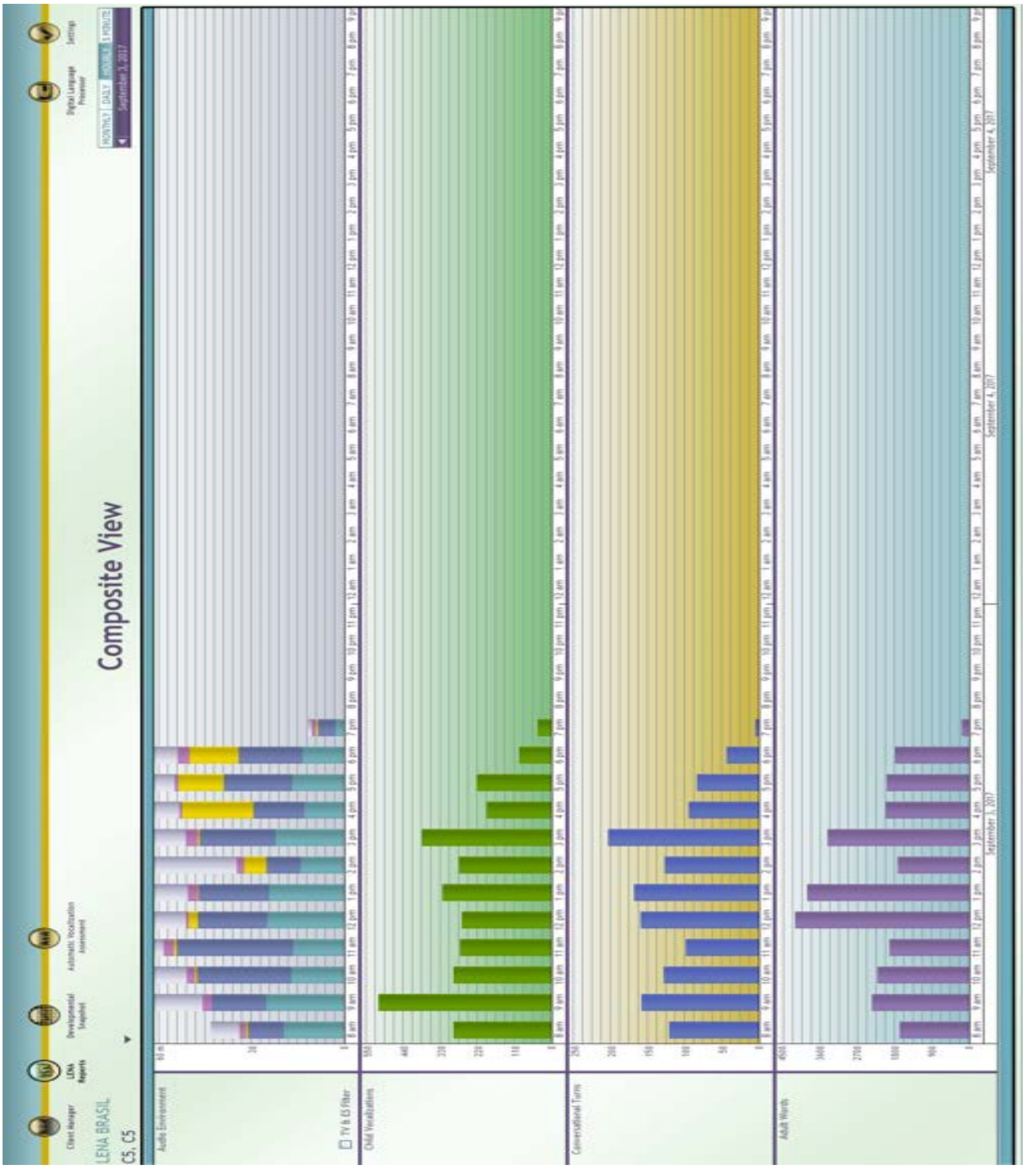
AVA pontuação padrão: 101 pts **AVA percentil**: 52%



Nome da criança: C5 **Gênero:** Masculino
Nome da Mãe: XXX
Data de nascimento: 08/2014 **Idade no dia da gravação:** 41 meses
Data do implante: ___/___/___ **Idade auditiva:** 23 meses

Áreas de avalição

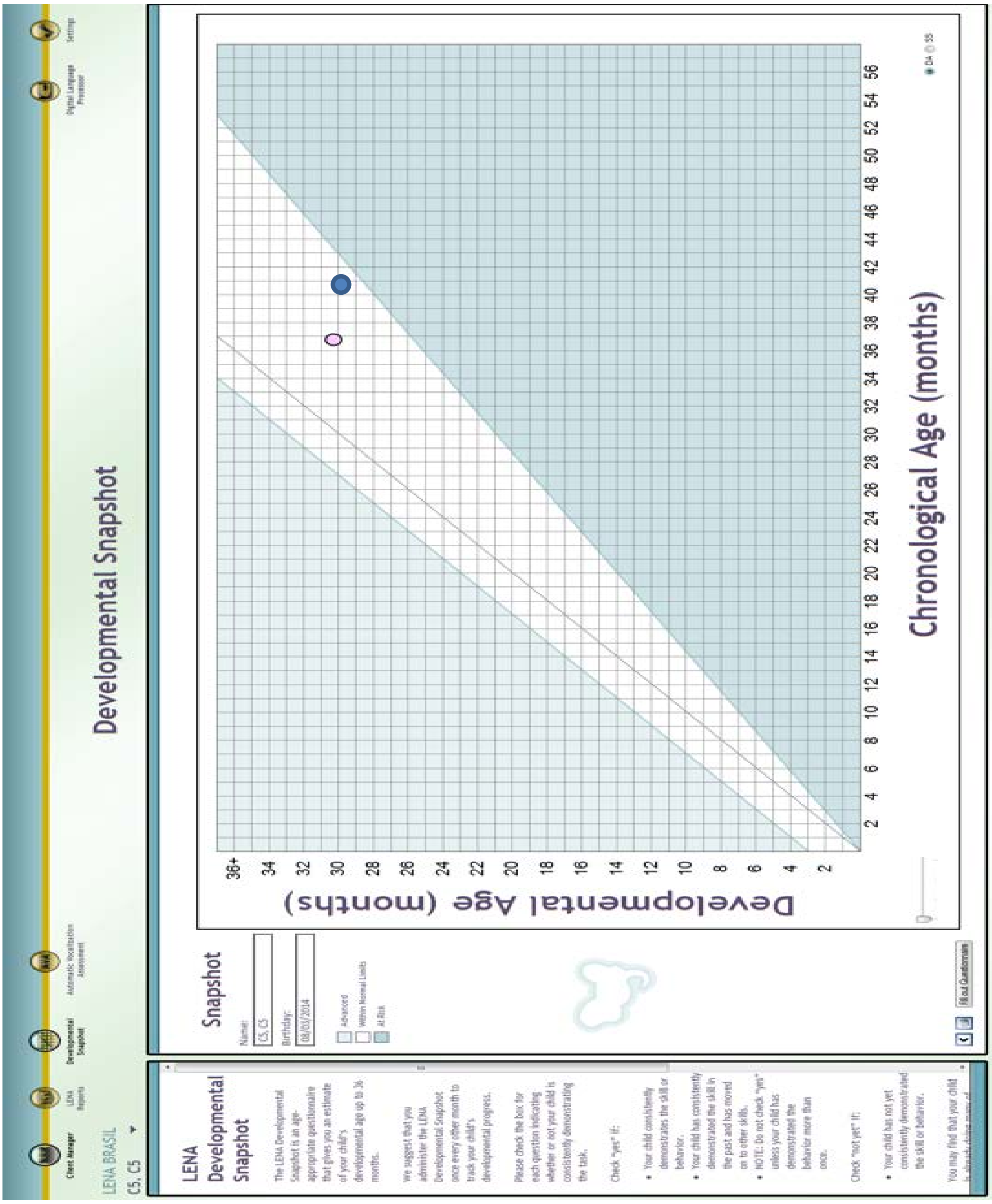
Ambiente sonoro (%)		Tempo total de gravação: 10h 53m
Silêncio: 18% Barulho: 5% TV/rádio/eletrônicos: 10%	Fala distante: 36% Fala significativa: 31%	Vocalizações infantis: 3528 Turnos conversacionais: 1548 Palavras enunciadas por adultos: 30252



Nome da criança: C5 **Gênero:** Masculino
Nome da Mãe: XXX
Data de nascimento: 08/2014 **Idade no dia da gravação:** 41 meses
Data do implante: ___/___/___ **Idade auditiva:** 23 meses s

Ponto de desenvolvimento

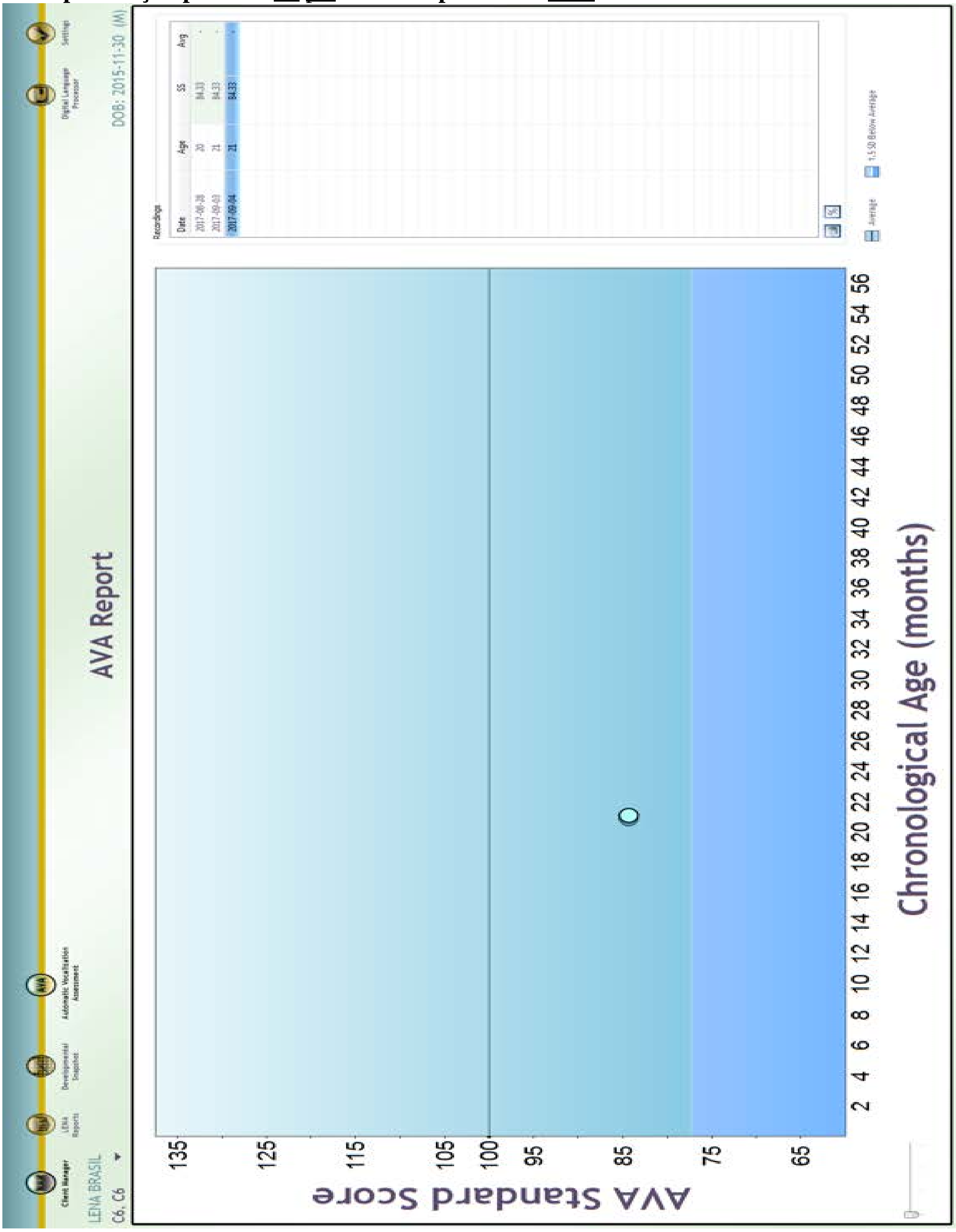
Idade de desenvolvimento: 30 meses
DevSnap pontuação padrão: 87 pts DevSnap percentil: 18%



Nome da criança: C6 **Gênero:** Masculino
Nome da Mãe: XXX
Data de nascimento: 11/2015 **Idade no dia da gravação:** 21 meses

Relatório da avaliação automática de vocalização

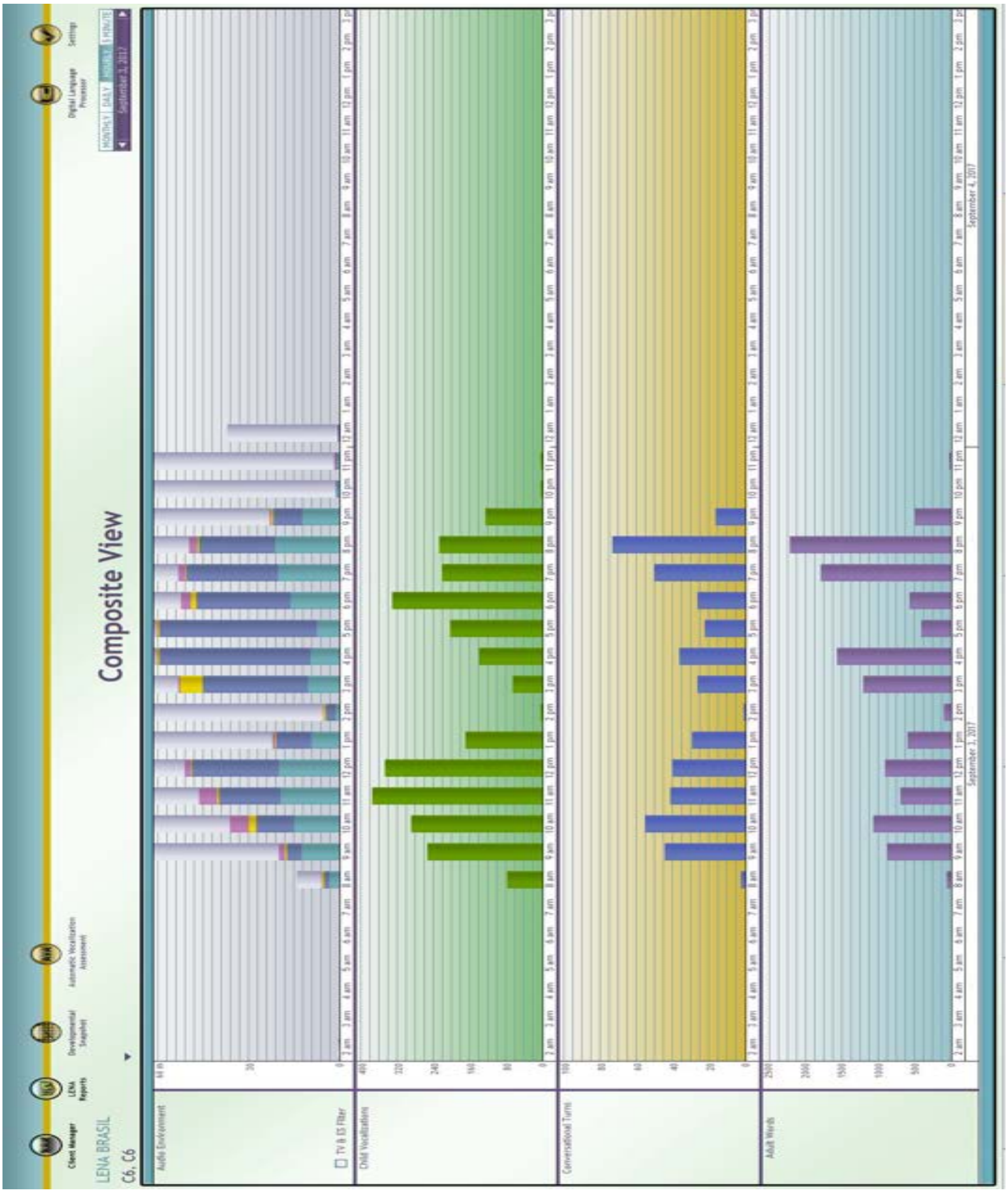
AVA pontuação padrão: 84 pts **AVA percentil**: 14%



Nome da criança: C6 **Gênero:** Masculino
Nome da Mãe: XXX
Data de nascimento: 11/2015 **Idade no dia da gravação:** 21 meses

Áreas de avalição

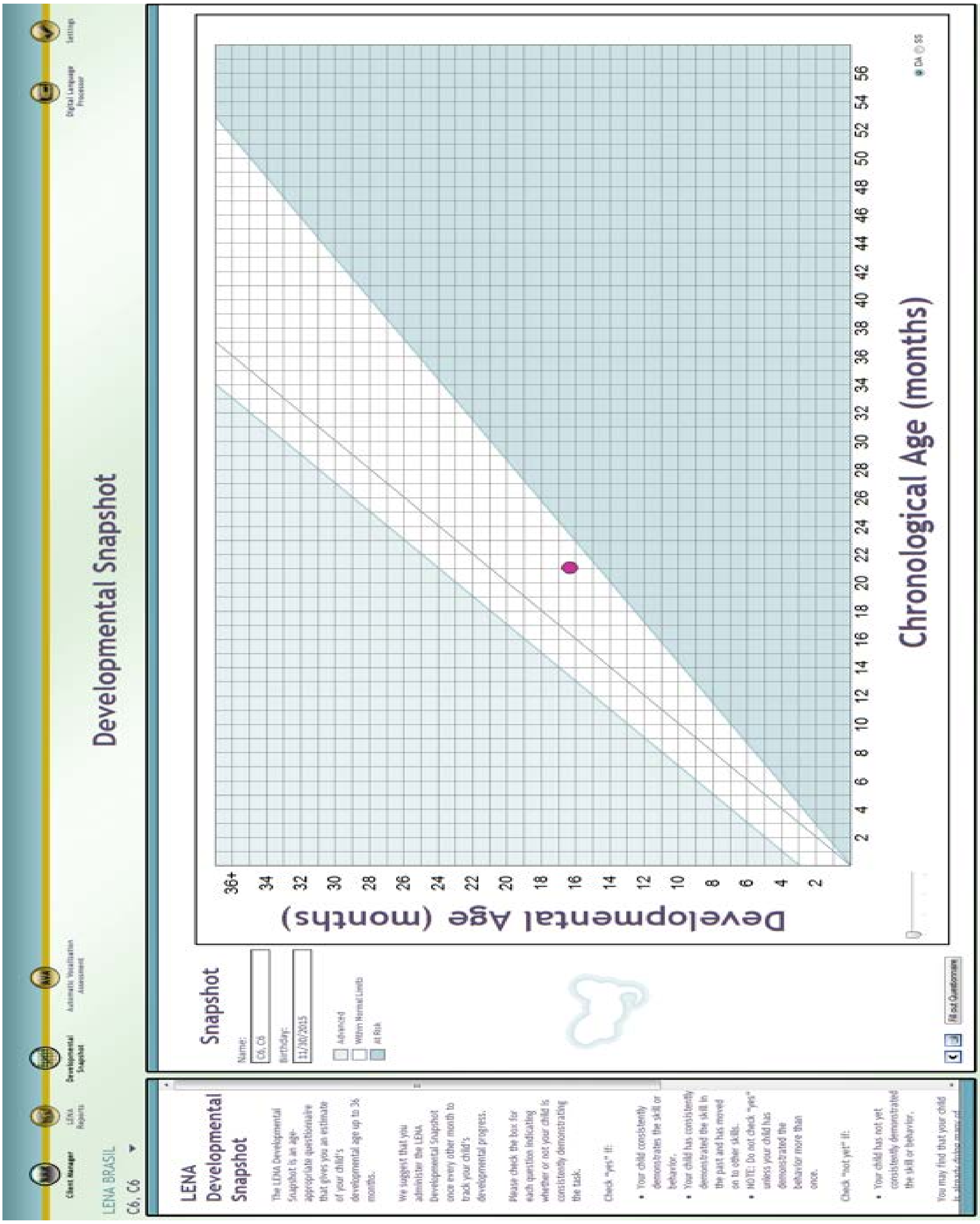
Ambiente sonoro (%)		Tempo total de gravação: 15h 14s Vocalizações infantis: 2256 Turnos conversacionais: 372 Palavras enunciadas por adultos: 1668
Silêncio: 42% Barulho: 4% TV/rádio/eletrônicos: 1%	Fala distante: 34% Fala significativa: 19%	



Nome da criança: C6 **Gênero:** Masculino
Nome da Mãe: XXX
Data de nascimento: 11/2015 **Idade no dia da gravação:** 21 meses

Ponto de desenvolvimento

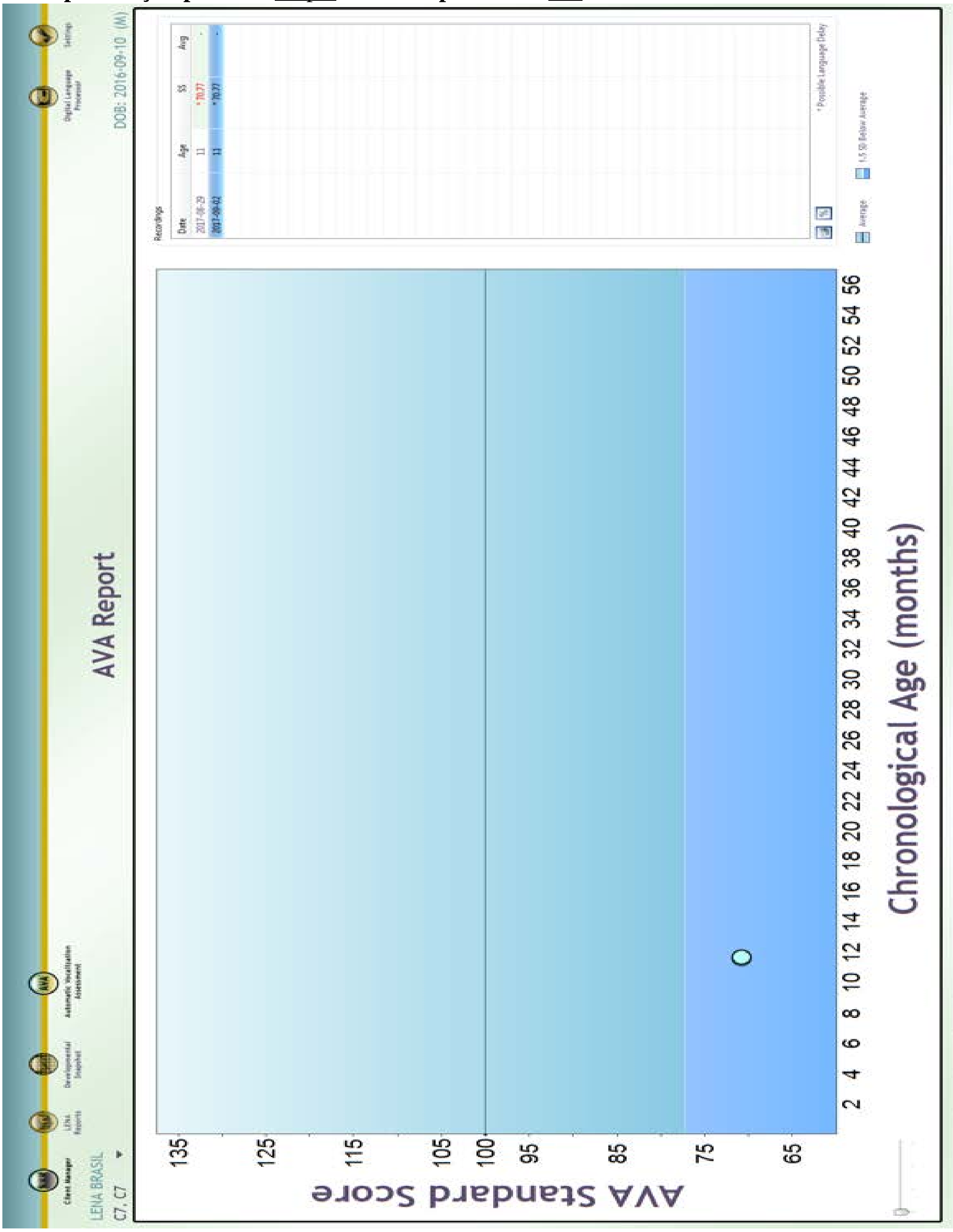
Idade de desenvolvimento: 16 meses - *desenvolvimento dentro do esperado*
DevSnap pontuação padrão: 83 pts **DevSnap percentil:** 12%



Nome da criança: C7 **Gênero:** Masculino
Nome da Mãe: XXX
Data de nascimento: 09/2016 **Idade no dia da gravação:** 11 meses

Relatório da avaliação automática de vocalização

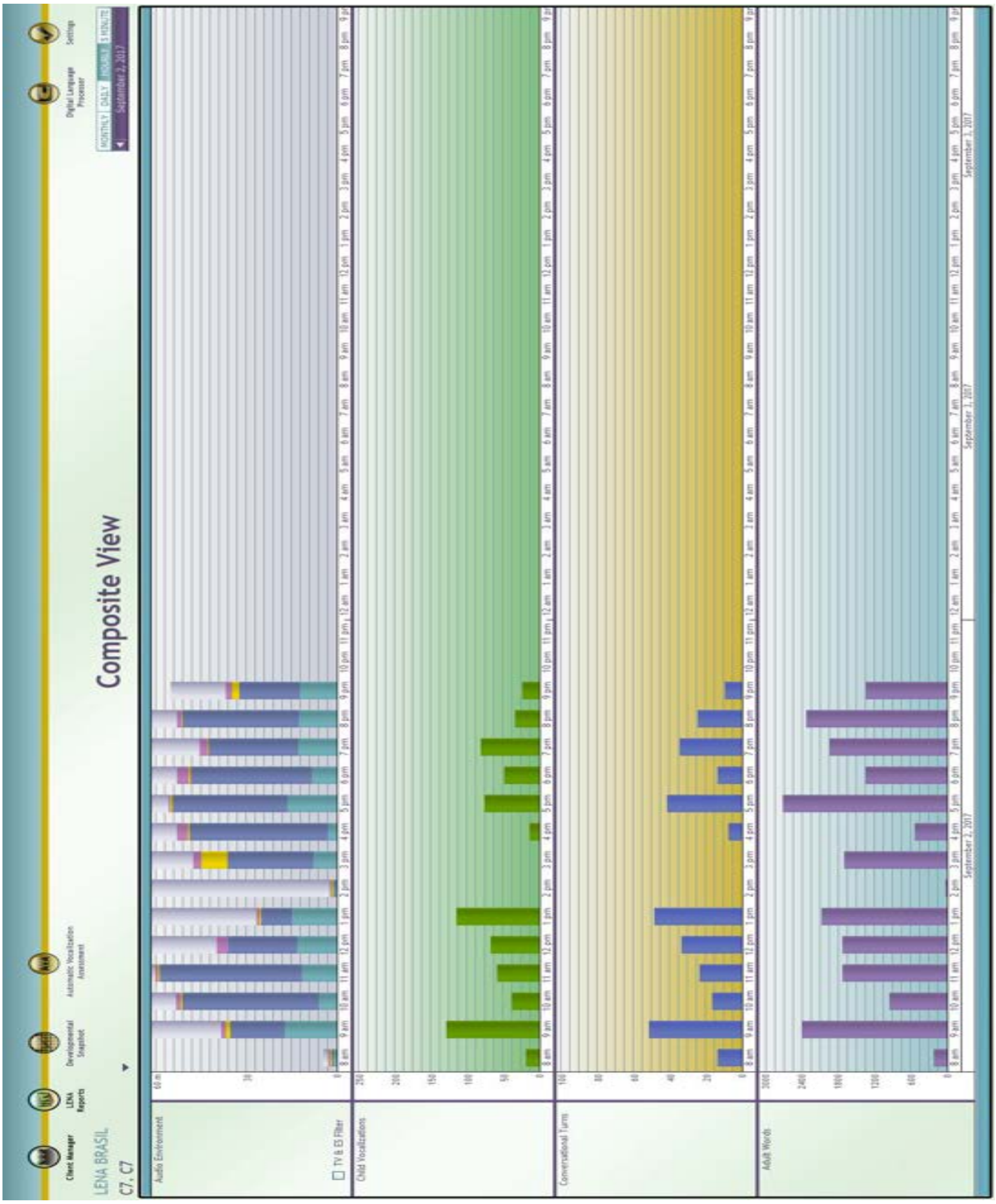
AVA pontuação padrão: 71 pts **AVA percentil**: 2%



Nome da criança: C7 **Gênero:** Masculino
Nome da Mãe: XXX
Data de nascimento: 09/2016 **Idade no dia da gravação:** 11 meses

Áreas de avalição

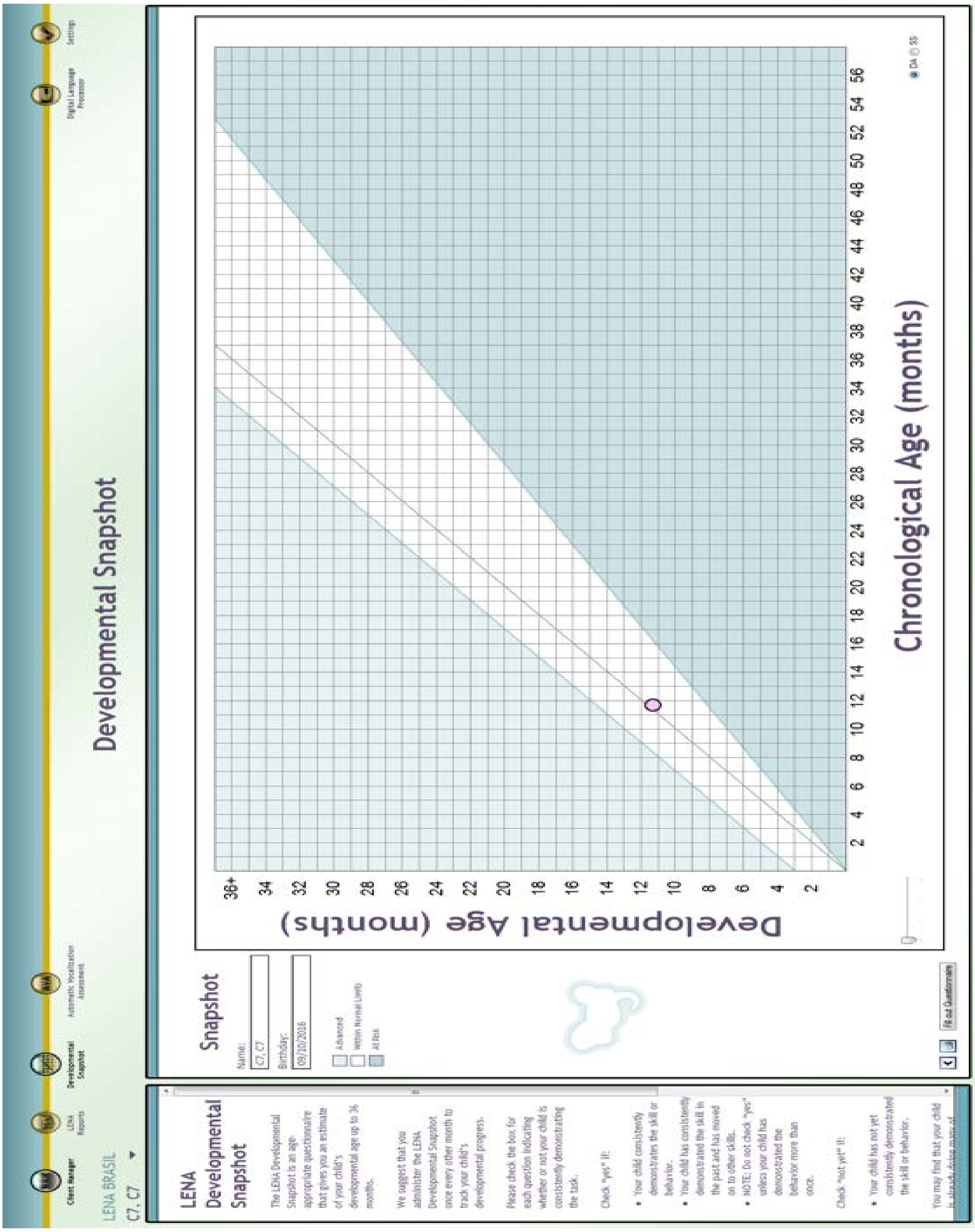
Ambiente sonoro (%)		Tempo total de gravação: 12h 58m
Silêncio: 29% Barulho: 3% TV/rádio/eletrônicos: 2%	Fala distante: 48% Fala significativa: 18%	Vocalizações infantis: 660 Turnos conversacionais: 372 Palavras enunciadas por adultos: 9936



Nome da criança: C7 **Gênero:** Masculino
Nome da Mãe: XXX
Data de nascimento: 09/2016 **Idade no dia da gravação:** 11 meses

Ponto de desenvolvimento

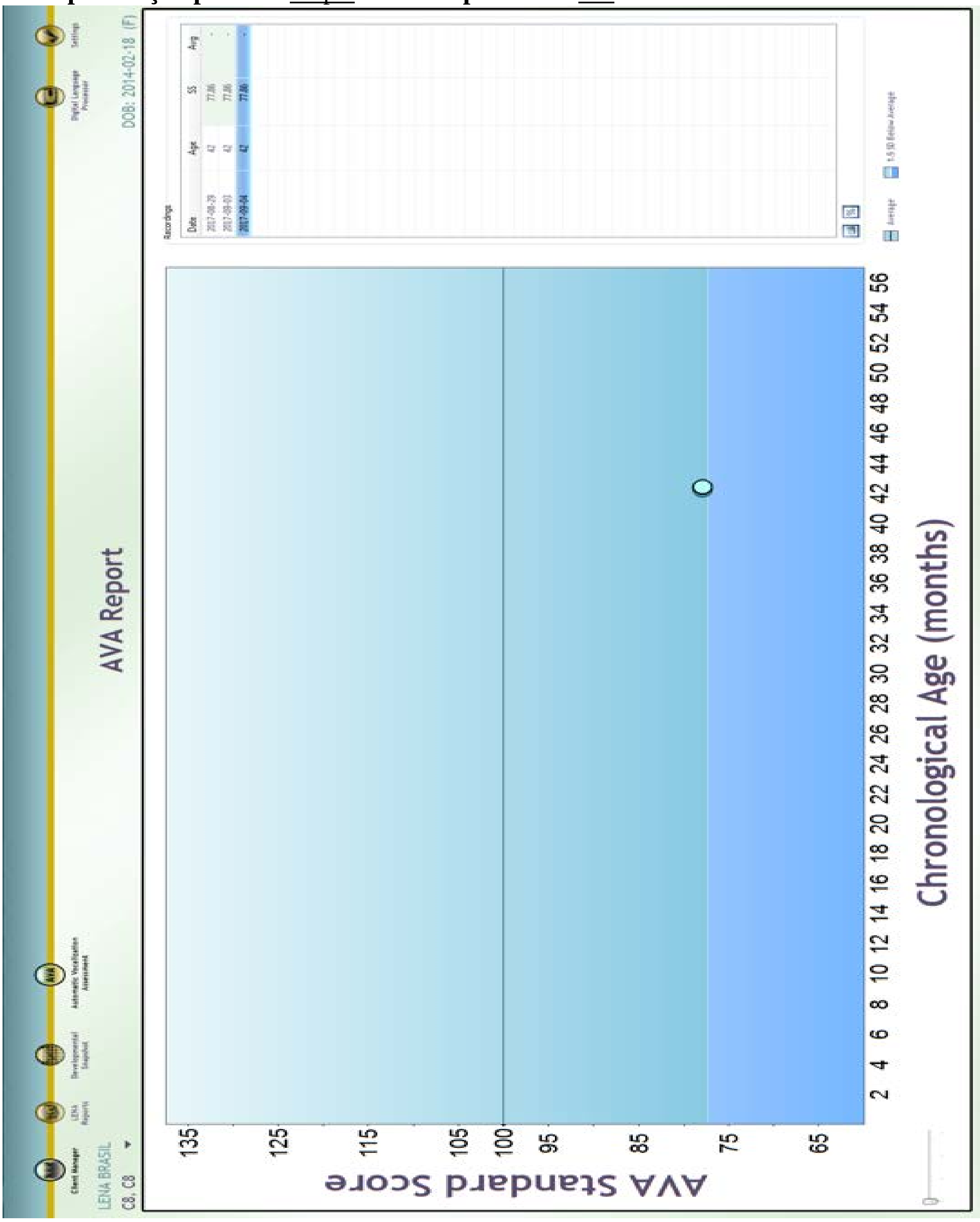
Idade de desenvolvimento: 11 meses - *desenvolvimento dentro do esperado*
DevSnap pontuação padrão: 109 pts **DevSnap percentil:** 73%



Nome da criança: C8 **Gênero:** Feminino
Nome da Mãe: XXX
Data de nascimento: 02/2014 **Idade no dia da gravação:** 42 meses
Data do implante: ___/__/___ **Idade auditiva:** 12 meses

Relatório da avaliação automática de vocalização

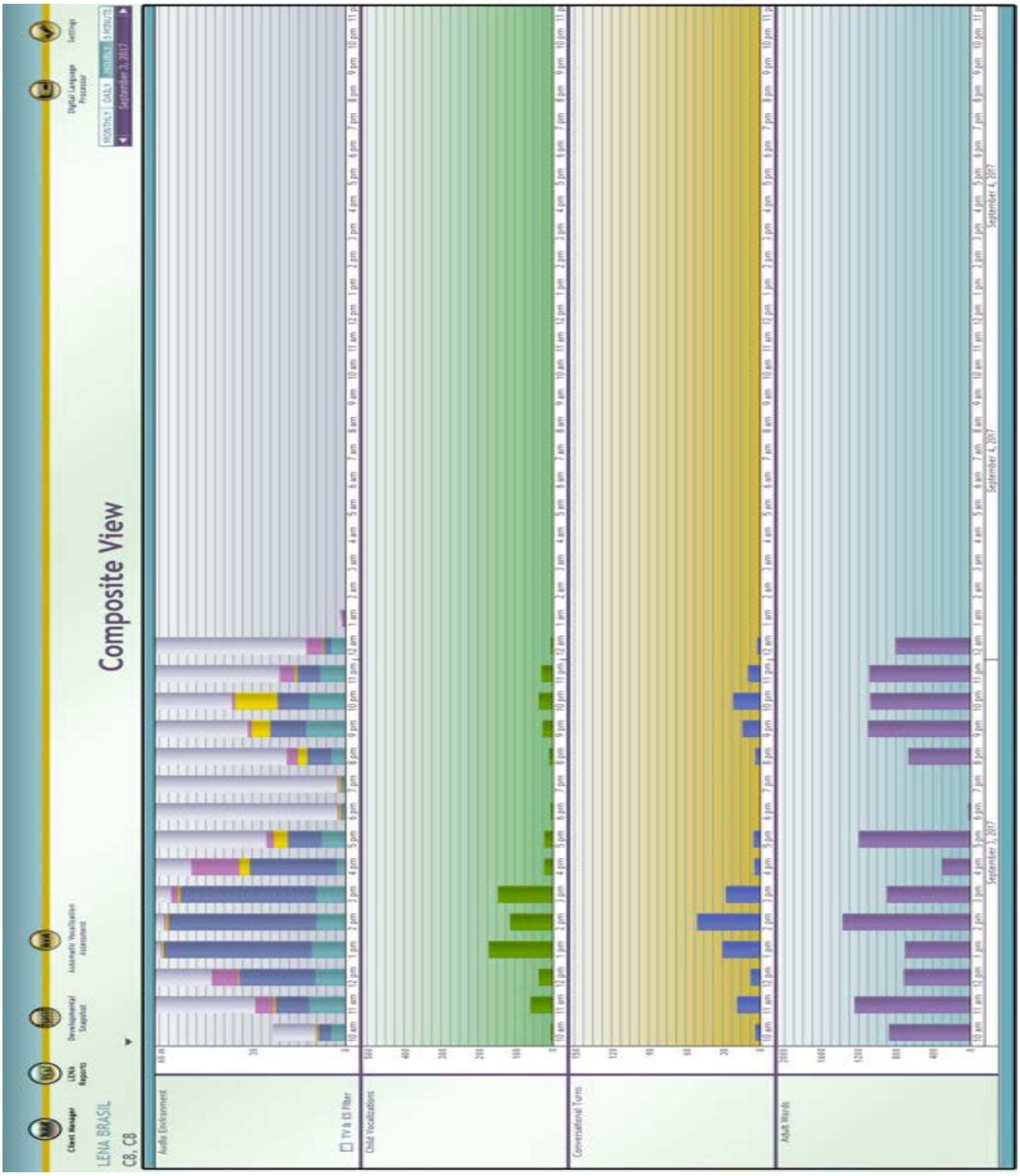
AVA pontuação padrão: 78 pts **AVA percentil**: 6%



Nome da criança: C8 **Gênero:** Feminino
Nome da Mãe: XXX
Data de nascimento: 02/2014 **Idade no dia da gravação:** 42 meses
Data do implante: ___/__/___ **Idade auditiva:** 12 meses

Áreas de avalição

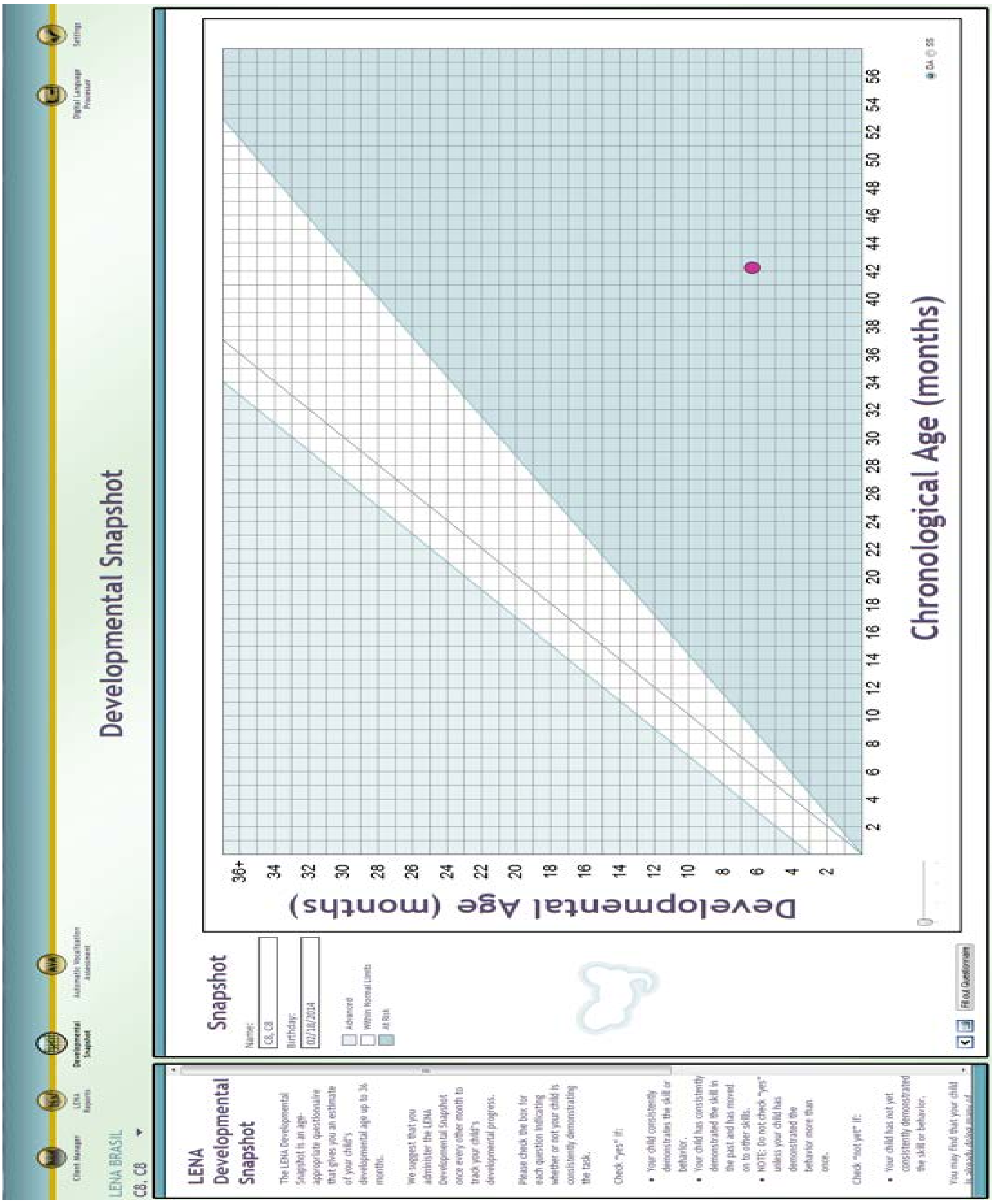
Ambiente sonoro (%)		Tempo total de gravação: 13h 23m
Silêncio: 46% Barulho: 6% TV/rádio/eletrônicos: 4%	Fala distante: 31% Fala significativa: 13%	Vocalizações infantis: 636 Turnos conversacionais: 180 Palavras enunciadas por adultos: 10068



Nome da criança: C8 **Gênero:** Feminino
Nome da Mãe: XXX
Data de nascimento: 02/2014 **Idade no dia da gravação:** 42 meses
Data do implante: ___/__/___ **Idade auditiva:** 12 meses

Ponto de desenvolvimento

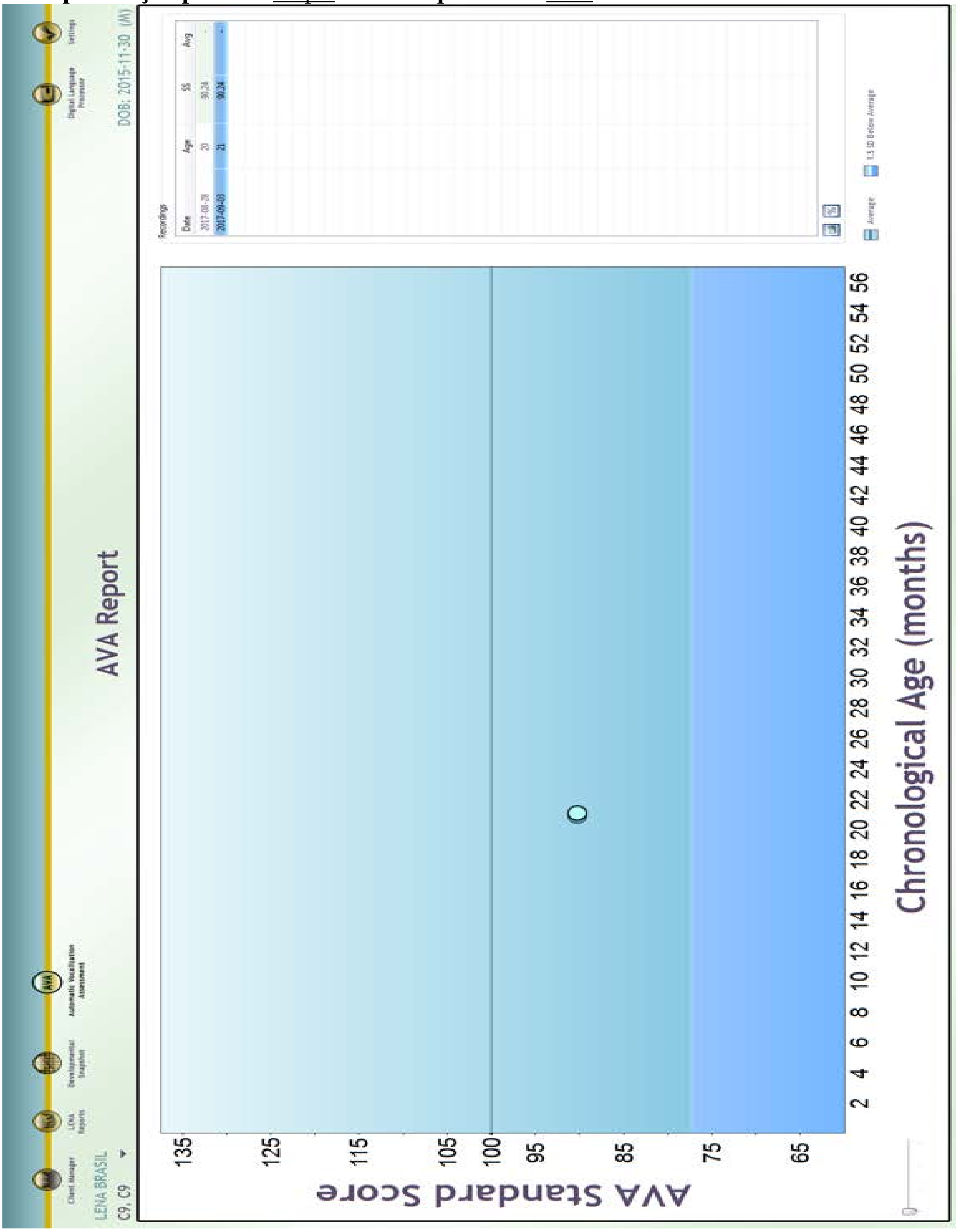
Idade de desenvolvimento: 6 meses – *risco de atraso no desenvolvimento*
DevSnap pontuação padrão: idade > 36 meses **DevSnap percentil:** não calculado



Nome da criança: C9 **Gênero:** Male
Nome da Mãe: XXX
Data de nascimento: 11/2015 **Idade no dia da gravação:** 21 meses

Relatório da avaliação automática de vocalização

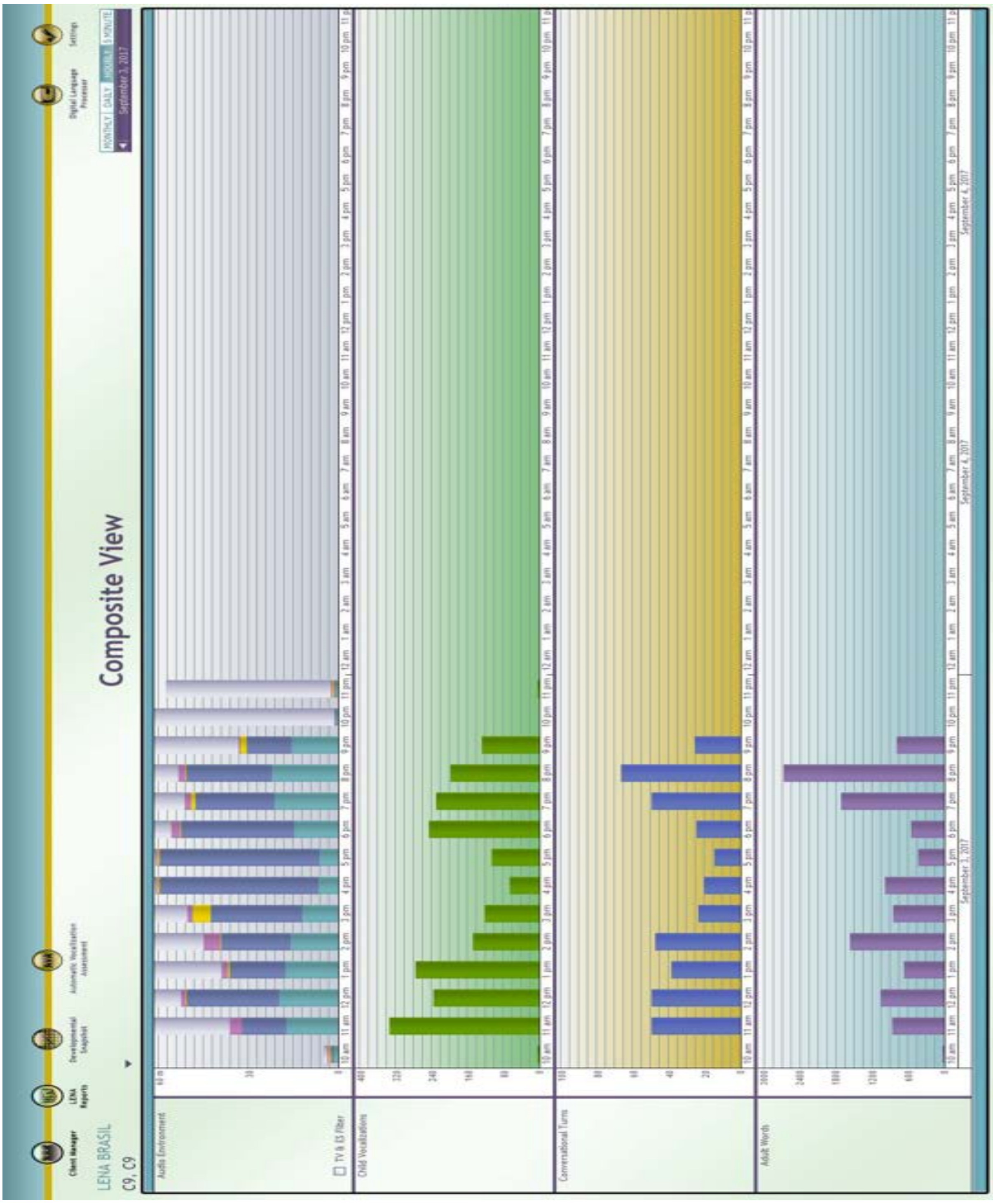
AVA pontuação padrão: 90 pts **AVA percentil**: 25%



Nome da criança: C9 **Gênero:** Male
Nome da Mãe: XXX
Data de nascimento: 11/2015 **Idade no dia da gravação:** 21 meses

Áreas de avalição

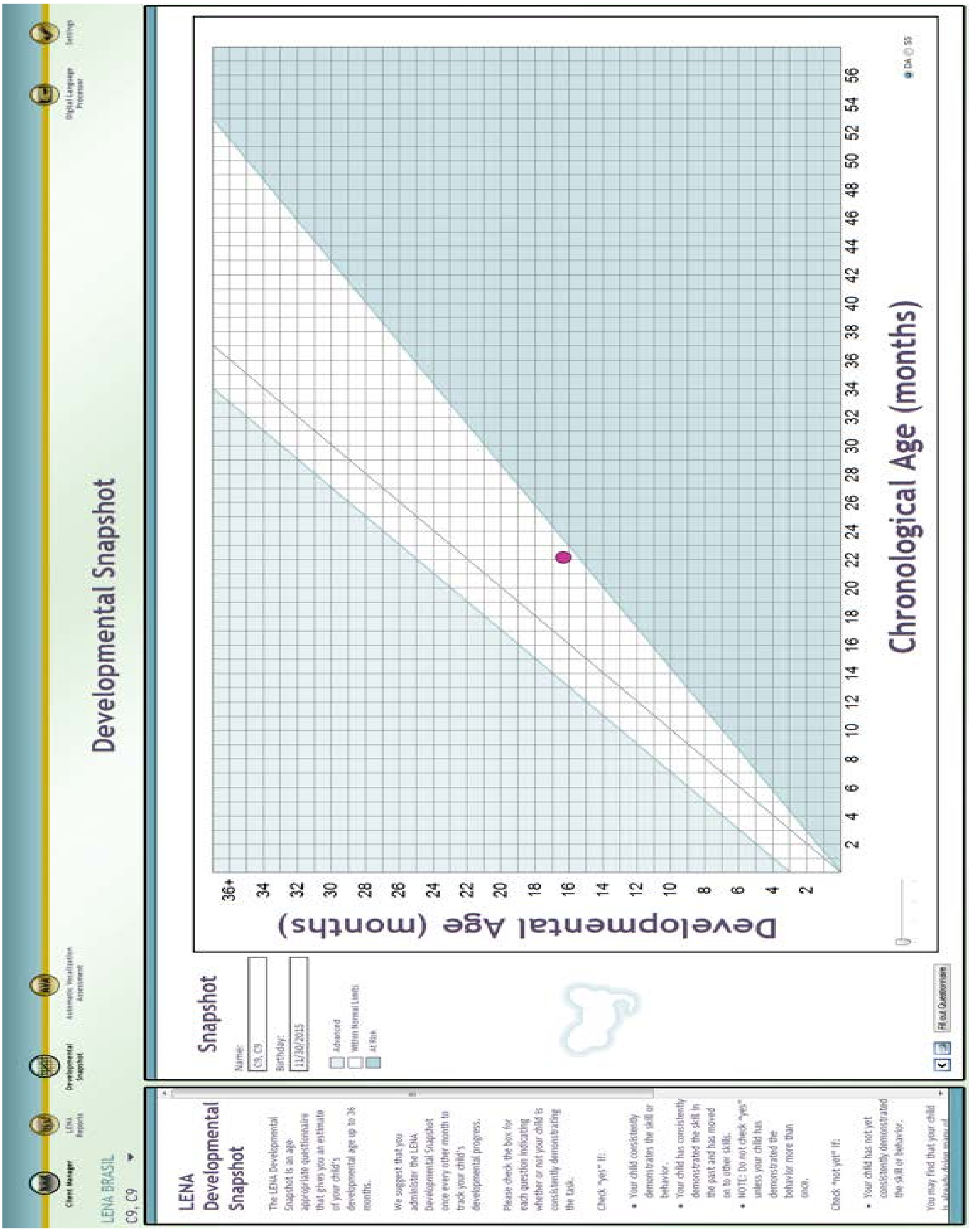
Ambiente sonoro (%)		Tempo total de gravação: 13h 01m
Silêncio: 32% Barulho: 3% TV/rádio/eletrônicos: 2%	Fala distante: 41% Fala significativa: 22%	Vocalizações infantis: 1944 Turnos conversacionais: 372 Palavras enunciadas por adultos: 6876



Nome da criança: C9 **Gênero:** Male
Nome da Mãe: XXX
Data de nascimento: 11/2015 **Idade no dia da gravação:** 21 meses

Ponto de desenvolvimento

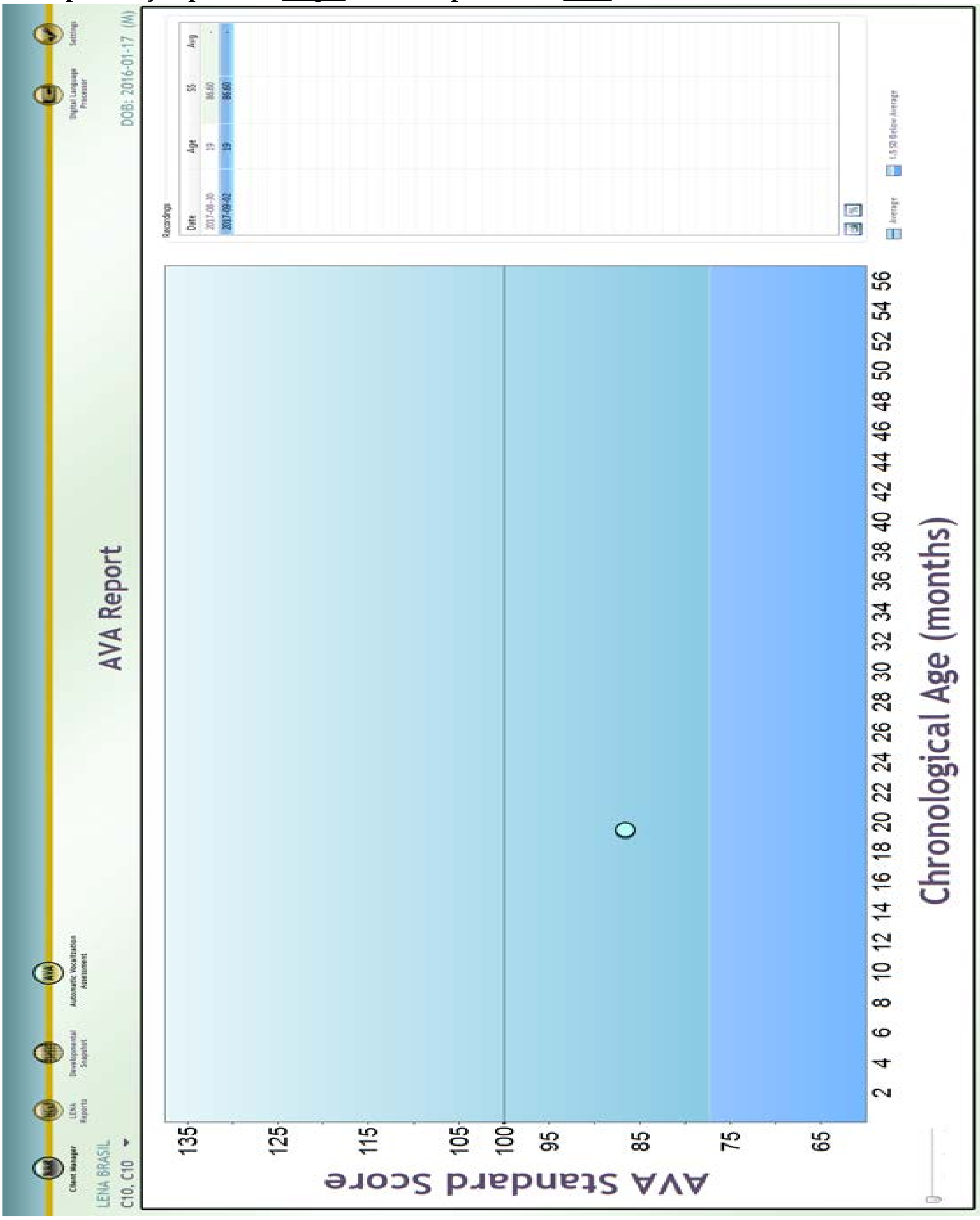
Idade de desenvolvimento: 16 meses – *desenvolvimento dentro do esperado*
DevSnap pontuação padrão: 80 pts **DevSnap percentil:** 8%



Nome da criança: C10 **Gênero:** Masculino
Nome da Mãe: XXX
Data de nascimento: 01/2016 **Idade no dia da gravação:** 19 meses
Data do implante: ___/___/___ **Idade auditiva:** 13 meses

Relatório da avaliação automática de vocalização

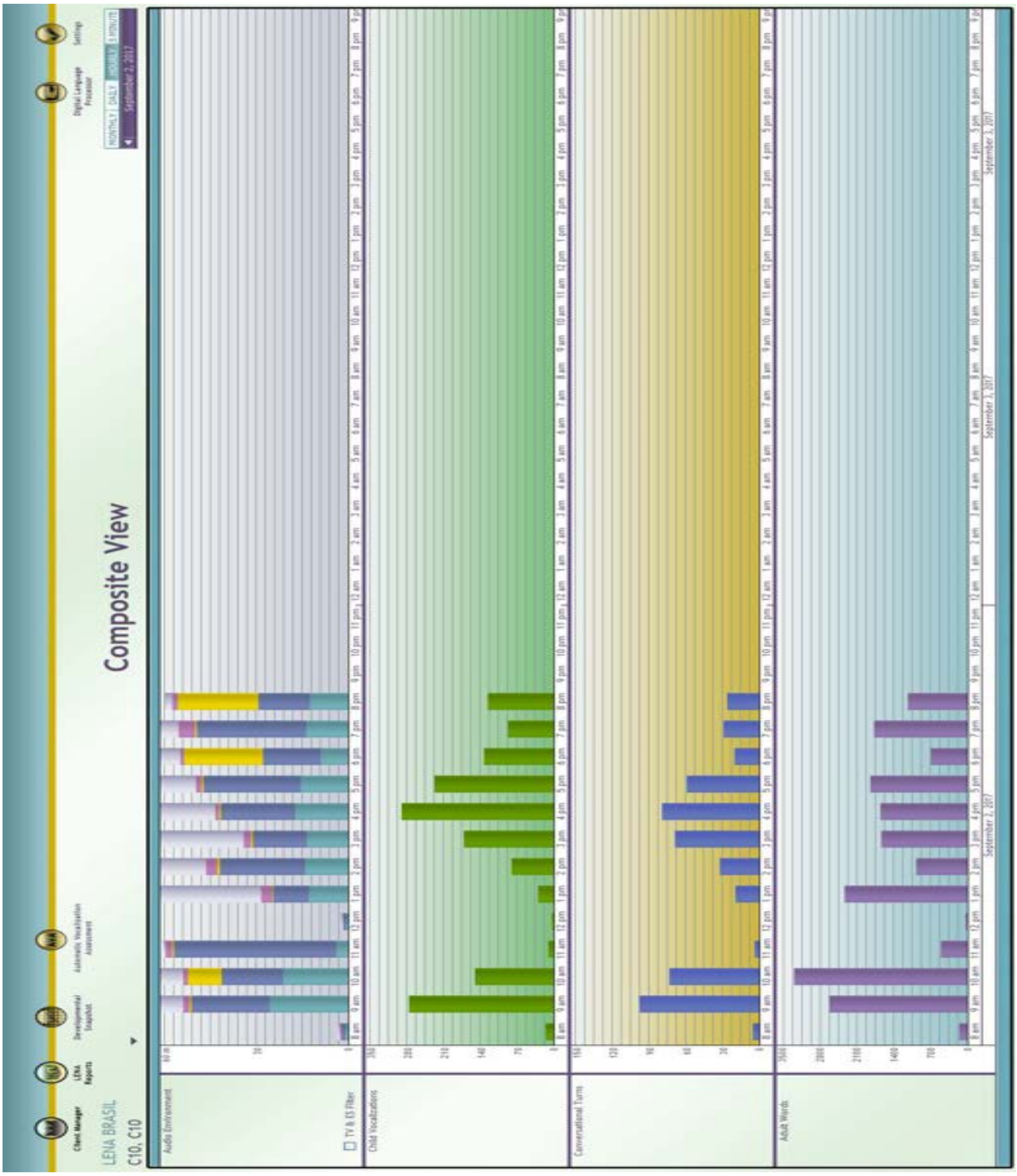
AVA pontuação padrão: 87 pts **AVA percentil**: 18%



Nome da criança: <u>C10</u> **Gênero:** <u>Masculino</u>
Nome da Mãe: <u>XXX</u>
Data de nascimento: <u>01/2016</u> **Idade no dia da gravação:** <u>19 meses</u>
Data do implante: ___/___/___ **Idade auditiva:** <u>13 meses</u>

Áreas de avalição

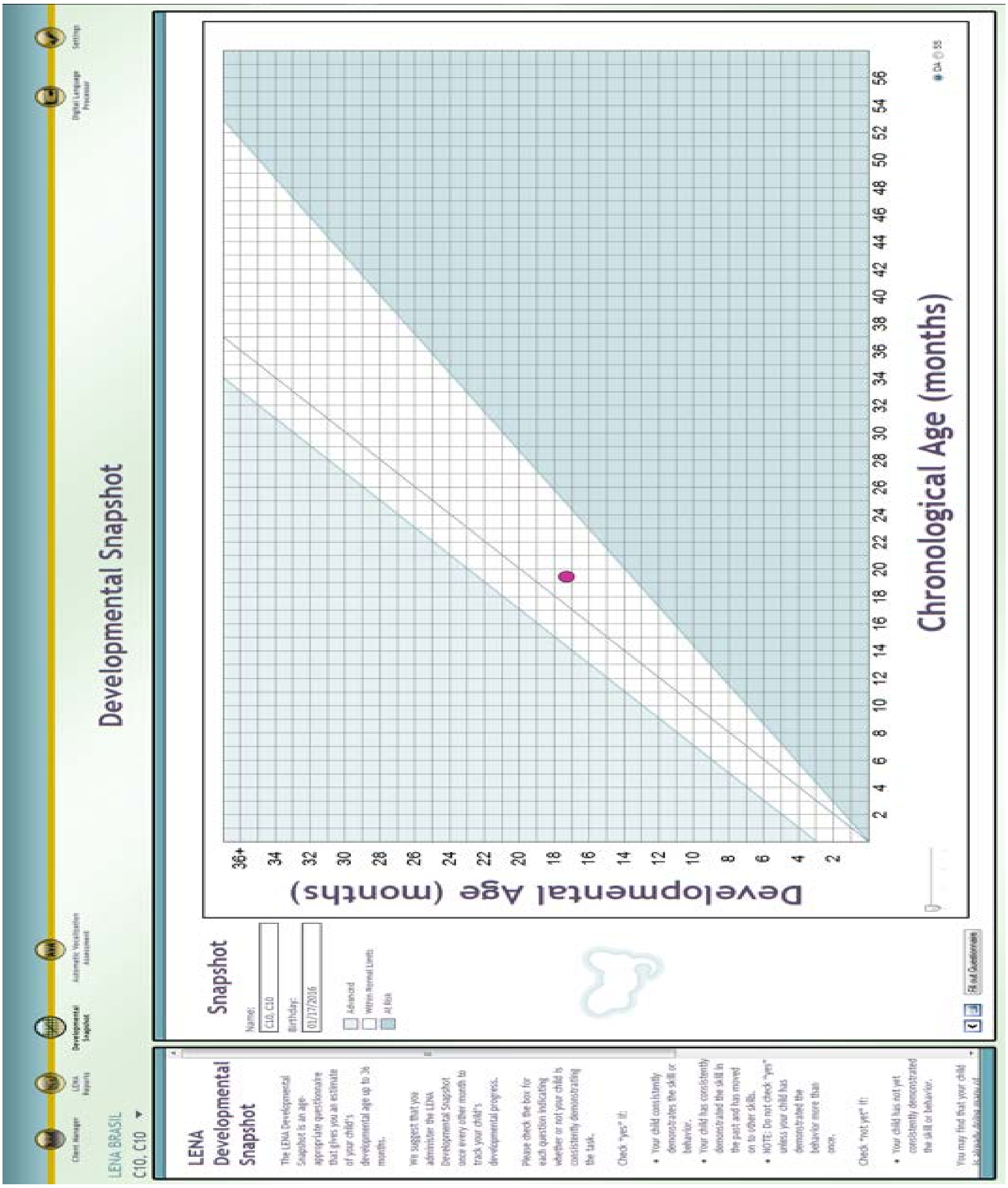
Ambiente sonoro (%)		Tempo total de gravação: 11h 03m
Silêncio: 20% Barulho: 4% TV/rádio/eletrônicos: 10%	Fala distante: 42% Fala significativa: 24%	Vocalizações infantis: 1752 Turnos conversacionais: 564 Palavras enunciadas por adultos: 22176



Nome da criança: C10 **Gênero:** Masculino
Nome da Mãe: XXX
Data de nascimento: 01/2016 **Idade no dia da gravação:** 19 meses
Data do implante: ___/___/___ **Idade auditiva:** 13 meses

Ponto de desenvolvimento

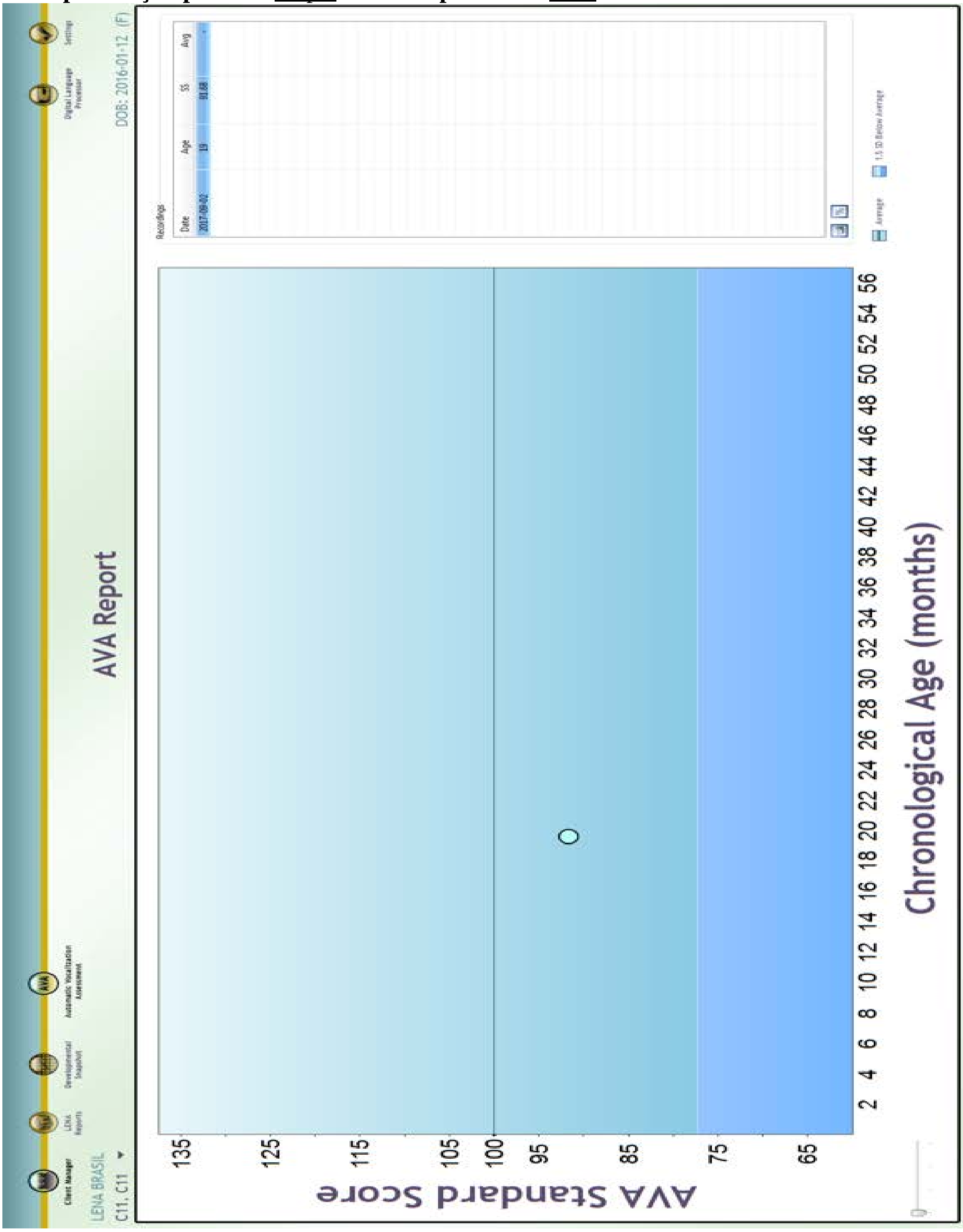
Idade de desenvolvimento: 17 meses - *desenvolvimento dentro do esperado*
DevSnap pontuação padrão: 93pts **DevSnap percentil:** 32%



Nome da criança: C11 **Gênero:** Feminino
Nome da Mãe: XXX
Data de nascimento: 01/2016 **Idade no dia da gravação:** 19 meses

Relatório da avaliação automática de vocalização

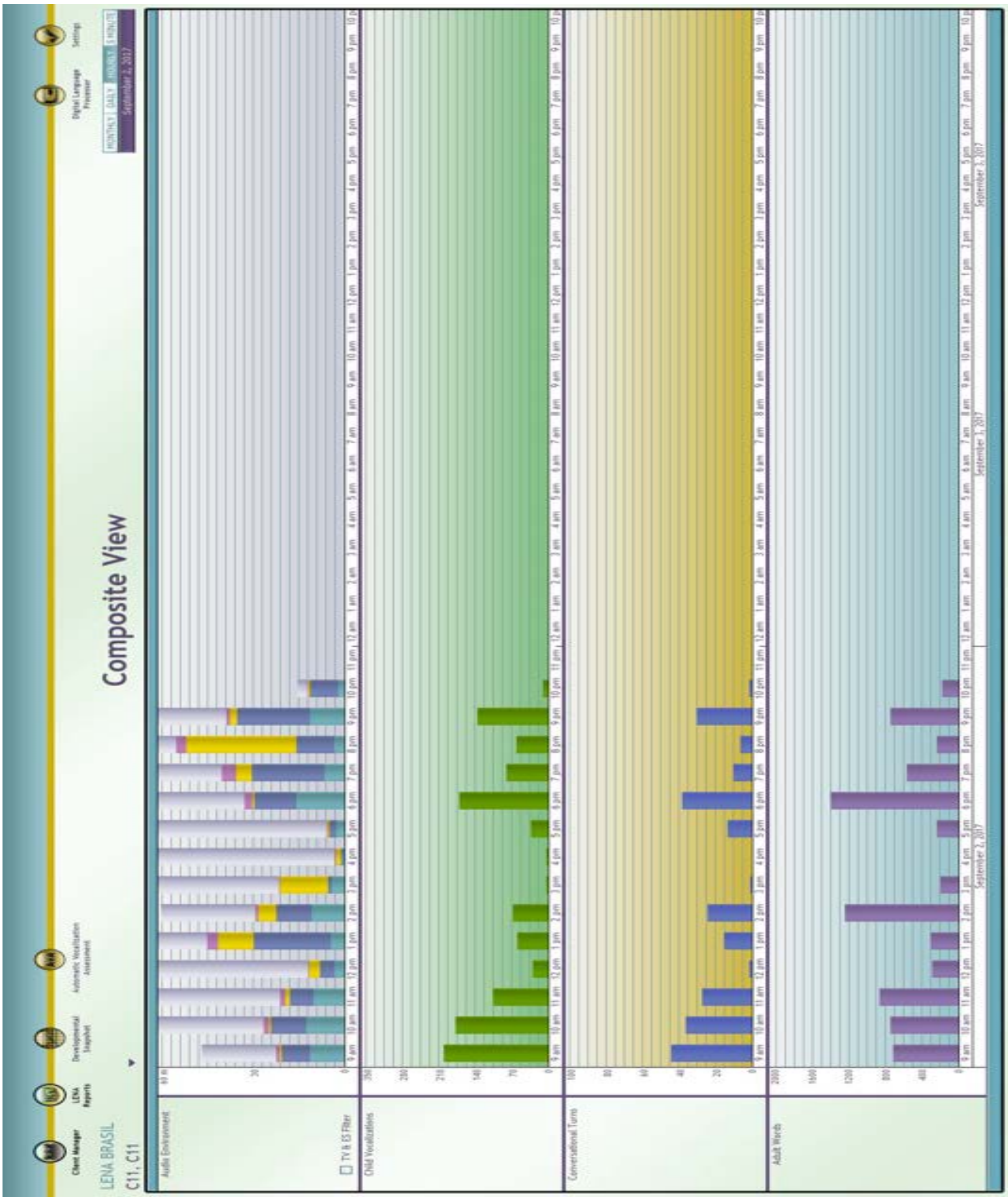
AVA pontuação padrão: 92 pts **AVA percentil**: 28%



Nome da criança: C11 **Gênero:** Feminino
Nome da Mãe: XXX
Data de nascimento: 01/2016 **Idade no dia da gravação:** 19 meses

Áreas de avalição

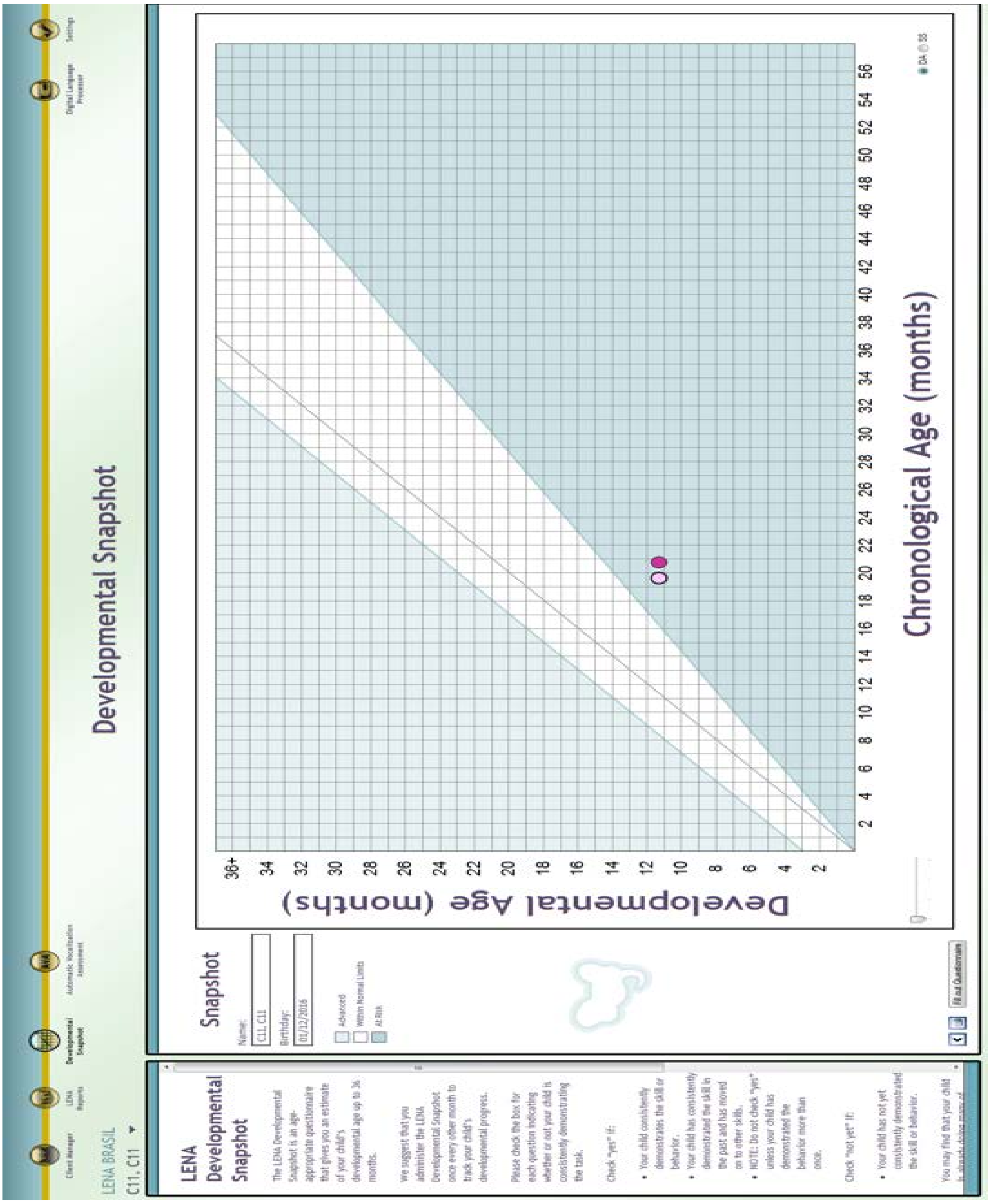
Ambiente sonoro (%)		Tempo total de gravação: 13h 00m
Silêncio: 54% Barulho: 3% TV/rádio/eletrônicos: 11%	Fala distante: 19% Fala significativa: 13%	Vocalizações infantis: 1068 Turnos conversacionais: 240 Palavras enunciadas por adultos: 7152



Nome da criança: C11 **Gênero:** Feminino
Nome da Mãe: XXX
Data de nascimento: 01/2016 **Idade no dia da gravação:** 19 meses

Ponto de desenvolvimento

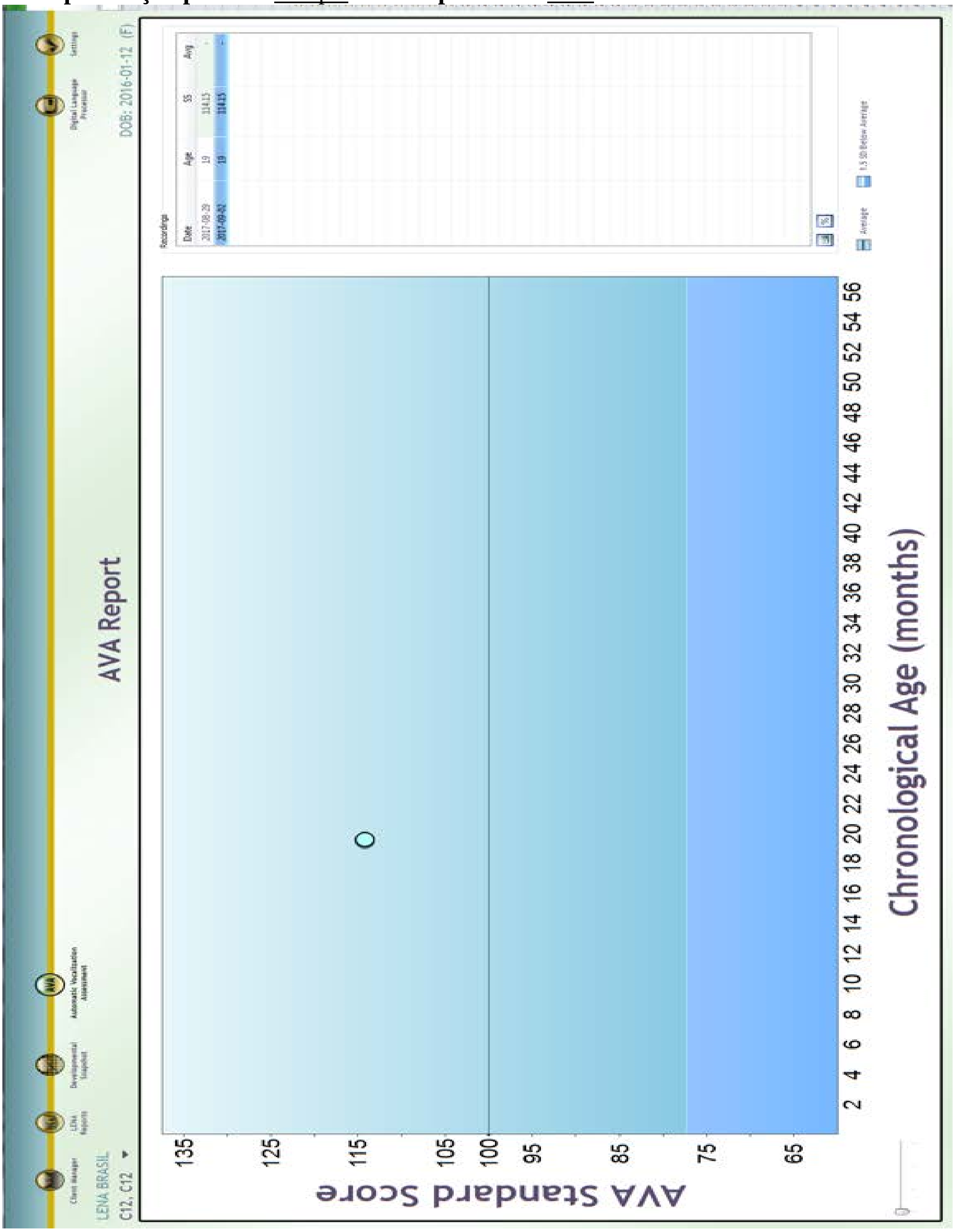
Idade de desenvolvimento: 11 meses – *risco de atraso no desenvolvimento*
DevSnap pontuação padrão: 74pts **DevSnap percentil:** 4%



Nome da criança: C12 **Gênero:** Feminino
Nome da Mãe: XXX
Data de nascimento: 01/2016 **Idade no dia da gravação:** 19 meses

Relatório da avaliação automática de vocalização

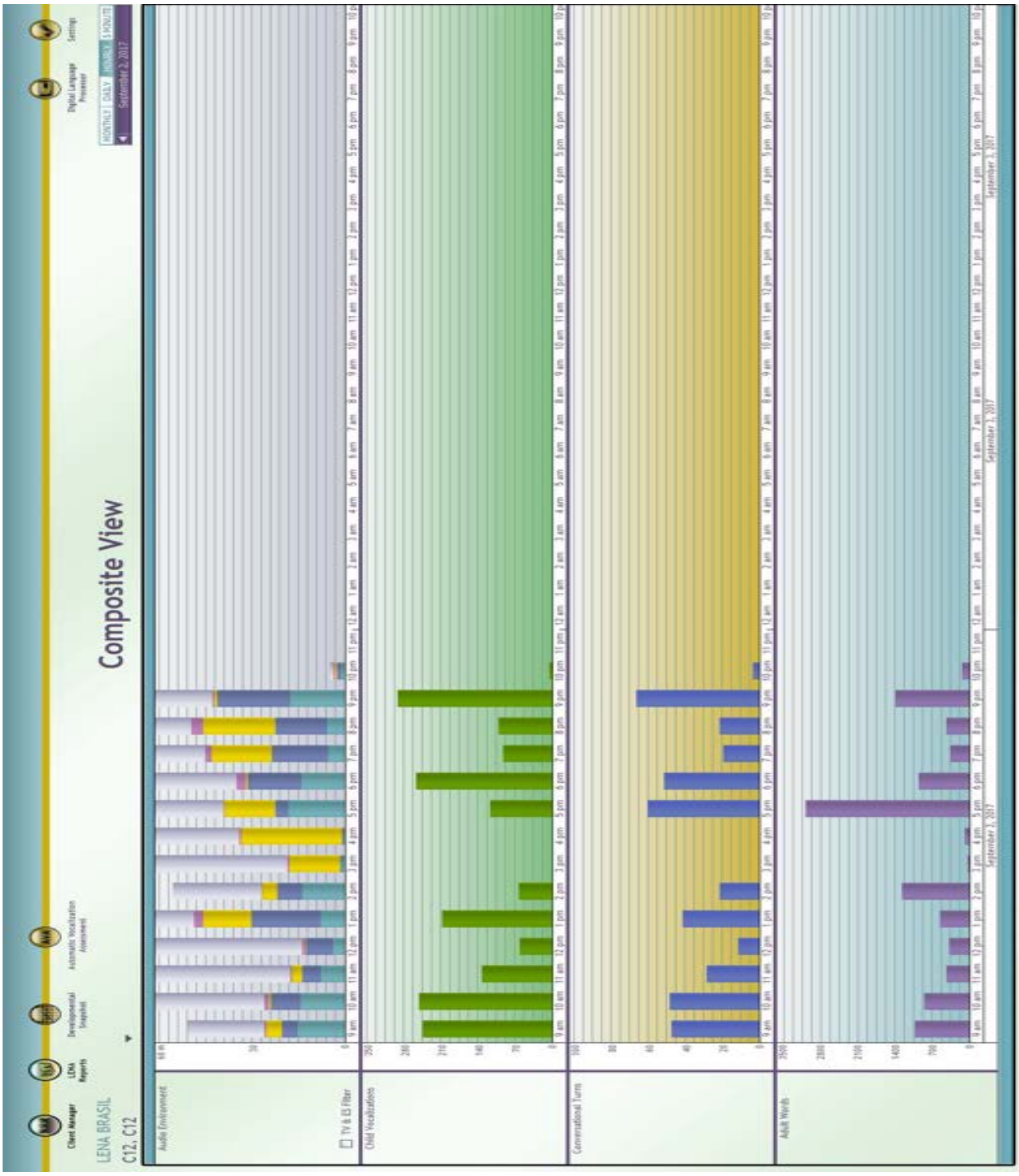
AVA pontuação padrão: 114 pts **AVA percentil**: 82%



Nome da criança: C12 **Gênero:** Feminino
Nome da Mãe: XXX
Data de nascimento: 01/2016 **Idade no dia da gravação:** 19 meses

Áreas de avalição

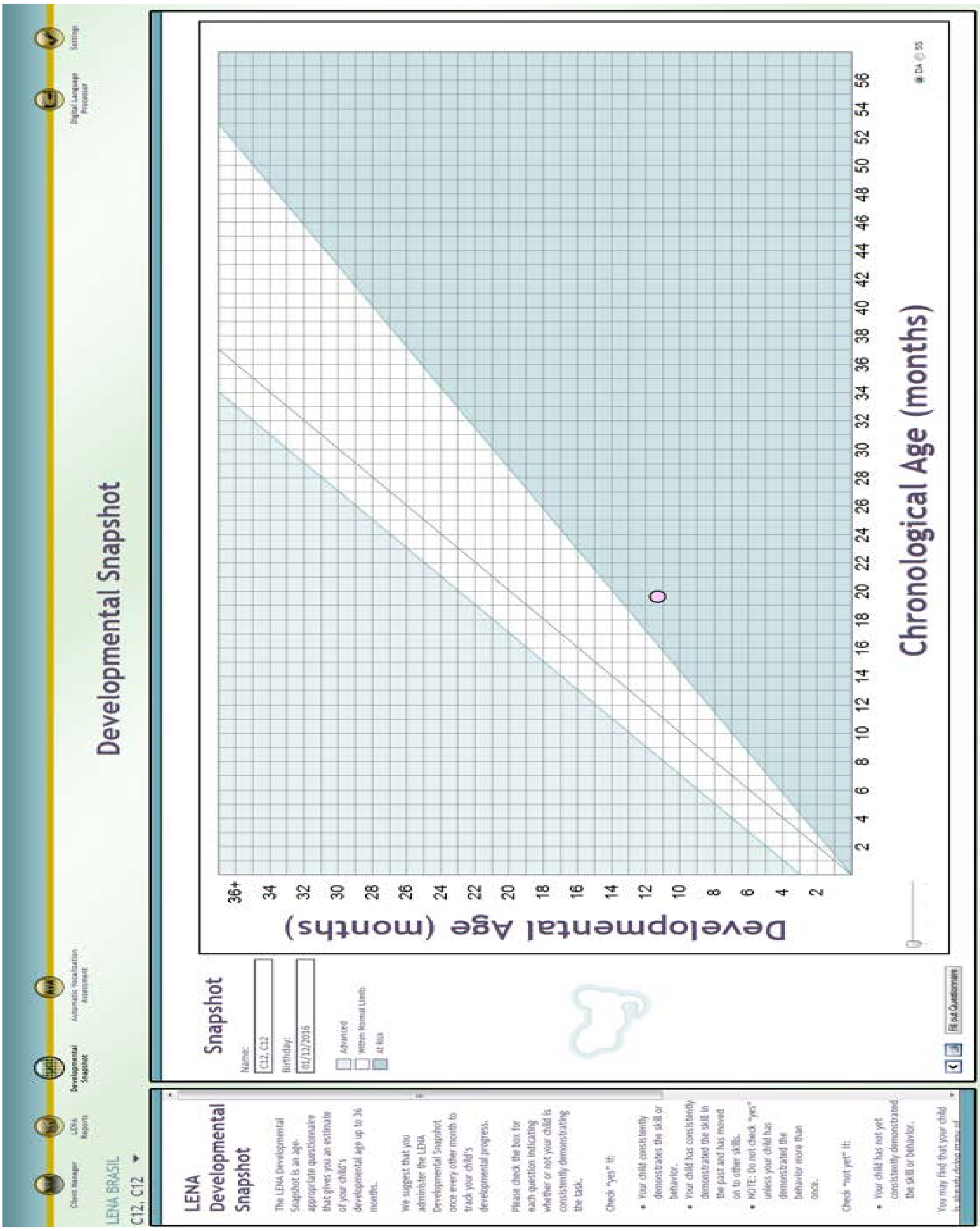
Ambiente sonoro (%)		Tempo total de gravação: 12h 49m
Silêncio: 46% Barulho: 2% TV/rádio/eletrônicos: 18%	Fala distante: 18% Fala significativa: 16%	Vocalizações infantis: 1728 Turnos conversacionais: 396 Palavras enunciadas por adultos: 10392



Nome da criança: C12 **Gênero:** Feminino
Nome da Mãe: XXX
Data de nascimento: 01/2016 **Idade no dia da gravação:** 19 meses

Ponto de desenvolvimento

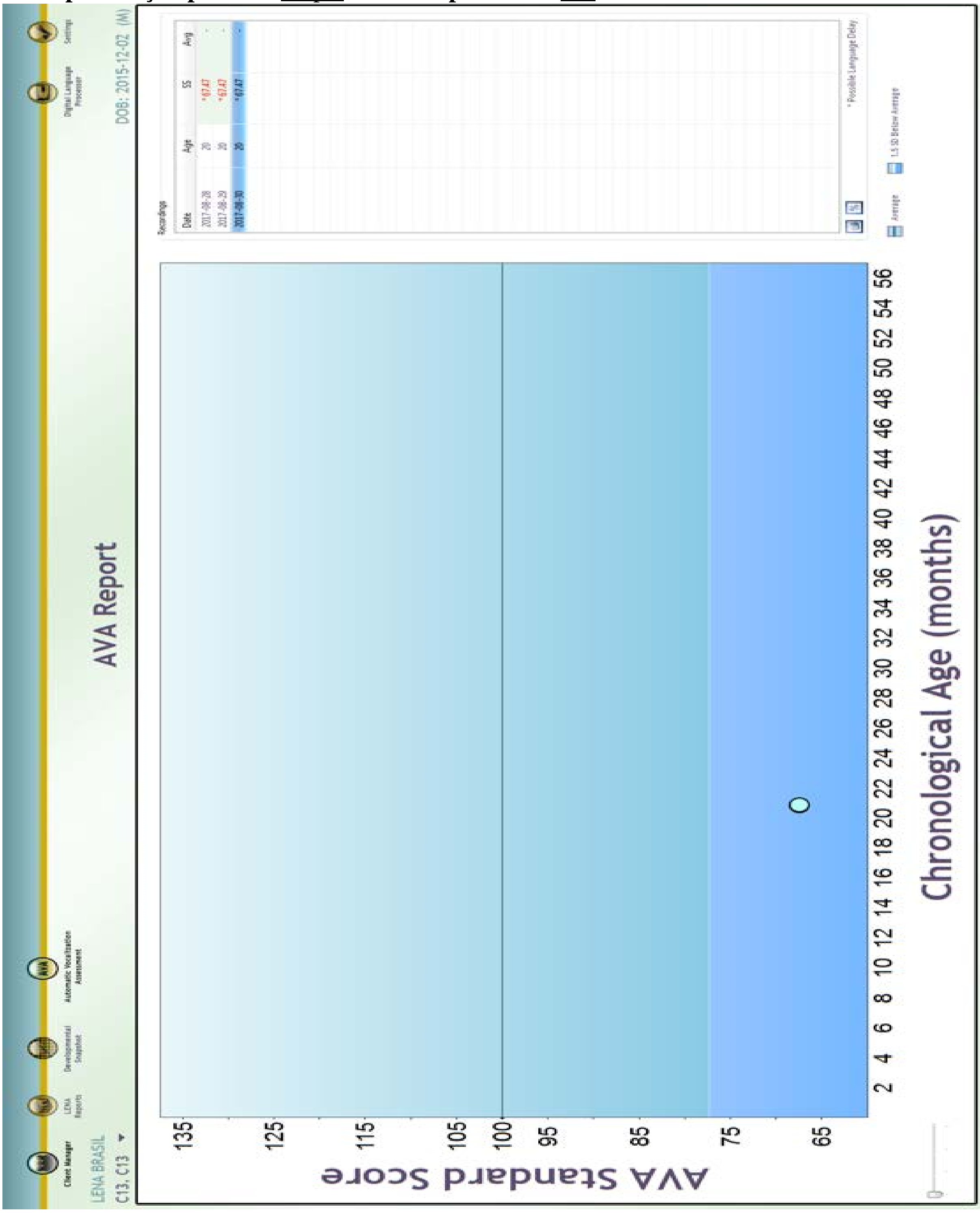
Idade de desenvolvimento: 11 meses – *risco de atraso no desenvolvimento*
DevSnap pontuação padrão: 74 pts **DevSnap percentil:** 4%



Nome da criança: C13 **Gênero:** Masculino
Nome dos pais: XXX
Data de nascimento: 12/2015 **Idade no dia da gravação:** 20 meses
Data do implante: ___/___/___ **Idade auditiva:** 4 meses

Relatório da avaliação automática de vocalização

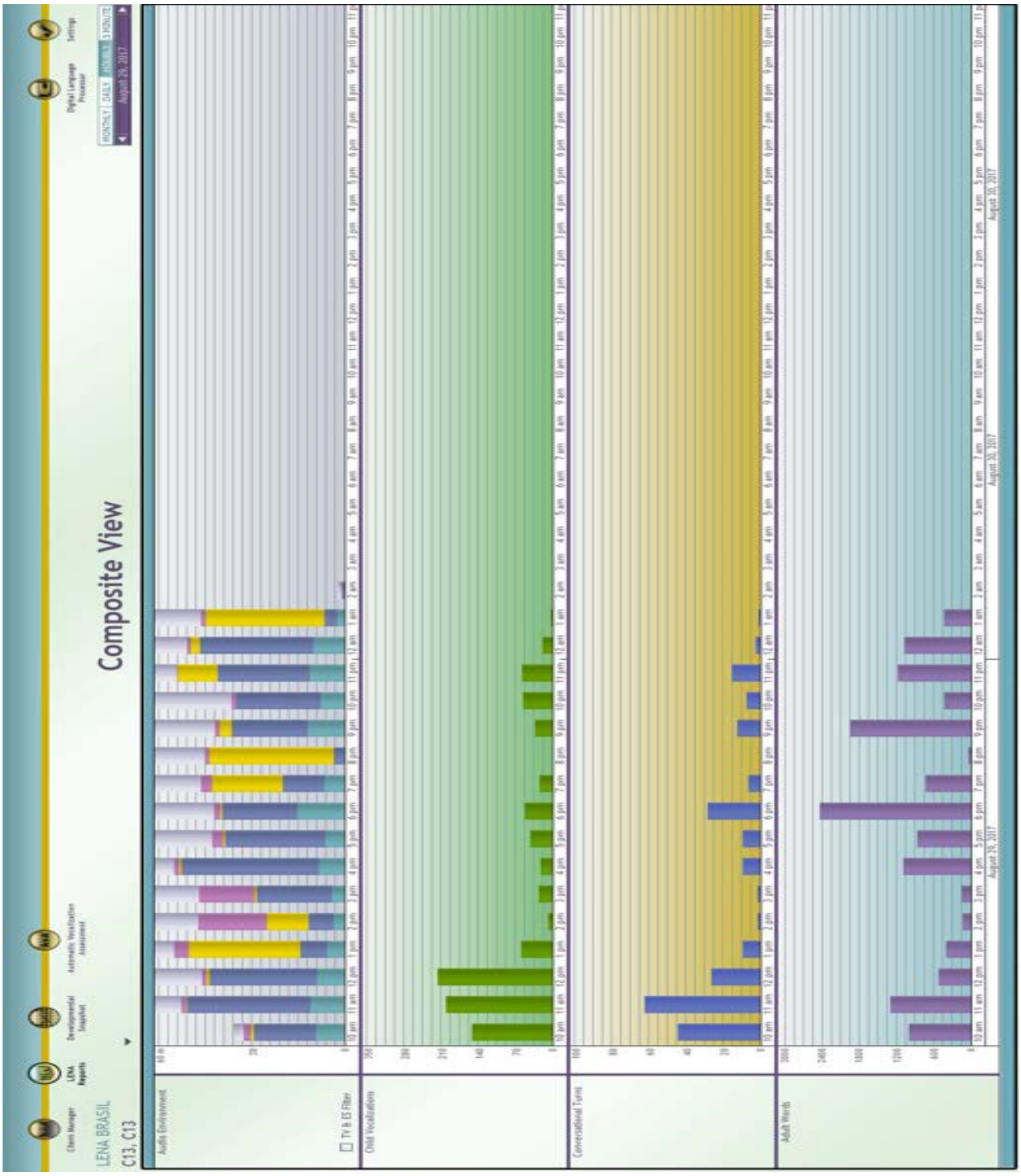
AVA pontuação padrão: 67 pts **AVA percentil**: 1%



Nome da criança: C13 **Gênero:** Masculino
Nome dos pais: XXX
Data de nascimento: 12/2015 **Idade no dia da gravação:** 20 meses
Data do implante: ___/___/___ **Idade auditiva:** 4 meses

Áreas de avalição

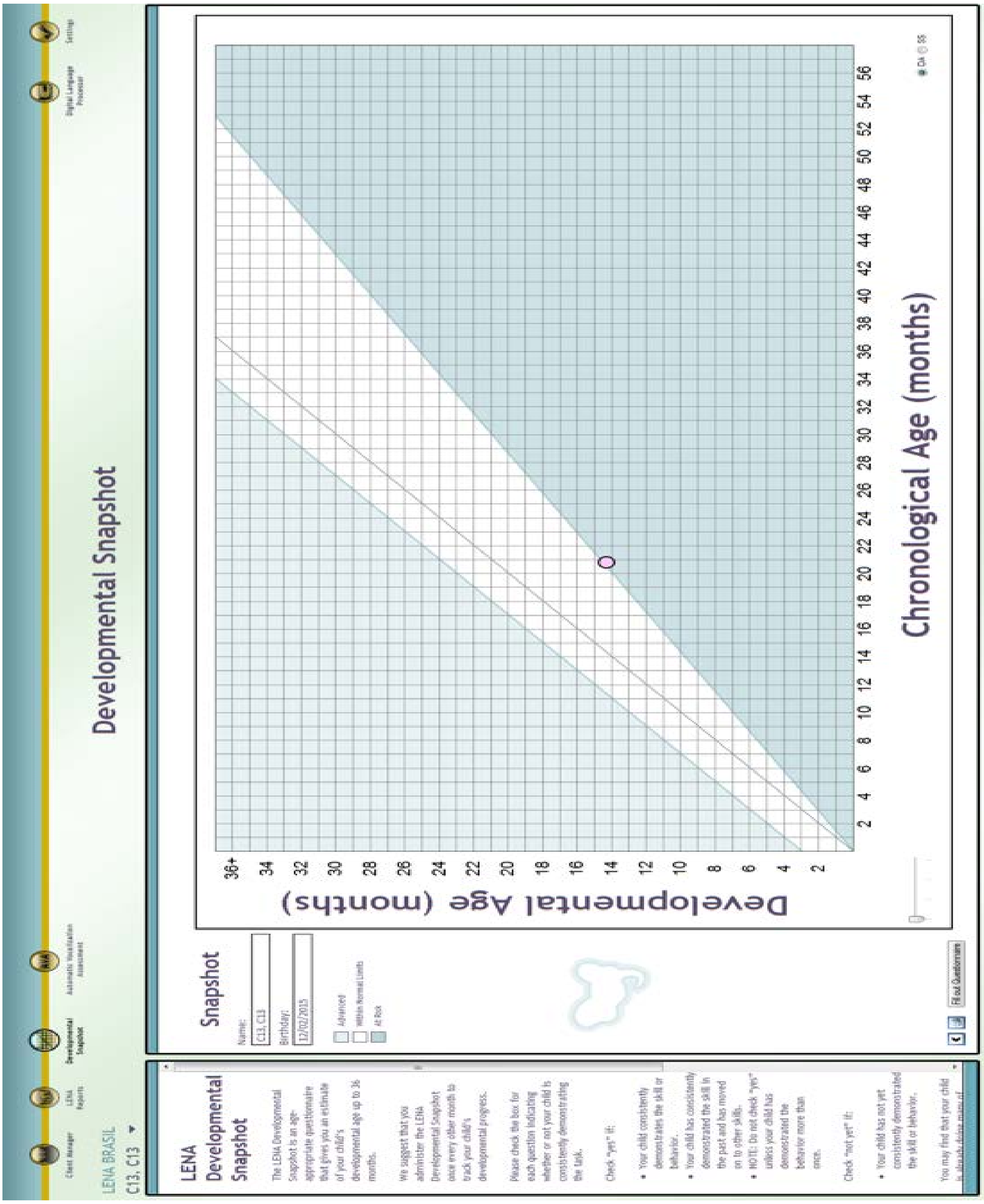
<table>
<tr><td colspan="2">Ambiente sonoro (%)</td><td rowspan="2">Tempo total de gravação: 13h 35m
Vocalizações infantis: 852
Turnos conversacionais: 204
Palavras enunciadas por adultos: 10848</td></tr>
<tr><td>Silêncio: 23%
Barulho: 7%
TV/rádio/eletrônicos: 17%</td><td>Fala distante: 39%
Fala significativa: 14%</td></tr>
</table>



Nome da criança: C13 **Gênero:** Masculino
Nome dos pais: XXX
Data de nascimento: 12/2015 **Idade no dia da gravação:** 20 meses
Data do implante: ___/___/___ **Idade auditiva:** 4 meses

Ponto de desenvolvimento

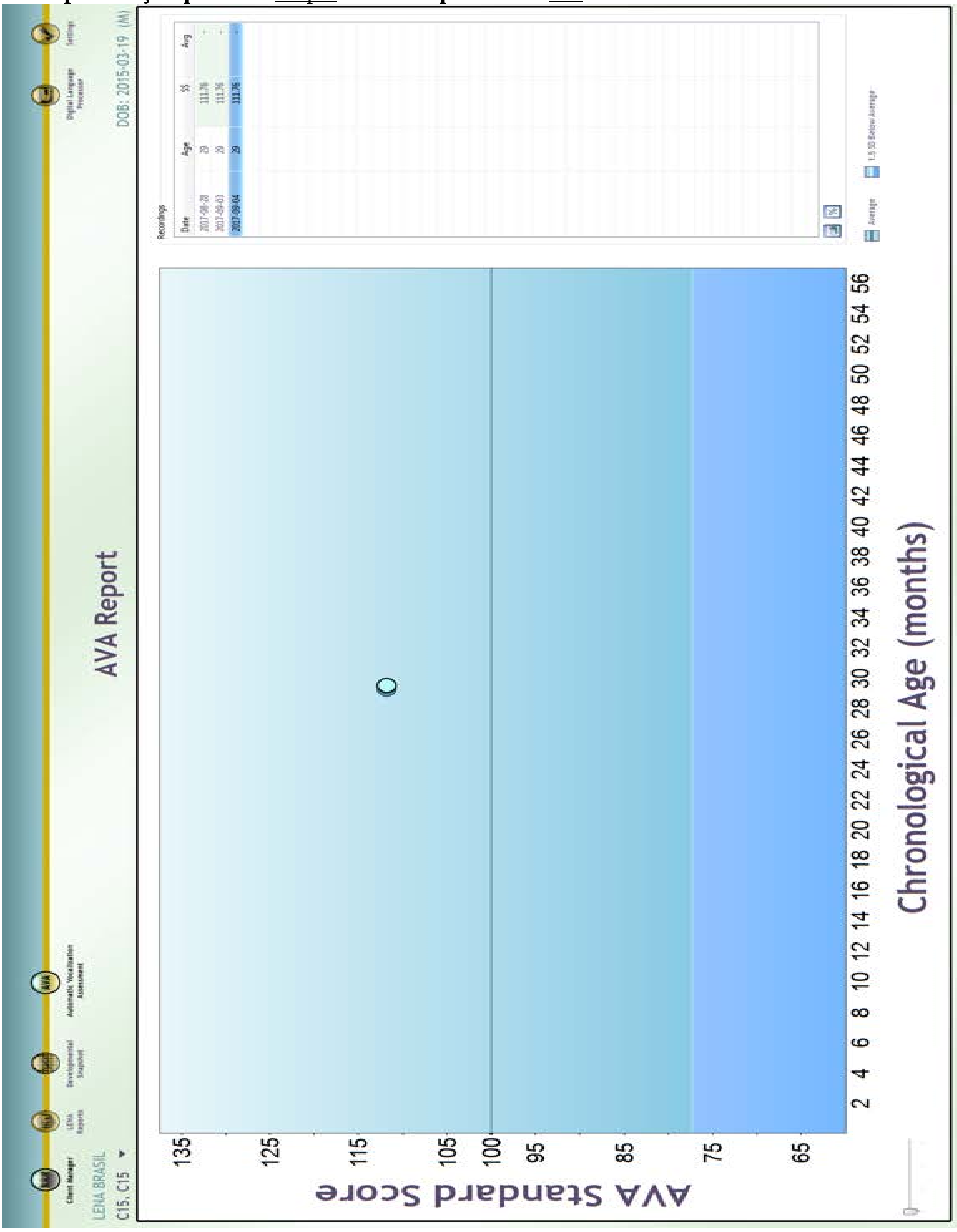
Idade de desenvolvimento: 14 meses – *risco de atraso no desenvolvimento*
DevSnap pontuação padrão: 81 pts **DevSnap percentil:** 10%



Nome da criança: C15 **Gênero:** Masculino
Nome da Mãe: XX
Data de nascimento: 03/2015 **Idade no dia da gravação:** 29 meses

Relatório da avaliação automática de vocalização

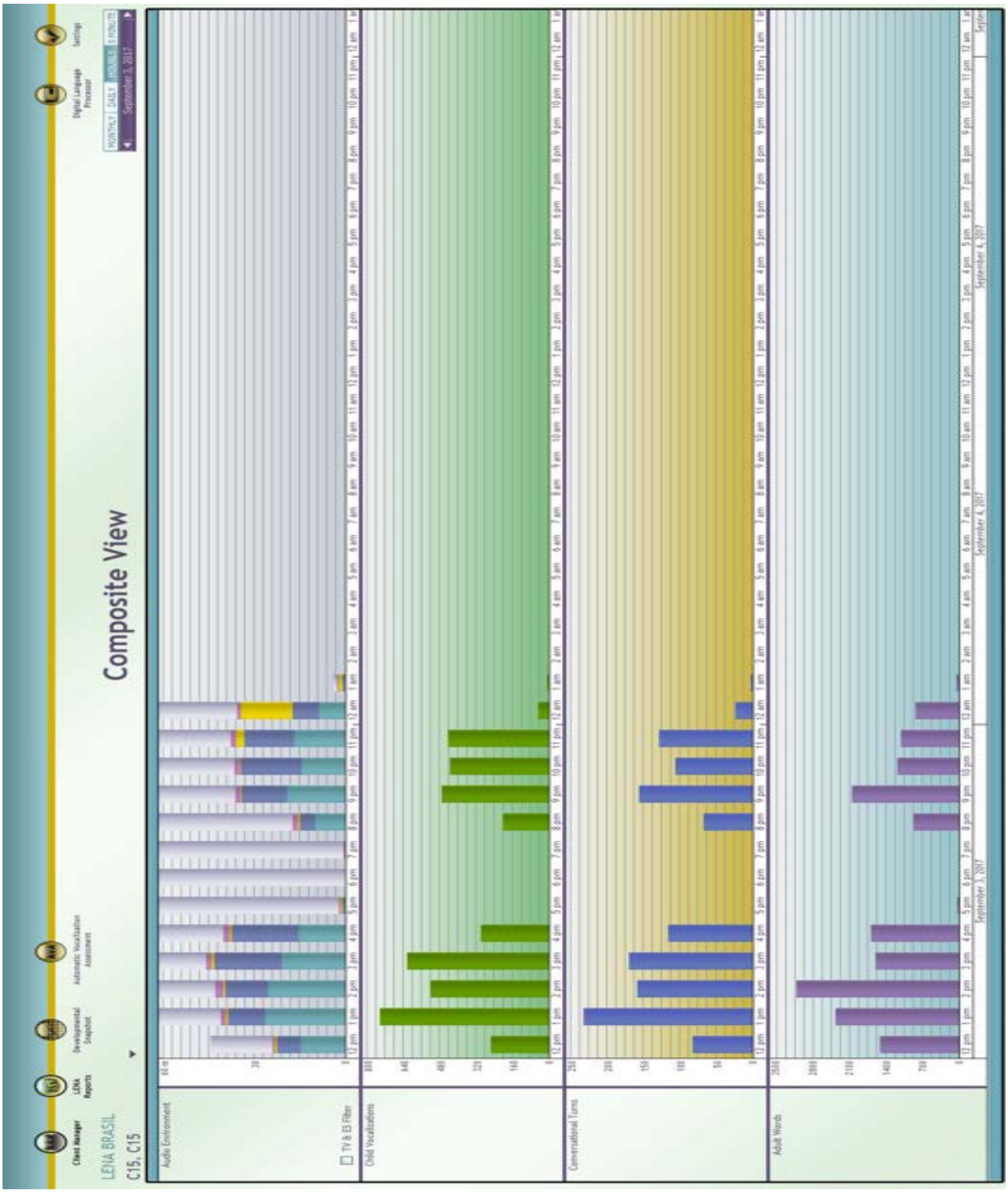
AVA pontuação padrão: 67 pts **AVA percentil**: 1%



Nome da criança: C15 **Gênero:** Masculino
Nome da Mãe: XX
Data de nascimento: 03/2015 **Idade no dia da gravação:** 29 meses

Áreas de avalição

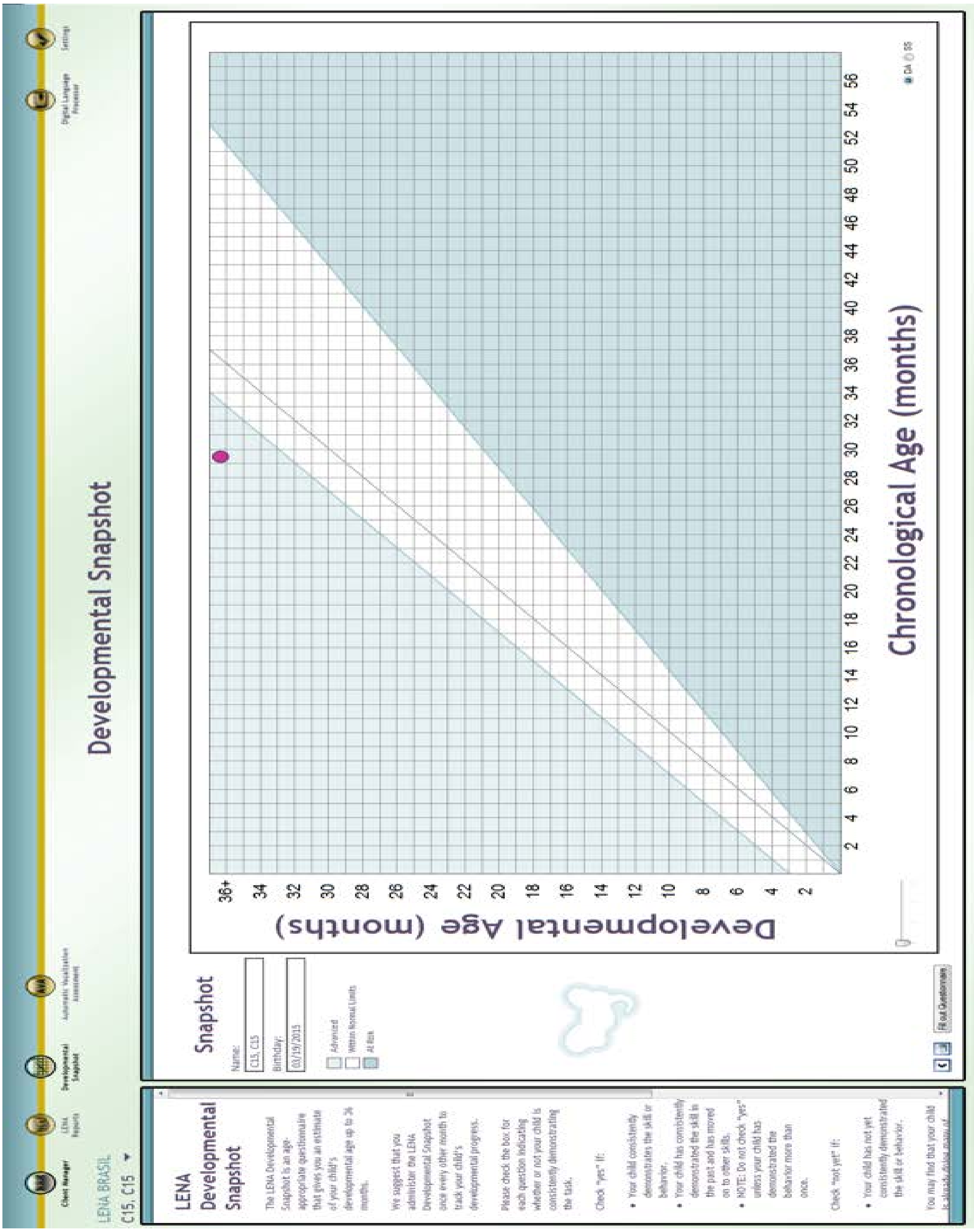
Ambiente sonoro (%)		Tempo total de gravação: 11h 43m
Silêncio: 55% Barulho: 2% TV/rádio/eletrônicos: 1%	Fala distante: 19% Fala significativa: 23%	Vocalizações infantis: 4128 Turnos conversacionais: 1248 Palavras enunciadas por adultos: 15864



Nome da criança: C15 **Gênero:** Masculino
Nome da Mãe: XX
Data de nascimento: 03/2015 **Idade no dia da gravação:** 29 meses

Ponto de desenvolvimento

Idade de desenvolvimento: +36 meses – *desenvolvimento avançado*
DevSnap pontuação padrão: 123 pts **DevSnap percentil:** 93%



Appendix IX – Article

Pre-validation of the LENA system for Brazilian Portuguese in the homes of toddlers with normal hearing and comparison of the language environment in children with hearing impairment

Miriam Ferreira[1], Cilmara Levy[2], Ulrika Löfkvist[1, 3]

1. Department of Special Needs Education, University of Oslo. Postbox 1140, Blindern 0318, Oslo, Norway
2. Department of Audiology and Speech Pathology, Santa Casa Hospital. Rua Apinajés, 1818, São Paulo, SP – Brazil 1258000
3. Department of CLINTEC, Karolinska Institutet, Cochlear Implant Section, Huddinge, M43, 141 86, Stockholm, Sweden

***Corresponding to:**

Ulrika Löfkvist
Department of Special Needs Education
University of Oslo
Postbox 1140, Blindern 0318, Oslo, Norway
E-mail: ulrika.lofkvist@isp.uio.no
Tel: +4722859165

The authors have no conflicts of interest to declare with regard to this paper.

Pre-validation of the LENA system for Brazilian Portuguese in the homes of toddlers with normal hearing and comparison of the language environment in children with hearing impairment

Abstract

Objective: The purpose of the present study was to pre-validate the Language Environment Analysis (LENA) system (www.lena.org) for Brazilian Portuguese (BP).The pre-validation process consisted of the investigation of the language and audio environment of Brazilian families of children with normal hearing (NH). Another aim was to compare their results to a sample of age-matched children with hearing impairment (HI). **Methods:** The LENA system was the speech streaming technology used for segmenting the sounds recorded in the home environment of the participating families. A pre-validation study was devised for verifying the accuracy of the LENA automated counts to the manual transcriptions done by two linguists in BP. The relationship between children language development and the automated measure of adult words (AW) and child vocalizations (CV) was investigated. A comparative cohort study including a correlation analysis of the language and audio environment of children with HI and children with NH were conducted. **Results:** Moderate to strong interrater agreement was found for CV and AW. Weak to moderate agreement was found between the LENA automated results and the means of the human counts for the same variables. The LENA system tended to overestimate human counts for AW and underestimate it for CV. Comparative analysis suggested similarities on the language and listening environment of the two groups (normal hearing vs HI). The audio environment of the two groups of children differed only in relation to their exposure of silence (Md= 37%, U= 8, p= .04) and noise (Md= 4%, U= 42, p= .03) in their home environment. Children with NH spent more time in silence and children with HI spent more time in noisy environments. Children's language development was supported by parent-child interaction. Earlier age of 1st fitting of HA/CI influenced positively on the language development of children with HI. **Conclusion:** The LENA system was sensitive to BP. Therefore, it should be used in Brazilian settings. The implications for use of the LENA system in Brazilian clinical settings were discussed.

Keywords: LENA system, hearing impairment, language development, natural environment, validation

1. Introduction

The Language Environment Analysis (LENA) system [12] is an advanced speech streaming technology, which provides metrics on the language and audio environment of children aged between 0 and 48 months. Although its normative data is for American English, a number of studies have been conducted to validate the LENA system in other languages [2, 3, 4, 6, 8, 14, 15, 17]. This study is so far the first to use the LENA system in BP speaking settings.

Pre-validating the LENA system for BP is of scientific and clinical importance for three reasons. First, it could be deemed as a reliable tool for data collection which respects the ecological validity of the linguistic environment. Second, it would provide understanding of the characteristics of natural language and audio environment of Brazilian families. Last, a validated LENA method could be used as key component of family-centered programs for accelerating language development of at-risk children in Brazilian settings, e.g. children with hearing impairment.

1.1. The LENA^{tm} system

As an advanced speech streaming technology, the LENA system is known for being a non-invasive instrument for data collection. This unique system enables the researcher to collect a large amount of high-quality audio recordings collected in a naturalistic fashion. It is also known for facilitating the data analysis because all of the recordings are processed within a matter of minutes by the LENA software for analyzing linguistic and acoustic information. Therefore, the LENA system allows scholars to conduct large-scale research and to collect 12-16-hour long naturalistic samples of linguistic and auditory information in younger children’s home environment.

The LENA System is composed by a recorder and an advanced software, developed to measure and analyze the recordings of the spoken language used in the home environment of younger children. This software relies on statistical algorithms that turn voice and sound recordings into measurable data. The basic LENA measures are numbers of Adult Words (AW), parent-child conversational turns (CT) and child vocalizations (CV), uttered per hour. LENA also measures children’s expressive language development with the Automated Vocalization Assessment (AVA). In addition, the software identifies the characteristics of the audio environment, which is measured in percentage of silence, electronic sounds (TV, IPad), meaningful language (spoken language presented on close distance to the key child) and distant language (spoken language on distance or overlap of speech). The recordings are usually done during a whole day, in all-day recordings for about 12-16 hours.

The LENA system has three main purposes. The first one is to evaluate the listening and language development of children in their everyday environment. Second, LENA results can demonstrate the importance of early language input for parents by tracking the amount of talk and interaction between i.e. parents and their children [3]. Last, this system is used with a purpose of contributing to the development of family-centered intervention programs aiming to enhancing parent-child daily close interaction.

1.2. Previous LENA studies

A number of studies have focused on validating the LENA system to other languages besides AE, i.e. Spanish, French, Italian, Vietnamese, Korean, Chinese, and Swedish [2, 3, 4, 6, 8, 14, 15, 17]. A common concern among these scholars was whether this automated, algorithm-driven system was sensitive to differences in geographically, linguistically and culturally diverse environments. For this reason, it was argued the LENA system is not language dependent because it measures speech segmentation of the audio stream by identifying the sound sources [8].

The existing validation studies tested the accuracy of the LENA system on three measures, namely the number of AW, CV and CT. A correlational analysis between the automated and the human counts was conducted on each of these studies. In the French study, Canault et al. [3] observed a significant correlation for AW (r_s=.64, $p< .001$) and CV ($r_s = .71$, $p< .001$). A strong correlation in CT ($r= .72$, $p< .001$) and AWC ($r= .73$, $p< .001$) was found in the validation study for Chinese [6]. Ganek & Eriks-Brophy [6] validated the LENA system for Vietnamese. Statistical analysis showed a strong correlation in CT ($r_s (18) = .70$, $p<.001$) and no significant difference between the human and the automated counts ($U= 143$, $p= .12$).

A pilot study conducted by Pae et al. [15] verified the validity of the LENA system for Korean. LENA and human estimates on AW and CV were significantly correlated at baseline ($r= .72$, $p= <.001$ and $r= .67$, $p= .001$, respectively). The purpose of the pilot study conducted by Schwarz et al. [17] was to evaluate the reliability of the LENA system for Swedish. Pearson's correlations coefficient indicated high interrater reliability for AW ($r= .95$, $p< .01$)

and moderate correlation with LENA AW ($r = .67$, $p < .05$). These findings suggested that the reliability of the data would strengthen with a greater volume of data. For this reason, Canault et al. [3] and Ganek & Eriks-Brophy [6] suggested that no large samples were needed for validating the LENA system based on measures of AW, CV, and CT.

Other relevant results were also observed in the previous validation studies of the LENA system to other languages than AE. Gilkerson et al. [8] observed that the LENA system sometimes mixed up the voice of the mothers with the key child. This was mainly explained by the rise in pitch associated with motherese voice, although the system was sensitive enough in identifying adult and child voice patterns. Contrary to the French validation study [3], noise-related factors such as overlapping speech, whining noises, and noise in the environment did affect the LENA automated counts both on the Vietnamese and on the Korean study [6, 15].

1.3. The LENA^{tm} system in clinical settings

Two validating studies investigated the feasibility of the LENA system in Italian and Spanish-speaking households of children with HI [2, 4]. Da Prato [4] compared the listening and language environment in Italian-speaking households of children with NH and in children with HI. The analysis of the LENA 12-projections on AW, CV, and CT indicated an association between hearing and linguistic stimulation measured with LENA and the children's spoken language development [4]. Her results were in line with similar results for American children in a comparative study by Aragon and Yoshinaga-Itano [2].

Aragon and Yoshinaga-Itano [2] compared the LENA results for children in English-speaking households and in a cohort of children from Spanish-speaking households with children who either had HI or who were NH (four groups; English-speaking with HI, English-speaking with NH, Spanish-speaking with HI and Spanish-speaking with NH). Research results indicated a relationship between the HI and NH groups, regardless of their linguistic background. As a matter of fact, all children with HI were more exposed to more AW than the English- and Spanish-speaking controls. The number of CT for children with HI was also comparable to the results for English-speaking controls with NH. However, Spanish-speaking children with HI produced fewer vocalizations than the Spanish-speaking controls with NH. Aragon and Yoshinaga-Itano [2] concluded that children with HI need a higher amount of language input to develop spoken language levels comparable to NH peers.

LENA results (CV, AW, and CT measures) has previously been associated to the socio-economic status level (SES) of families [2, 14, 18, 20, 21]. It has also been suggested that an increased amount of parental-directed speech to infants of families of lower SES level could boost the children's e.g. vocabulary outcomes and real-time language processing skills [18]. It is important to have a cohort representative of the whole population in order to achieve more valid results. In the Swedish pre-validation study, there were 25 % of the parents (aged 25-44) who hold a high school diploma whereas the distribution based on the Census 2012 was 52.5% in the sample [14].

1.4. Children with hearing impairment in Brazil

Brazilian National Health Research [16] has estimated that 0.2% of the population are born deaf. In addition, an unknown number of children acquire hearing loss early in life. For this reason, the early diagnose of HI in Brazilian infants is of paramount importance. Due to the implementation of the Federal Law # 12,303 of August 2010, it is now possible to screen Brazilian children for HI after birth. The text of this law demanded that every hospital and maternity clinic should offer the otoacoustic emissions test (OAE) to every family of a newborn. The rehabilitation services is provided by the public health services through the Neonatal Auditory Screening Program. Although individuals with severe levels of HI represented 20.6% of the population, only 8.4% of the total population with HI received rehabilitation services [16].

The Early Hearing Detection and Intervention (EHDI) guidelines suggest that children should have their hearing screening by 1 month of age, diagnosis of hearing loss by 3 months and intervention actions no later than at 6 months at age [11, 13]. The Neonatal Auditory Screening Program in Sao Paulo, Brazil, aim to follow these guidelines. Following the EHDI guidelines would potentially minimize the impact of the HI on children's language development [5, 19, 22]. If the LENA system would be validated in BP and implemented in the clinical settings it could be a useful tool for more objective evaluation of the early language and audio environment of families to children with HI. In addition, LENA recordings could be used to support these families with new strategies for stimulating their child's listening and language development from a very early age. Thereby, in combination with hearing technology it could minimize the impact of the hearing impairment on their early and later spoken language outcomes.

1.5. Research hypothesis and objectives

Based on the evidence from previous research, it was hypothesized in this study that (1) the LENA system would be sensitive to measure speech segments of BP regardless of diverse linguistic and cultural characteristics observed among of Brazilian families [8], and (2) that children with HI need more child-directed language input than age-matched peers with NH in order to achieve better language abilities.

The objectives of this study were threefold. The first objective was to pre-validate the LENA system to BP by investigating the listening and language environment of children with NH with focus on the number of AW and CV. The second aim was to compare the language and audio environment of children with NH in comparison to children with HI. The third objective was to correlate the environmental variables to children's general language performance, measured with a parent questionnaire and an automatic assessment of speech ability. Demographic factors like the level of parental education was also examined in relation to the children's language abilities.

2. Materials and Methods

This research project is part of a larger research project that evaluates the listening and language environment in children with HI in different linguistic contexts, which is called Words Make a Difference (Karolinska Institutet & University of Oslo). The present research was developed in cooperation with the University of Oslo, Norway, and the Santa Casa Hospital-SP, Brazil.

2.1. Participants

The inclusion criteria for participation was that all children must be a monolingual speaker of BP. The exclusion criteria was that none of the children had a known neurodevelopmental diagnose or multi-handicap. The families of children with HI were recruited from the case-load and network from two different centers for Speech-Language-Pathology (SLP) and Audiology in São Paulo, Brazil, namely the Santa Casa Hospital and the Centro Especializado Paulista. The families of children with NH were recruited from the network of professionals working at the centers. Twelve families were asked to participate and all of them volunteered in participating in this study, resulting in fifteen children (including two twin pairs and two brothers). All families lived either in the city of São Paulo or in the Metro area. They were all monolingual speakers of BP. The sample was relatively homogeneous regarding their SES level (parent education level). Seventy-nine percent of the participating parents had a college degree.

There were seven children with NH aged between 11 to 29-months (M= 21 mo, SD= 6 mo) who participated in the study (table 1). Among these children, there were two sets of twins, being one set of twin boys and one set of twin girls. Another eight children with moderate to profound HI, aged between 20 to 43-month-old (M= 34 mo, SD=10 mo) comprised the clinical group (table 2). The causes of HI varied. In the sample, there was one case with congenital CMV infection, two cases with genetic causes (siblings), one who were preterm, one case of Waardenburg syndrome, and two cases of unknown cause. Due to diverse causes of HI, only two of these children were identified as HI at birth, but all of them had been fitted with hearing technology at the time of data collection (one CIs, four HA+CI, and one HAs). Their hearing age ranged from 4 to 34-months (M= 17 mo, SD= 11 mo). Brazilian Portuguese was the primary language of communication for both groups (NH and HI). However, two of the children with HI also knew and used some Brazilian sign language.

At the time of the recording, one family faced some difficulties in handling the Digital Language Processor (DLP), a recording device. Consequently, only two hours of their day were recorded. Due to incomplete recording, that child with HI had to be excluded from the research after the recording had been processed by the LENA software.

Table 18: Table of demographics, children with NH (n= 7)

Table of demographics			
ID	Gender	Age (Months)	Parental education
C2	F	25	College
C6	M	21	College
C7	M	11	College
C9	F	21	College
C11	F	19	College
C12	F	19	College
C15	M	29	College
Mean		21	
Median		21	
SD		6	
Min-max		11-29	

Note: Child age as of the recording day (28-31 August 2017). The level of parental education is a combination of both mother and father level of education. As of the control group, all of the participating parents had a college degree.

Table 19: Table of demographics, children with HI (n= 7)

Table of demographics							
ID	Gender	Age (Months)	Hearing Age	Hearing Technology	Degree of HL	Cause of HL	Parental education
C1	M	37	8	CI	Profound	CMV infection	College
C3	F	43	27	HA+CI	Profound	Unknown	High School
C4	M	38	34	HA	Moderate	Preterm	College
C5	F	41	23		Moderate	Genetic	College
C8	F	42	12	HA+CI	Profound	Unknown	College
C1 0	M	19	13		Moderate	Genetic	College
C1 3	M	20	4	HA+CI	Profound	Waadenburg syndrome	High School
Mean		34	17				
Median		38	13				
SD		10	11				
Min-max		19-43	4-34				

Note: Child age as of the recording day (28-31 August 2017). The level of parental education is a combination of both mother and father level of education. As of the clinical group, the participating parents had either a combination of college degree or a combination of high school diploma.

2.2. LENA technology

The LENA system consist of an advanced software that is used for analyzing linguistic information (PC compatible), and of special clothing (vests or t-shirts) that are used for placement of the DLP. The DLP is a small recording device, which is able to capture up to 16 hours of a child's natural audio and language environment. The LENA software analyzes the audio file and organizes the data into different composite views. The data was sorted by the number of CV, AW, CT, and AE characteristics, such as the amount of exposure to silence, noise, screen time (TV, Ipad), meaningful speech (speech presented close to the key child) and distant speech (speech heard from longer distances from the key child or overlapping speech) (www.lena.org). The AVA is an automatic measurement of the children's expressive language ability (type of consonant and vowel use) that is screened and compared with American norms (0-48 months) [12].

In addition to the LENA recording, the participating families were asked to complete the translated developmental snapshot (DevSnap) (from AE to BP), the Words Make a Difference (WMD) demographic background form and a LENA activity log (diary from the recording day). The DevSnap was developed as part of the LENA method and is a parental checklist designed for assessing children's general language abilities at the time of recording [12]. It measures the development of children up to 36 months of age. The WMD is a form that yields demographic information about the child health condition and the SES level of the family. The LENA activity log allows parents to keep a record of the activities the key child was involved in throughout the recording day, hour by hour, if they were in- or outside and who was nearby in the environment together with the key child.

2.3. Data collection in Brazil

Parents were first personally informed by a local clinician before the study about the study and received written information. Thereafter a meeting with interested families was arranged at the clinic with the Brazilian test administrator (an experienced teacher and linguist, from University of Oslo). All the recruited families decided to participate in the study and were asked to sign a letter of informed consent. After that, they also completed the DevSnap and the WMD form together with the test administrator (an experienced teacher and linguist). Then, parents received a DLP and a special vest for placing the DLP in and they were taught in how to operate the recording device**.** An activity log was also given to each family. Each family was given the chance to ask questions about the study, of adding comments about their child's development, and of practicing using the DLP. The families were informed that they could withdraw from the study at any time and that their data would be deleted if they already had done the recording.

The recordings were completed on the next-coming weekend after the meeting with the parents. The participating families were requested to follow their regular routine during the day. The key child had the DLP placed in the pocket of the vest designed by the LENA Foundation. Parents were instructed not to pause the recording, but to place the vest close to the child during bath and nap time. Each participant was recorded for 12 consecutive hours on average. A total of 176 hours of recordings were collected (M= 12:47, SD= 1:12, 10:53-15:14) from 14 participants. The recordings were transported to Norway and then transferred and analyzed at a dedicated computer with LENA Pro, at the Oslo Assessment Intervention & Learning Lab (OAILL), Department of Special Needs Education, University of Oslo, Norway.

2.4. Pre-validating study

A pre-validating study was initially conducted with the objective of testing the reliability of the LENA system in BP by comparing the computer-generated estimates to the human counts. For this reason, a 15-minute sample of the recording for each child with NH (n=7). The disclosure of the content in the recordings would allow the researchers to manually do blinded human transcripts of the variable counts (CV and AW) and then check them against the automated count done by the LENA software. Two linguists in BP transcribed the data following the same coding protocol for human coders of BP. The BP protocol was adapted by the main author (MF) in similar ways as the one created to conduct the LENA validation for European French [3]. The percentage of matching between human transcripts and LENA results and a correlation analysis measuring the reliability between the means of the average of the two raters and the LENA automated estimates of CV and AW.

The 15 min samples were initially selected based on the analysis of the LENA composite view (hourly). One of the authors (UL) identified the hour, when the software indicated that there were the highest numbers of CT during the day. It was then necessary to identify and select the 5-min region which had the highest CT within that hour as indicated by the LENA composite view – 5-minute. Then, the two subsequent 5-min regions were selected, regardless of the number of CT, in similar way as in the LENA norm study (AE) [7].

2.5. Results of the pre-validating study

The average agreement between raters was measured and compared to LENA automated estimates for AW (84%) and CV (66%). Pearson's correlation analysis generated strong, positive correlation between these variables for both AW and CV (r= .936 and r= .932, n= 7, p= .002). Overall, there was a strong, positive correlation between the LENA automated estimates and the human counts. Increases in the sample size would generate a stronger correlation between the automated and the human counts.

Table 20: Interrater agreement based on AW and CV, control group (n= 7)

Interrater percentage of matching										
ID	Gender	Chronological age	AW				CV			
			Human average	LENA estimates	Words Difference [a]	Matching %	Human average	LENA estimates	Words Difference [a]	Matching %
C2	F	25	596	655	**-59**	91	342	150	**192**	44
C6	M	21	624	700	**-76**	89	142	58	**84**	41
C7	M	11	1033	1021	12	99	46	49	-3	94
C9	M	21	835	1054	**-219**	79	81	50	31	62
C11	F	19	341	372	**-31**	92	89	86	**3**	97
C12	F	19	486	640	**-154**	76	45	67	-22	67
C15	M	29	349	557	**-208**	63	399	237	**162**	60
M		21	610	714	**-104**	84	163	99,5	**64**	66
Min-Max		19-29	341-1033	372-1054	12-219	63-99	45-399	49-237	3-192	41-97
SD		5	254	245	83	11	146	70	78	20

Note: *Percentage of matching between the means of the human raters and the LENA estimates. Human average represents the mean counts of the manual transcriptions done by two rates. The negative results suggested that the LENA counts overestimated the human ones.*

Figure 7: Correlational analysis between child age and CV, CT, and AW (NH)

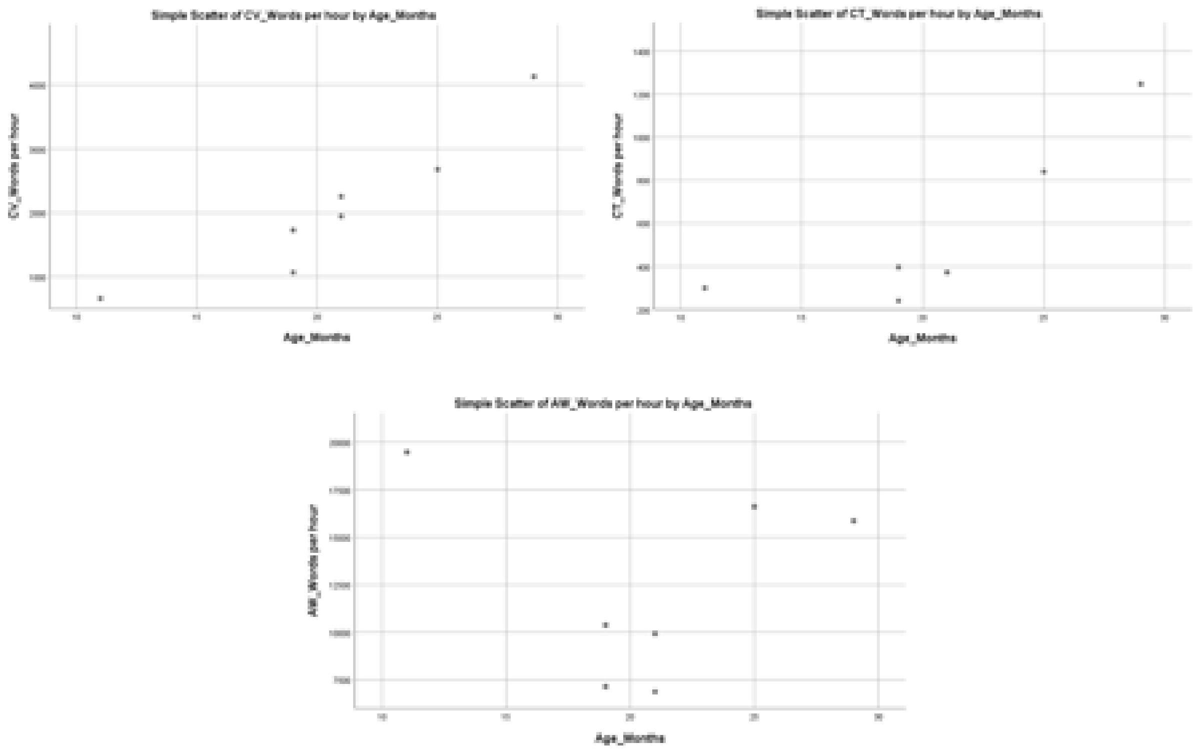


Figure 8: Correlational analysis between child age and CV, CT, and AW (NH)

2.6. Statistical analysis

An analysis of the language environment of children with HI in comparison to the group of children with NH was conducted. This analysis was based on the estimates the LENA system provided for the variables presented. The Mann-Whitney U nonparametric test was used to compare the medians between these two groups with the purpose to identify any significant differences between them.

Paired sample t-test was used for calculating the possible differences in the amount of exposure to female (FAN) and male (MAN) words to which children were exposed during the recording. A Spearman’s rank analysis investigated if an increase in numbers of LENA results (CV, CT and AW) correlated with an increase in child age (chronological, hearing, and developmental).

2.7. Ethical issues that were discussed and taken into consideration

This research received the approval from the Committee on Ethics in Research of the Santa Casa Hospital in São Paulo[8] (nbr 2.216.543) and the Norwegian Regional Committees for Medical and Health Research Ethics[9] (nbr 2016/2235) prior to its commence. After we had received the approval from both committees, families were recruited and informed about the purpose of this study and the terms of taking part of it. These families were aware that their participation was voluntary and that they could withdraw from participating in the research study, at any time.

Those families who chose to take part in the study were also asked to sign an informed consent. In the consent, it was guaranteed to decode personal information and to keep the code list separated from the data files. It was guaranteed that all the collected data, including the recordings, would be deleted upon the final completion of the study or upon their request. Thus, protecting their personal data, integrity, and privacy.

After the finalizing of the LENA analyzes, the participating families received one-to-one feedback from the researchers in the local clinics in Sao Paulo. The feedback regarded the individual patterns of their child's language and listening environment. It was also given suggestions on how parents could stimulate their child's listening and language environment and development even more.

3. Results

3.1. Comparative pilot study

3.1.1. Language environment

The total recording time of the participating children varied between 10 hours 53 minutes and 15 hours 14 minutes (M= 12:47). For this reason, the total number of CV, CT, and AW needed to be evenly distributed within the period of 12 hours, as in Nilsson and Olsson (2015). Descriptive results for the total recording time, chronological age of each child, and

[8] Comitê de Ética em Pesquisa em Seres Humanos – Santa Casa Hospital, São Paulo (http://www.santacasasp.org.br/portal/site/administracao/gerencias/comissoesmedicas/pub/2579/comite-de-etica-em-pesquisa-em-seres-humanos)

[9] Regionale Komiteer for Medisinsk og Helsefaglig Forskningsetikk (https://helseforskning.etikkom.no/)

the number of CV, CT, AW, MAN and FAN words measured by the LENA system is presented in table 4 and 5.

Table 21: The LENA estimates for CV, CT, AW, FAN and MAN words, control group (n= 7)

ID/NH	Total recording time	C. age	CV 12h	CT 12h	AW 12h	FAN Word	MAN Word
C2	12:56	25	2676	840	16608	16331	4374
C6	15:14	21	2256	372	9936	11080	1537
C7	12:58	11	660	300	19476	14658	**6398**
C9	13:01	21	1944	372	6876	9832	2407
C11	13:00	19	1068	240	7152	5861	1889
C12	12:49	19	1728	396	10392	8723	2380
C15	11:43	29	4128	1248	15864	**9500**	**6903**
M	13:05	21	2066	538	12329	10855	3698
Min-Max	11:43-15:14	11-29	660-4128	240-1248	6876-19476	5861-16331	1537-6903
SD	01:02	6	1137	369	4965	3579	2212

Note: the total number of CV, CT, and AW estimated by the LENA system as recorded were averaged to the total of 12 hours [14].

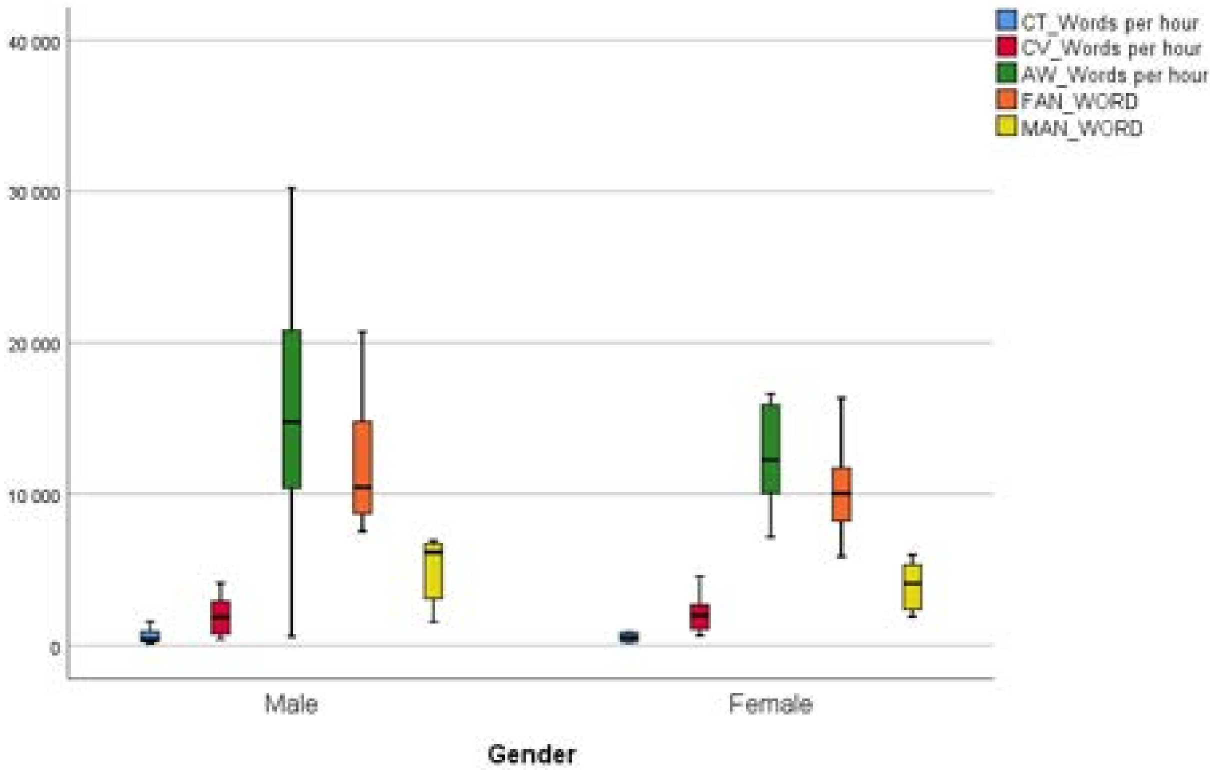
Table 22: Total number of CV, CT, and AW divided by 12 hours for each child with HI (n= 7)

ID/HI	Total recording time	C. age	CV 12h	CT 12h	AW 12h	FAN Word	MAN Word
C1	12:27	37	384	144	13668	**7541**	**6644**
C3	11:38	43	2244	648	15888	11348	**5967**
C4	14:29	38	4565	852	14100	11710	**5311**
C5	10:53	41	3528	1548	30252	**20733**	**6709**
C8	13:23	42	636	180	10068	8224	3820
C10	11:03	19	1752	564	22176	14926	3741
C13	13:35	20	852	204	10848	**7898**	**5899**
M	12:29	34	1994	591	16714	11769	5442
Min-Max	10:53-14:29	19-43	384-4565	144-1548	10068-30252	7541-20733	3741-6709
SD	1:22	10	1572	501	7170	4759	1230

Results from a Mann-Whitney U test showed no significant differences between groups regarding the characteristics of their language environment (Cf. table 4 and 5). This mean that the amount of CV (Md= 1848, U=21, *p*= .71), CT (Md= 384, U= 23, *p*= .90), AW (Md= 13884, U= 34, *p*= .25), FAN (Md= 10456, U=26, *p*= .90) and MAN (Md= 4843, U=35, *p*= .20) words were similar in the two groups, regardless of the children's hearing condition.

No significant differences between male and female participants were found in the medians for CV (Md= 1848, U= 26, *p*= .86), CT (Md= 384, U= 26, *p*= .86), AW (Md= 13884, U= 19, *p*= .57), FAN (Md= 10456, U=21, *p*= .75), and MAN (Md= 4843, U=15, *p*= .28), regardless of their hearing condition (n= 14).

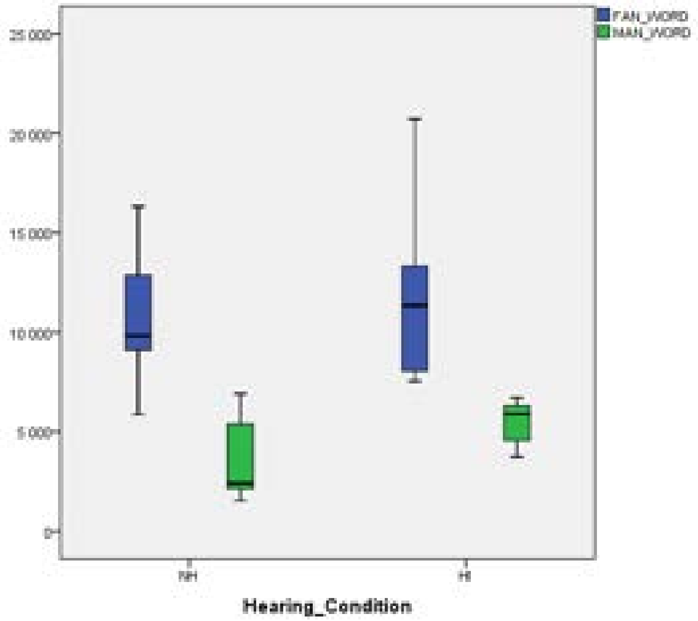
Figure 9: Comparative analysis of the language environment of male and female participants regardless of their hearing condition (n= 14)



Note: Distribution of the CV, CT, AW, FAN, and MAN words by child gender (8 male and 6 female). No significant difference was observed between male and female participants among these variables.

Paired samples tests suggested that children with NH were significantly more exposed to FAN words (M=10855, SD= 3579) than to MAN words (M=3968, SD= 2212); *t* (6) = 5.9, *p*= .001. Significant difference in means was also observed among children with HI. They were also significantly more exposed to FAN words (M= 11769, SD= 4759) than to MAN words (M=5442, SD= 1230); *t* (6) = 3.5, *p*=.013 **(Cf. figure XX, p. XX)**. Such results confirmed the hypothesis that mothers or female caregivers talk more close to their child than fathers or male caregivers do [8].

Figure 10: Comparative analysis between female and male voice counts directed to children with NH (n=7) and to children with HI (n= 7)



Note: No significant difference was observed between subgroups regarding their exposure to MAN and FAN words. However, significant difference was observed on the number of FAN words were significantly higher than the number of MAN words directed to children, regardless of their hearing condition.

3.1.2. LENA language assessment tools

Tables # and # show the results for the DevSnap and AVA scores of the 14 participating children (NH=7 and HI=7). Great variability was observed on the level of language ability among children regardless of their hearing condition. Among the participants with NH, two of them were reported to be at-risk of experiencing language delay both on the results on DevSnap and on AVA scores (C7, C11, and C12). Furthermore, one of the participating children could not have the developmental age calculated due to higher chronological age than the DevSnap norms for AE (C15).

The group of children with HI was heterogeneous and varied with regards to their observed chronological-, hearing-, and developmental ages. Child four (C4) with HI could not have her developmental age calculated, because her developmental performance was estimated to be above of a 36-month old child. Due to the advanced age of three children with HI, the DevSnap standard score and its percentile could neither be calculated (C3, C4, and C8). Among the participants with HI, three children were reported as at-risk of having language delays according to results from AVA and DevSnap, namely C1, C8, and C13.

A Mann-Whitney U test was then conducted for comparing the results of the language assessment tools between the two groups of participants (NH and HI). The results suggested that there was no statistical significant differences in the two groups regarding chronological age (Md= 23 mo, U= 40, *p*= .53), developmental age (Md= 16 mo, U= 28, *p*= .71), AVA standard score (Md= 91, U= 17, *p*= .38), or DevSnap (Md= 83, U= 11, *p*= .65). Furthermore, no significant difference between male and female participants in chronological age (Md= 23 mo, U= 31, *p*= .41), developmental age (Md= 16 mo, U= 23, *p*= .85), AVA standard score (Md= 91, U= 39, *p*= .59), and DevSnap (Md= 83, U= 9, *p*= .63), regardless of the children's hearing condition.

Table 23: Language assessment tests, children with NH (n= 7)

ID/NH	Gender	Chrono. age	DS dev. age	DS std. score	DS %	AVA std. score	AVA %
C2	F	25	33	116	86	122	92
C6	M	21	16	83	12	84	14
C7**	M	11	11	109	73	71	2
C9	M	21	16	80	8	90	25
C11**	F	19	11	74	4	92	28
C12**	F	19	11	74	4	114	82
C15	M	29	36+	123	93	112	78
M		21	16	94	41	98	46
Min-Max		11-29	11-36+	74-123	4-93	71-122	2-92
SD		6	9	21	42	18	37

Note: The developmental age of C15 could not be calculated, for his performance on the DevSnap was equal or above 36 months, which is the age limit the DevSnap is able to calculate.

Table 24: Children with HI: CDI, DevSnap, and AVA scores. *Children at risk of language delay. **n=4.

ID/HI	**Gender**	**C. age**	**H. age**	**Age fitting HA**	**DS dev. age**	**DS std. Score****	**AVA std. score**	**CDI**
C1*	M	37	8	29	12	<65	71	2
C3	F	43	27	16	32	N/A	92	223
C4	F	38	34	4	36+	N/A	114	459
C5	M	41	23	18	30	87	101	268
C8*	F	42	12	30	6	N/A	78	8
C10	M	19	13	6	17	93	87	54
C13*	M	20	4	16	14	81	68	3
M		34	17		19	82	34	145
Min-Max		19-43	4-34		6-36+	<65-93	68-114	2-459
SD		10	11		10	12	5	177

Note: The DevSnap is sensitive up to the expressive and receptive language of children up to 36 months. The developmental age of C4 was estimated over 36 months. For this reason, it could not be calculated. The DevSnap standard score was equal or below <65, which is the minimum calculated by the DevSnap. The DevSnap standard score could not be calculated for C3, C4, and C8 due to their chronological age be above 36 months.

3.1.3. Audio environment

Tables 8 and 9 show the descriptive statistics and the estimates of the AE variables provided in percentage for each group of participants.

Table 25: Audio environment, control group (n= 7)

ID/NH	**Gender**	**Age**	**Silence**	**Noise**	**TV**		**Distant**	**Meaningful**
2	F	25	50	3	4		22	21
6	M	21	42	4	1		34	19
7	M	11	29	3	2		48	18
9	M	21	32	3	2		41	22
11	F	19	54	3	11		19	13
12	F	19	46	2	18		18	16
15	M	29	55	2	1		19	23
M			44	3	6		29	19
Min-max			29-55	2-4	1-18		18-48	13-23
Range			26	2	17		30	10
SD			10	1	7		12	4
Median			46	3	2		22	19

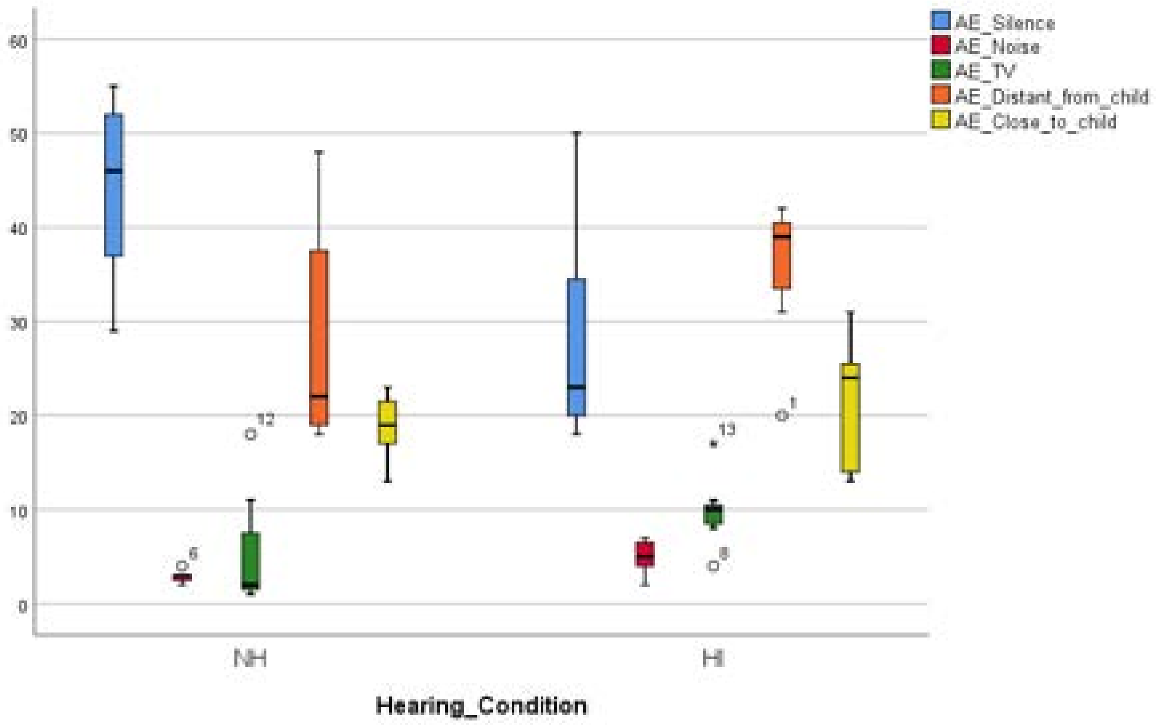
Note: The audio environment in children with *NH was* measured in %.

Table 26: Audio environment – Clinical group (n= 7)

ID/HI	Gender	Age	Silence	Noise	TV	Distant	Meaningful
1	M	37	50	7	9	20	14
3	F	43	23	4	8	41	24
4	F	38	20	2	11	40	27
5	M	41	18	5	10	36	31
8	F	42	46	6	4	31	13
10	M	19	20	4	10	42	24
13	M	20	23	7	17	39	14
M			29	5	10	36	21
Min-max			18-50	2-7	4-17	20-42	13-31
Range			32	5	13	22	18
SD			13	2	4	8	7
Median			23	5	10	39	24

Table 27: Audio environment in children with HI, measured in %.

Figure 11: Characteristics of the audio environment of children with NH in comparison to the audio environment of children with HI.



A Mann-Whitney comparative analysis of the audio environment of the participating children have suggested that children in both groups were exposed to a similar amount of; screen time (TV/radio) (Md= 9%, U= 36, *p*= .17), exposure to language spoken close to the child (meaningful listening) (Md= 20%, U= 31, *p*= .46) and distance listening (Md= 35%, U= 34, *p*= .26). However, the listening environment differed between groups (NH vs HI) in relation to the time of silence exposure (Md= 37%, U= 8, *p*= .04) and noise in the environment (Md= 4%, U= 42, *p*= .03) as shown in **figure XX (p. XX)** with more silence and less noise exposure in the NH group.

Table 28: Gender differences in the audio environment of the participating children (n= 14).

Mann-Whitney U test			
	Md	U	p-value
AE_Close to	20%	20	.57
AE_distant from	35%	15	.28
AE_TV/radio	9%	34	.23
AE_noise	4%	15	.28
AE_silence	37%	30	.49

3.2. Correlation study

The correlation analysis was organized in three parts. First, it analyzed the correlation variables based on the data from the participants with NH, a second analysis considered only the data of the children with HI, and a third analysis consisted of the combined data of the two groups. The focus of this analysis was on how well child age (chronological, developmental, and hearing) correlated with the language environmental variables, and with the results of the language assessment tools.

Normal Hearing (n= 7)

Children's chronological age strongly correlated with number of CV (r_s= .98, p= .04), and with the amount of CT (r_s= .79, p= .04), and to the amount of language spoken close to the child (r_s= .82, p= .02). Chronological age strongly correlated with child developmental age (r_s= .97, p= .00). A strong, positive correlation was found between children's developmental age and DevSnap standard score (r_s= .77, p= .04). No correlation was found between child age and the amount of AW, FAN, and MAN words recorded. No significant results were observed between the investigated variables and the SES of the participating families.

Hearing impaired (n= 7)

No correlation was found between the chronological age and any of variables related to the language environment. Children hearing age strongly correlated with the number of CV (r_s= .86, p= .01), and with the number of CT (r_s= .79, p= .04). A strong, positive correlation was found between child developmental age and the amount of language spoken close to the child (r_s= .86, p= .01), with the number of CV (r_s= .93, p= .00), and with the number of CT (r_s= .86, p= .01). A very strong correlation was observed between hearing and developmental age (r_s=

.86, p= .01), between hearing age with AVA standard score (r_s= .96, p= .00), and between developmental age and AVA (r_s= .82, p= .02).

No correlation was found between child age (chronological, developmental, and hearing age) and the number of AW, FAN, and MAN words recorded. Similarly, no correlation was found between child age (chronological, hearing, and developmental) with DevSnap standard score, and between chronological age and AVA standard score. No significant results were observed between the investigated variables and the SES of the participating families.

Whole cohort (n= 14)

A strong, positive correlation was found between children's developmental age and the amount of language spoken close to them (r_s= .83, p= .00), with the number of CV (r_s= .88, p= .00), with the number of CT (r_s= .83, p= .00). A positive, moderate correlation was found between children developmental age and the number of FAN words they heard (r_s= .56, p= .04). A moderate correlation was observed between child developmental age and AVA (r_s= .57, p= .04) and DevSnap (r_s= .68, p= .02).

No correlation was found between the chronological age and any of variables related to the language environment as for whole cohort (n= 14). The correlation analysis between child chronological age and AVA, and DevSnap standard score yielded no significant results. Taking in the whole cohort, the correlational analysis between the level of parental education and all the other variables did not yield significant results.

4. Discussion

The objective of the present pilot study was (1) to pre-validate LENA^{TM} in a Brazilian context, (2) to explore the listening and language environment in Brazilian toddlers with NH, and (3) to compared it to children with different types and degrees of hearing impairment, and in in relation to language abilities.

4.1. Pre-validation of LENA^{TM} in a Brazilian Portuguese context

In the present pre-validation of LENA, it was investigated whether AW and CV could be assessed in BP by using the results from the LENA system and compare with human transcripts. Reliability tests showed a strong degree of agreement between the LENA system's automated estimates and the means of the two blinded, human raters' counts, and with a high interrater reliability. The current research provided reasonably accurate estimates for AW and CV for the selected recordings and sample of children. Therefore the devised coding protocol for BP was deemed valid and could preferable be used in a prospective, larger validation study of the same LENA variables (AW and CV) in a BP context with more subjects, and with a higher variability in ages and variety in SES level.

Despite the strong, positive correlation between human and LENA estimates, the differences in AW and CV counts should be viewed at with caution. LENA tended to overestimate human AW and to underestimate CV. Taking in consideration that LENA relies on automated signal-processing algorithms and human transcribers rely on intelligible speech signal for judgment, differences between the automated and the human counts might indicate some degree of labeling error produced [8]. According to Canault et al. [3], difficulties in labeling speech productions might be related to differences between human and automated forms of assessing speech. Human coders relied on speech intelligibility for making qualitative perceptual judgments of the data whilst LENA relied on automated signal processing algorithms [3]. The same pattern was observed in other pilot studies [3, 4, 6, 8, 15, 17].

4.2. Comparative pilot study

No significant difference was observed on chronological and developmental age between the children in the control and in the clinical groups. It was observed that children's performance on the language assessment tests (DevSnap, CDI, and AVA) varied greatly within groups regardless of children's hearing condition.

The age of fitting HA/CI accounted for children with HI level language performance. Those who were fitted with HA/CI at younger age displayed better language skills than their peers. This result was in line with Ambrose et al. **(2015)** who observed that the amount linguistic input provided by parents to children with HI increases as child age. As of the performance of the participants in the control group, the varied level of language skills was associated with the very young age of three of the participants (11 to 19 months). Investigating subgroups differences in language skills and language environment was not within the scope of this study. Yet, it should be further investigated in future studies.

Children expressive and receptive language abilities were assessed with the DevSnap and AVA [7]. First, the DevSnap score and percentile for three children with HI could not be calculated because they were older than 36 months. Consequently, the analysis of group results on DevSnap performance relied on the data of only four of the seven children with HI.

AVA score results indicated that one child with NH and three children with HI were believed to be experiencing a possible expressive language delay.

At the follow-up occasion with parents (when they were informed about their individual child's LENA results) it was obvious that the majority of the children in the cohort used pacifier on a regular and frequent basis. This was not formally investigated in parent questionnaires, but could potentially contribute to the somewhat unexpected variation in expressive ability in some of the participating children with low AVA scores (one child with NH and one with HI).

Interestingly, it was observed among the three children with HI that all of them had profound HI and that they were exposed to less AW per 12 hours, than children whose language development was on track. These results suggest that children expressive language was dissociated to the level of HI and associated with the amount of AW they were exposed to. In other words, Brazilian children with moderate HI tended to have better expressive language than those with profound HI in the current study.

4.3. The SES level of the participating families

Evidence from a previous study has shown a correlation between children expressive language and family SES level [8]. Research results suggested that children from low SES families received fewer stimuli for developing their language skills whilst children from higher SES families received more support for developing language [2, 14, 20, 21].

In this study, nine out of eleven participating families came from middle to high SES background. The level of parental education was very high (86% of them hold a college degree). It resulted in a rather homogeneous cohort despite the diverse language environment of these families. However, no correlation was found between language environment and the level of parental education/SES.

It was observed that both children's language performance and adult input varied greatly between both groups of participants, regardless of the level of parental education. Consequently, the profile of language profile of children from low SES families is still unknown. A similar pattern was observed in Pae et al. [15]. Thus, future study should further investigate the SES of the participating families in relation to their children language skills.

4.4. Gender differences

Regarding gender differences, the performance of male and female children in language assessment tests was alike despite their hearing condition. Similarly, the characteristics of the language and listening environment of male and female children were comparable. It suggests that Brazilian parents provided the same language and developmental opportunities to their male and female offspring.

A statistical significant gender-related difference was found between the amount of FAN and MAN words in this study. This result indicated that mothers or female caregivers talked significantly more to their children than fathers or male caregivers, regardless of children hearing condition. Future studies should be done with a larger cohort with focus on subgroup differences in relation to their exposure to male vs. female adult-child directed speech.

As observed in this cohort, women had a major role in stimulating children's language development regardless of the children's hearing condition. These findings highlighted the need of fathers having more verbal interactions with their children. Fathers' involvement in childcare could support not only the child's language development, but it would also strengthen the father-child relationship. Such result was in line with the data from the latest demographic census in Brazil [9], which indicated that women still have major responsibility for family/childcare affairs.

4.5. Audio environment

Regarding the characteristics of the audio environment, evidence from statistical analysis suggested that there was no difference between the two groups as for children's exposure to meaningful language, distant language, and TV/radio. However, their environment differed as for their exposure to noise and silence in the environment. Children with NH were more exposed to a silent environment whereas those with HI were more exposed to noise in the environment. Their longer exposure to silence in the environment is explained by their young age. Those children were reported to take naps in the afternoon and going to bed early in the evening.

4.6. Correlation study

Evidence from previous studies has suggested that the amount of interaction and the number adult-child directed words would be predictors of children's language skills in relation to their age [8, 14]. However, in the present study it was observed that child age was in line with the exposure to linguistic input close to the child, parent-child interaction, and CV.

Evidence from research suggested that increase in child age leads to increase on the exposure to linguistic input, on the number of involvement in parent-child interaction, and consequently on the number of vocalizations [6, 14]. The impact of exposure to linguistic input and parent-child interaction was observed on the results of the language assessment tools. Therefore, it suggested that the amount of linguistic input directed to children stimulated them to speak more, which consequently impact on their performance on assessment tests. The more caregivers interact with their child; the better will be the child's language outcomes in relation to her age [9, 14].

As for the cohort of children with HI, it was observed that oral language development only takes place after the fitting of HA/CI. Due to the advanced age of fitting HA/CI, aspects of their language environment and development did not correlate with their chronological age. Such result suggests that measures should be taken to urge the early diagnosis and treatment of HI following the 1-3-6 guidelines [13] in Brazilian context.

The correlational analysis combining the data of the whole cohort suggested that children's chronological age did not correlate with any of the examined factors. It was here suggested that these factors were (1) the large age range of the participating children (11-43 mo), (2) their diverse environment, and (3) varied levels of language development. Therefore, child developmental age was considered as a more reliable measure to investigate the aspects of the language environment and development in such diverse scenario.

5. Conclusion

The findings of this research study suggests that the LENA system is a promising tool to be used also in the Brazilian cultural settings. LENA results demonstrated the importance of the active participation of parents in stimulating their young children's language acquisition and auditory stimulation soon after birth, especially in cases of children with any degree of hearing loss. Future research should focus on the natural language development of Brazilian children so that the LENA normative data for BP could be established. Therefore, the LENA system could be implemented as a tool to be used in screening and habilitation settings nationwide. The implementation of the LENA system could empower Brazilian professionals with new knowledge that is needed for the evaluation of family-centered intervention programs, with focus on empowering both female and male caregivers, for promoting optimal stimulation of their child's overall language development, immediately from infancy, both in clinical groups and typical hearing children with caregivers who are poor in interactive communication.

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7. Declaration of conflicting interests

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9. References

[1] Ambrose, S. E., Walker, E. A., Unflat-Berry, L. M., Oleson, J. J., & Moeller, M. P. (2015). Quantity and quality of caregivers' linguistic input to 18-month and 3-year-old children who are hard of hearing. *Ear and hearing*, *36*(0 1), 48S.

[2] Aragon, M., & Yoshinaga-Itano, C. (2012, November). *Using Language Environment Analysis to improve outcomes for children who are deaf or hard of hearing*. In Seminars in speech and language (Vol. 33, No. 04, pp. 340-353). Thieme Medical Publishers.

[3] Canault, M., Le Normand, M. T., Foudil, S., Loundon, N., & Thai-Van, H. (2016). Reliability of the Language ENvironment Analysis system (LENA™) in European French. *Behavior research methods*, *48*(3), 1109-1124.

[4] Da Prato, I. (2016). *The application of LENA Method to a sample group of Italian children* (Master's thesis). University of Pisa, Italy.

[5] Fulcher, A., Purcell, A. A., Baker, E., & Munro, N. (2012). Listen up: children with early identified hearing loss achieve age-appropriate speech/language outcomes by 3 years-of-age. *International journal of pediatric otorhinolaryngology*, *76*(12), 1785-1794.

[6] Ganek, H. V., & Eriks-Brophy, A. (2017). A Concise Protocol for the Validation of Language ENvironment Analysis (LENA) Conversational Turn Counts in Vietnamese. *Communication Disorders Quarterly*, 1525740117705094.

[7] Gilkerson, J., Coulter, K. K., & Richards, J. A. (2009). Transcriptional Analyses of the LENA Natural Language Corpus, (September 2008), 1–11.

[8] Gilkerson, J., Zhang, Y., Xu, D., Richards, J. A., Xu, X., Jiang, F. ... & Topping, K. (2015). Evaluating Language Environment Analysis system performance for Chinese: A pilot study in Shanghai. *Journal of Speech, Language, and Hearing Research*, *58*(2), 445-452.

[9] Hart, B., & Risley, T. R. (1995). *Meaningful differences in the everyday experience of young American children*. Paul H Brookes Publishing.

[10] Instituto Brasileiro de Geografia e Estatística, Censo Demográfico 2010, from http://www.censo2010.ibge.gov.br/apps/mapa/

[11] Joint Committee on Infant Hearing. (2007). Year 2007 position statement: Principles and guidelines for early hearing detection and intervention programs. *Pediatrics*, *120*(4), 898-921.

[12] LENA Research Foundation. (2015). *User Guide LENA Pro* [Brochure]. Author.

[13] Muse, C., Harrison, J., Yoshinaga-Itano, C., Grimes, A., Brookhouser, P. E., Epstein, S., ... & Martin, P. (2013). Supplement to the JCIH 2007 position statement: Principles and guidelines for early intervention after confirmation that a child is deaf or hard of hearing. *Pediatrics*, *131*(4), e1324-e1349.

[14] Nilsson, C., & Olsson, L. (2015). LENA-En stegmätare för ord: Lyssnings-och talspråksmiljö hos en grupp svenska barn vid 18-24 månaders ålder mätt med Language Environment Analysis. Uppsala University.

[15] Pae, S., Yoon, H., Seol, A., Gilkerson, J., Richards, J. A., Ma, L., & Topping, K. (2016). Effects of feedback on parent–child language with infants and toddlers in Korea. *First Language*, *36*(6), 549-569.

[16] Pesquisa nacional de saúde: 2013 : ciclos de vida : Brasil e grandes regiões / IBGE, Coordenação de Trabalho e Rendimento. - Rio de Janeiro: IBGE, 2015.

[17] Schwarz, I. C., Botros, N., Lord, A., Marcusson, A., Tidelius, H., & Marklund, E. (2017). The LENA^{TM} system applied to Swedish: Reliability of the Adult Word Count estimate. *In:* Proceedings of the 18th Annual Conference of the International Speech Communication Association (INTERSPEECH 2017) / [ed] Marcin Wlodarczak, STockholm: The International Speech Communication Association (ISCA), 2017, p. 2088-2092, article id 1287 Conference paper (Refereed).

[18] Suskind, D. L., Leffel, K. R., Graf, E., Hernandez, M. W., Gunderson, E. A., Sapolich, S. G., . . . Levine, S. C. (2015). A parent-directed language intervention for children of low socioeconomic status: A randomized controlled pilot study. *Journal of Child Language*. Advance online publication. doi: 10.1017/S0305000915000033

[19] Wake, M., Ching, T. Y., Wirth, K., Poulakis, Z., Mensah, F. K., Gold, L., ... & Rickards, F. (2016). Population outcomes of three approaches to detection of congenital hearing loss. *Pediatrics*, *137*(1), e20151722.

[20] Weisleder, A., & Fernald, A. (2013). Talking to children matters: Early language experience strengthens processing and builds vocabulary. *Psychological science*, *24*(11), 2143-2152.

[21] Wood, C., Diehm, E. A., & Callender, M. F. (2016). An investigation of language environment analysis measures for Spanish-English bilingual preschoolers from migrant low-socioeconomic-status backgrounds. *Language, Speech, and Hearing Services in Schools*, 47(2), 123-134. doi: 10.1044/2015_LSHSS-14-0115

[22] Yoshinaga-Itano, C., Sedey, A. L., Wiggin, M., & Chung, W. (2017). *Early hearing detection and vocabulary of children with hearing loss*. Pediatrics, e20162964.