

Toward modelling indirect effects in longitudinal phonetics research: The case of Queen Elizabeth II's age, voice quality, and pre-aspiration

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Many, if not all, linguistic changes over the lifespan are complex, with a wide range of possible direct and indirect effects between variables. However, the linear mixed-effects models typically employed in phonetic research (whether frequentist or their Bayesian corollaries) do not test for indirect effects. In this paper, we take as our case study a simplified analysis of the lifespan trajectory of one speaker's pre-aspiration, considering also longitudinal changes in local breathiness and local glottalization as rough measures of overall voice quality. We compare how we could model their interactions through time with typical mixed-effects models versus Bayesian Mediated Structural Equation Modeling (SEM). We propose that approaches like SEM that model indirect effects are well-suited to testing hypotheses regarding the complex realities of lifespan changes in phonetic phenomena.

Pre-aspiration has been increasingly reported in varieties of English across the world, including among young Southern Standard British English (SSBE) speakers [1]. Apparent-time studies in other parts of Britain also suggest that pre-aspiration may be more frequent among younger speakers [2, 3, 4]. However, no previous longitudinal studies have reported rates of pre-aspiration across the lifespan of an individual. We examine here a subset of Queen Elizabeth II's Christmas speeches from 1952 to 2018, coding 2,061 tokens for the presence/absence of pre-aspiration, breathiness, and glottalisation. We find that her overall rate of pre-aspiration decreased over the course of her life; her rate of local breathiness also declined over time, while her rate of local glottalisation increased.

Regression approaches allow us to model the interactions of age, breathiness, and glottalisation on the prevalence of pre-aspiration. However, the negative effect of age on pre-aspiration could conceivably be driven by overall changes in voice quality that accompany the aging of the vocal folds, among other factors; breathiness has been shown to be prerequisite to pre-aspiration, while creakiness has been shown to inhibit it [5]. Our usual statistical toolkit in phonetics falls short when we want to test the hypothesis that age has an effect on voice quality, which in turn predicts the rate of pre-aspiration; the high amount of covariation among the voice quality variables and pre-aspiration also poses challenges for linear mixed-effects regression. Mediation models, on the other hand, evaluate causal relationships where antecedent variables (X) influence an outcome (Y) through intervening mediators (M) [6]. This framework estimates both direct effects and indirect causal sequences (e.g., $X \rightarrow M \rightarrow Y$) and can be extended to multivariate contexts to accommodate multiple variables in both Bayesian and frequentist frameworks. We therefore employed a Bayesian approach to estimate the indirect effects of age and foot final vs. foot medial environment on pre-aspiration, mediated by glottalisation and breathiness, by calculating the product of posterior draws and their associated credible intervals [7].

Our results indicate that increasing age and foot final environment negatively predict rates of pre-aspiration. While both factors positively predict glottalisation and negatively predict breathiness, the mediators themselves are both positive predictors of pre-aspiration (Figure 1). Our modelled indirect effects (Figure 2) indicate dual, competing mechanisms: age and foot-finality indirectly support pre-aspiration through increased glottalisation, while simultaneously suppressing it via reduced breathiness. Rather than assuming a uniform effect, this SEM approach illustrates that the prevalence of pre-aspiration is contingent on how age and metrical environment independently influence mediating factors, which in turn influence pre-aspiration.

While our study is on pre-aspiration, the potential applications of SEM to phonetics and other subfields of linguistics go far beyond this one case, particularly where researchers' hypotheses regarding longitudinal phenomena involve possible indirect effects.

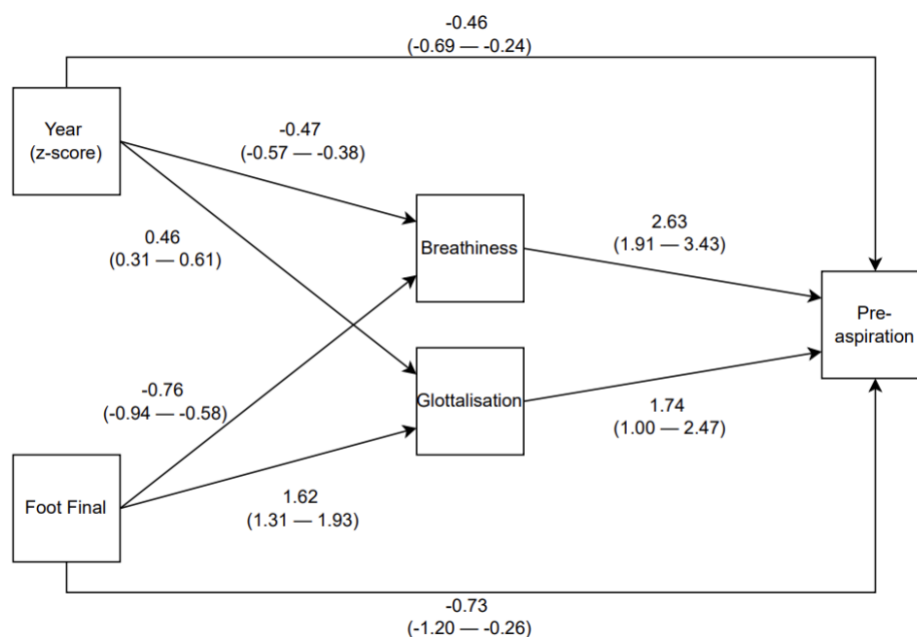


Fig. 1. Summary of direct effects within the model. Estimates represent log-odds with 95% credible intervals.

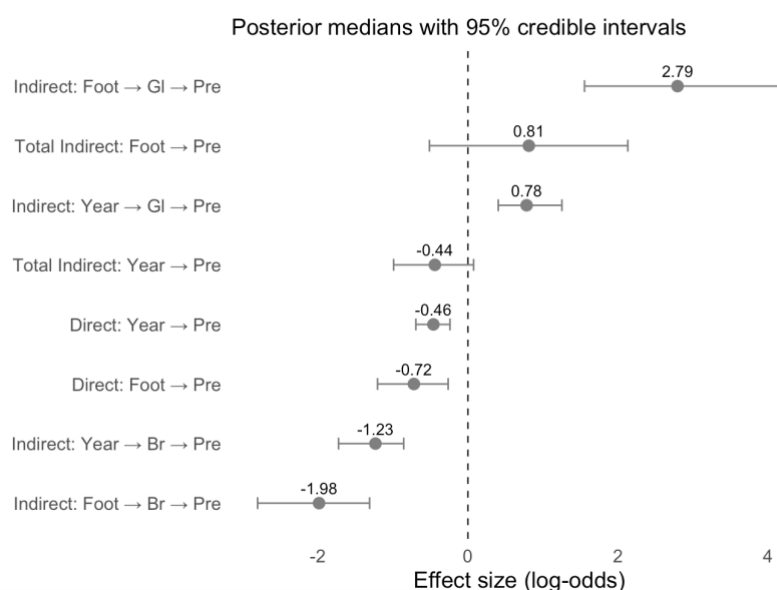


Fig. 2. Summary of indirect effects within model. Estimates represent log-odds with 95% credible intervals.

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