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## A Corpus Analysis of Patterns of Age-Related Change in Conversational Speech

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### Abstract

Conversational speech from over three hundred speakers aged 17 to 68 years old was analyzed for age-related changes in the timing and content of spoken language production. Overall, several relationships between the lexical content, timing, and fluency of speech emerged, such that more novel and lower frequency words are associated with slower speech and higher levels of disfluencies. Speaker age was associated with slower speech and more filled pauses, particularly those associated with lexical selection. Increasing age, however, was also associated with longer utterances and greater lexical diversity. On balance, these analyses present a picture of age-related changes in speech performance that largely support data obtained from controlled laboratory studies. However, particular patterns of age-related change may be moderated in conversational situations.

### Keywords

conversation; corpus analysis; aging; speech

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As any methods textbook tells us, the experimental control associated with laboratory tasks permits greater inferential power than would be possible from observation alone. For empirical findings to be informative about behavior, though, there should be a predictable (but not necessarily simple) relationship between laboratory results and performance in the world. In the present paper, we consider the relationship between age-related changes in language production observed in the laboratory and in language use outside the lab. Experimental studies suggest a range of changes across the lifespan in component processes of language production. However, many laboratory tasks necessarily impose artificial constraints on speakers in order to isolate relatively specific aspects of language processing. Here, we examine a corpus of spontaneous dialogue for evidence of similar patterns of age-related change across a variety

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of measures. In examining this corpus of natural speech, our goal is to provide a picture of age-related change to aspects of speech production that would be difficult to assemble from experimental studies alone.

Laboratory studies have documented age-related changes across many discrete aspects of language production. During single word production, older adults are generally slower and more error-prone than younger adults (e.g., Barresi, Nicholas, Connor, Obler, & Albert, 2000; Bowles, Obler, & Albert, 1987; Feyereisen, Demaeght, & Samson, 1998), are more influenced by competition during lexical selection than younger speakers (LaGrone & Spieler, 2006), and encounter difficulties in the assembly of phonological forms (Burke, MacKay, & James, 2000; MacKay & James, 2004). Older speakers also exhibit slower speech rates and reduced fluency during the production of isolated sentences (Spieler & Griffin, 2006) as well as during more open-ended response tasks (e.g., Bortfeld, Leon, Bloom, Schober, & Brennan, 2001; Kemper, Herman, & Lian, 2003).

Speech outside the laboratory, however, operates under a number of macro-level constraints that potentially constrain the impact of age-related processing changes. Language use occurs within social contexts that condition the behavior of speakers and listeners (Adams, Smith, Pasupathi, & Vitolo, 2002). Conversational conventions provide specific guidance in how information should be packaged, what to include, and what can be safely left out (Grice, 1975). Also, speech is expected to occur with reasonable fluency while simultaneously providing signals to the listener about deviations from ideal delivery (Clark, 2002). Violating these soft constraints may carry costs that range from a loss in social standing to a simple reduction in communicative efficiency. Importantly, though, speakers in real-world contexts have wide leeway in how they achieve possible communicative goals (Levelt, 1989). This flexibility may influence how age-related processing changes are expressed in conversation because speakers, in particular, may change how they allocate resources (Stine-Morrow, Miller, & Hertzog, 2006) in order to buffer performance against any underlying changes in processing ability.

Here, we focus on questions directly related to findings from laboratory studies of language production. In particular, we are interested in the timing, fluency and lexical properties of conversational speech, and how these aspects of spoken language production are associated with age. We recognize this leaves out a range of possible influences on conversational speech, but our interest is in the relationship between laboratory studies of age-related change and language change outside the laboratory.

## Conversational Evidence and Method

### Speech Data

For this project, we used the Switchboard I Corpus (Godfrey, Holliman, & McDaniel, 1992), an extensive corpus of conversational speech collected for research in speech and speaker recognition. The full corpus includes over 2400 telephone conversations, or 240 hours of conversation, corresponding to roughly three million words spoken by over 500 different individuals of both genders ranging in age from 17 to 68. Upon signing up, participants were asked to select from 70 preferred conversational topics (e.g., “air pollution”). When a speaker dialed into the system, an automatic “operator” connected them with another individual who had indicated an interest in the same topic. Individual conversations averaged six minutes in length, and there were no restrictions on whether speakers stayed on topic. Many speakers participated in multiple conversations, paired on each occasion with a different partner. Very basic demographic information was collected for each speaker, including age, gender, and education level.

Trained court reporters produced standardized transcripts of the conversational recordings and subsequently, a time alignment file for each conversation was created that indicated the beginning time and duration, in centiseconds, of each word in the transcript. The bulk of these timing data were produced using an automated speech recognition system. The subset of the Switchboard corpus that we examined has been hand-coded for basic linguistic information, such as disfluencies and sentence and turn information. These characteristics provide a unique opportunity to examine how aging might influence conversational speech.

### Speaker Characteristics

Our sample consists of speech from 336 different speakers, taken from 913 unique conversations and including over one million words. In our dataset, 21% of speakers participated in a single conversation, 45% participated in two to five conversations, and 34% participated in six or more conversations. Our sample includes 166 female speakers and 170 male speakers, ranging in age from 20 to 67 years old ( $M = 36.9$ ;  $SD = 10.6$ ). With a median age of 34, the distribution of ages in this sample is skewed toward younger speakers, with just 10% of the sample over the age of 50. Because many of the effects of aging are observable as relatively monotonic age-related changes across adulthood, we use the complete age range to examine relationships between speaker age and characteristics of conversational speech.

### Analysis Strategy

We began by developing a basic profile of properties of the speech, and how these properties are related to speaker age. These specific observations were motivated by basic findings of age-related change in work on language production. Due to the size of the dataset, we used measures that could be automatically extracted whenever possible. In all analyses, we take the individual speaker as our unit of analysis. For speakers who participated in multiple conversations, we first obtained information about each measure within a conversation and then computed the means for that speaker across all relevant conversations. Across speakers, we then examine the inter-correlations between our descriptive measures of conversational speech and speaker age. Although these measures involved aggregating over conversations, we recognize that an individual's speech is highly likely to be influenced by characteristics of the conversational partner. However, the present data do not allow us to conditionalize our analyses on both speaker and conversational partner properties. In particular, the skewing of our sample towards relatively younger speakers means that conversational partners were likely to be "young" for all speakers. This limited variability in age largely precludes comparisons of how partners of different ages may have influenced speakers. In general, then, our analyses focus on the behaviors of individual speakers, and fall into several categories related to the content, timing, and fluency of speech.

## Analyses and Results

### Lexical Properties

To examine changes in speech content, we focused on lexically-based measures. Lexical retrieval is commonly identified as being adversely influenced by aging, including age-related increases in the likelihood of word retrieval failure (Barresi et al., 2000; Burke, MacKay, Worthley, & Wade, 1991; Burke et al., 2000; Goral, Spiro, Albert, Obler, & Conner, 2007) and difficulties in lexical selection (LaGrone & Spieler, 2006). In conversational settings, speakers have wide latitude in word choice, so increased difficulty in lexical retrieval may be associated with patterns of word use intended to alleviate these difficulties. More specifically, because frequently used words are easier to retrieve (e.g., Jescheniak & Levelt, 1994), aging may be associated with the increased use of such words. We examined this possibility with two measures: type/token ratio and lexical frequency.

First, speakers may reuse words they have produced earlier in the conversation, thereby decreasing the number of word types relative to the number of tokens (i.e., type/token ratio; Miller, 1981; Owens, 1991). Because type/token ratio is sensitive to the size of the speech sample, after computing type/token ratios for our data, we applied a transformation known as the Uber index<sup>1</sup> (Dugast, 1980, cited in Jarvis, 2002) that partially compensates for varying sample sizes. In general, as the number of unique words goes down, the Uber index should also decrease (we will continue to use the term “type/token ratio”). However, it is also known that vocabulary knowledge is maintained or even increases with age (Uttl, 2002; Verhaegen, 2003). To the extent that larger vocabularies are associated with higher type/token ratios, this could lead to a relatively stable type/token ratio over the lifespan. Even so, speakers in naturalistic conversations may restrict themselves to a relatively limited vocabulary if doing so has other benefits, such as fostering communicative fluency.

Second, we asked whether there is an age-related change in the lexical frequency of words used during conversation. Words that have a high frequency of usage in the language are typically produced more quickly and accurately (Jescheniak & Levelt, 1994). Thus, higher frequency words should be more available and easier to produce during conversation. To increase confidence that we were comparing similar words across speakers, we limited our analysis to the set of nouns used during each conversation. We first applied an automatic part-of-speech tagger (TreeTagger; Schmid, 1994) to our dataset to identify each word’s likely grammatical class (e.g., noun, past participle, determiner), and then extracted every word that had been tagged as either a noun (NN) or plural noun (NNS), excluding proper nouns. We used the CELEX English spoken word-form database (a 17.9 million spoken word corpus) to obtain frequency estimates for each noun, measured as frequency of occurrence per million words (*CobSMIn*; Baayen, Piepenbrock, & van Rijn, 1993). Because word frequencies are heavily skewed (i.e., most words occur extremely infrequently), our analyses use log-transformed frequencies. In general, these analyses of both type/token ratio and lexical frequency were intended to provide a picture of whether speakers make an attempt to limit the difficulty of production by selecting simpler or fewer words.

Table 1 presents the complete correlation matrix for our set of measures, including speaker age. It is worth noting, first, that, across our sample, there was a significant negative correlation between type/token ratio and log word frequency,  $r = -.13, p < .03$ . That is, as speakers’ word selection became more diverse, they also exhibited a tendency to use more low frequency words. With respect to speaker age, we found a significant positive correlation between age and type/token ratio,  $r = .11, p < .05$ , suggesting that older adults used a greater variety of words. The correlation between age and log word frequency, though, was not significant,  $r = .06, p = .24$ , suggesting that older adults did not necessarily select more common words. This suggests that in conversational speech, like in other more constrained production contexts, type/token ratio increases and word frequency decreases with age (see also Kavé, Samuel-Enoch, & Adiv, 2009).

Another way that older speakers may reduce processing demands is by producing utterances with less complex grammatical structures (Kemper et al., 2003). We looked for age related changes in grammatical complexity using two measures: overall utterance length and clause density. For utterance length, we relied on the fact that the Switchboard corpus has been hand-annotated into “slash-units” (Meteer, Taylor, MacIntyre, & Iyer, 1995) that correspond maximally to sentences but which also indicate incomplete utterances terminated with a pause. Using this measure, we counted the number of utterances produced by each speaker, and

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$${}^1\text{Uber index } U = \frac{(\log \text{Tokens})^2}{\log \text{Tokens} - \log \text{Types}}$$

divided this by the counts of individual words to obtain an average utterance length for each speaker. This measure is highly correlated with the morphologically based mean length of utterance (MLU; Parker & Brorson, 2005).

For clause density, we used the “Treebank-3” corpus, which includes a subset of 650 syntactically parsed and tagged conversations from the full Switchboard corpus, covering 308 of the 336 speakers in our primary dataset. Treebank 3 includes five tags marking clause boundaries: S (simple declarative), SBAR (subordinating), SBARQ (direct wh-question), SINV (inverted declarative), and SQ (inverted yes/no question). To calculate clause density, we tallied the occurrence of these clause-level tags along with tags used to mark sentence boundaries, summed the number of clausal tags for each speaker in a conversation, and computed the average clauses per sentence across all conversations in which that speaker took part.

Average utterance length in our sample was uncorrelated with both type/token ratio ( $r = .07$ ,  $p = .22$ ) and mean log word frequency ( $r = -.02$ ,  $p = .76$ ) but positively associated with age,  $r = .12$ ,  $p < .03$ , indicating an age-related trend toward longer sentences. On average, utterance length increased from  $M = 7.76$  words per utterance for speakers younger than 30 years of age to  $M = 8.25$  words for speakers 50 or older. In contrast, clause density did not correlate with speaker age,  $r = .04$ ,  $p = .51$ . Thus, although utterance length correlated positively with age in our full sample, this putatively more direct measure of complexity did not show a similar relationship with age. This suggests that the observed increase in sentence length across age may be driven at least in part by factors other than simple clause density.

It is also important to note that age related changes in grammatical complexity may be most noticeable in speakers over the age of 70 to 75 (Kemper, Thompson, & Marquis, 2001). The relatively younger age range for our speakers allows us to examine change over adulthood but does not allow us to observe more abrupt changes that may be present in samples of older speakers. At the same time, however, unconstrained dialogue of the kind we examine here may be less cognitively demanding than many of the monologic production tasks commonly used in lab studies (e.g., Pickering & Garrod, 2004). If so, this could change the relationship between grammatical complexity and available cognitive resources observed in more controlled production contexts.

### Timing and Fluency of Speech

During speaking, words must be retrieved and coordinated such that utterances are produced in a timely fashion. Consequently, aspects of speech content may be related in systematic ways with speech timing and fluency. Indeed, if we look at a gross measure of speech rate in our sample—that is, the total number of words uttered by each speaker divided by his or her total time speaking (calculated as words per minute), we find that speech rate is negatively correlated with the type/token ratio,  $r = -.19$ ,  $p < .001$ . That is, as speakers use more unique words, their speech rate decreases. Similarly, as individuals produce more low frequency words, there is a concomitant decrease in speech rate,  $r = .16$ ,  $p < .01$ . These relationships are consistent with the notion that speech rate is partially a reflection of the difficulty of word retrieval. Given these patterns, we looked at age-related changes in speech timing. This is particularly important given that many aspects of speeded performance show a monotonic decrease across the lifespan (Salthouse, 1996). We found that speaker age was negatively correlated with speech rate,  $r = -.11$ ,  $p < .04$ , consistent with previous findings documenting modestly slower speech rates in older adults (e.g., Spieler & Griffin, 2006). In our sample, this corresponds to change in average speech rate from 194 wpm for 20 year olds to 169 wpm for 60 year olds.

Of course, speech rate is a relatively gross measure of the fluency of production. If a speaker finds herself at a point where what is to be said next is not ready for articulation, there may be

some disruption in the flow of speech. Disfluencies such as fillers (e.g., *uh* and *um*) and repairs (e.g., *the woma- I mean man*) often reflect difficulties with underlying processes of utterance planning and execution (although they may also be used as devices to “hold the floor;” Goffman, 1981; Levelt, 1989). As previously mentioned, such difficulties have commonly been observed in laboratory studies of language production in older adults. For example, older adults are disproportionately slowed relative to younger adults when multiple words compete for production (LaGrone & Spieler, 2006), and they are more susceptible to failures in phonological encoding during word retrieval, as evidenced by increased rates of tip of the tongue states (Burke et al., 1991). Moreover, in controlled studies of single sentence production, older adults show greater rates of disfluencies than do younger adults (Spieler & Griffin, 2006). Given that lexical selection remains an important part of spontaneous dialogue, one can expect age-related increases in disfluencies associated with word retrieval (cf. Bortfeld et al., 2001). The limited production required in most laboratory tasks, though, gives less guidance for predictions about disfluencies related to higher-level utterance planning.

We focus primarily on fillers because these are both common and easily identified forms of disfluency. We counted each instance of “uh” and “um” in the transcripts and calculated occurrences per 100 words for each filler type separately, as well as the total rate of fillers. Because lexical diversity, lexical frequency, utterance length, and speech rate are all factors that could influence the difficulty of production, we first examined the correlations between each of these factors and the overall rate of disfluencies. Although word frequency was not correlated with the overall rate of fillers,  $r = -.06$ ,  $p = .27$ , there was a significant negative correlation between type/token ratio and disfluency rate,  $r = -.12$ ,  $p < .04$ , indicating that greater lexical diversity was associated with more fillers. Similarly, a positive correlation between filler rate and utterance length,  $r = .31$ ,  $p < .001$ , indicated that speakers who produce longer sentences were also more likely to produce fillers (Oviatt, 1995; Shriberg, 1994). Finally, there was a significant negative correlation between filler production and speech rate,  $r = -.35$ ,  $p < .001$ , indicating that slower speech was associated with higher rates of fillers (Maclay & Osgood, 1959). Part of the reason for slower speech rates may have been the additional delay introduced by the fillers (Clark & Fox Tree, 2002), although individuals who produce fillers can exhibit generally slower speech even when fillers are not counted toward the calculation of speech rate (Shriberg, 2001).

We correlated speaker age with both overall filler rate and rates of “uh” and “um” separately. In general, age showed a positive correlation with rates of fillers,  $r = .17$ ,  $p < .002$ , consistent with previous work (e.g., Bortfeld et al., 2001). Note, though, that previously we reported a positive relationship between age and type/token ratio. Because greater diversity in word choice might also boost rates of filled pauses, we computed the partial correlation between age and filler rate, controlling for the mean type/token ratio of words produced by each speaker. We still find a positive correlation between age and rate of fillers,  $r = .20$ ,  $p < .001$ , suggesting that the general increase in fillers with age is not due to the greater lexical diversity. In a similar fashion, we asked whether the decrease in speech rate with age could be accounted for by the increase in fillers. A partial correlation between age and speech rate that controlled for the rate of filler production was non-significant,  $r = -.06$ ,  $p = .28$ . Thus, the positive correlation between age and speech rate may have been due to the increase in fillers produced by speakers over the lifespan.

Turning to each filler type, we obtain the same positive correlation between speaker age and rates of “uhs” per 100 words,  $r = .27$ ,  $p < .001$ , consistent with increased word-finding problems with age (e.g., Burke et al., 1991; Goral et al., 2007). However, we found a significant *negative* correlation between age and rates of “ums” per 100 words,  $r = -.19$ ,  $p < .001$ . The divergent correlations between age and “uh” versus “um” production may be due to their different discourse functions. Shriberg (1994), in a detailed analysis of disfluencies produced

by a subset of 30 speakers from the Switchboard corpus, found that “uh” was more likely to occur in utterance-medial position whereas “um” was more frequent in utterance-initial position. If “ums” are mostly associated with message-level planning, then their decrease with age may be due to different planning strategies by older speakers (cf. Bortfeld et al., 2001).

## Discussion

Taking as a starting point the results from laboratory studies of language production, we used a corpus analysis to investigate several aspects of age-related changes in conversational speech. Consistent with laboratory studies, we found that speakers generally speak more slowly and become less fluent with age. However, there were also deviations from a pattern that would suggest simpler language use with age. In particular, we found stability in clause density along with age-related increases in lexical diversity (see also Kavé et al., 2009) and a general increase in utterance length. Given that these latter patterns should actually increase the difficulty of production, it seems unlikely that they reflect direct adaptations to underlying declines in processing resources. Of course, speakers operate under a variety of constraints that potentially shape how adaptations to age-related changes in processing are expressed. The present results indicate that lexical content may be particularly resistant to changes that might make production easier. Rather, modest changes in disfluencies and speech rate may be either more acceptable avenues for accommodating age-related change in spontaneous dialogue, or simply easier to implement in response to such changes.

The magnitude of these relationships is quite small. We believe, though, that this is a property of these results worth emphasizing. Real world contexts are rife with compensatory possibilities that are often not available in laboratory settings. In natural conversation, saying what you want, when you want, is a relatively soft constraint on language production that presumably allows speakers a number of options in terms of how they may satisfy these constraints. Consider, for example, the simplest and most widely documented finding in cognitive aging, which is the general decrease in processing speed with age. In Figure 1 we present a scatter plot of average speech rate by age calculated from the present data, normalized as z-scores. To better observe the age trend, we have also plotted the average speech rate for each age decile within our sample. For comparison, we include a trendline representing the age-related decline in a traditional measure of psychomotor speed (Digit Symbol) from a large sample of individuals across the lifespan (Park et al., 2002), also plotted as z-scores. The line is shifted above our sample because of the larger age range within the Park et al. data. The important point about this comparison is that the age relationship for our measure of speech rate is considerably attenuated relative to a standardized measure of processing speed. That is, the age-related slowing of conversational speech is markedly less than the equivalent change in domain-general processing speed over the same age range. This suggests that factors that contribute to laboratory observations of age-related cognitive decline may be at least partially ameliorated when one looks at similar behaviors “in the wild.”

There are at least two likely factors at work that act to attenuate these age differences in language use. First, conversational speech is a quintessentially complex behavior that affords speakers a large number of options for satisfying the demands associated with spoken language. As individuals age, they may develop ways of allocating processing resources in ways that best suit current communicative goals (Stine-Morrow et al., 2006). As a result, the effects of pervasive age differences in component processing may be spread across many aspects of language production. Second, speakers can be thought of as experts in the complex behavior of language production in ways similar to expert typists and musicians. In these cases, aging experts are able to make adjustments to performance to maintain high levels of performance, such as slowing down speech to facilitate the timing associated with lexical retrieval. In this

sense, we believe the relatively small age differences observed in the present study are an important part of the picture of age-related change in real world behavior.

It is important to note, though, that the present data are necessarily limited by the fact that this is a found dataset, which disallows careful matching of speakers and systematic investigations of possible effects due to partner characteristics. Also, we recognize that the age range of our sample is truncated relative to other aging studies. If the cognitive processes most relevant for language production are generally stable over the lifespan, decreasing precipitously only later in life (Kemper et al., 2001), one might predict relatively small changes over the age range examined here, as suggested by our examination of clause density. Nonetheless, in addition to revealing several important correspondences with previous experimental findings, these analyses also suggest how conversational contexts may moderate the effects of certain age-related cognitive changes upon language production.

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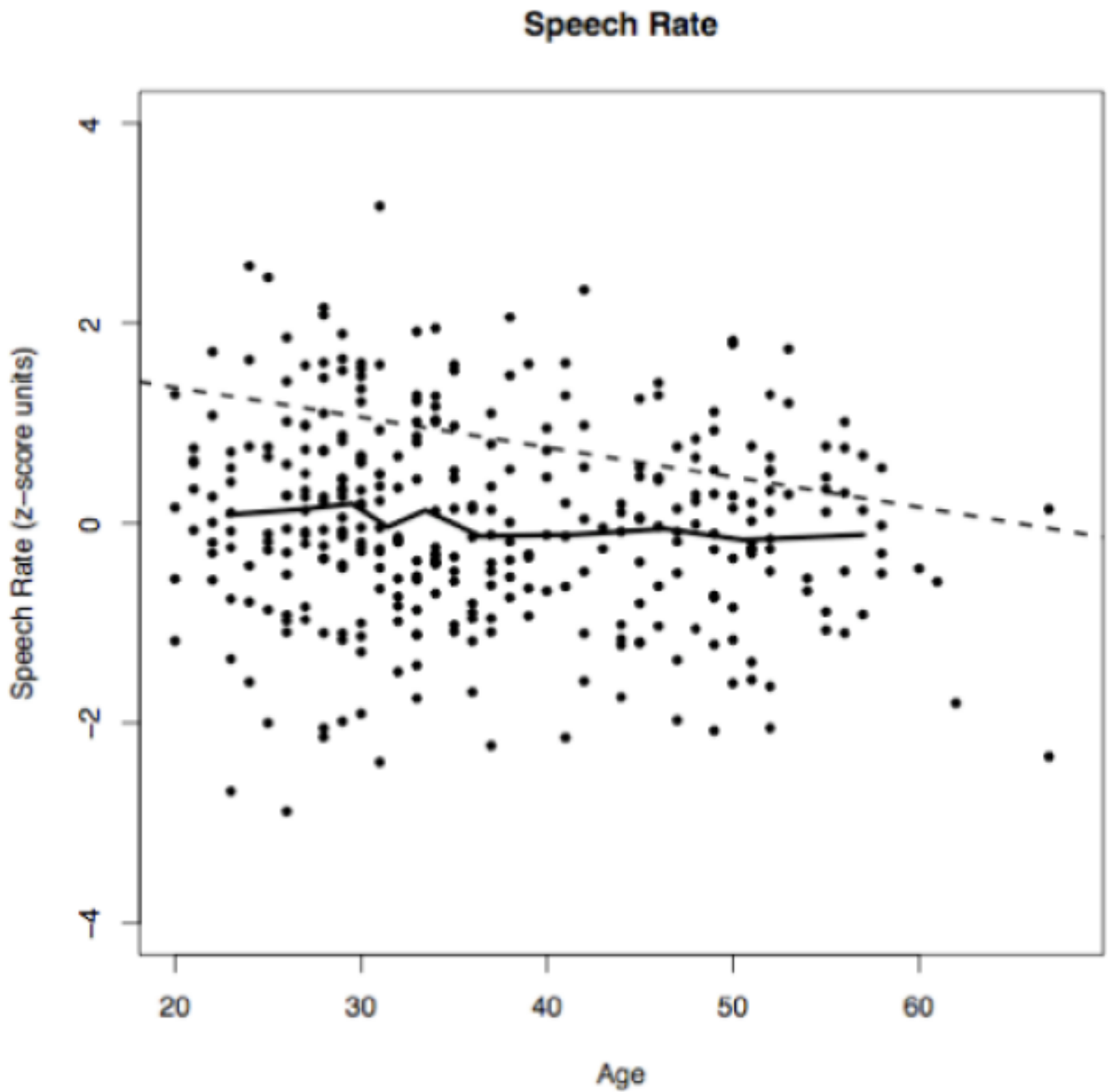
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**Figure 1.** Scatterplot of z-transformed speech rate plotted as a function of speaker age. The solid line connects the mean z-transformed speech rate for each age decile within the Switchboard sample. The dashed line is the fitted linear function relating Digit Symbol performance and age reported in Park et al. (2002).

**Table 1**  
**Correlation matrix for the measures of spoken language in the sample and speaker age (N = 336)**

	Filled pause rate	“Uh” rate	“Um” rate	Sentence length	Clause density <sup>a</sup>	Type/ token ratio	Log frequency	Age
Speech rate	-.35 ***	-.30 ***	-.14 *	.01	.06-	-.19 ***	.16 **	-.11 *
Filled pause rate	-	.89 ***	.30 ***	.31 ***	.16 ***	-.12 *	-.06	.17 ***
“Uh” rate		-	-.16 **	.35 ***	.20 ***	-.07	-.05	.27 ***
“Um” rate			-	-.06	-.06	-.10 ~	-.03	-.19 ***
Sentence length				-	.86 ***	.07	-.02	.12 *
Clause density					-	-.01	.08	.04
Type/token ratio						-	-.13 *	.11 *
Log frequency							-	.06

<sup>a</sup>Correlations involving clause density are based on a subsample of 308 speakers.

\*\*\*  
*p* < .001.

\*\*  
*p* < .01.

\*  
*p* < .05.

~  
*p* = .07.