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Phonetic Reduction is Associated with Positive Assessment and other Pragmatic Functions

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Abstract

A fundamental goal of speech science is to inventory the meaning-conveying elements of human speech. This article provides evidence for the inclusion of phonetic reduction in this inventory. Based on analysis of dialog data, we find that phonetic reduction is common with several important pragmatic functions, such as the expression of positive assessment, in both American English and Mexican Spanish. For American English, we find, in a controlled experiment, that people that speaking in a positive tone generally do indeed use more reduced forms.

Keywords: reduced articulatory precision, hypoarticulation, prosody, pragmatic functions, corpus study, annotation, English, Spanish, positive assessment, perception

Highlights

- We undertook the first perception-based study of the pragmatic functions of reduction
- We used dialog data in American English and Mexican Spanish
- Phonetic reduction is a common correlate of positive assessments in both languages
- Phonetic reduction is also associated with other pragmatic functions
- Phonetic reduction seems to function as a prosodic feature

1 Introduction

A fundamental goal of speech science is to inventory the meaning-conveying elements of human speech. Success may be near: the inventory of the possible phonemes has long been essentially complete, and various prosodic-feature inventories are good enough to be often useful. Yet the quest to complete the inventory of meaningful features has lost energy, especially in speech technology. With the rise of machine learning and increasing amounts of data available for many problems, it became clear that more features bring more power, even if many have little perceptual or linguistic motivation, as seen in the influential OpenSmile set of 6552 features, including, for example, the kurtosis of the second derivative of the shimmer, and the third quartile of the

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zero-crossing rate (Eyben et al. 2010). Currently, the mainstream approach is to ignore considerations of feature meaning, and instead use features learned by pretraining, such as the 1024 of the last HuBert layer (Hsu et al. 2021, Mohamed et al. 2022), which have been shown to work very well for many tasks, including some previously thought to require handcrafted features (Yang et al. 2021, Lin et al. 2022).

Nevertheless, there is still value in features which are directly hearable, as they can support "explainable" models, whose behavior we can fully understand. Further, such features can serve as understandable control parameters for speech synthesis, enable comprehensible descriptions of language patterns to support learners, and provide a leg-up for machine learning to achieve good performance from less data. This paper presents evidence that suggests that phonetic reduction may be such a feature: not only hearable but also meaningful and useful.

2 Motivation

While the existence of phonetic reduction is well known, speech technology researchers have not generally seen it as useful. This section provides an overview of related research: we briefly sketch out ways in which reduction is important in human language, and why it nevertheless has had no applications impact. We leave a more thorough treatment to several comprehensive surveys (Ernestus & Warner 2011, Jaeger & Buz 2017, Cangemi & Niebuhr 2018, Zellers et al. 2018).

It is common experience that speakers sometimes produce words that are difficult to recognize, sounding perhaps mumbled, sloppy, or just unclear. These phenomena have been studied under various technical terms, including hypoarticulation, reduced articulatory precision, speech reduction, and the term we will use here: phonetic reduction or, for short, just "reduction." We can group related work in three categories.

First, many studies of reduction build on the perspective that speakers tend to minimize effort, and in particular, often provide only just enough phonetic accuracy to successfully convey the intended content to the hearer (Lindblom 1990, Levshina & Lorenz 2022), a perspective that reflects a general tension in language between economy and redundancy (Horn 1993). This is seen in the well-established correlation between durational reduction and lexical predictability (Jurafsky et al. 1998, Bell et al. 2003, 2009). Dialog systems developers may think of these connections, not as capabilities worth emulating, but as reflections of the foibles of human speech production, that dialog systems should avoid. Certainly it is true that pervasive reduction and poor intelligibility can be due to a lack of language proficiency, depression, or neural and physical impairments (Helfer et al. 2013, Jiao et al. 2016, Tu et al. 2018, Wynn et al. 2022). Reduction can also, of course, be a indicator of disengagement and can cue perceptions of negative personality attributions such as laziness. Reduction can also result from speaker-internal factors, as when specific words are reduced due to priming effects (Gahl et al. 2012, Kahn & Arnold 2015) or due to properties of the mental lexicon (Johnson 2004, Munson & Solomon 2004, Schubotz et al. 2015, Warner 2019, Mulder et al. 2022).

Second, many studies have elucidated the structural factors involved in reduction, including the ways that it is conditioned on the prosodic properties of specific words, on syntactic structure, on grammatical roles (for example, more reduction for function words), and on prosodic

structure (Zellers et al. 2018, Machač & Fried 2023, Bodur et al. 2023). While these factors are important for synthesizing natural-sounding speech in many styles, such reductions have generally been seen as not worth modeling explicitly, but rather left to be learned implicitly from data.

Third, a few studies have elucidated the connections between reduction and specific pragmatic functions, beyond marking things as not new. Identified pragmatic functions include turn hold in English, German and possibly Swedish (Local & Walker 2012, Niebuhr et al. 2013, Zellers 2017), repair and agreement in Dutch (Plug 2005, 2011), and sarcasm in German (Niebuhr 2014). In English it may also be present in self-deprecating asides (Gustafson, Székely & Beskow 2023), cues for backchannel feedback, expressions of a self-sufficient stance, and topic closings (Ward 2019). Reduction is also known to be involved in certain functions in specific phrases — for example English *gonna* (c.f. *going to*) in statements of intent, *why dontcha* (c.f. *why don't you*) for suggestions, *dunno* (c.f. *I don't know*) to convey indifference, and so on (Hawkins 2003, Schubotz et al. 2015). None of these pragmatic functions, however, are top-of-mind for speech applications builders.

Indeed, for the classically-framed problems of text-to-speech and speech-to-text, reduction is just a nuisance: a source of noise in the mappings between speech sounds and word sequences. However, there is an increasing realization that, for spoken dialog systems to be useful in newer scenarios, such as those involving interpersonal sensitivity or situated robots, they will need to exploit more of the pragmatic information in the speech signal (Marge et al. 2022). This has led to great current interest in elucidating the extra information that is present in speech. This challenge has been taken up by the speech synthesis community, where, with the problems of intelligibility and naturalness largely solved, there is much interest in finding ways to improve the communicative range of synthesizers and to make them controllable, as surveyed in (Wagner et al. 2019, Mohan et al. 2021, Lameris et al. 2023). In particular, there is interest in modeling prosody as a way to improve synthesis quality, either for human-controllable parameters, or to build better loss functions for training (Huang et al. 2023), but this interest has not yet spilled over to the topic of reduction. For example, in the 90-some papers on speech synthesis at Interspeech 2023, over half included discussion of prosody, but the features considered were mostly pitch and duration, with only 10% mentioning intensity and 1% voicing properties, and none mentioning phonetic reduction.

Thus, phonetic reduction is not currently a mainstream topic in speech technology. But glimmerings of change may be present. A few individuals and groups have, over the years, called for its inclusion into the prosodic features inventory (Beller et al. 2008), stressed that speech can be noticeably reduced and still adequately intelligible (Niebuhr 2016), pointed out its importance in conversational-style speech Adigwe et al. (2024), and developed experimental synthesizers with the ability to control the level of reduction (Picart et al. 2014, Birkholz et al. 2016, Gustafson, Székely, Alexandersson & Beskow 2023). However, none of these systems are ready for general use, no commercial synthesizers support such control, and, in general, reduction remains a niche topic.

Overall, while there is some scattered knowledge of the pragmatic functions that reduction can serve, none of these have been of compelling importance for applied speech researchers. There is something of a chicken-and-egg problem here: detailed studies of reduction functions are difficult without tools, but tool builders have no motivation to add reduction abilities without

evidence of its potential utility. Here we aim to jump-start a virtuous cycle, of greater appreciation of the importance of reduction leading to better tools, in turn leading to greater knowledge and to practical applications.

The rest of this paper is structured as follows: Section 3 describes the data we used, Section 4 describes our initial explorations and the hypotheses they led to, Section 5 describes a systematic corpus study that identified functions associated with reduction, and Section 6 describes a production study that confirmed the connection between reduction and positive assessment.

3 Data and its Annotation for Reduction

The previous section surveyed reasons to seek a better understanding of how reduction works, especially in dialog, and showed that our current knowledge of the pragmatic functions of reduction is very limited. This motivated us to seek a more complete view of the functions that reduction serves. As our aim was discovery, we started with a corpus-based approach: we annotated corpora for perceived reduction, and then did qualitative-inductive and statistical analyses to identify the associated functions. This section discusses our strategy, procedure, and initial observations. For this we used a well-structured process, which we describe in some detail in the hope that this will be useful for those contemplating similar studies, but do not intend this intial analysis to be replicable in any sense. In any case, more detail on our procedure and preliminary findings appear in the companion technical report (Ward & Ortega 2024) and companion website, `https://www.cs.utep.edu/nigel/reduction`.

3.1 Data

The first critical choice was of what data to use. Our most fundamental decision was the choice to use dialog data, not read speech, because the most important potential applications relate to dialog. We chose to examine two languages: English, as a well-studied language where we still hoped to find something new, and Spanish, as a first look at a non-Germanic language.

Our specific choice of data was based on five desiderata: 1) exhibiting diverse pragmatic functions, 2) having diverse speakers, 3) having good audio quality, 4) being among friends or peers (as reduction is more common in informal conversation), 5) having mostly dialects, topics, and dialog styles with which we are familiar, to enable confident annotation. To meet these needs we selected a few conversations from our own data, originally collected for another purpose (namely, subsequent partial re-enactments in another language) (Ward et al. 2023). This was collected locally in El Paso, Texas. The dialects were General American English and Mexican-American Border Spanish, and all of the conversations selected were on freely chosen topics, with neither prompts nor scenarios. The selection was made on the basis of interestingness and diversity. For example, the English conversations include talk about upcoming internships and fall classes, the aftermath of a spat, talk about participating in sports, stories of working in a jail, and discussion of anime. As will be seen below, this data supported all phases of the work, in different subsets and via different processes.

3.2 Reduction Annotation Procedure

The second critical choice was how to annotate the data for reduction. We did this by hand, because there were no good alternatives. Existing automatic reduction-detection methods are untested for temporally fine-grained discriminations (Tu et al. 2018, Lubold et al. 2019, Lee et al. 2006, Jiao et al. 2016, Chen et al. 2022, Ward & Ortega 2024). Word duration reductions are easy to measure and commonly used (Jurafsky et al. 1998, Kahn & Arnold 2015), but are not a reliable proxy for other measures of reduction nor for perceptions of reduction.

Our specific annotation target was perceived reduction. This is an unusual strategy, as most previous work has annotated for correlates or aspects of reduction, such as phoneme durations, more centralized vowels, more co-articulation, and the effects of various language-specific phonological rules, such as coda-consonant deletion in English (Jurafsky et al. 1998, Turnbull 2015, Koreman 2006, Aguilar et al. 1993, Picart et al. 2014, Machač & Fried 2023, Niebuhr & Kohler 2011). Other work has exploited one of those rare corpora which have both full segmental labels and canonical transcriptions, from which one can infer where certain types of reduction occur (Jurafsky et al. 1998, Niebuhr et al. 2013). The problems with these methods are that hand labeling does not scale, and that no single feature correlates adequately with all reduction phenomena (Burdin & Clopper 2015).

Since no previous work seems to have created a corpus annotated for perceived reduction, we had to design our own annotation procedure. We started with an initial rough examination of some data and our perceptions, listening together to a few minutes of each language. We then developed lightweight annotation guidelines, which were subsequently given to the annotators in the form seen in Figure 1. The Granularity clause reflects our working assumption that reduction in dialog is mostly suprasegmental. (Of course, reduction occurs at various times scales. Most previous work has focused on "short-term" occurrences, lasting for a phoneme, a syllable, or a word, while other work has examined reduction over the "long-term," across a conversation or an extended speech sample. With our interest in pragmatic functions, we are interested in reduction at the level of a few words or phrases: "mid-term" reduction phenomena.) In practice, most of the labeling was done at the scale of regions that covered one or a few words, depending on the granularity of the perceived variations in articulation level. (Most words occurred in larger utterances, of various lengths.) The Codes clause reflects our observation that, while reduction is a gradient phenomenon, we could at most reliably annotate for four steps of the continuum: highly reduced, reduced, normal, and enunciated (clearly articulated). The Criteria clause acknowledges the essential subjectivity of these judgments. The Scope clause reflects the fact that non-lexical items (Ward 2006) — such as *umm*, *wow*, and *uh-huh* — lack reference pronunciations in the same sense as words, so it would make no sense to try to annotate them for reduction. The Confounds clause was intended to prevent annotation by proxy percepts, with the specific cautions based on the literature on the prosodic correlates of reduction in read speech; however, as it turned out, none of these actually correlated with reduction in this data (Ward & Ortega 2024).

We note that this annotation was done before we had any idea of what the associated pragmatic functions might be, and, indeed, before we even envisaged using them directly for analysis (Ward & Ortega 2024).

Granularity: We are labeling at the level of utterances, phrases, or words. We do not label individual syllables or phonemes.

Codes: 3 = highly reduced, 2 = reduced, 1 = normal, 0 = enunciated

Criteria: Subjective judgments of being poorly articulated or possibly hard to understand without context.

Scope: We only label words. We label all words. That is, we label all word-containing parts of utterances. Every one of these should have one of the four labels above. We do not label laughter, word fragments, tongue clicks, or nonlexical utterances (*uh-huh, umm*, etc.).

Confounds: We know that some things correlate with reduced speech (fast rate, low intensity, low pitch, narrow pitch range), but we try not to let these things affect our judgments.

Figure 1: Reduction Annotation Guidelines

3.3 Yield and Quality Assessment

The third author, a Spanish-English bilingual, annotated a sampling of English and Spanish conversations, totaling 31 and 25 minutes, respectively, for every word in both tracks, left and right, using Elan as the annotation tool. This gave a total of 3051 annotated regions for English and 1614 for Spanish. For both languages, some degree of reduction was very common, present in 26% and 31% of the regions in English and Spanish, respectively. The annotations are available for download at `http://www.cs.utep.edu/nigel/reduction` and the audio for the dialogs via `http://www.cs.utep.edu/nigel/dral`; we note that this is the first publicly released collection of data annotated for perceived reduction.

To roughly estimate the reliability of these annotations, we had a second annotator label 2 minutes each of the English and Spanish. Cohen's Kappa between the two annotators, for both English and Spanish, was 0.25 for the four categories, and 0.35 for the two-category discrimination of 0 or 1 versus 2 or 3. Noting that the second annotator tended to perceive reduction more often, we also computed the correlation: it was 0.57, giving a somewhat brighter picture of the agreement.

We note that one could certainly obtain higher agreement by using a more structured process, or by leveraging more objectively identifiable correlates of reduction. However this would run counter to our strategy of using direct perceptions, and would prematurely constrain what we might find (Aroyo & Welty 2015). Further, detailed analysis of all differences of opinion between the annotators (Ward & Ortega 2024) revealed that these usually affected at most one or two words per phrase, and only rarely differed by more than one point. For the analysis below, which relies only on average behavior across multi-word phrases and across many such phrases, such differences are just an acceptably small minor noise source. Further, none of the complicating factors (Ward & Ortega 2024) seem likely to much relate to any of the pragmatic functions that we ended up investigating.

4 Initial Analysis

With the annotated data as a resource, we began analysis, using qualitative inductive methods, over many steps, to develop hypotheses.

For English, our first step was to examine all regions in ten minutes of dialog that were labeled as reduced and note down the functions observed at these times. Second we grouped these into several categories. Third we refined these as we examined the instances more carefully, leading to nine categories: 1) fillers, interjections, and backchannels, 2) prosody carriers like *like* and *you know*, 3) uncertainty markers, 4) recapitulations, 5) predictable words, 6) downplayed phrases, including parentheticals, 7) topic closing moves, 8) turn grabs, 9) personal feelings, including preferences and desires. These categories are neither mutually exclusive nor exhaustive; for example, there was a case of reduction occurred as part of yielding to resolve a moment of speech inadvertently overlapping that of the other speaker.

Fourth, to winnow out the categories not truly associated with reduction, we wrote short descriptions of the nine categories and used these to systematically label all regions in the remaining 21 minutes of data for these functions, plus two controls, negative assessment and positive assessment, defined as noted below. Examining the strength of the associations with reduction, we found, to our surprise, that the positive assessment category (explained below) was strongly associated with reduction. Of 9 functions, all except prosody carriers and fillers seemed significantly correlated with reduction. This was unsurprising for recapitulations and predictable words, based on the literature, but the connections with the others were novel.

The procedure for Spanish was similar. We examined dialogs from the same corpus, but not overlapping the reduction-labeled set, and after some iteration arrived at 7 categories: uncertainty markers, topic closings, turn grabs, personal feelings, downplayed phrases, positive assessment, and agreement, with only the latter something not also seen in English.

4.1 More on Positive Assessment in English

For the experiment, below, we chose to focus on the function of positive assessment, for three reasons: its connection with reduction was the most surprising, it was the second-best supported in the initial analysis, and it is potentially the most practically important. Here we briefly explain what we mean by this function.

For us, the "positive assessment" category is quite broad: for annotation purposes we defined it as "positively assessing or expressing positive feelings about something, some happening, or someone, including the interlocutor or the speaker himself." Here are three examples. In each, the underlining marks the reduced region, the * marks the start of the region where the pragmatic function (here positive assessment) is clearest, and the / marks speaker change.

- *I want to work with the inmate population / *oh wow, that's interesting* (006@1:53)
- *Yeah, because I got the research position here, and I thought, *it was a good, opportunity, because I want to do my Ph.D.* (006@2:39)
- *I was in taekwondo . . . no, but. *It was, it was pretty cool. I liked it.* (033@0:15)

- *I've seen Bleach, I've seen Akame ga Kill / *That one's so good; I love that one. That one's like, a nice short one ...* (043@2:28)

While there is a fair body of work on the prosodic properties of positive assessment and positive sentiment more generally, as surveyed in (Niebuhr 2010, Ward & Jodoin 2019), nowhere has the connection of positivity with reduction been previously noted. There is an even larger body of work on the properties of positive emotion, affect, and valence. While positive assessment relates at best marginally to these phenomena — since in these conversations the participants were generally in a good mood, and certainly not reacting emotionally to anything — it is interesting that the correlation found here does not align with the finding of the only work connecting reduction to emotion: that there is more reduction in sad speech (Lee et al. 2006) (and depression (Hall-Lew 2024)). Interestingly, the reduction often affects only some of the words in positive phrases, and in particular, does not always affect the most valenced words, including *good*, *love*, and *liked* in the examples above.

5 Corpus Study

Having arrived at some initial ideas for the functions associated with reduction, we next did a corpus study to determine which functions are statistically associated with reduction. We did this for both English and Spanish.

Our method was to obtain an independent annotation of the data for 8 pragmatic functions, derived from our initial analysis, as shown in Figure 2. We expected 7 of these to likely correlate with reduction in one or both languages, and included negative assessment as a control. Annotation was done by the fourth author, a Spanish-English bilingual, who at the time was naive to the aims of the annotation. She received about 10 minutes of explanation, with illustrations of how to annotate. She then annotated the same 21 minutes of English and all 25 minutes of Spanish.

We then applied a script to compare the reduction annotations and the functional annotations. This computed two types of indication. The first type was the average reduction level for each functional region, and, derived from this, the average across all regions for each function. These are shown in the second column of Tables 1 and 2 below. We also used an unpaired, one-sided t-test to estimate the evidence that the distribution of average reduction levels for a function was significantly above the distribution for all regions. The second indication was, aggregating across all regions with a given functional label, the percent of the time they were in each reduction level. As noted above, these ranged from 0 (enunciation) through 1 (normal) and 2 (reduced) to 3 (highly reduced).

5.1 Results and Discussion: English

The results for English are seen in Table 1. The most strongly associated function was Positive Assessment, and the other strongly associated function was Topic Closings, as, for example, in

- *. . . it's like cloud services, it's like AWS / oh, okay / *that kind of stuff yeah yeah, you know, I don't know, this is what happens I guess.* (013@0:57)

PO Positively assessing or expressing positive feelings about something, some happening, or someone, including the interlocutor or the speaker himself.

NE Negatively assessing or expressing negative feelings, like *super dangerous*, and *I peaked back then*. More often, the negative feeling is not in the words but in the tone.

UC Marking Uncertainty, for example with phrases such as *I don't know, hopefully, I'm not sure yet*, and *I feel like*.

DP Downplaying something, such as in a parenthetical, aside, self talk, or in a side comment that is not intended to be responded to. Repair markers are also in this category, as in *I'm taking Machine Learning, no, sorry, uh, Deep Learning*.

TG Making a Turn Grab, when a speaker takes the turn before knowing quite what he wants to say. Also in this category we include "rush-throughs," where a speaker seems to revoke a turn yield by speaking quickly to forestall the other from taking the turn after all.

TC Making Topic Closing moves, for example with cliched phrases and other ways to show that the speaker has nothing more to say, and no further interest in, a topic.

AG Agreeing with something the other has said, or confirming what they have asked, for example with words like *exactly* or *that's true*.

PF Expressing Personal Feelings, including simple statements of wants and preferences, and also more thoughtful or introspective statements.

Figure 2: Pragmatic Function Annotation Categories

Four other functions had tendencies to connection with reduction, namely Downplayed Phrases, Agreement, Turn Grabs, and Uncertainty Markers. (Examples for these appear in (Ward & Ortega 2024).) With the overall standard deviation being 0.89 steps, the effect sizes ranged from modest to reasonably large: for example, the effect size of being part of a positive assessment was 0.28 standard deviations, and of being part of a topic closing 0.60.

5.2 Results and Discussion: Spanish

The results for Spanish are seen in Table 2. For Spanish also, the connection with Positive Assessments was the strongest. The other functions with strong connections were Turn Grabs and Downplayed Phrases. There were also tendencies for Negative Assessments, Topic Closings, and Personal Feelings.

With an overall standard deviation of 0.83, the effect sizes were modest, for example, 0.19 standard deviations for positive assessment.

To illustrate the three functions with solid connections:

1. Positive Assessment

    - *abrieron una sección nueva de Star Wars, que *está bien chida vato.* (001@1:02)

	average	n	p	percent with reduction label: 0	1	2	3
all regions	0.98	3051	–	35%	38%	21%	6%
Positive Assessments	1.23	40	.008	26%	35%	30%	9%
Topic Closings	1.51	8	.015	4%	49%	40%	7%
Downplayed Phrases	1.17	26	.101	30%	30%	33%	7%
Agreement	1.13	32	.122	32%	33%	26%	9%
Turn Grabs	1.08	37	.137	33%	33%	26%	8%
Uncertainty Markers	1.09	41	.156	36%	28%	26%	9%
Negative Assessments	0.96	65	.571	44%	25%	22%	9%
Personal Feelings	0.89	39	.850	43%	29%	22%	5%

Table 1: Reduction Statistics for Various Pragmatic Functions in English. The second column indicates the average reduction levels. The third column shows the number of occurrences: the count of function-labeled regions that overlapped at least one region with a reduction-level label. Functions are ordered by strength of evidence for a relation to reduction, as measured by p values for the t-tests, in the fourth column. The remaining columns show the percentages of 10-millisecond frames at each reduction level. The "all regions" statistics are for all regions with reduction-level labels, not limited to those at times for which a functional label was assigned.

*they opened a new Star Wars section, which is so *cool dude.*

- *. . . *si disfruto ver a bastantes amigos y todas las cosas.* (001@4:15)
  *. . . *yes I enjoy seeing a lot of friends and all that.*
- *es que *están ricos, ella los hace bien ricos.* (008@0:17)
  *it's just that *they are delicious, she makes them very delicious.*

2. Turn Grabs (many of which here involved actually cutting off the other speaker)

   - *. . . esas si estan hechas a mano y luego / *pues es que no no es como que hechas a mano. . .* (008@0:46)
     *. . . it's just that those are made by hand and then well / *It's because no not that like it's hand-made. . .*
   - *El huevo con tocino no va en sandwich / Pues tienes razon. / Si no / *O que te digo. . .* Pues a ti, ¿Que te gusta el café o el té? (012@1:24)
     - *Bacon and egg don't go together in a sandwich / Well, you're right./ Yes / *Oh what do I tell you. . .* Well, do you like coffee or tea? (012@1:24)
   - *que no ibas a aplicar a eso lo de / *pues si pero pues no me, como que no tiene. . .* (012@3:26)
     *weren't you going to apply to that of / *well yes but well it doesn't, like it doesn't have. . .*

3. Downplayed Phrases

	average	n	p	percent with reduction label: 0	1	2	3
all regions	1.03	1614	–	31%	38%	29%	2%
Positive Assessments	1.19	39	.022	24%	37%	35%	4%
Turn Grabs	1.25	27	.029	19%	43%	32%	6%
Downplayed Phrases	1.36	12	.036	16%	38%	41%	5%
Negative Assessments	1.15	72	.054	26%	36%	36%	3%
Topic Closings	1.27	4	.198	24%	25%	51%	0%
Personal Feelings	1.10	23	.294	32%	29%	36%	3%
Agreement	1.02	22	.522	21%	55%	22%	1%
Uncertainty Markers	0.94	39	.819	35%	38%	26%	2%

Table 2: Reduction Statistics for Spanish.

- *Le fui a preguntar que si / al profesor/ * el profe, el profe. Bueno le fui a preguntar que si podía buscar en mi mochila, a ver si tenía otro (lapiz) porque él no tenía nada. . . .* (003@0:24)

  [talking about needing a pencil during an exam] *I went to ask him / the teacher / *the teacher, the teacher. Well I went to ask him if I could look in my backpack, to see if I had another one because he didn't have anything.* (003@0:24)
- *Yo apuesto que me fue medio bien. Hay muchas cosas que pues yo digo que sí me sé, si me supe. *Porque, lo que estudié ayer. Pero no estudie, no estudie, me faltaron estudiar dos capítulos del libro.* (003@1:28)

  *I bet it went pretty well for me. There are many things that, well, I say that I do know, I did know. *Because, of what I studied yesterday. But I didn't study, I didn't study, I missed two chapters of the book.* (003@1:28)

6 Experimental Verification

Based on the corpus study, we hypothesized that English speakers would reduce more in utterances said in a positive tone. To evaluate this, we designed an experiment: In overview, we obtained both positive and neutral versions of the same phrases, and then got judgments on which were more reduced. Both of these procedures were deemed exempt from human-subjects review by our local Institutional Review Board. This section presents the experiment design and the results.

6.1 Elicitation of Positive and Neutral Productions

Wanting to control all factors other than the level of positivity, we had participants create two versions of several phrases, one positive and one neutral. Thus each positive-neutral pair had the same lexical content and was produced by the same speaker.

Our first issue was deciding what words to have the participants say. Because the results of a preliminary study indicated that reduction in monologues may pattern differently from re-

and you want to work with kids? / I want to work with the inmate population / *oh, wow [that's interesting]*
I was born in El Paso but raised in Juarez. I was here literally for a day and then I moved back / *[me too, actually]*
I think I will be boasting, but I was on the varsity team / ah, okay, okay / *I actually went, like, for [two tournaments] to Cathedral*
what class are you taking in the summer? / Applied Agile Software Development. *It's like cloud services, [like AWS], that kind of stuff*
Do you know what classes you're taking next semester? / *yeah I'm taking [computer security]*
next semester? / in the summer, hopefully. / *[which Summer is it] gonna be?* the first one or the second one?

Table 3: The phrases, including the context that the reenactors heard. The re-enacted parts are in italics, and the parts heard by the judges (the "payloads") are in brackets. In the corpus, the first three of these were positive in tone and the last three neutral.

duction in dialog (Ward & Ortega 2024), we wanted to collect dialog-style samples. We biased the participants towards a conversational style by 1) giving them phrases from actual conversations, with enough context to make them clearly real, and 2) asking them to "say the phrase in the way you might if you were part of this conversation." Thus the participants served as reenactors. Table 3 shows the phrases we chose. These were taken from the same corpus of student conversations (Ward et al. 2023), since we wanted our reenactors to be able to comfortably imagine themselves talking to a peer about these topics. Our primary criterion was to select phrases whose valence could easily vary, depending on how they were said. We did not consider whether their appearances in the corpus included reduction nor whether they included phonemes that would be likely to become reduced. To improve the likelihood that the results would generalize, we did aim to include some diversity, of three types: diversity of topic, of syntactic form, and of level of positivity in the original conversation (3 appeared without any positive feeling, and 3 with some degree of positive feeling, from weakly expressed to strongly expressed).

The second issue was the design of the recording protocol. Here we had to address a potential confound: speaking rate. Pilot experiments showed a tendency for the positive renditions to be generally faster than the neutral ones. Increased rate is a known cause of reduction, and if not controlled, could explain away any effects. As our aim here is to show a *direct* connection between positivity and reduction, we needed to rule out this confound. In order to get positive clips that were no shorter than the neutral ones, we did two things. First, we ordered the reenactments so that for each phrase each subject did the positive rendition first, thinking that the second version, as a repetition of something already said, would tend to be faster. This appeared to have only a small effect. Second, we added a step, such that if the neutral payload came out slower than the positive one, the reenactor would redo the former until it was about as fast as,

or faster than, the positive rendition. (We also considered obtaining the desired rate relation by having the reenactors say the positive version slower, but found that this often came out sounding condescending.)

Thus, for each phrase, each reenactor

1. Heard the phrase as used in a real conversation.
2. Re-enacted it with a positive frame of mind.
3. Re-enacted the phrase with a neutral frame of mind, then waited for the experimenter to measure the durations, and if necessary produced another neutral version, this time faster.
4. Read aloud each of the words in the payload, as if making sample recordings for a dictionary.

We recruited 6 reenactors. For each, the procedure started with an explanation of the procedure and giving consent to release their recordings to the public domain. They then donned a Shure BRH441M head-mounted microphone connected via a VOLT1 USB audio interface to a laptop. Their audio was recorded using Reaper, which allowed realtime monitoring of volume, and the ability to subsequently mark the duration of each payload.

Overall this took about 20 minutes for most reenactors, but #12 found it difficult to produce neutral versions sufficiently short, so he took more time. The dictionary style recordings were generally clearer, but we noticed that Reenactor #1 produced *interesting* with 3 syllables in dictionary style, but 4 syllables in both her positive- and negative-tone versions.

Regarding the durations, in the end, the average duration of a positive clip was 916 milliseconds, 57 milliseconds longer than the average negative clip, 859 milliseconds. For only 6 of the 36 pairs was the positive version shorter/faster than the negative, and most of these were by less than 10 milliseconds, which is approaching the limits of measurement accuracy. The pair for which the positive was relatively shortest was Reenactor #12's production of *which summer is it*, where the positive and neutral durations were 578 and 600 milliseconds, respectively. Thus, despite repeated attempts, he was only able to get the neutral to within 22 milliseconds (4%) of the duration of the positive.

6.2 Evaluation of Which Versions were More Reduced

Given these collected productions, we needed a way to determine which were more reduced. As noted above, no suitable automatic methods are available, so we chose to use perceptions. Specifically, we chose to use the perceptions of untrained subjects, to avoid any possible theory-induced bias. Because reduction is often subtle, we designed the judgment process to make it as easy as possible for them. Our considerations and choices were: 1) Since absolute judgments of reduction are difficult, we only asked participants to make comparisons of stimulus pairs. 2) Since "which is more reduced" might be tricky, we asked them to select the ones that "are more clearly articulated." 3) Since judgments of reduction over longer spans involve both perceptual and cognitive processes, we had them rate at the phoneme level, which is likely closer to a pure perception task. 4) Since our subjects were phonetically-naive, for each word we gave them the list of phonemes in conventional spelling. 5) Since phonemes in isolation often don't sound like anything, each stimulus was an entire word with a little context, specifically at least 20ms both

Figure 3: Data entry screen for judgments. For each phoneme, subjects selected whether it was clearer in the first or second stimulus.

before and after the word, and more if needed to be able to perceive all the phonemes of the word. 6) As an anchor we gave them references, namely the dictionary-style productions. 7) Since the differences were often subtle, at best, we gave subjects the ability to play each of the clips as often as they wanted. 8) Since we wanted to glean every perception, no matter how weak, we gave the judges no option to skip a pair. Rather, the instructions specified "if not sure, please just make your best guess."

Participants entered their judgments though screens like that in Figure 3. The instructions were "please mark which of the pair is more clearly articulated (which is generally the one more similar to the careful-reading-style reference)." The parenthetical was included due to the issue with one production, mentioned above.

To control for possible order bias, we randomized whether the positive or neutral clip was presented on the left or right. To reduce the chance that participants could perceive the positive or negative feeling, which might affect their judgments in some way, we randomized the order of presentation of the words, so they never heard a full phrase. This was not entirely successful, in that, for a couple of word pairs, it seemed obvious, to us, even from the word in isolation, which was more positive (usually by high pitch and faster rate); but of course the subjects weren't looking for this, as we didn't tell them our hypothesis until the debriefing stage.

There were 6 judges. Each judge made 150 judgments: 75 phoneme pairs each across the productions of 2 reenactors. Thus every phoneme pair production was judged by two judges.

Judges listened through headphones. They were proctored by the experimenter, sitting by their side and watching, to encourage them to continue to devote the high level of attention needed for these subtle judgments. Overall, including explanations, this took 15 to 50 minutes, with Judge #22, the one who by far took the most time, very saliently putting in a lot of effort, listening to all the stimulus pairs again and again.

6.3 Participants

All the reenactors and all the judges were students. There was no overlap between the two groups. All were recruited by word of mouth, mostly from among friends, plus one who had participated in previous studies and had asked to be invited back. There were no exclusion conditions. The reenactors and judges were both gender-balanced. Each was compensated US $20 for their time.

positive	387
neutral	513
Total	900

Table 4: Number of times that the rendition which was judged clearer came from the positive source utterance, versus from the neutral one.

6.4 Results

Aggregating all the judgments, as seen in Table 4, the phonemes from the positive recordings were generally perceived as more reduced (less clear) than the ones from the negative recordings. Using the binomial distribution, we reject the null hypothesis, that the perception of greater reduction could be at chance, with $p < 0.00002$. Thus the hypothesis was supported. (It was also supported if the pair with the noticeably shorter positive utterance was excluded.)

6.5 Further Analysis

Although this experiment was not designed for systematic investigation of other factors, we did two post-hoc investigations.

First we investigated individual effects. As seen in Figure 5, results varied by reenactor, from #12, whose productions were strongly aligned with the hypothesis (and who the one who spent the most time on his productions) to #1, whose productions were judged opposite to the predicted direction. It is not surprising that the association between reduction and positive assessment, while prevalent, is not valid for all speakers of English, and it would be interesting to explore this (Ward & Ortega 2024). Results also varied by judge, as seen in Figure 6, from #5, whose judgments were near chance, to #22, who overwhelmingly judged the neutral phonemes to be clearer, and who was the one who had devoted the most time to the task.

Reenactor	positive	neutral
1	**82**	68
2	65	**85**
4	60	**90**
12	55	**95**
16	64	**86**
17	61	**89**
Total	387	**513**

Table 5: Overall selection of clearer phonemes per reenactor.

Second, we investigated the per-phoneme tendencies. As seen in Figure 4, while most phonemes were more reduced in the positive case, some had the opposite tendency. Post hoc, we noticed two factors that may explain this. The first factor seems to be various kinds of novelty or stress. This could explain the countervailing tendencies seen: for *AWS* which was entirely new information in the corpus, entirely unpredictable from the context; for the *too* of *me too*, which was, of all the original phrases, the one with the most positive feeling; and for the word *summer*,

Judge	positive	neutral
5	74	**76**
7	60	**90**
8	71	**79**
10	62	**88**
22	49	**101**
1325	71	**79**
Total	387	**513**

Table 6: Overall selection of clearer phonemes per judge.

which was used in an unusual, novel sense, to refer to a branded time period, either the first summer half-semester or the second. The second factor is likely general reducibility, as seen in the unstressed syllables of *interesting*, *actually*, *double-yu*, *computer*, and *security*, and in the /m/ of *summer*. Perhaps such generally-reduced syllables lack capacity to be even more reduced in positive-toned productions. Together, these observations suggest that a more accurate description would state that the increased reduction on positive renditions affects all phonemes except those in positions that are generally highly reducible or those in highly novel or stressed words. Further work will be needed to refine and test this statement.

To support further analysis, we make all stimuli, judgments, and documentation available at https://www.cs.utep.edu/nigel/reduction/ .

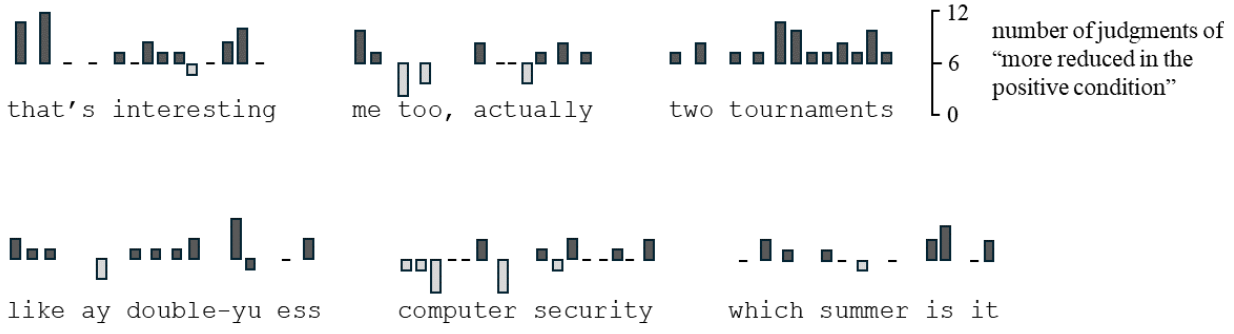

Figure 4: Per-phoneme tendencies to more reduction (dark gray) or less reduction (light gray) for the positive productions versus the neutral ones. As each phoneme pair appeared in 6 stimuli, and was judged twice, there were 12 total judgments. For each phoneme, horizontal lines indicate parity, with 6 judgments each way, and the bars indicate the number of times, ranging from 3 to 11, that the positive member of the pair was perceived as more reduced.

7 Summary, Implications, and Open Questions

The major contribution of this paper is the finding that reduction is associated with important pragmatic functions (Table 7), notably including positive assessment in American English.

This finding could be quickly applied to improve dialog systems. In one direction, there

	English	Spanish	German	Dutch
positive assessment	⇑+	⇑		
topic closings	⇑	↑		
downplayed phrases	↑	⇑		
agreement	↑	–		
turn grabs	↑	⇑		
uncertainty markers	↑	↓		
personal feelings	↓	↑		
turn hold	⇑		⇑+	
given/recapitulated/predictable	⇑+			
sarcasm			⇑+	
repair				⇑

Table 7: Summary of Functions Associated with Reduction. ⇑ means good corpus evidence, ↑ means a corpus tendency, ↓ means an inverse tendency, – means no tendency, + means experimental confirmation, and blank means not yet studied. The first seven rows and two columns summarize our findings here; the rest are based on the literature surveyed in Section 2.

are many reasons to want to continuously track the user's state of satisfaction, utterance by utterance, but this has always proved difficult (Schmitt & Ultes 2015). Monitoring variations in the user's level of phonetic reduction could enable more accurate tracking and thereby more responsive dialog systems. In the other direction, dialog systems should be able to synthesize utterances in a positive tone, for many reasons. For example, a task-oriented system should be able to redundantly mark statements that convey something good, such as completing a successful authentication step, finding a way to satisfy the user's request, or even just having understood what the user said; a tutoring systems should be able to praise the user for a correct answer or a thoughtful guess; and chat system personas should be able to convey when they feel positively about some topic or entity, and be able to show warmth when the user shares a happy thought or discloses something personal. Doing these things better, by strategically modulating reduction levels, could help dialog systems convey positivity more clearly, more convincingly, and more naturally.

To achieve these benefits, the first research priority is creating methods for accurately estimating the degree of reduction in speech, phrase-by-phrase. Just as F_0 estimators are, though not infallible, very useful, reduction estimators could become widely used. For improving speech synthesis, such estimators would make it easy to add a term for faithfulness in reduction-level to the loss function to enable the training of systems that appropriately control the level of reduction, word-by-word. Beyond practical applications, such methods would greatly accelerate progress in the study of reduction, for example, by enabling automatic corpus annotations. Synthesizers able to vary the degree of reduction over arbitrary regions would, among other things, enable testing whether and when reduction actually contributes to perceptions of increased positivity.

A remaining research question is, what type of feature is reduction? Two aspects of our findings are relevant: reduction is often suprasegmental, as are prosodic features, and reduction

seems to interact in complex ways with lexical and phonetic content, as do prosodic features. Further, reduction often seems to combine with other features to form "prosodic constructions" (Ward 2019). This is seen by the fact that, although several functions involve reduction, there is no reason to think they are generally confusable. This is likely because of the contributions of other prosodic features. These may include, for positive assessment, fast rate and loudness, and for topic closings, slow rate, long pauses, and low volume. Further, uncertainty markers may involve slow speaking rate, turn grabs may involve fast rate and high pitch, and predictable words may involve low pitch and low volume. Thus, we should probably describe reduction not as conveying these meanings by itself, but as being part of various prosodic feature configurations, constructions, which bear meanings. While further investigation is needed, overall there are good reasons to consider reduction to be a prosodic feature (Beller et al. 2008).

Future work aside, our findings already significantly broaden our view of reduction: it not just a matter of careless speech nor a mere side effect of various mental processes, but a "first-class" feature, one that can likely help convey meaning in its own right. It should therefore be added to the armamentarium of speech scientists and technology developers.

More generally, our findings indicate there are still interesting things left to discover about the features that are meaningful in speech, and that examination of dialog data, in all its richness, can be a productive strategy for this quest.

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