ACES: Promoting Empathy Towards Aphasia Through Language Distortion Emulation Software

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ABSTRACT

Individuals with aphasia, an acquired communication disorder, constantly struggle against a world that does not understand them. This lack of empathy and understanding negatively impacts their quality of life. While aphasic individuals may appear to have lost cognitive functioning, their impairment relates to receptive and expressive language, not to thinking processes. We introduce a novel system and model, Aphasia Characteristics Emulation Software (ACES), enabling users (e.g., caregivers, speech therapists and family) to experience, firsthand, the communication-distorting effects of aphasia. By allowing neurologically typical individuals to "walk in another's shoes," we aim to increase patience, awareness and understanding. ACES was grounded in the communication science and psychological literature, and informed by an initial pilot study. Results from an evaluation of 64 participants indicate that ACES provides a rich experience that strong increases understanding and empathy for aphasia.

INTRODUCTION

Receiving empathy and understanding are a constant need for those living with aphasia [16]. Aphasia is an acquired language disorder that impairs expressive and receptive language (both spoken and written)[17]. Over one million Americans are affected by aphasia [24]. There is considerable variability in the effects of aphasia, but all individuals with aphasia display difficulty producing words accurately and with ease. Specific disruptions in language include dropping key words, substituting incorrect words for the target word, mixing up sounds or letters within words, describing items that are difficult to name, having difficulty organizing coherent strings of words, and making multiple attempts to correct such production errors.

To an outsider it may appear that an aphasic individual has poor cognitive function. However, the problem resides in the individual's receptive and expressive language, not their ability to think. Aphasia most profoundly affects the ability to communicate with others, whose lack of understanding and empathy has the potential to "erode the social bonds that give life meaning" [16].

Our goal is to promote empathy and understanding of aphasia in unimpaired individuals. We made it possible for those without aphasia to metaphorically "walk in another's shoes" by interacting with a system which emulates the effects of aphasia through distortion of written text. This system has the potential to help family and friends of individuals with aphasia, and to serve as a training tool for physicians, nurses, and speech-language pathologists.

We introduce a novel system and model, called **A**phasia **C**haracteristics **E**mulation **S**oftware (ACES), that enables users to experience the speech-distorting effects of aphasia. This model adheres to the wealth of literature in language distortions resulting from aphasia. It was informed though a series of interviews and demonstrations (using an early prototype of ACES) with professionals and students from the field of aphasia and other language disorders.

The ACES system was designed to distort a user's Instant Messages (IMs) from the original message to one that appears like a message spoken by an individual with aphasia. Thus, the conversation that develops between the user and their IM partner has similar difficulties and hurdles to those experienced by an individual with aphasia. By experiencing these challenges firsthand, we hypothesize that users will have increased empathy, knowledge, and understanding of aphasia. Results from an evaluation of 64 participants indicate that ACES provides a rich experience that strongly increases understanding and empathy for aphasia.

The foremost contribution of our system is a demonstration of how existing literature about language distortions/errors due to cognitive impairment, age, or other language-based challenges can be extended to an interactive system that increases knowledge, empathy, and awareness. Our goal is not to perfectly emulate aphasia.

RELATED WORK

We describe aphasia, empathy and how our work builds upon, and extends, the literature on the linguistic effects of aphasia.

Aphasia

Aphasia is a term used to describe an acquired language disorder that is caused by damage to the left or dominant hemisphere of the brain and impairs an individual's ability to produce and understand language in both written and spoken forms [1]. The severity and pattern of aphasic symptoms vary, depending in part on the specific locations of brain damage. Clinical researchers have developed classification systems that identify different patterns or sub-types of aphasia. For example, diagnostic batteries [11,27] based on the Boston classification system are designed to categorize an individual's aphasia symptoms as either a type of non-fluent aphasia (Broca's, Transcortical Motor, Global) or fluent aphasia (Wernicke, Transcortical Sensory, Conduction, Anomic). Of particular interest to the goals of the current study is that all individuals with aphasia will display at least some difficulty with writing, and although writing may be more or less impaired than spoken language, the linguistic deficits in writing will be generally consistent with those of the person's spoken language [2]. Recent research focusing on issues of treatment and functional recovery in aphasia[5] has drawn attention to the need for clinical interventions to attend not only to the areas of deficits in the patient with aphasia, but also to the person's communicative and social systems more broadly. This paper focuses on increasing empathy for those interacting with aphasics.

Empathy and Aphasia

Empathy is one of the fundamental underpinnings of interpersonal communication. It is an emotional response to the experiences of others, through which an empathetic person can understand and predict the feelings, emotions, and thoughts of others [9,29].

Non-technical approaches have been used to increase awareness and empathy in other situations by placing students in the "role" of an individual with an impairment. For example, students have been tasked to spend a day in a wheelchair to develop an awareness of the challenges confronting a paraplegic [26]. In another course, students were given AAC[1] devices and told to emulate being "non-vocal" communicators while performing tasks such as going to a coffee shop [14].

If individuals relating to those with aphasia lack empathy and understanding, it can greatly reduce quality of life for aphasic individuals [16]. Often, family members can deny or underestimate the severity and presence of aphasic errors [6]. Further, in speech therapy, empathy is necessary to motivate the aphasic client, with motivation being one of the three key aspects of effective treatment [28]. To date, research has shown that family member's ability to relate and empathize is based on how well they understand the distortions that their partners make [10].

Technology, Empathy and Aphasia

Technology has been used as a tool to enhance the functioning and communication of individuals with aphasia [7,19,30] and other speech and language disorders [15,23]. Specifically, work in the Human Computer Interaction (HCI) community has examined technological solutions to help with day planning [22], communication [3], and increased access to web-content [8] for aphasic individuals. Most of this HCI research has focused on providing support for the individual, their communication, and providing peripheral awareness of their activities to those around them. Unlike work that focuses on developing empathic agents [20], this work aims to increase empathy, knowledge, and understanding of aphasia of those who support aphasic individuals.

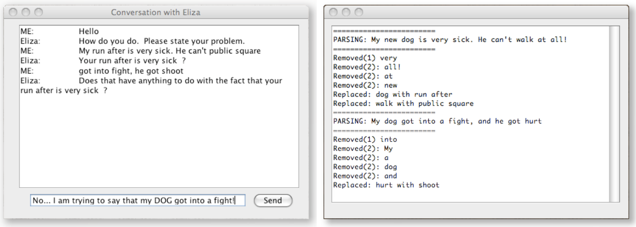

Figure 1. Prototype Chat Window (left) and Distortion Window (right)

Notice how the participant's text is hard to decipher after it has been distorted by the Aphasia Model.

Removed (1) is a dropped Function word, Removed (2) is a random word drop and Replaced is when a word is substituted.

EARLY PROTOTYPE AND INITIAL INVESTIGATION

Although there is a wealth of technology that aids individuals with aphasia, to our knowledge there is none that aims to increase empathy among those associated with aphasic individuals. Following the existing work in other domains [26], we hypothesized that if individuals were to experience the effects of aphasia first hand, they might better understand the disorder and become more empathetic to its challenges.

To this end, we built a prototype chat client that randomly distorted messages sent by its user using an aphasia language model. We chose IM, because it eliminates any bias from voice inflection and focuses on communication and the language disorder itself.

To gain insight into aphasia, empathy, and the type of interaction design that may best support such a tool, we conducted an exploratory study (guided demonstrations and interviews) with ten individuals (students, professionals, and researchers) with experience in aphasia (speech and hearing science and psychology). They averaged 10.3 years of experience in aphasia/language disorders, with mean age of 34.6 years.

The initial prototype (Figure 1) was built in Java and simulated an IM conversation between the user (whose text was distorted) and Eliza [31], a simple text-based computerized conversational partner. The system provided a simplistic approximation of the effects of aphasia by randomly dropping the user's function words (16-33%), randomly dropping any words (20-40%), and randomly replacing non-function words with other random words from a dictionary file. While this prototype was a simplified representation of some effects of aphasia, it illustrated the concept and functionality of ACES in order to gather informed feedback. Users saw how their messages were distorted through an IM window, and through a log of distortions (Figure 1).

Each participant met with a researcher for one session of approximately 40 minutes duration. Sessions began with an explanation/demonstration of the prototype. Participants then used the prototype to have a conversation with Eliza. Following the IM conversation, researchers had a discussion with

[1] Augmentative and Alternative Communication (AAC) devices, such as text-to-speech systems, assist those with impairments or restrictions on the production or comprehension of spoken or written language.

each participant, and concluded with a brief questionnaire using a 7-point Likert scale (7 agree, 1 disagree). There was no remuneration for participation.

Results And Lessons Learned

Overall, participants agreed that this tool could be used to teach empathy and understanding for aphasic individuals to: friends (μ=6.1), family (μ=6.2), clinicians (μ=5.9) and professionals (μ=6.1)[2]. In addition, participants provided explicit guidance on system improvements and general suggestions on the project. For example, one participant stated that:

> *This could be shown to people outside of the community of communication experts and their clients. It could teach empathy and acceptance to a group/ community as a whole. -P4*

Another participant stated that this software was critical for training clinicians:

> *I don't think treatment will be successful at all if the clinician is not understanding! They are the individuals who should be, and without that empathy, few gains will be achieved . -P5*

Another participant echoed P5 by stating that:

> *I believe that as a simulation of a disorder... this software could be used in classrooms as early as undergrad . -P3*

All participants stated the need for a customizable future system. Given the spectrum of aphasic disorders and the manifestation variety within each sub-disorder, such a tool needs to be robust enough to emulate different types of aphasia. Participants also felt that while the emulation would not need to be 'spot on,' it would need to emulate the key distortions of each condition reasonably well.

Participants suggested applications for an aphasia emulation system. One professional speech language pathologist suggested political applications, such as helping to raise awareness to increase both funding and accessibility. Another felt there to be a need for greater empathy by physicians and nurses in hospital and ER settings, who can seem dismissive of patient struggles. Most felt that an emulation system could be used by therapists with families that have a member with aphasia. All saw direct application of the software in the classroom. Some suggested that students use the software in class. Others suggested use at home, while attempting to communicate with friends for one evening. Participants mentioned that current practice in speech and hearing classrooms is to "role play" the effects of the aphasia (similar to acting). They reported that this approach is often awkward and inaccurate, indicating that such an emulation system would be a tremendous improvement over the status quo.

Perhaps the most tangible benefit of our study was the direct resources our participants provided. Students, faculty and professionals each mentioned key aspects of aphasia that should be emulated, if this system were to be useful.

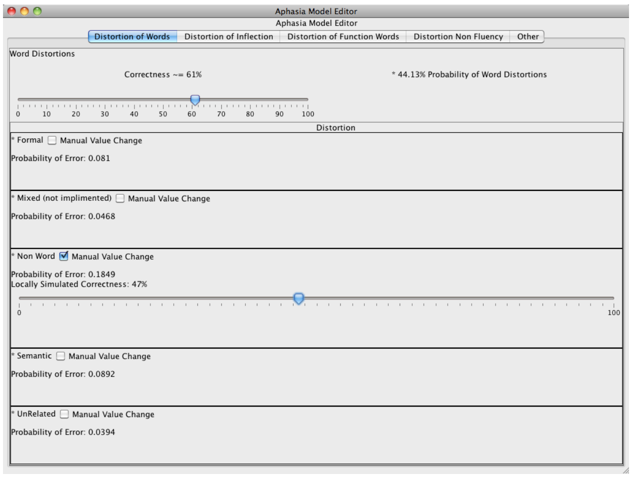

Figure 2. ACES Model Editor - Distortion of Word Tab
The overall correctness set to 61%, but the user has manually set the nonword errors to have a higher probability of occurring, increasing the overall probability of error to be 44.13%

ACES: APHASIA EMULATION SOFTWARE

ACES is a both an IM client and an instantiation of a model of linguistic distortions caused by aphasia. ACES distorts messages in a manner similar to those of an individual with aphasia. Our model determines the specific nature and rate of distortions, based upon feedback from study participants and the large body of related literature. In the following sections we describe the underlying model of aphasia distortions and the user interface components of ACES. While ACES was modeled on aphasia, our system could, in principle, be used to emulate other linguistic disorders.

Please note that the contribution of our work is to promote empathy and understanding in people through experiencing the linguistic challenges of aphasic individuals. It is not to perfectly emulate aphasia. Moreover, this project focuses on expressive language distortion, and does not address those with receptive language distortion.

Modeling The Effects of Aphasia

The effects of aphasia can vary widely based on the severity of the impairment, the type of aphasia, and even on the type of word that is subject to error. Therefore, we constructed a modeling system, **A**phasia **C**haracteristics **E**mulation **M**odel **E**ditor (**ACE-ME**), providing controls that allows the user to configure the degree and type of distortions that will be applied to their messages (Figure 2).

ACE-ME sub-divides the distortions into 5 conceptual categories: Distortion of Content Words, Distortion of Inflections, Distortion of Function Words, Distortion of Fluency, and Other. Each category defines error types that affect similar types of words (e.g., only function words or only content

[2] Number in parenthesis is the mean (μ) subject response to each statement.

words). By grouping similar errors together, we leverage existing literature that focuses on specific distortion types and provide an intuitive interface for users.

ACES includes the breadth of distortions experienced by individuals with aphasia. Although not every aphasic linguistic error is included, our goal was not to create a linguistically exhaustive emulation tool, but one that was communicatively disruptive in a manner similar to those with aphasia. As knowledge of aphasia and natural language processing expand, so can the capabilities of our system.

Distortion of Content Words

Most forms of aphasia affect the production of content words (verbs, nouns, adjectives, and adverbs). However, the effect and frequency of each error type differs depending upon the disorder and severity. Schwartz [25] highlights five key ways that content word production can be distorted: Formal Errors, Nonword Errors, Semantic Errors, Unrelated Errors and Mixed Errors. ACE-ME implements the first four error types. We omit Mixed Errors due to their technical complexity and low incident rate.

- Formal errors occur when a user mistakenly says a content word that is phonetically similar, yet semantically different [25]. For example: intending to say 'population' but stating 'pollution.' Formal errors are common with most aphasic individuals. ACE-ME emulates formal errors by utilizing a spell check system, JaSpell [4]. We force JaSpell to return an alternative for a word users enter (even though spelled correctly). We then randomly select one of the possible alternatives as a replacement. By using a spell check system, the word replaced would be similar to the original word given that suggested "alternatives" are based on the spelling of the original word.
- Nonword errors occur when a generated word is not a valid English word [25]. The generated nonword can be phonetically similar to the source word. For example: the word 'castle' is changed to 'kaksel.' Nonword errors are common for many aphasic speakers, particularly those with conduction or Wernike's aphasia. ACE-ME emulates the effects of a nonword error by randomly replacing a random number of letters in the original word. Vowels are replaced by other vowels, and consonants are replaced by consonant digraphs (e.g., 'sh,' 'ch' etc) or other consonants (excluding x and z, which are uncommon in English language). All generated words are then verified to not be 'real words.'
- Semantic errors occur when the target word is replaced by another word which is semantically similar [25]. For example: 'birthday' is replaced with 'anniversary,' or 'cake' with 'bread.' While anniversary is not a synonym for birthday, nor bread for cake, they are associated. This error occurs with all aphasic types. Because semantic errors are broader than synonyms, using a thesaurus would not capture the nuance of semantic errors. Therefore, ACE-ME identifies the root of the original word [18], searches the root in a ConceptNet database [13], and chooses a random word from possible semantic matches. ConceptNet is a NLP project that, among other things, attempts to group words together based on their semantic similarity. We extracted a relational database linking words to lists of semantically related terms.
- Unrelated errors are valid English words, that have no semantic or strong phonetic relationship to the original word [25]. These errors occur particularly in severe cases of aphasia. ACE-ME randomly selects another content word from a list and replaces the original word with the unrelated term.
- Mixed errors are similar to formal errors, except the target words are semantically similar [25]. For example: 'start' is distorted to 'stop,' or 'snail' to 'snake.' Mixed errors are are conceptually similar but programmatically very difficult. While we can readily generate semantically or phonetically similar words, we do not posses a large enough data set of either semantically or phonetically similar words to have a suitable intersection of the two. These errors are not very common, so not generating them should have little impact.

To understand how severity of aphasia correlates with frequency of word errors, Schwartz [25] performed an analysis of errors made in picture naming tasks. Aphasic subjects were shown a picture and asked to identify it. Schwartz examined the errors and created regression models to predict how likely a given error was to occur based on a subject's overall level of impairment. Using the raw data published in Schwartz's paper, we re-generated the probability of each of the five error types based on subject impairment. We used these probabilistic models in ACE-ME to calculate estimated frequency of each error. The user can move a "correctness" slider,to set the probability of each of the five content word errors based on Schwartz's work ACE-ME also allows the user to manually set each specific content word distortion (Figure 2).

ACE-ME also displays the total probability of any content word error, calculated by summing the probabilities of all possible content word errors (Figure 2). If the user has not manually adjusted an error rate, the probability of content word error is one minus the correctness percentage.

Distortion of Inflections

Grammatical inflection is the modification of a word to express different grammatical categories such as tense, mood, voice, aspect, person, number, gender and case. English inflections are usually suffixes, such as the plural inflection on nouns ("apple" versus "apples").

ACE-ME distorts only verb inflection, the most common type of inflection error for aphasic individuals (especially for those with agrammatic speech). An example of such a distortion is changing "running" to its base form, "run." ACE-ME emulates verb inflection distortion by stemming verbs [18] and using the verb's infinitive form.

Users can set the probability of Inflection Distortion using the interface slider labeled "Inflection Morphology of Verbs."

Distortion of Function Words

A common error made by aphasic individuals (especially those with agrammatic aphasia) is to omit function words. Function words are pronouns, articles, conjunctions, auxiliary verbs, interjections, particles, expletives, and prepositions. ACE-ME removes randomly selected function words.

Users can set the probability of Function Word Distortion using the interface slider labeled "Dropping Function Words."

Distortion of Fluency

The fluency of sentence construction can also be affected by aphasia. ACE-ME targets three common types of distortions that can affect sentence fluency: Conduit d'approche, Omissions, and Semantic Description.

- *Conduit d'approche*: Commonly affecting those with conduction aphasia, Conduit d'approche occurs when an individual adds/removes or distorts the production of a word, then iteratively repairs the errors until arriving at the intended production [12]. For example: a series of Conduit d'approche would be 'brepple,' 'gresles,' 'glasles,' and then completing the effort with 'glasses.' ACE-ME emulates Conduit d'approche errors by repeatedly applying a random number of nonword errors to the same word. The errors are then replayed in reverse order in the sent message, giving the appearance of correcting the specific word. Each attempt is put in a separate message followed by ellipses. The slight pause gives the impression that the sender is attempting to correct the word. Once the word is 'correct,' the remainder of the message is sent.
- *Omissions*: Most aphasic individuals omit or drop words from their sentences [17]. To emulate the effects of random omission, ACE-ME randomly drops words from a user's message.
- *Semantic Description:* Many aphasic individuals can describe the features of a target word when they cannot recall the specific word[17]. This is a semantic description error (unlike a semantic error which is a one-to-one substitution). For example, an individual trying to describe glasses may say, 'seeing, head, face, eyes, round.' ACE-ME utilizes the ConceptNet database [13], to search for a random number of semantically related terms and replaces the original word with a set of semantic descriptors (separated by ellipses).

Users can set the probability of all errors related to Fluency using ACE-ME interface sliders. As there is more than one type of Fluency error, ACE-ME also displays the total probability of a Fluency error occurring.

Other

There are two other effects common to aphasia that ACE-ME emulates. These are pauses and distortion awareness. Aphasic individuals often pause at atypical times. ACE-ME emulates these interruptions by randomly breaking up a message, sending each part as a separate IM.

People with certain types of aphasia (e.g., Wernicke's) can be unaware of the errors in their speech, while others (e.g., Broca's) are generally aware of their errors. To allow users to experience the frustration of not knowing why their conversation partner is confused (by not seeing the distorted message), as well as the frustration of not being able to send the intended message (e.g., seeing the distorted text), ACE-ME allows the user to toggle between displaying the original or the distorted message.

Users can set the probability of pauses by using the interface slider. Distortion awareness can be toggled by an interface check box in ACE-ME.

ACES Interface Components

Our system has three main components: an IM Window for engaging in instant message conversations; a Model Editor for configuring the distortions; and an Admin Window for login and switching between the IM and the Model Editor.

Upon launch, users are presented with an Admin Window (Figure 3). Users can input an AOL Instant Message user name, password, and a subject ID (used for logging all conversations to protect privacy). Once login information is entered, users can launch the other two components.

The ACES Model Editor (Figure 2) consists of five tabs corresponding to the five categories of distortions. Users can switch between tabs and interact with all sliders and checkboxes. All changes made to the model editor affect the current IM conversation in real-time.

The IM Window (Figure 4) is a standard IM interface with a message history, text input field, send button, and buddy list. IM history is color coded for easy identification of message origin (red=user, blue=conversation partner).

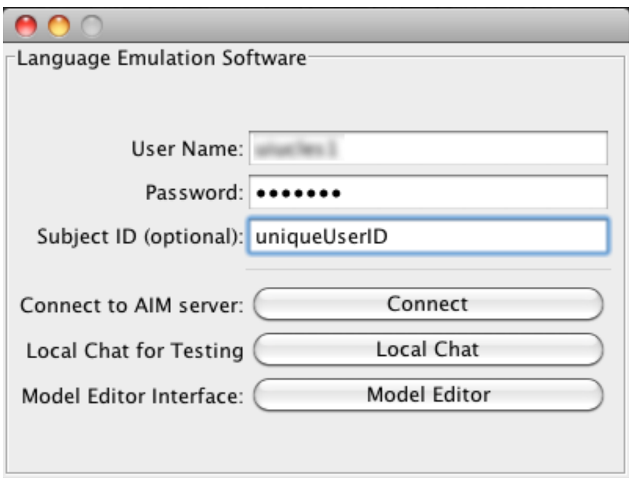

Figure 3. ACES Admin Window

Flexible Implementation

Our system leverages a plug-in architecture for distortions. Researchers, instructors, or therapists can create or customize a specific distortion type. The ACES system examines a directory where the distortion descriptions reside, including any new distortion from this directory.

ACES sends IMs over the AOL Instant Message network, though it can easily be extended to other protocols, because it leverages the JBuddy library [32] to facilitate connection with the AOL servers. JBuddy also supports ICQ, MSN, Yahoo, Google Talk, XMPP (Jabber), Lotus Sametime, Microsoft OCS 2007, and LCS 2005.

ACES was implemented using Java 1.6, allowing the software to execute on nearly any machine, though our system has only been tested on Apple's OSX. As a result, teachers, medical staff, and researchers need not invest in new hardware to run ACES.

ACES Logging

ACES is also conducive to post-conversation analysis and reflection because it logs all conversations in an HTML file of the perceived conversation (the user's sent messages), and in an XML file of the conversation (including the original message, the distorted message, and which distortion were applied). The HTML version is ideal for analyzing the conversation and reflecting upon difficulties in the user experience. The XML file allows researchers to analyze how users changed their behavior while trying to communicate with aphasic distortions.

USER STUDY

In order to observe the effects of using ACES on awareness and empathy, we conducted an in-depth user study. Sixty-four individuals (grouped in pairs) engaged in IM conversations with each other. Of these individuals, half had prior knowledge of aphasia (through formal education or personal exposure) and half did not. Participants were given questionnaires pre- and post-IM conversations, to gauge their reaction to ACES and aphasia.

Independent Variables

To assess the impact of ACES' distortion of messages on subjects' knowledge and understanding of aphasia, we compared responses with a control group, where ACES did not distort any text even though participants were told that text would be distorted. To ensure equal perception of conversations, participants in the treatment group whose text was distorted did see the actual messages that were sent (i.e., distortion awareness was turned on).

To determine if there was any bias based on relevant education or experience with aphasia, we ran our experiment with subjects who had an educational or personal background with aphasia, who will be referred to as the *Informed Group*, and subjects with no previous experience with aphasia, who will be referred to as the *Uninformed Group*.

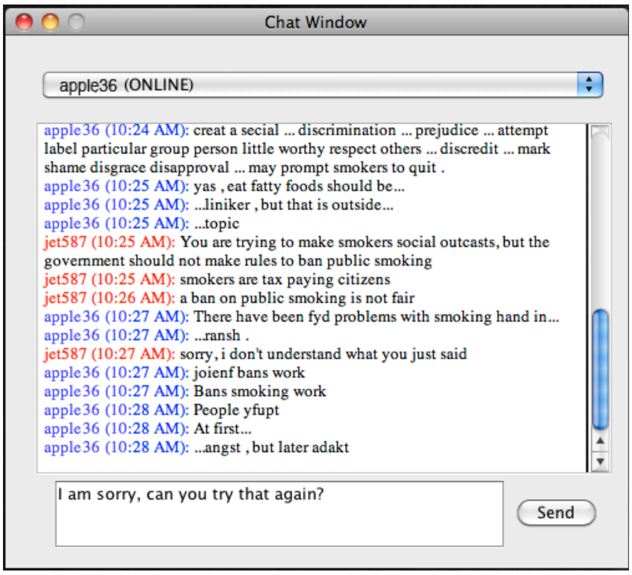

Figure 4. ACES Instant Message Window

The current (red) user's partner (blue) has their text distorted. Note: this is a log from an actual experiment conversation

Methodology

Each study session consisted of five steps (Table 1) lasting a total of 45-60 minutes. A session involved IMs between two participants who did not know each other and remained physically separated. Pairs had comparable backgrounds with respect to aphasia: both either did or did not have a background with aphasia. Each member of a pair was placed in separate identical rooms with a 23" iMac computer. All questionnaires were digital and administered using third-party software.

All participants completed both a demographic survey and a questionnaire to assess empathy using Mehrabian's measure[3] of emotional empathy [21]. Each participant also answered

	Description
Step #1	Demographic Questions
	Empathy Evaluation
	Pre-Study Questions on Aphasia
Step #2	Conversation with Partner, Prompt #1
Step #3	Post Conversation Questions
Step #4	Conversation with Partner, Prompt #2
	Participant Roles are Switched
Step #5	Post Conversation Questions Again
	Final Set of Questions

Table 1. Study Session Order

[3] Mehrabian's quantitative measure of empathy assigns an individual an empathy score based on responses to 33 questions. Scores range from -132 to +132. According to Mehrabian, a representative population should yield a mean score of 33 and standard deviation of 24.

	User 1 (Aphasia)	User 2 (Normal)		User 1 (Normal)	User 2 (Aphasia)
Topic #1	Pro	Against	**Topic #2**	Pro	Against
	Pro	Against		Against	Pro
	Against	Pro		Pro	Against
	Against	Pro		Against	Pro

Table 2. Factorial Design
Topic by User Role by Debate Position

questions about their knowledge of aphasia and feelings about communicating with persons with the disorder.

During the session, each pair had two ten-minute IM conversations with each other.[4] To guide the conversations, we asked participants to have a 'debate,' or 'discussion,' around a specific topic. Each participant was assigned a position (pro or against) and provided a suggested list of topics to support their position (they could also use their own). The two debate topics were:

- *The age at which people gain the right to vote should be lowered to 16 years*
- *Smoking should be banned in all public places*

During each IM conversation, participants were assigned a role. One participant was told that *their* IM software would distort their text with aphasic errors, while the other was instructed that their *partner's* text would be distorted. Participants switched roles after the first IM conversation. At the end of each conversation, participants completed a brief questionnaire about their experience. Participants were also asked to complete a final set of questions, a large portion of which involved reflection on any change in their awareness and empathy regarding aphasia.

Study Controls and Factorial Design
To control for the effects of role and debate position, we utilized a between-subject factorial design with counterbalancing. This would normally require four conversations (see Table 2) to cover all permutations of role and debate position. To further account for our control and treatment groups, and to test both subject groups, we would need 16 conversations. To increase statistical power, we doubled our sample size to 32 conversations (64 participants).

Dependent Measures & Statistical Tests
In order to assess the effects of using ACES on awareness and empathy, we analyzed subject responses to questionnaires at the end of the study. Since the majority of questions were on a 7-point Likert scale, a quantitative analysis was used. Responses to short-answer questions were also examined for qualitative reactions to ACES.

Because the quantitative data was not normally distributed, non-parametric Wilcoxon rank-sum tests (the non-parametric equivalent of a Student's t-test) were used. Data is presented as median and inter-quartile range (the range of values that cover the middle 50% of the data).

	% Male	Age (SD)	Empathy (SD)
Overall	39.06	26.05 (7.30)	34.52 (25.82)
Overall - C	28.12	25.06 (7.27)	40.09 (22.60)
Overall - T	50.00	27.03 (7.30)	28.94 (27.92)
Informed	37.50	25.35 (6.83)	39.25 (25.38)
Informed - C	25.00	24.13 (6.54)	46.81 (21.28)
Informed - T	50.00	26.56 (7.11)	31.69 (27.51)
Uninformed	40.62	26.75 (7.78)	29.78 (25.76)
Uninformed - C	31.25	26.00 (8.04)	33.38 (22.50)
Uninformed - T	50.00	27.50 (7.69)	26.19 (28.95)

	Highest Level of Education Completed (%)		
	High School	*Bachelors*	*Graduate*
Overall	25.00	56.25	18.75
Overall - C	28.12	56.25	15.63
Overall - T	21.88	56.25	21.87
Informed	34.38	53.12	12.50
Informed - C	43.75	37.50	18.75
Informed - T	25.00	68.75	6.25
Uninformed	15.62	59.38	25.00
Uninformed - C	12.50	75.00	12.50
Uninformed - T	18.75	43.75	37.50

Table 3. Population Demographics
Empathy refers to Mehrabian's measure of emotional empathy. Mean age and empathy scores are shown.
C = Control T = Treatment

Subjects
Sixty-four participants completed the ACES experiment (Table 3). More than 75% of the Informed population had an educational background in psychology, speech and hearing science, or traditional sciences. Participants in the Uninformed population came from a wide variety of areas spanning engineering, science, and liberal arts.

Given the empathy scores (Table 3), our population's empathy closely follows that of the original paper by Mehrabian[21]. With a balanced male/female population, Mehrabian's expects a mean score of 33 (standard deviation of 24). Our study cohort had a mean empathy score of 34.5 (standard deviation of 25.8). This is nearly identical to Mehrabian. To ensure control and treatment groups were equivalent, we examined the groups' empathy scores and the four initial self-response questions regarding participant knowledge of and sensitivity to the challenges of communication with aphasia. We examined any differences overall, and within the Informed/Uninformed demographics. There were no statistically significant differences ($p > 0.05$) between the control and treatment groups in a priori disposition, knowledge of, or empathy towards individuals with aphasia (results not shown).

[4] Participants were logged into IM accounts created for this study, not requiring subjects to disclose their own user names or passwords.

	Control Group		Treatment Group		Rank Sum
	Median [IQ range]	*Mean (SD)*	*Median [IQ range]*	*Mean (SD)*	**p Value**
1 In hindsight, this experience made me < > empathetic to individuals with aphasia.†	5 [4,5]	4.75 (0.80)	6 [6,6]	5.91 (0.77)	0.0001
2 In hindsight, this experience made me < > empathetic to people who try to understand an individual with aphasia. †	4 [4,5]	4.62 (0.87)	6 [5,6]	5.59 (0.87)	0.0001
3 This tool is useful for building empathy for family members‡	4 [4,5]	4.19 (1.47)	6.5* [5,7]	6.09 (1.06)	0.0001
4 This tool is useful for building empathy for speech therapists‡	4 [4,5]	4.47 (1.59)	6 [5,7]	6.09 (1.03)	0.0001
5 This tool is useful for building empathy for nurses and doctors‡	4.5* [4,5]	4.47 (1.54)	7 [5,7]	6.22 (0.91)	0.0001
6 This tool is useful for building empathy for care givers‡	4 [4,5]	4.38 (1.50)	7 [6,7]	6.38 (0.91)	0.0001
7 This tool is useful for education/training of individuals who treat/ interact with individuals with aphasia‡	4 [4,6]	4.5 (1.65)	7 [6,7]	6.53 (0.80)	0.0001
8 Which role helped you understand aphasia better?§	4 [3.5,4]	3.91 (1.42)	2 [1,3]	2.28 (1.55)	0.0001
9 Which role increased your empathy for the the perspective of understanding an individual with aphasia? §	4 [4,4.5]*	4.5 (1.03)	1.5* [3.5,6]*	3.72 (2.40)	0.28
10 Which role increased your empathy for the the perspective of an individual with aphasia? §	4 [3.5,4]*	3.69 (1.38)	2 [1,4.5]	2.72 (2.25)	0.02

Table 4. Results

Median represents median value and interquartile range [IQ range]. Rank Sum represents Wilcoxon Rank Sum test

* *Half values are due to even number of data points where the vale separating the higher half from the lower half lies between two different value, resulting in a median which is the average of the two values. For example a data set of [1,4,4,5,5,7] would have a median of 4.5 although 4.5 is not a possible value.*

† *Question Choices Were: 1=Much Less, 2=Less, 3=Slightly Less 4= No Change, 5= Slightly More, 6=More, 7=Much More*

‡ *Question Choices Were: 1= Disagree, 4=Neutral, 7 = Agree*

§ *Question Choices Were: 1= Aphasia, 4=Equal, 7=No Distortions/Normal*

Results

Overall, participants in the group experiencing aphasic distortions by the ACES were strongly affected by their experience relative to the control group (Table 4, Questions 1 & 2). For example, participants indicated that the experience made them more empathetic to individuals with aphasia compared to the control group who felt only a slight change, with $p<0.0001$. Participants in the treatment group strongly agreed that ACES should be used in all applications explicitly listed, while the control group felt neutral as to ACES' applicability (Table 4, Questions 3 - 7). Participants in the Treatment group strongly agreed that ACES could be used to increase empathy in caregivers while participants that did not experience distortions felt neutral towards ACES use, with $p<0.0001$. Participants in the Treatment group felt that they gained understanding and empathy from having their text distorted, while the control group did not rank one role higher than another (Table 4, Questions 8 & 10).

When analysis was stratified by the Informed and Uninformed groups separately, results were similar to those of the full cohort (results not shown). Finally, we compared the Informed treatment group with the Uninformed treatment group to see if a priori knowledge of aphasia influenced subject response. Both treatment groups found ACES beneficial in increasing knowledge and empathy.

Figure 4 is a representative conversation between two subjects (taken from our study). The IM window is from jet587, whose partner, apple36, is having his text distorted.

Post Hoc Results

One question with a non-significant value overall was: "*Which role increased your empathy for the the perspective of understanding an individual with aphasia?*" Given the large inter-quartile range within the Treatment group, we suspected the lack of significance was due to order effects (which role the participant played first). To test this hypothesis, we performed a X^2 test comparing role against subject response for the Treatment group and found $p=0.05$.

Whichever role the participant experienced second was the role reported to have increased their empathy more. Thus, participants who experienced aphasic distortions first, reported that the 'no distortion' condition (which they experienced second) increased their empathy from the perspective of understanding an individual with aphasia *more* than the aphasic distortion condition (median = 6, [2.5,7.0]). Similarly, participants who experienced the aphasic distortion role second reported that this role increased their empathy from the perspective of understanding an individual with aphasia more than the no distortion role, which they had experienced first (median = 2, [2,4]). We tested the other questions for order effects and did not find any.

DISCUSSION

Participants who experienced the distortions of aphasia had a much stronger response than those in the control group. Those participants in the treatment group reported "strong" effects from the experiment, including increased empathy and envisioning a wide variety of potential uses of ACES. In contrast, participants who did not have their text distorted reported little or no change in their perception of or empathy towards aphasia. The median quantitative responses from the control group were almost unanimously at 4 (a neutral opinion, or no change), with inter-quartile ranges indicating little deviation. The control group also saw no strong application for ACES to increase empathy or awareness of aphasia. This is a stark contrast to those with exposure to aphasic distortions.

There is always the possibility of a change in empathy resulting from being in an experimental condition (known as experimental demand). However, given the great difference in responses between the two groups (qualitatively and statistically), we are confident that ACES demonstrates a real impact on increasing awareness and empathy by experiencing distortions caused by aphasia. This is further supported in that both groups were given identical prompts, and the experiment was fully counterbalanced.

While quantitative feedback provides strong evidence of the effectiveness of ACES, qualitative feedback highlights how informative the ACES experience was for participants, and how supportive they are of the project. For example, one participant from the Informed Treatment group stated:

> *This was a wonderful way to gain empathy! I've learned about aphasia in classes, but this perspective was very helpful and will make a lasting impression.*

The qualitative feedback supported how prior experience with aphasia was not a prerequisite for gaining insight. One participant from the Uninformed Treatment group stated:

> *It was the most eye-opening from the point of view of having my text distorted. It was amazing how hard it can be sometimes to get a point across. From the aphasic side it is almost like experiencing it from both sides, because you see how difficult what you say can be for the 'normal' person.*

Participants also suggested that even short exposure could make a lasting impact, saying, *"it would only take a few minutes to gain perspective."*

In contrast, qualitative feedback from subjects in the control group supported our quantitative findings, indicating that this was not a meaningful experience. Given the stark difference in qualitative and quantitative responses between the control and treatment groups, we believe that ACES can provide a meaningful experience for all users who seek to better understand and empathize with aphasic individuals.

FUTURE WORK

Our experiment examined the impact of ACES on participants' empathy and understanding of aphasic individuals. However, our long term goal is to meaningfully improve real-world interactions, thereby improving quality of life and therapy for individuals with aphasia. We propose conducting a follow-up study to explore whether a subject's experience with ACES can positively impact their real-world interactions with individuals with aphasia. We further wish to investigate the long-term impact of ACES.

While ACES supports a robust set of distortions, there are always refinements and less common errors that can be implemented. Over time, we hope to increase the capabilities and functionality that ACES provides.

Though this project explicitly targets aphasia, our goal is to introduce language distortion emulation as a new approach to increasing empathy for those with other language impairments. We envision, for instance, a system similar to ACES that distorts text as though it comes from a young child. This can teach patience, understanding, and empathy to parents, teachers, and caregivers.

CONCLUSION

Empathy and understanding from family members, friends and clinicians can enhance the quality of life of aphasic individuals. Family members can deny or underestimate the severity and presence of aphasic errors. Without empathy, the quality of speech therapy can suffer, jeopardizing the speed and recovery of aphasic individuals. Our work has made several contributions to address these concerns stemming from a lack of empathy.

First, we leveraged speech-language and psychological theory to design and construct a model of aphasic distortions. Second, from an initial investigation we refined our model and designed a system to increase awareness and empathy with aphasic individuals. Third, we developed a novel system (ACES) that allows a neurologically typical individual to experience firsthand, the linguistic distortions of aphasia. Fourth, ACES was validated in an investigation with 64 participants (with and without background on aphasia). Results from this study strongly show that using ACES can increase empathy and awareness of aphasia.

Our model and system demonstrate how technology can play a central role in increasing empathy, awareness and understanding for individuals with a language disorder. Our approach can be used in many other domains where atypical language is present and can be emulated. It is through empathy that we learn to understand each other.

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