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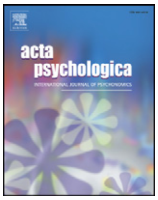

Is the fluency of language outputs related to individual differences in intelligence and executive function?

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ABSTRACT

There has been little research on the fluency of language production and individual difference variables, such as intelligence and executive function. In this study, we report data from 106 participants who completed a battery of standardized cognitive tasks and a sentence production task. For the sentence production task, participants were presented with two objects and a verb and their task was to formulate a sentence. Four types of disfluency were examined: filled pauses (e.g. *uh*, *um*), unfilled pauses, repetitions, and repairs. Repetitions occur when the speaker suspends articulation and then repeats the previous word/phrase, and repairs occur when the speaker suspends articulation and then starts over with a different word/phrase. Hierarchical structural equation modeling revealed a significant relationship between repair disfluencies and inhibition. Conclusions focus on the role of individual differences in cognitive ability and their role in models and theories of language production.

1. Introduction

Naturalistic speech is often disfluent (Maclay & Osgood, 1959). It has been estimated that disfluencies occur on average six to ten times per 100 words (Fox Tree, 1995; Shriberg, 1996, 2001). In this study, we focused on four types of disfluency. The first are filled pauses, such as *uh* and *um*. The second are unfilled (or silent) pauses. The third are repetitions, which refer to unintended repeats of a word or a string of words (e.g., *the papaya … the papaya was sweet*). The fourth are repairs. A repair occurs when a speaker stops speaking and then starts over with some new word or phrase (e.g., *the mango … papaya*). Different types of disfluency are thought to arise from a variety of problems and difficulties in the course of speaking (Arnold, Tanenhaus, Altmann, & Fagnano, 2004; Bock, 1996; O'Connell & Kowal, 2005). Filled pauses, for example, often occur at sentence initial positions, which suggests that they are linked with planning difficulty (Bortfeld, Leon, Bloom, Schober, & Brennan, 2001; Clark & Fox Tree, 2002). Other work has suggested that filled pauses serve a variety of other more "pragmatic" functions, such as an announcement that new information is upcoming and as a tool for managing turn-taking in conversation (e.g., the speaker has more to say and wants to continue "holding the floor"). In contrast, unfilled pauses, repetitions, and repairs are more directly indicative of processing difficulty within the language production system, for example, planning what is to be said, retrieving words, and formulating phrasal structure (Barr, 2001; Clark, 1994; Clark & Wasow, 1998; Fox Tree & Clark, 1997).

One prominent model designed to capture the processes and demands of language production was proposed by Levelt (1983, 1989, 1999). His model consists of three main stages: conceptualization, formulation, and articulation. The fundamental idea is that a nonlinguistic representation is sequentially elaborated lexically, syntactically, and phonologically in the course of speaking (Bock & Levelt, 1994; Ferreira & Engelhardt, 2006). Many models, including Levelt's, additionally assume the existence of a monitor, which is a mechanism whereby speakers check the appropriateness of their speech prior to articulation (for reviews, see Blackmer & Mitton, 1991; Hartsuiker & Kolk, 2001; Postma, 1997, 2000). The speech monitor in Levelt's model is a centralized mechanism that receives the output from the conceptualization and formulation stages, and it operates by perceiving internal speech. This occurs as the production system incrementally produces phonetic plans, which are stored in a buffer prior to articulation. It has been estimated that articulation takes

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place 200–250 ms after the creation of a phonetic plan (Postma, 2000), which corresponds to the time that information is stored in the buffer. The speech monitor, which "listens" to or comprehends inner speech, is assumed to require processing time in the neighborhood of 150–200 ms (Marslen-Wilson & Welsh, 1978). These timing estimates therefore, suggest that the language production system has at most 100–150 ms to detect an error, and then initiate a correction so that the error does not become part of the speech signal (Nooteboom, 1980).

1.1. Intelligence and executive function

An important, but understudied, factor in the production of disfluency is individual differences. The mean distribution, as assessed by several corpus analyses, is six-to-ten disfluencies per 100 words. However, individual speakers vary by up to three times that amount (Shriberg, 2001), and individuals also differ in the types of disfluency they tend to produce (Bortfeld et al., 2001). The current study focuses on individual differences in disfluency production, and whether intelligence and/or executive functions have an influence both on speaker's tendencies to be disfluent and on the types of disfluencies they produce. To our knowledge, there has never been a systematic investigation of these issues.

A relationship between disfluency production and intelligence would be interesting because it would suggest that some problems associated with language production may be linked to more general processing abilities, and not to specific mechanisms of the language production system (e.g., the speech monitor). Relatedly, a relationship between disfluencies and executive function would also be interesting because it would begin to reveal how lower-level cognitive control mechanisms affect language outputs. Executive functions are typically defined as control mechanisms that regulate and modulate performance of various higher-order cognitive processes (Burgess, 1997; Denckla, 1996; Logan, 1985; Miyake et al., 2000; Rabbitt, 1997).

The three most frequently postulated executive functions are set shifting, updating/monitoring working memory, and inhibition (Miyake et al., 2000). Previous research has shown that these three executive functions are related to one another, but can be dissociated in statistical models (Duncan, Johnson, Swales, & Freer, 1997; Miyake & Friedman, 2012; Teuber, 1972). In the current study, we utilized four cognitive tasks that are believed to tap two executive functions (i.e., set shifting and inhibition). Set shifting reflects the ability to switch back and forth between tasks or mental sets (Mayr & Kliegl, 2000; Rogers & Monsell, 1995; Spector & Biederman, 1976), and a classic measure of set shifting is perseveration errors in the Wisconsin Card Sorting task (Stuss & Benson, 1986). Inhibition, on the other hand, reflects the ability to inhibit or suppress competing responses and/or distracting stimuli. Examples of inhibition tasks are the Stroop task and the Stop Signal task (Casey et al., 1997; Friedman & Miyake, 2004; Logan, 1994).

There have been many latent variable studies of executive function and intelligence. A prominent example was conducted by Friedman et al. (2006). Their study investigated the extent to which executive functions and intelligence are related to one another (see also Friedman et al., 2007; Kline, 1991; Miyake et al., 2000). Executive functions and intelligence both involve general cognitive ability, and so one would naturally expect some degree of shared variance (Ardila, Pineda, & Rosselli, 2000). Indeed, Jester et al. (2009) showed that intelligence and executive functions were correlated-dissociable factors, and that these abilities transmitted independently in families (see also Martin, 2001). However, there is variability in the amount of shared variance between the different executive functions and intelligence. Friedman et al. (2006) reported that the shared variance between intelligence and inhibition and intelligence and set shifting was relatively low (i.e., only 2–14% of the variance was shared). In contrast, working memory has much more shared variance with intelligence (.70–.79) (Ackerman, Beier, & Boyle, 2005; Friedman et al., 2006, 2007; Miyake et al., 2000).

1.2. Current study

In the current study, we examined the relationships between intelligence and executive function, and how they relate to the tendency to produce different types of disfluency. The data for this investigation came from a large-scale research project that involved community-recruited adolescent and adult participants. The primary aim of that study was to investigate the cognitive profile of individuals with Attention-Deficit/Hyper-Activity Disorder (ADHD). However, the project also recruited a large number of typically-developing (control) participants. For the purposes of this investigation, we focused only on the data provided by controls. We utilized a latent-variable approach, which has several advantages given the goals of the study and the nature of the dataset. The first is that latent variables represent shared variance from multiple tasks used to tap the same underlying construct. Therefore, latent variables are less susceptible to idiosyncratic task properties. The second advantage is because measurement error is separated from a latent variable, the latent variable provides a purer measure of the constructs of interest. We used three subtests from the *Wechsler Intelligence Scales* (Wechsler, 1997a,b) to construct a latent variable representing intelligence (Spearman, 1927). For executive functions, the dataset contained tasks that assessed both set shifting and inhibition. Participants completed the Wisconsin Card Sorting task and the Trail Making task, which both assess set shifting, and they also completed the Stop Signal task and the Stroop task, which both assess inhibition.

For inhibition, we included one additional variable, which was hyper-active/impulsive *T*-scores from the Conner's behavioral rating scale. We did this for three reasons. First, prominent theories of ADHD assume that deficits in inhibitory control underlie ADHD symptomology (Barkley, 1997; Nigg, 2001; Pennington & Ozonoff, 1996; Schachar, Tannock, Marriott, & Logan, 1995; Tannock & Schachar, 1996). Second, the pattern of correlations between hyperactive–impulsive symptoms and the two inhibition tasks suggested shared variance. Third, Conner's questionnaires are well validated and assess (dys)executive symptomologies (Burgess, Alderman, Evans, Emslie, & Wilson, 1998; Nigg, Carr, Martel, & Henderson, 2007). Therefore, by including hyperactive–impulsive symptoms, the latent variable indexed executive dysfunction in everyday activities, which is consistent with the view of executive functions providing "control" for a wide range of higher-order cognitive processes (Burgess, 1997).

Our main research question was whether individual differences in disfluency production are more related to intelligence or to executive function. Theoretically, this question is important because it asks whether disfluencies are more related to low-level cognitive control (i.e. executive function) or whether disfluencies are more related to intelligence. We assume that intelligence reflects functioning across broader and wider neural networks, whereas executive functions reflect more specific cognitive-control abilities. To address this research question, we created a structural equation model that included three latent variables (i.e., intelligence, inhibition, and set shifting). We ensured that our data fit the model, and then, we added a disfluency variable. To examine the contribution of each latent variable on disfluency production, we used hierarchical tests.

To conduct hierarchical tests, we built pathways from each latent variable to the disfluency variable. We first ensured that model fit was good with disfluency included. Second, we sequentially set each of the pathways from the latent variables to the disfluency variable equal to zero. If model fit significantly decreased when a particular pathway was set to zero, then it indicates that there is significant variance associated with that pathway. We elected to test each type of disfluency separately because some have argued that the surface form of different types of disfluency reflect distinct problems within the production system (Garrett, 1982). However, the literature is far from clear on this issue (for a review, see Bock, 1996). Maclay and Osgood (1959) reported relatively low correlations between the