Research Article

# Analysis of Real-World Language Use in a Person With Wernicke's Aphasia

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**Purpose:** In this study, we evaluate the use of a technology called the Language ENvironment Analysis (LENA) Pro System to quantify the language of a participant with severe Wernicke's aphasia in their home environment. We aimed to characterize language use at home, particularly as it changed in response to an intensive aphasia treatment.
**Method:** The participant was trained to use a wearable recording device pre and post 30 hr of intensive aphasia treatment. LENA software was used to process the language data and to determine word counts and conversational turns and compared to manual analysis. Various communication variables were coded for all conversation samples.
**Results:** The participant operated the device independently and provided 30 hr of recordings for analysis. Posttreatment, the participant demonstrated a 78.4% increase in adult word count, a 27.5% increase in conversational turn count, an increase in the number of communication partners, and in the diversity of communication environments. There was a 26% decrease in the amount of time spent on electronics and a 140% increase in the number of instances conversing in a social setting. Manual and automated measures showed poor agreement for this particular participant.
**Conclusions:** In this study, we establish the feasibility of using LENA to collect language samples in a participant with severe Wernicke's aphasia in their home environment. Using this method, we were able to characterize and quantify language samples in multiple dimensions before and after language treatment.

Traditional standardized tests for aphasia, with their focus on impairment level approach, are used widely in clinical and research settings. These tests divide language into a series of interrelated but functionally independent modules and aim to elucidate deficits at the word or sentence level (e.g., word retrieval or syntactic formulation) that represent damage to specific brain areas directly involved in language and cognitive processing (Basso, 2010; Martin et al., 2007). Decontextualized linguistic tasks that are a part of standardized aphasia batteries are highly constrained and often fail to capture functional and psychosocial aspects of rehabilitation (Aftonomos et al., 2001; Doedens & Meteyard, 2020). There is a growing consensus that, in order to measure the real-world effectiveness of rehabilitation strategies, one must also aim to measure functional aspects of aphasia and its impact on a person's everyday life (Brady et al., 2012; Davidson et al., 2003; Doedens & Meteyard, 2020; Wallace et al., 2014). The functional-based approach addresses the use of language for communication in daily living and determines the impact of the aphasia on life participation. It takes into account that aphasia affects not only language processes; its consequences also have a significant impact on individuals' quality of life (Basso, 2010; Martin et al., 2007).

The World Health Organization (WHO) published the International Classification of Functioning, Disability and Health (ICF) framework (WHO, 2001) to describe the health and functioning of an individual with a health condition such as a stroke in a more comprehensive manner. The ICF model aims to describe health conditions in terms of an individual's body functions and structures (e.g., impaired language function resulting from aphasia) and also describes the broader impact of a stroke in terms of activity and participation (e.g., the impact of aphasia on conversational activities and life roles that involve communication). The ICF further considers the contextual factors that have an impact on an individual, such as environmental factors (e.g., communication partners) and personal factors (e.g., positive coping style; Worrall & Wallace, 2015). Living with Aphasia: Framework for Outcome Measurement (A-FROM; Kagan et al., 2008) is an adaption of the ICF into a more meaningful construct for aphasiologists. A-FROM is a conceptual guide to outcome measurement for people with

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aphasia that considers the impact of aphasia on life areas considered essential by them and their families. It includes four domains: language and related impairments, communication and language environment, participation in life situations, and personal factors (e.g., identity, attitudes, and feelings) relevant to a person with aphasia (PWA). Each of these should be kept in mind when assessing and determining the progress of a PWA.

To measure the progress of functional communication of PWA, some standardized tests have attempted to examine real-world language use in a clinical setting. Amsterdam-Nijmegen Everyday Language Test (Blomert et al., 1994), Communicative Abilities in Daily Living 2 (Holland et al., 1999), and the Scenario Test (van der Meulen et al., 2010) attempt to examine and quantify functional communication as the degree of communicative success through hypothetical simulation of possible everyday real-life situations using pictures and questions, or role-play (Doedens & Meteyard, 2020). The use of role-playing in a clinical setting, however, has been suggested to require additional cognitive demands that are often not needed in real-life situations (Doedens & Meteyard, 2020). Other observational tools, such as ASHA Functional Assessment of Communicative Skills in Adults (Frattali et al., 1995), in which clinicians, family members, or acquaintances rate the person with aphasia's functional communication, are considered to be subjective and indirect measures (van der Meulen et al., 2010). Answers provided by acquaintances and family members may be susceptible to observer biases and can also be biased by factors such as relationships with the PWA and their emotional well-being (Doedens & Meteyard, 2020; Glueckauf et al., 2003). Thus, these tests often fail to provide objective data required for systematic reporting of clinical outcomes in people with aphasia.

The home environment provides the setting for what we imagine to be the most ecologically valid type of language sample, but there are only very few reports of this work, presumably due to logistical and technological barriers. Early work by Davidson et al. (2003) compared PWA's everyday communication activities with neurotypical individuals living in the community through naturalistic observations. In this study, researchers observed participants and took field notes for 8 hr over three occasions within a week. As compared to neurotypical individuals, it was reported that PWAs engaged in limited communication activities, PWAs had fewer communication partners, and their communication activities were restricted in social situations. They also noted that PWAs are not as likely to participate in communication activities or express their opinions as healthy individuals and often limit communication activities that are important to them (Davidson et al., 2003). More recently, Brandenburg et al. (2017) explored "talk time" as a performance-based indicator of participation for 12 people with nonfluent aphasia using an app that measured the total amount of time talking in everyday environments. Though authors claim they were limited by participant numbers and the fact that most were categorized as having mild aphasia, they found that talk time was an indicator of participation but not necessarily communicative activity. The authors reiterated the point that, in addition to the severity of aphasia, multiple social and environmental factors affect the ability of a PWA to engage in everyday communication (Brandenburg et al., 2017). Talk time alone is not enough to explore these factors.

Specific analyses of discourse may be a more useful method of determining aphasia severity and, for better understanding, those areas most in need of work. Various measures, such as content units (Yorkston & Beukelman, 1980), correct information units, or (Nicholas & Brookshire, 1993), percent information unit (McNeil et al., 2001), have been developed over the years to provide more quantitative measures for discourse production. Prevalent methods of discourse elicitation tend to be carried out in a clinical setting using picture description or story retell tasks resulting in a monologue type of output (Doedens & Meteyard, 2020), thus falling short of what most would consider "natural conversation." Additionally, despite widespread use of discourse analysis in the research setting, it has yet to gain traction in clinical settings, likely due to wide variations in methodology for discourse elicitation, sample preparation, and analysis methods, which have made it impractical and inefficient for clinical purposes (Armstrong, 2000; Bryant et al., 2016; Togher, 2001).

To address some of these shortcomings, there has been an upsurge in applying qualitative research methodologies to understand the complexity of aphasia within a naturalistic context and to engage with a more authentic and naturalistic data (Damico et al., 1999). Conversational analysis is one such method, and this approach uses recordings of naturally occurring conversations. It helps capture the interactive nature of the speaker with aphasia and the conversation partner, the communicative context, and the physical environment in which the communication is made (Beeke et al., 2007; Doedens & Meteyard, 2020). Beeke et al. used video recordings of conversations at home to demonstrate ways in which language use differs significantly depending on the context. Discourse elicited from tasks that are artificial and administered in a noninteractive setting is likely to be quite different than discourse naturally occurring at home (Beeke et al., 2007, 2008). However, videotaping is likely to be obtrusive and may cause the participant to feel self-conscious, thereby affecting the naturalness of the sample (Jones et al., 2015).

In the current study, we analyze conversations of a participant with severe Wernicke's aphasia in her home. To do so, we make use of Language ENvironment Analysis (LENA; LENA Foundation) and the adapted version of the Social Environment Coding of Sound Inventory (SECSI; Mehl et al., 2006; Mehl & Pennebaker, 2003; Ramírez-Esparza et al., 2014) to code and measure the naturalistic language. We investigate the quantity and quality of the communication and language environment, the interactions between the participant and the communication partners, and personal factors (negative emotional expressions of the participant) before and after an intensive aphasia treatment.

LENA technology has been widely used to contribute to the current understanding of language use of children at home (Caskey et al., 2011; Caskey & Vohr, 2013; Gilkerson et al., 2017; Romeo et al., 2018). It has been used to investigate the association between television exposure and delayed language development (Christakis et al., 2009) and measure the impact of parent-directed language intervention in children's early language environments (Suskind et al., 2016). Its use has also provided confirmation of the Word Gap (Hart & Risley, 1995), in which it is reported that children living in professional homes were exposed to 30 million more words on average than children from homes of lower socioeconomic status during the first 4 years of life (Gilkerson et al., 2017). LENA was also used to highlight the enduring effects of economic disadvantage on language, cognitive development, and school readiness in children (Wang et al., 2017).

LENA technology has rarely been used with adults. It was used in one study to quantify the auditory and social environments experienced by adults in a retirement community (Li et al., 2014). In another study, it was used to study how hearing aids changed an adult's experience in an auditory environment (Klein et al., 2018). Both studies demonstrated the feasibility of using the LENA system to objectively characterize the real-world auditory environment in older adults. The authors found that the advantage of using the LENA system is the ability to capture large quantities of data that are capable of providing highly descriptive, objective, and noninvasive reports on the language environments in participant's daily lives (Klein et al., 2018; Li et al., 2014).

In this study, we pilot test the use of LENA with a person with severe Wernicke's aphasia. By using a combination of analysis of the transcripts collected using LENA and communication diaries, we aim to provide a fine-grained characterization of PWA's real-world communication environment before and after an intensive aphasia intervention. We designed the current study to address the following aims: (a) to determine the feasibility of collecting and then analyzing natural language occurring spontaneously within the home environment over a period of 2 days and (b) to characterize the language in the home environment and determine whether there are quantifiable changes in response to treatment.

# Method

## Participant

The participant, M. M., was a 77-year-old right-handed woman who spoke English as her native language. She had suffered a left middle cerebral artery ischemic stroke 30.5 months before enrolling in the study. She was no longer receiving regular speech and language therapy, as her performance was said to have plateaued. M. M. was an active traveler and hiker; she had completed a PhD and worked as a professor of art. She resides at home with her husband and has daily contact with her adult daughter. Administration of the Western Aphasia Battery–Revised (WAB-R; Kertesz, 2007) revealed severe fluent aphasia (Aphasia Quotient [AQ] = 31) and a resulting classification of Wernicke's aphasia. M. M. demonstrated both receptive and expressive language deficits characterized by frequent perseveration, poor awareness of errors, and frequent use of neologisms. At the outset of the study, M. M. had difficulties following simple directions and with language and gesture repetition. M. M.'s reading and writing ability exceeded her oral and verbal ability but were still extremely variable. No motor or vision deficits were noted. The participant gave informed consent to participate in the study. The study was approved by the institutional review board of the University of Connecticut.

## Standardized Language and Cognitive Assessments

Prior to treatment, pure-tone hearing and visual screening was conducted. Pretreatment assessments were administered 1 week before the start of treatment, and post therapy assessments were administered 1 week posttreatment. Standardized assessments included the WAB-R (Kertesz, 2007), the Auditory Comprehension Test for Sentences (Shewan, 1979), and Communicative Effectiveness Index (CETI; Lomas et al., 1989).

## Language Therapy

M. M. underwent 30 hr of aphasia treatment using *Schuell's Stimulation Approach*. This intervention is not the focus of this article and will not be detailed here. Interested readers are directed to a detailed chapter on this treatment type by Coelho et al. (2008). Treatment was provided for a total of 30 hr over 2 weeks (3 hr every weekday spread evenly across 10 sessions). Each session was divided into two 90-min treatment blocks with approximately 15 min of break time in between. Tasks included point-to, following directions, yes–no questions, sentence or phrase completion, and self-initiated verbal tasks.There is an inherent risk of participants being unable to tolerate intense therapeutic interventions. To reduce this risk, we calibrated the difficulty levels so that the participant could respond with 60%–80% accuracy (Brady et al., 2016). We also tried to start each treatment block with an easier task to help maintain a positive attitude.

## LENA

LENA technology quantifies language by using advanced speech identification algorithms that automatically analyze daylong audio recordings (Gilkerson et al., 2008). The LENA system includes a digital language processor (DLP), which is a small, wearable digital recorder, and it includes language analysis software that processes the audio captured by the device. The DLP records the vocalizations and language environment within an approximate 4- to 6-ft radius and collects up to 16 hr of continuous audio recording. The language analysis software uses a Gaussian mixture model approach to segment and process the audio sample. It incorporates speech recognition algorithms modified to differentiate environmental background noise from speech and speech-related sounds. It also provides an overview of statistics on the adult vocal environment and the interactive vocal exchanges. The types of data generated include adult word count (AWC; the number of adult words spoken) and conversational turn count (CTC; the number of conversational interactions; Warren et al., 2010).

**Data Collection**

During the pretreatment period, M. M. was provided with two DLPs (see Appendix A), one charger, one set of instructions on operating them (see Appendix B), and a lanyard and mesh bag to wear the DLP. M. M. was instructed on their use and asked to record at least 10 continuous hours on each of 2 days before and 2 days after treatment. Two days were deemed important to account for the language variability often experienced day to day in PWA. Recordings yielded approximately 40 hr of audio data. The recorder was to be turned on upon waking, worn throughout the day, and turned off at bedtime. The primary communication partner was asked to assist with this, as needed. M. M. was also provided with a communication diary in which she was asked to enter the date and log relevant activities throughout the day (e.g., at home having dinner, at her daughter's house, and walking her dog) for each of the 4 days that she wore the recorder.

**Data Preparation**

The audio data were transferred from the DLPs to the LENA system. The audio recordings were processed using LENA software that automatically analyzed audio files and produced language activity reports. The software was used to locate intervals with the language activity of interest, which were later analyzed for Social Environment Coding (see below) by the first author. The total word count and the total number of conversational turns were automatically calculated for each interval.

Using LENA's Advanced Data Extractor Tool (ADEX), the recorded audio was divided into 30-s segments. ADEX was used to automatically estimate a total AWC for each segment. Segments with no adult words were removed; the remaining segments were arranged in decreasing order of AWC. We wanted to identify segments with the most language activity to allow for meaningful analysis. We chose a total of 120 segments each, with the largest AWC (120 segments from pretreatment and 120 segments from 1 week posttreatment). This approach helped to avoid selecting segments for coding where there was no language activity. Similar approaches have been used in the literature to measure social behaviors and language use in adults and children (i.e., Garcia-Sierra et al., 2016; Mehl et al., 2001, 2007; Ramírez-Esparza et al., 2014, 2017a, 2017b, 2019).

## *SECSI and Coding SECSI Categories*

The adapted version of the SECSI (Ramírez-Esparza et al., 2014) was used to assess naturalistic language use, the communication environment, the interactions between the participant and the communication partners, and personal factors. SECSI provides guidelines that allow for the coding of complex language behaviors. Using these guidelines, we can break these behaviors into 73 categories and six clusters, which include, but are not limited to, speech partners or interaction, types of conversation, social context, speech utterances, activities, and mood (Ramírez-Esparza et al., 2017b, 2019). We examined four different broad dimensions based on the SECSI categories to analyze naturalistic language use at home at two time intervals —pretreatment and 1 week posttreatment. The coding system for the current study was composed of four major category clusters: (a) language productivity (AWCs and CTC), (b) activities and participation (types of conversation and functional everyday life activities). The types of conversations were coded for small talk and substantive conversations. Small talk was defined as uninvolved conversations where only trivial information is exchanged, whereas substantive conversations incorporate involved and meaningful information exchange, (c) communication environment (the number of communication partners and physical location), and (d) personal feelings (expressed negative emotions).

**Manual Analysis**

In addition to automated counts performed by LENA and coding of language behaviors, manual analysis of AWC and conversational turns were performed to compare with machine counts. AWCs included the total number of intelligible words in context to someone who knows the topic being discussed, not including fillers (e.g., um and uh) as per Nicholas and Brookshire (1993). Conversational turn counts were shifts of continuous utterances from PWAs to other communication partners. Continuous utterances are the back and forth conversation with no more than 60 s of to-and-from interactional exchange between PWAs and other communication partners.

**Coding the Interactive and Contextual Language Use at Home**

A trained research assistant orthographically transcribed 240 segments verbatim (i.e., 120 segments from pretreatment and 120 segments from posttreatment). The research assistant listened to one transcript several times until each utterance was captured. The research assistant also received additional training in identifying the SECSI categories. After training, point-to-point interrater reliability was calculated. The primary investigator and the research assistant independently coded and analyzed 25% of the transcripts. There was an 89% agreement between the primary investigator and the research assistant, indicating effective training and reliable coding. According to Shriberg et al. (2010), a point-to-point interjudge agreement in the 80%–90% range is considered acceptable for most research needs.

The research assistant had access to the time interval, segment number, date and time of the audio recording, day of the week, and communication diary in addition to the transcribed audio recordings. The transcribed 30-s segments were coded for each of the SECSI categories associated with the segment. For every 30-s segment, if the behavior of interest occurred, it was coded as "Yes." This resulted in a matrix of "Yes" or "No" responses that characterized the presence or absence of a specific SECSI category in a given segment. These categories are not mutually exclusive or exhaustive (e.g., the participant is talking to other adults, the participant is involved in small talk, the participant is laughing—all within a single 30-s interval); therefore, several SECSI categories can be coded within a single interval.

The relative time use or the proportion of time use was calculated for each SECSI category by calculating the percentage of segments where the category of interest was coded as "Yes." This was done for samples collected at pretreatment and 1 week posttreatment. For example, a proportion of time-use estimate of 20% for the interaction category "PWA is talking to the partner" indicated that this category was coded YES in 24 of the 120 coded intervals.

## Results

### *Pre–Post Standardized Language Measures*

All tests administered pretreatment were reexamined after completion of treatment to assess for change. An increase of at least five points on the WAB-R AQ is considered clinically significant (Katz & Wertz, 1997; Kiran & Johnson, 2008). On all other tests, a change of 20% or more is considered clinically significant (Ramsberger & Marie, 2007). M. M.'s score on the WAB-R AQ showed clinically significant improvement from pretreatment 31 to 1 week posttreatment 37.7. M. M. had a raw score of 12 on the Auditory Comprehension Test for Sentences at pretreatment, which did not change posttreatment.

### *Pre–Post Therapy Outcome Measurement*

#### Language Productivity

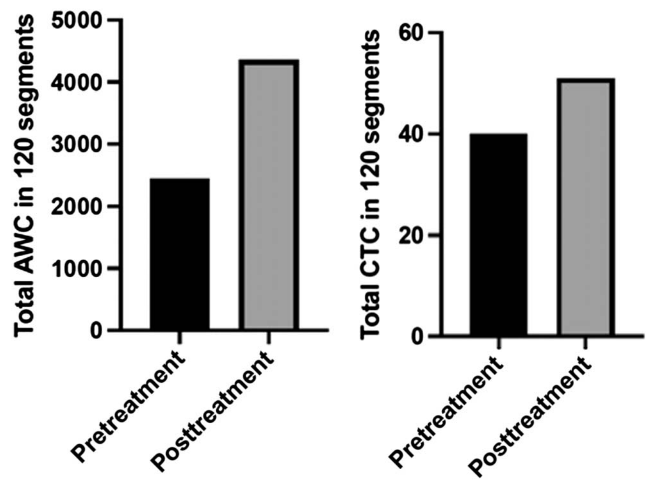
Figure 1 shows language productivity pre and posttreatment. These were raw counts of AWC and the number of CTC. M. M. showed a 78.42% increase in manually measured total intelligible AWC and a 27.5% increase in CTC from pretreatment to posttreatment. Interrater reliability was 82% for manual AWC and 89% for manual CTC, which fell in an acceptable range and exceeded the clinical criterion of 80% for conversation (Oelschlaeger & Thorne, 1999).

The agreement between LENA-automated AWC and manual AWC was 24.16% for pretreatment and 20% for posttreatment for a total of 120 segments each (120 segments from pretreatment, and 120 segments from one-week posttreatment). LENA AWC estimates resulted in more words than human-transcribed estimates because it included neologisms and jargon that are unintelligible and would thus not count toward a total word count according to Nicholas and Brookshire (1993).

#### Activities and Participation

The identified segments were coded for two types of conversation—small talk and substantive conversations. Figure 2 shows that in the quality of conversation, M. M.

**Figure 1.** This figure shows the language productivity pre- and posttreatment. These are the raw counts of AWC (first column) and the number of CTC (second column) from using the digital language processor (DLP). AWC = adult word count; CTC = conversational turn count.

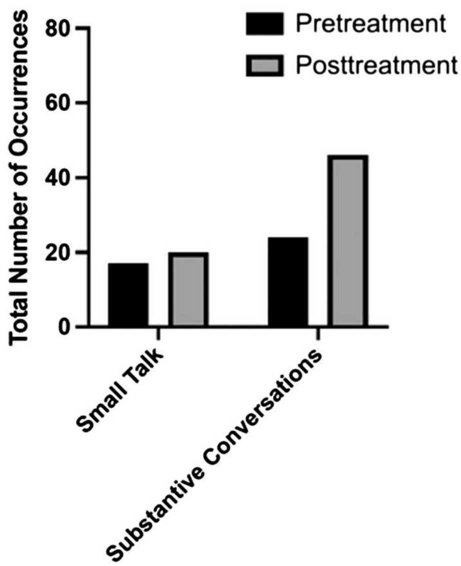



showed a 17.65% increase in instances of small talk (e.g., M. M. talking to partner while watching TV *"Look it. I love that. Look at these. I love those. Those are nice. I like him"*) such as using the language for practical everyday conversation and a 91.66% increase in instances of substantive conversation (e.g., M. M. describing a fair in Wyoming *"I love going to it. I see you went there. We we get allenates it. Doing things, we get mekethins, too. I love to do things. I love, I love the things. They nice and uh fun"*) after treatment. Functional everyday activities were also coded at pretreatment and posttreatment for an ongoing behavior or task in which M. M. was involved during the 30-s segment. Activities were characterized by a 26% decrease in the amount of time spent listening to radio/music or watching television and a 140% increase in instances of conversing in a social setting (see Figure 3).

#### Communication Environment

The communication environment was coded for the number of communication partners and the number of exchanges with those partners, and the physical location in which M. M. was present during the 30-s segment. Figure 4 shows the different communication partners and the number of exchanges with those partners at pretreatment and posttreatment. At pretreatment, M. M. mostly talked to her husband, but posttreatment, there was an increase in the number of exchanges with different communication partners such as acquaintances, relatives, and pets. There was a 27.86% increase in the number of conversational exchanges with communication partners after treatment (see Table 1). Figure 5 shows the location where communication activities took place. There was overall more variety in the location where communication activities took place posttreatment, such as outdoors and in transit (e.g., walking, in a car).

**Figure 2.** This figure shows the quality of conversation specifically the increase of instances and in small talk (column 1) and in substantive conversations (column 2).




## Expressed Negative Emotions

The percentage of expressed negative emotion was compared at baseline and posttreatment from the selected 30-s segments (e.g., *"Come on. Oh, what a mess. Come on. I don't like this. I don't like this. I don't wannadoin' this. I wanna talk ed. I no doin' anything"*). Overall, there was a 36% decrease in expressed negative emotions from pretreatment to posttreatment. There was a reduction in the expression of negative feelings such as frustration and anger due to being unable to express her thoughts.

**Figure 3.** This figure shows the functional everyday activities that were coded at pre- and posttreatment for an ongoing behavior or task. This includes the following activities: listening to radio/music, watching television, and socializing/social gathering.

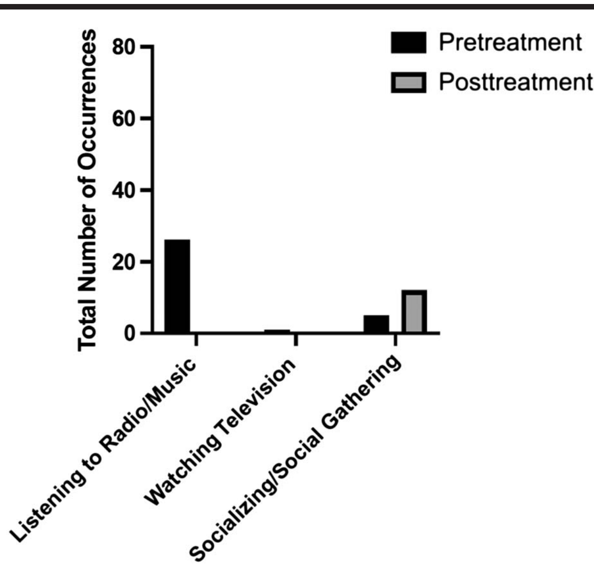
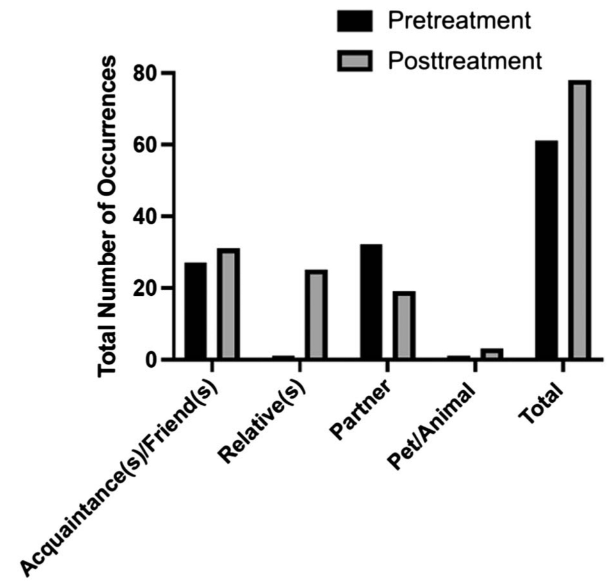



**Figure 4.** This figure shows the different communication partners and the number of exchanges with those partners at pre- and posttreatment. This includes the following: acquaintance(s)/friend(s), relative(s), partner, and pet/animal.




## CETI and its Relationship to LENA Measures

The CETI (Lomas et al., 1989) was administered to evaluate changes in the participant's functional communicative abilities in situations outside the clinic, as perceived by one of her primary communication partners. The CETI consists of 16 items chosen for their importance in everyday life. Each item is scored separately on a visual analogue-type scale (0 = *not at all able*, 10 = *as able as before stroke*). The CETI was completed at pretreatment and then posttreatment by M. M.'s adult daughter. She completed the CETI by making a mark on a 10.5-cm line to indicate her perception of M. M.'s abilities at the time of assessment compared to before her stroke. Results on the CETI were calculated by measuring the distance along the line (in millimeters; Lomas et al., 1989). As seen in Table 2, M. M.'s CETI results indicated clinically significant improvement (a change of greater than 20% from pretreatment) of communicative behaviors in 5/16 areas from pretreatment to posttreatment. Clinically significant decline was seen for one item: (1) getting somebody's attention. We were unable to score one item due to a missed response on the pretreatment version of the assessment: (16) describing or discussing something in depth.

There was a concordance between changes seen in LENA measures and the CETI rating scale. As seen in Table 1, the qualitative changes in M. M.'s communicative behaviors in the real world included increased social interaction (increased conversations with friends, neighbors, and

**Table 1.** Pre- and posttreatment outcome measurement.

| Category clusters of the coding system | Pretreatment | Posttreatment | % Change |
|---|---|---|---|
| Language productivity | | | |
| AWC | 2443 | 4359 | 78.43 |
| CTC | 40 | 51 | 27.50 |
| Activities and participation | | | |
| Small talk | 17 | 20 | 17.65 |
| Substantive conversations | 24 | 46 | 91.67 |
| Listening to radio/music | 26 | 0 | –100.00 |
| Watching television | 1 | 0 | –100.00 |
| Socializing/social gathering | 5 | 12 | 140.00 |
| Communication partners | | | |
| Acquaintance(s)/friend(s) | 27 | 31 | 14.81 |
| Relative(s) | 1 | 25 | 2400.00 |
| Partner | 32 | 19 | –40.63 |
| Pet/animal | 1 | 3 | 200.00 |
| Total | 61 | 78 | 27.87 |
| Physical location | | | |
| Home | 58 | 46 | –20.69 |
| Outdoors | 0 | 23 | |
| In transit | 0 | 5 | |
| Total | 58 | 74 | 27.59 |
| Expressed negative feeling | 11 | 7 | –36.36 |

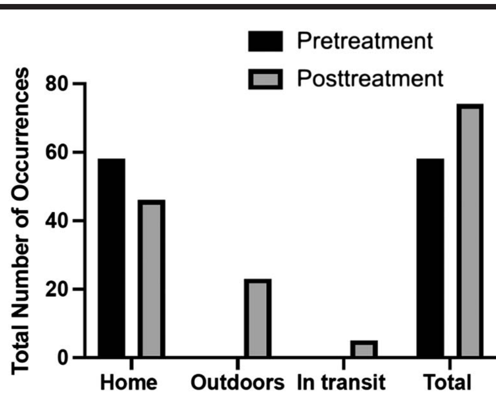
*Note.* AWC = adult word count; CTC = conversational turn count.

strangers) were also captured by LENA measures such as an increase in small talk and substantive conversations and increase in the number of communication partners across different social settings.

## Discussion

In this study, our aims were (a) to test the feasibility of collecting and then analyzing natural language occurring spontaneously within the home environment over a period of 2 days and (b) to characterize the language in the home environment to determine whether there are quantifiable changes in response to treatment. This pilot work tracks only one individual of one aphasia type and sample language from a total of only 4 days. Nevertheless, results demonstrate the potential power of analyzing language use in the home environment. The participant independently operated the recording device, kept a communication diary, and was successful in delivering more than 40 hr of recordings. The participant clearly normalized to wearing the recording device after a short initial period of time. Unlike video recordings, where one is always conscious of the camera or short audio recordings, this device is small and easily forgotten over time. The conversations were clearly natural and unselfconscious.

**Figure 5.** This figure shows the location where communication activities took place. There was overall more variety in the location where communication activities took place posttreatment, such as home, outdoors, and in transit.




We were also able to successfully use ADEX, the companion software to LENA, to organize and parse recorded segments based on the total number of words spoken. This helped streamline the transcription process and allowed us to transcribe the segments that were the longest and most substantial conversations (according to word count). There was poor agreement between the AWC, as counted using ADEX, and AWC measured by manual transcription of the same segments, and therefore, automation of this type of discourse analysis would be considered unsuccessful. The participant in this study displayed classic Wernicke's aphasia characteristics, and thus, her language production consisted of a high volume of neologisms and nonintelligible words that were counted in the automated processing. LENA is not a speech recognition device but rather an audio processing unit that relies on the acoustic characteristics of the audio signal to define a "word," explaining its inability to recognize neologisms/jargon. In the child literature, AWC agreement ranges between 71% and 82% (Canault et al., 2016; Gilkerson et al., 2015; Oetting et al., 2009; Xu et al., 2009). We expect that in future studies with participants with nonfluent aphasia, or with milder aphasia types, we might find better agreement between the automated and manual measurements.

**Table 2.** Summary of CETI (Communicative Effectiveness Index) data.

| Item | Pretreatment | Posttreatment | Change |
|---|---|---|---|
| **Getting somebody's attention.** | **10.50 cm** | **7.95 cm** | **–2.55 cm** |
| Getting involved in group conversations that are about him/her. | 9.60 cm | 7.95 cm | –1.65 cm |
| Giving yes and no answers appropriately. | 5.45 cm | 5.05 cm | –0.40 cm |
| Communicating his/her emotions. | 7.55 cm | 8.60 cm | +1.05 cm |
| Indicating that he/she understands what is being said to him/her. | 5.70 cm | 8.15 cm | +2.45 cm |
| Having coffee-time visits and conversations with friends and neighbors (around the bedside or at home). | 2.80 cm | 8.30 cm | +5.50 cm |
| Having a one-to-one conversation with you. | 10.30 cm | 9.55 cm | –0.75 cm |
| Saying the name of someone whose face is in front of him/her. | 1.05 cm | 2.70 cm | +1.65 cm |
| Communicating physical problems such as aches and pains. | 8.95 cm | 9.30 cm | +0.35 cm |
| Having a spontaneous conversation (i.e., starting the conversation and/or changing the subject). | 9.65 cm | 9.35 cm | –0.30 cm |
| Responding to or communicating anything (including yes or no) without words. | 9.65 cm | 8.10 cm | –1.55 cm |
| Starting a conversation with people who are not close family. | 5.65 cm | 8.35 cm | +2.70 cm |
| Understanding writing. | 5.80 cm | 4.90 cm | –0.90 cm |
| Being part of a conversation when it is fast and there are a number of people involved. | 10.00 cm | 8.60 cm | –1.40 cm |
| Participating in conversations with strangers. | 6.00 cm | 9.50 cm | +3.50 cm |
| Describing or discussing something in depth. | [a] | 2.95 cm | NC[a] |

*Note.* Underlined items indicate clinically significant positive change, while boldfaced items indicate clinically significant negative change.
[a]Missing pretreatment data; this question is not calculable for change.

Most importantly, the software highlighted the times of day where language activity occurred, allowing a close analysis of discourse at home pre- and posttreatment. The use of a typical recording device would have limited us in terms of the length of the samples collected and would also have been more labor intensive to find the times where language occurred since silence, television, and radio comprise much of the samples.

The 4 days' worth of recordings provided insight as to whether changes in language use would be evident outside the clinic. It also allowed for an examination of M. M.'s participation in the communication activities of daily life. Findings suggest that LENA may be a useful tool for capturing functional, real-world communication, allowing us to quantify outcomes within the A-FROM framework and to characterize functional deficits in PWAs. In line with the A-FROM framework, a qualitative meta-analysis identified seven factors (participation, meaningful relationships, support, communication, positivity, independence, and autonomy) that allow PWAs to successfully navigate life (Brown et al., 2012). We were able to quantify some of these factors as M. M. showed an increase in participation in everyday activities, an increase in the number of communication partners and the number of exchanges with those partners, and a reduction in the expression of negative feelings. The results of the current study may help to promote the use of A-FROM by providing clinicians with a way to quantify the use of language in the home environment.

Research shows that people with severe aphasia can experience social exclusion at infrastructural level (e.g., housing, employment), interpersonal level (e.g., social isolation), and personal level (e.g., low self-esteem, dependence; Parr, 2007). By tracking conversations held over four full days of recording, we were able to characterize changes in each of the levels mentioned above. At pretreatment, the participant conversed with only a few communication partners demonstrating a restricted social interaction in which she mostly talked to her husband. Analysis of communication activities and participation showed a limited number of everyday life activities. This included primarily watching television and listening to music, with most communication activities occurring within the home.

Results after an intensive aphasia treatment showed several indicators of change in the participant's language performance at home, corresponding with the clinically significant improvements observed on the WAB-R and the CETI. Analysis of the range of communication outcome measures indicated that she produced a higher number of conversational turns and a total number of intelligible words. There was also an increase in the number of communication partners, such as acquaintances, friends, and relatives. The findings also showed qualitative differences in the conversations she engaged in after treatment. For example, there were several indications that she took charge of her communication, such as an increase in the total number of substantive conversations that involved meaningful information exchange. SESCI analysis also showed an increase in activities outside the house, including more visits with friends and neighbors.

Our findings shed light on the interaction between environmental factors, participation in everyday functional activities, and language outcomes in individuals with aphasia. Results indicate that M. M. expressed fewer negative emotions, had more communication partners, and interacted across more social settings. These findings are rarely captured in traditional clinical assessments of aphasia, which tend to focus on the transactional component of communication. By providing a more holistic view of the participant's communication environment, we were able to highlight the role played by social interaction, desire to interact, and the pleasure resulting from being in the company of others. The importance of these factors has been well described in the literature. It is recommended that clinicians remain sensitive to the interpersonal purposes for which people may engage in communication and how PWAs value the quality of the performance in social activities over the quantity. They not only want to perform and participate more, but they want their interactions to be meaningful and satisfying (Dalemans et al., 2010; Ramsberger & Rende, 2002). Our preliminary quantitative data support this.

The participant's more positive emotional expression may be a result of increased interaction between her and the direct environment (relatives, friends, and neighbors), demonstrating how inextricable variables such as confidence, social interactions, and actual proficiency are linked. Van de Ven et al. (2005) described the central role of the process of interaction as the subjective experience of integration, such as participation in social activities, not feeling hindered in activities, and taking responsibility for being in control of one's own life. The influencing factors in reaching engagement involve personal, societal, and support factors (van de Ven et al., 2005). Results from this study demonstrate that several factors may have influenced the participant's ability to engage and achieve social participation after therapy. She was a motivated person living with a stimulating caregiver in an accessible environment with people around her willing to adapt to the participant's communicative possibilities.

Davidson and Worrall (2000) discussed the interrelationship of the ICF classification dimensions and described the increasing impact of contextual factors relevant to assessing the dimensions of impairment, activity, and participation. Comparisons of the contextual variables, including the number and category of communication partners and the places where communication took place, help to examine the possible barriers to social participation and improved communication abilities. For example, this study's findings show comparisons of the occurrence of particular communication activities (such as coffee visits) before and after treatment, providing information on the reduction in the frequency of communication events and the activity limitation that accompanies individuals with long-term aphasia before therapy.

### *Limitations and Future Directions*

This study provides an in-depth analysis of a single participant. While we observed positive changes, clearly our interpretation is limited by an inability to run statistical analyses. In future iterations, with a larger number of participants, we will be able to perform analyses to analyze the relationship between our outcome measures and quality of life indicators, and hopefully will determine the variables that best predict change.

We are also limited by a lack of literature within the field from which to build. Understanding the home environment means more than simply understanding communicative interactions with a primary partner, as is largely the focus in today's literature. An enriched communicative environment likely includes many more variables, including the physical setup, the number of people in the home, access to people and activities outside the home, and more. We agree with Hengst et al. (2019) who posit that enriching the environment is a potentially important rehabilitation avenue. First though, we need to understand exactly what it is that constitutes this sort of environment. Going forward, we intend to begin determining the factors that contribute to a richer communicative environment in order to maximize language recovery at home.

## Conclusions

The findings of this pilot study support the current evidence base in favor of functional assessment, in addition to the traditional impairment level approach, detailing a dynamic and comprehensive understanding of real-world communication abilities and factors influencing the interaction between the people with aphasia and the direct environment. It also highlights the potential to measure and quantify rehabilitation's effectiveness in a meaningful way, which is also ecologically valid. We cannot separate language from the communicative context; therefore, speech-language pathologists need to be more aware of the consequences of aphasia in real life and to prepare people with aphasia to build a bridge for reengagement in life.

## Author Contributions

**Louisa B. Suting:** Investigation (Equal), Methodology (Equal), Project administration (Equal), Visualization (Lead), Writing - Original Draft (Lead). **Jennifer Mozeiko:** Conceptualization (Lead), Data curation (Equal), Funding acquisition (Lead), Methodology (Equal), Project administration (Equal), Resources (Lead), Software (Lead), Supervision (Lead), Writing - Review & Editing (Lead).

## References

**Aftonomos, L. B., Steele, R. D., Appelbaum, J. S., & Harris, V. M.** (2001). Relationships between impairment-level assessments and functional-level assessments in aphasia: Findings from LCC treatment programmes. *Aphasiology, 15*(10–11), 951–964. https://doi.org/10.1080/02687040143000311

**Armstrong, E.** (2000). Aphasic discourse analysis: The story so far. *Aphasiology, 14*(9), 875–892. https://doi.org/10.1080/02687030050127685

**Basso, A.** (2010). "Natural" conversation: A treatment for severe aphasia. *Aphasiology, 24*(4), 466–479. https://doi.org/10.1080/02687030802714165

**Beeke, S., Maxim, J., & Wilkinson, R.** (2007). Using conversation analysis to assess and treat people with aphasia. *Seminars in Speech and Language, 28*(2), 136–147. https://doi.org/10.1055/s-2007-970571

**Beeke, S., Maxim, J., & Wilkinson, R.** (2008). Rethinking agrammatism: Factors affecting the form of language elicited via clinical test procedures. *Clinical Linguistics & Phonetics, 22*(4–5), 317–323. https://doi.org/10.1080/02699200801918911

**Blomert, L., Kean, M. L., Koster, C., & Schokker, J.** (1994). Amsterdam—Nijmegen everyday language test: Construction, reliability and validity. *Aphasiology, 8*(4), 381–407. https://doi.org/10.1080/02687039408248666

**Brady, M. C., Kelly, H., Godwin, J., & Enderby, P.** (2012). Speech and language therapy for aphasia following stroke. *Cochrane Database of Systematic Reviews, 2012*(5), CD000425. https://doi.org/10.1002/14651858.CD000425.pub3

**Brady, M. C., Kelly, H., Godwin, J., Enderby, P., & Campbell, P.** (2016). Speech and language therapy for aphasia following stroke. Cochrane Database of Systematic Reviews, *2016*(6), CD000425. https://doi.org/10.1002/14651858.CD000425.pub4

**Brandenburg, C., Worrall, L., Copland, D., & Rodriguez, A.** (2017). An exploratory investigation of the daily talk time of people with non-fluent aphasia and non-aphasic peers. *International Journal of Speech-Language Pathology, 19*(4), 418–429. https://doi.org/10.1080/17549507.2016.1209558

**Brown, K., Worrall, L. E., Davidson, B., & Howe, T.** (2012). Living successfully with aphasia: A qualitative meta-analysis of the perspectives of individuals with aphasia, family members, and speech-language pathologists. *International Journal of Speech-Language Pathology, 14*(2), 141–155. https://doi.org/10.3109/17549507.2011.632026

**Bryant, L., Ferguson, A., & Spencer, E.** (2016). Linguistic analysis of discourse in aphasia: A review of the literature. *Clinical Linguistics & Phonetics, 30*(7), 489–518. https://doi.org/10.3109/02699206.2016.1145740

**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. https://doi.org/10.3758/s13428-015-0634-8

**Caskey, M., Stephens, B., Tucker, R., & Vohr, B.** (2011). Importance of parent talk on the development of preterm infant vocalizations. *Pediatrics, 128*(5), 910–916. https://doi.org/10.1542/peds.2011-0609

**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. https://doi.org/10.1111/apa.12195

**Christakis, D. A., Gilkerson, J., Richards, J. A., Zimmerman, F. J., Garrison, M. M., Xu, D., Gray, S., & Yapanel, U.** (2009). Audible television and decreased adult words, infant vocalizations, and conversational turns: A population-based study. *Archives of Pediatrics & Adolescent Medicine, 163*(6), 554–558. https://doi.org/10.1001/archpediatrics.2009.61

**Coelho, C. A., Sinotte, M. P., & Duffy, J. R.** (2008). Schuell's stimulation approach to rehabilitation. In R. Chapey (Ed.), *Language intervention strategies in aphasia and related neurogenic communication disorders* (pp. 403–449). Lippincott Williams & Wilkins.

**Dalemans, R. J. P., de Witte, L., Wade, D., & van den Heuvel, W.** (2010). Social participation through the eyes of people with aphasia. *International Journal of Language & Communication Disorders, 45*(5), 537–550. https://doi.org/10.3109/13682820903223633

**Damico, J. S., Simmons-Mackie, N., Oelschlaeger, M., Elman, R., & Armstrong, E.** (1999). Qualitative methods in aphasia research: Basic issues. *Aphasiology, 13*(9–11), 651–665. https://doi.org/10.1080/026870399401768

**Davidson, B., & Worrall, L. E.** (2000). The assessment of activity limitation in functional communication: Challenges and choices. In L. E. Worrall & C. M. Frattali (Eds.), *Neurogenic communication disorders: A functional approach* (pp. 19–34). Thieme.

**Davidson, B., Worrall, L., & Hickson, L.** (2003). Identifying the communication activities of older people with aphasia: Evidence from naturalistic observation. *Aphasiology, 17*(3), 243–264. https://doi.org/10.1080/729255457

**Doedens, W. J., & Meteyard, L.** (2020). Measures of functional, real-world communication for aphasia: A critical review. *Aphasiology, 34*(4), 492–514. https://doi.org/10.1080/02687038.2019.1702848

**Frattali, C., Thompson, C. M., Holland, A. L., Wohl, C. B., & Ferketic, M. M.** (1995). *Functional Assessment of Communication Skills for Adults (ASHA-FACS)*. American Speech-Language-Hearing Association.

**Garcia-Sierra, A., Ramírez-Esparza, N., & Kuhl, P. K.** (2016). Relationships between quantity of language input and brain responses in bilingual and monolingual infants. *International Journal of Psychophysiology, 110,* 1–17. https://doi.org/10.1016/j.ijpsycho.2016.10.004

**Gilkerson, J., Coulter, K., & Richards, J. A.** (2008). *Transcriptional analyses of the LENA Natural Language Corpus.*

**Gilkerson, J., Richards, J. A., Warren, S. F., Montgomery, J. K., Greenwood, C. R., Kimbrough Oller, D., Hansen, J. H. L., & Paul, T. D.** (2017). Mapping the early language environment using all-day recordings and automated analysis. *American Journal of Speech-Language Pathology, 26*(2), 248–265. https://doi.org/10.1044/2016_AJSLP-15-0169

**Gilkerson, J., Zhang, Y., Xu, D., Richards, J. A., Xu, X., Jiang, F., Harnsberger, J., & 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. https://doi.org/10.1044/2015_JSLHR-L-14-0014

**Glueckauf, R. L., Blonder, L. X., Ecklund-Johnson, E., Maher, L., Crosson, B., & Gonzalez-Rothi, L.** (2003). Functional outcome questionnaire for aphasia: Overview and preliminary psychometric evaluation. *NeuroRehabilitation, 18*(4), 281–290. https://doi.org/10.3233/NRE-2003-18402

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

**Hengst, J. A., Duff, M. C., & Jones, T. A.** (2019). Enriching communicative environments: Leveraging advances in neuroplasticity for improving outcomes in neurogenic communication disorders. *American Journal of Speech-Language Pathology, 28*(1S), 216–229. https://doi.org/10.1044/2018_AJSLP-17-0157

**Holland, A., Frattali, C. M., & Fromm, D.** (1999). *Communication activities of daily living (CADL-2)*. Pro-Ed.

**Jones, R. L., Fonseca, J., De Martin Silva, L., Davies, G., Morgan, K., & Mesquita, I.** (2015). The promise and problems of video diaries: Building on current research. *Qualitative Research in Sport, Exercise and Health, 7*(3), 395–410. https://doi.org/10.1080/2159676X.2014.938687

**Kagan, A., Simmons-Mackie, N., Rowland, A., Huijbregts, M., Shumway, E., McEwen, S., Threats, T., & Sharp, S.** (2008). Counting what counts: A framework for capturing real-life outcomes of aphasia intervention. *Aphasiology, 22*(3), 258–280. https://doi.org/10.1080/02687030701282595

**Katz, R. C., & Wertz, R. T.** (1997). The efficacy of computer-provided reading treatment for chronic aphasic adults. *Journal of Speech, Language, and Hearing Research, 40*(3), 493–507. https://doi.org/10.1044/jslhr.4003.493

**Kertesz, A.** (2007). *WAB-R : Western Aphasia Battery–Revised*. The Psychological Corporation.

**Kiran, S., & Johnson, L.** (2008). Semantic complexity in treatment of naming deficits in aphasia: Evidence from well-defined categories. *American Journal of Speech-Language Pathology, 17*(4), 389–400. https://doi.org/10.1044/1058-0360(2008/06-0085)

**Klein, K. E., Wu, Y.-H., Stangl, E., & Bentler, R. A.** (2018). Using a digital language processor to quantify the auditory environment and the effect of hearing aids for adults with hearing loss. *Journal of the American Academy of Audiology, 29*(4), 279–291. https://doi.org/10.3766/jaaa.16114

**Li, L., Vikani, A. R., Harris, G. C., & Lin, F. R.** (2014). Feasibility study to quantify the auditory and social environment of older adults using a digital language processor. *Otology & Neurotology, 35*(8), 1301–1305. https://doi.org/10.1097/MAO.0000000000000489

**Lomas, J., Pickard, L., Bester, S., Elbard, H., Finlayson, A., & Zoghaib, C.** (1989). The Communicative Effectiveness Index: development and psychometric evaluation of a functional measure of adult aphasia. *Journal of Speech and Hearing Disorders, 54*(1), 113–124.

**Martin, N., Thompson, C. K., & Worrall, L.** (2007). *Aphasia rehabilitation: The impairment and its consequence*. Plural.

**McNeil, M. R., Doyle, P. J., Fossett, T. R. D., Park, G. H., & Goda, A. J.** (2001). Reliability and concurrent validity of the information unit scoring metric for the story retelling procedure. *Aphasiology, 15*(10–11), 991–1006. https://doi.org/10.1080/02687040143000348

**Mehl, M. R., Gosling, S. D., & Pennebaker, J. W.** (2006). Personality in its natural habitat: Manifestations and implicit folk theories of personality in daily life. *Journal of Personality and Social Psychology, 90*(5), 862–877. https://doi.org/10.1037/0022-3514.90.5.862

**Mehl, M. R., & Pennebaker, J. W.** (2003). The social dynamics of a cultural upheaval: Social interactions surrounding September 11, 2001. *Psychological Science, 14*(6), 579–585. https://doi.org/10.1046/j.0956-7976.2003.psci_1468.x

**Mehl, M. R., Pennebaker, J. W., Crow, D. M., Dabbs, J., & Price, J. H.** (2001). The Electronically Activated Recorder (EAR): A device for sampling naturalistic daily activities and conversations. *Behavior Research Methods, Instruments, & Computers, 33*(4), 517–523. https://doi.org/10.3758/bf03195410

**Mehl, M. R., Vazire, S., Ramírez-Esparza, N., Slatcher, R. B., & Pennebaker, J. W.** (2007). Are women really more talkative than men. *Science, 317*(5834), 82. https://doi.org/10.1126/science.1139940

**Nicholas, L. E., & Brookshire, R. H.** (1993). A system for quantifying the informativeness and efficiency of the connected speech of adults with aphasia. *Journal of Speech and Hearing Research, 36*(2), 338–350. https://doi.org/10.1044/jshr.3602.338

**Oelschlaeger, M. L., & Thorne, J. C.** (1999). Application of the correct information unit analysis to the naturally occurring conversation of a person with aphasia. *Journal of Speech, Language, and Hearing Research, 42*(3), 636–648. https://doi.org/10.1044/jslhr.4203.636

**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. https://doi.org/10.1044/leader.FTR3.14062009.20

**Parr, S.** (2007). Living with severe aphasia: Tracking social exclusion. *Aphasiology, 21*(1), 98–123. https://doi.org/10.1080/02687030600798337

**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. https://doi.org/10.1111/desc.12172

**Ramírez-Esparza, N., García-Sierra, A., & Kuhl, P. K.** (2017a). The impact of early social interactions on later language development in Spanish–English bilingual infants. *Child Development, 88*(4), 1216–1234. https://doi.org/10.1111/cdev.12648

**Ramírez-Esparza, N., García-Sierra, A., & Kuhl, P. K.** (2017b). Look who's talking now! parentese speech, social context, and language development across time. *Frontiers in Psychology, 8,* 1008. https://doi.org/10.3389/fpsyg.2017.01008

**Ramírez-Esparza, N., García-Sierra, A., Rodríguez-Arauz, G., Ikizer, E. G., & Fernández-Gómez, M. J.** (2019). No laughing matter: Latinas' high quality of conversations relate to behavioral laughter. *PLOS ONE, 14*(4), e0214117. https://doi.org/10.1371/journal.pone.0214117

**Ramsberger, G., & Marie, B.** (2007). Self-administered cued naming therapy: A single-participant investigation of a computer-based therapy program replicated in four cases. *American Journal of Speech-Language Pathology, 16*(4), 343–358. https://doi.org/10.1044/1058-0360(2007/038)

**Ramsberger, G., & Rende, B.** (2002). Measuring transactional success in the conversation of people with aphasia. *Aphasiology, 16*(3), 337–353. https://doi.org/10.1080/02687040143000636

**Romeo, R. R., Leonard, J. A., Robinson, S. T., West, M. R., Mackey, A. P., Rowe, M. L., & Gabrieli, J. D. E.** (2018). Beyond the 30-million-word gap: Children's conversational exposure is associated with anguage-related brain function. *Psychological Science, 29*(5), 700–710. https://doi.org/10.1177/0956797617742725

**Shewan, C. M.** (1979). *Auditory Comprehension Test for Sentences.* Biolinguistics Clinical Institutes.

**Shriberg, L. D., Fourakis, M., Hall, S. D., Karlsson, H. B., Lohmeier, H. L., McSweeny, J. L., Potter, N. L., Scheer-Cohen, A. R., Strand, E. A., Tilkens, C. M., & Wilson, D. L.** (2010). Perceptual and acoustic reliability estimates for the Speech Disorders Classification System (SDCS). *Clinical Linguistics & Phonetics, 24*(10), 825–846. https://doi.org/10.3109/02699206.2010.503007

**Suskind, D. L., Leffel, K. R., Graf, E., Hernandez, M. W., Gunderson, E. A., Sapolich, S. G., Suskind, E., Leininger, L., Goldin-Meadow, S., & Levine, S. C.** (2016). A parent-directed language intervention for children of low socioeconomic status: A randomized controlled pilot study. *Journal of Child Language, 43*(2), 366–406. https://doi.org/10.1017/S0305000915000033

**Togher, L.** (2001). Discourse sampling in the 21st century. *Journal of Communication Disorders, 34*(1–2), 131–150. https://doi.org/10.1016/S0021-9924(00)00045-9

**van de Ven, L., Post, M., de Witte, L., & van den Heuvel, W.** (2005). It takes two to tango: The integration of people with disabilities into society. *Disability & Society, 20*(3), 311–329. https://doi.org/10.1080/09687590500060778

**van der Meulen, I., van de Sandt-Koenderman, W. M. E., Duivenvoorden, H. J., & Ribbers, G. M.** (2010). Measuring verbal and non-verbal communication in aphasia: Reliability, validity, and sensitivity to change of the Scenario Test. *International Journal of Language & Communication Disorders, 45*(4), 424–435. https://doi.org/10.3109/13682820903111952

**Wallace, S. J., Worrall, L., Rose, T., & Le Dorze, G.** (2014). Measuring outcomes in aphasia research: A review of current practice and an agenda for standardisation. *Aphasiology, 28*(11), 1364–1384. https://doi.org/10.1080/02687038.2014.930262

**Wang, Y., Hartman, M., Aziz, N. A. A., Arora, S., Shi, L., & Tunison, E.** (2017). A systematic review of the use of LENA technology. *American Annals of the Deaf, 162*(3), 295–311. https://doi.org/10.1353/aad.2017.0028

**Warren, S. F., Gilkerson, J., Richards, J. A., Oller, D. K., Xu, D., Yapanel, U., & Gray, S.** (2010). What automated vocal analysis reveals about the vocal production and language learning environment of young children with autism. *Journal of Autism and Developmental Disorders, 40*(5), 555–569. https://doi.org/10.1007/s10803-009-0902-5

**World Health Organization.** (2001). *International classification of functioning, disability and health (ICF)*.

**Worrall, L., & Wallace, S.** (2015). The ICF, relationship-centred care and research outcome measurement: Carol Frattali's impact on aphasia research. *Perspectives on Neurophysiology and Neurogenic Speech and Language Disorders, 25*(3), 107–113. https://doi.org/10.1044/nnsld25.3.107

**Xu, D., Yapanel, U., & Gray, S.** (2009). *Reliability of the LENA Language ENvironment Analysis System in young children's natural home environment*. LENA Foundation. https://www.lena.org/wp-content/uploads/2016/07/LTR-05-2_Reliability.pdf

**Yorkston, K. M., & Beukelman, D. R.** (1980). An analysis of connected speech samples of aphasic and normal speakers. *Journal of Speech and Hearing Disorders, 45*(1), 27–36. https://doi.org/10.1044/jshd.4501.27

## Appendix A

LENA System

**Figure A1.** Digital Language Processor (DLP) dimensions: 3–3/8″ × 2–3/16″ × 1/2″. Instruction on how to use the DLP at home.

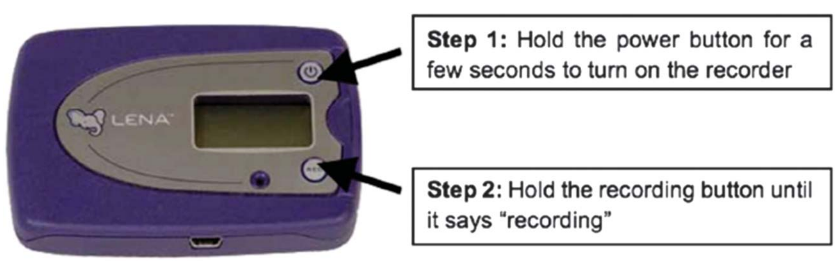
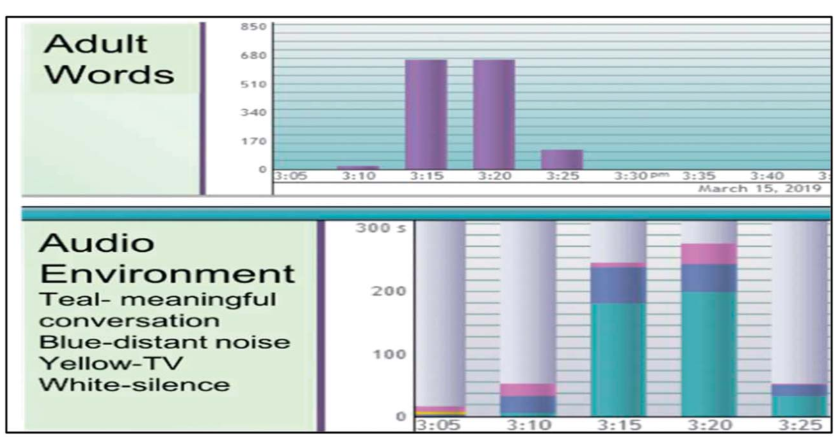



**Figure A2.** LENA software. LENA software depicting instances of conversation and breakdown of the audio environment.



**Appendix B**

Page 1 of the Instructions on How to Use the Digital Language Processor at Home

**STUDY CHECKLIST**

**If you have further questions about this project or if you have a research-related problem, you may you may contact the research team, at AphasiaRehabLab@gmail.com**

☐ You will be given 2 recorders

We want one weekday session and one weekend session. Each starts as soon as you wake up and ends at your bedtime. Each recorder can record up to 16 hours so you can use one recorder for the first day and the other for another day.
The recorders are labeled:

- **Day 1**
- **Day 2**

☐ At the beginning of the day, turn on the recorder and start recording


**Step 1:** Hold the power button for a few seconds to turn on the recorder

**Step 2:** Hold the recording button until it says "recording"

☐: Please check the tags on the recorder.

- Make sure you match the label on the recorder with the corresponding day you are using it (for example, **day 1** should be used with your armband the first day of).