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Complexity in articulatory and segmental levels of production

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Introduction

Romani, Galluzzi, Guariglia, and Golsin (2017) provide the most comprehensive attempt to date to assess Jakobson's (1941/1968) claim that the same underlying principles drive language learning, language loss, and the distribution of sounds within and across languages. Based on impressive error corpora from both children acquiring Italian and Italian-speaking adults with acquired speech impairment, as well as an Italian corpus providing phoneme frequencies, they propose that articulatory complexity is the core principle that binds these three issues. This is a compelling claim that has advanced the attempt to address this critical issue. However, there remain questions as to whether this claim will require additional support and/or refinements.

In this commentary, I address two areas where additional work could be directed. First, I discuss the operationalization of articulatory complexity as coming from errors of individuals diagnosed as having apraxia of speech by Galluzzi, Bureca, Guariglia, and Romani (2015), including both the approach to classifying patients and the structured (Staiger, Finger-Berg, Aichert, & Ziegler, 2012; Ziegler & Aichert, 2015) variation among the patients in this population. Second, I discuss the issue of articulatory complexity more generally and question whether the segmental accuracy measures are sufficient and even whether typological markedness patterns follow principles of articulatory complexity. In short, I maintain that the Romani, Galluzzi, Guariglia, Golsin (2017) formulation advances our understanding of the factors that unify these different domains and permits us to clarify the issues that remain for evaluating the role of articulatory complexity in this important issue first raised by Jakobson.

Acquired speech impairment

To evaluate the role of complexity, Romani, Galluzzi, Guariglia, and Golsin (2017) operationally define articulatory complexity as the types of sounds (or sound sequences) that lead individuals with articulatory deficits to make errors. These errors are then compared with the errors made by individuals with phonological (but not articulatory) deficits, as well as the measures of age of acquisition and within- and cross-language frequency. Their participant data came from Galluzzi et al. (2015; also see Romani, Galluzzi, Bureca, &

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Olson, 2011) in which they characterized individuals who make high rates of *phonetic* errors (i.e., slurred or distorted productions; visible or audible articulatory groping) as having apraxia of speech (AOS). In this series of studies, individuals were labelled as having AOS if they made at least 10% phonetic errors.¹

It is worth noting that the term AOS reflects a clinical category, and studies of AOS vary in their approach to diagnosis. For example, while Romani, Galluzzi, Guariglia, and Golsin (2017) use a clear and straightforward approach to identifying individuals as having AOS, it differs from other definitions in the clinical research literature on AOS where it is typically defined as a disorder of speech motor planning. For example, another prominent view on AOS has included additional features (e.g., slowed speech; dysprosodic speech; speech distortions) and has not typically included groping (Ballard et al., 2015; McNeil, Robin, & Schmidt, 2009; Wambaugh, Duffy, McNeil, Robin, & Rogers, 2006), while yet another approach used notably by Ziegler and colleagues includes dysprosody, distortions, and groping and other initiation difficulties (e.g., Staiger et al., 2012; Ziegler & Aichert, 2015). These differences in how individuals with AOS are diagnosed greatly complicate the comparison across studies that may identify different sets of individuals as falling into a category of interest, particularly when the performance of these individuals is used to illuminate the nature of normal processing as in the cognitive neuropsychological approach. The Romani, Galluzzi, Guariglia, and Golsin (2017) approach to AOS diagnosis is clear and replicable, and may be more well suited to this type of analysis. However, to avoid confusion with the literature on the clinical category of AOS, I use the term articulatory impairment² to refer to Romani et al.'s group of individuals who make >10% phonetic errors.

Much of the research on distinguishing phonological impairment from AOS has highlighted that the latter seldom occurs on its own in the absence of concomitant phonological impairment (or dysarthria, the presence of which was an exclusion criterion in the Romani, Galluzzi, Guariglia, and Golsin (2017), study). This has led to an approach in the clinical literature of comparing individuals with aphasia and AOS to individuals with aphasia without AOS (Haley, Jacks, & Cunningham, 2013; Maas, Gutiérrez, & Ballard, 2014; Maas, Mailend, & Guenther, 2015). For researchers working in an information-processing neurocognitive framework, the overlap in these deficits suggests that, for individuals with articulatory impairment and phonological impairment, on any given production errors can arise at either level. For this reason, it may be problematic to collapse all errors from individuals with articulatory impairment into a single theoretically meaningful category, particularly if we cannot rule out a concomitant phonological impairment. If we are to take phonetic errors as diagnostic of articulatory impairment, then it would be important to replicate the findings reported by Romani, Galluzzi, Guariglia, and Golsin (2017). Looking at all (and only) those errors that can be said to clearly have an articulatory locus. Within the context of their work, this could be done by examining the phonetic errors alone. It would

¹There are two minor empirical concerns on this point. First, it is unclear whether the denominator is the number of errors or the number of items. Second, setting criteria for phonetic error analyses may require additional work. At present, these errors are assessed by transcription alone with moderate-to-good agreement among coders (76%) performed on only 3 of the 11 participants in their AOS group.

²This is not intended as a judgment of which criteria are best for diagnosing AOS. I use this term here (and in my own research) when the questions being addressed are framed within an information-processing neurocognitive framework rather than questions about the clinical category of AOS in particular.

also be useful to consider whether the non-phonetic errors of their participants with articulatory impairment are more similar to their own phonetic errors or to the errors of their participants with phonological impairment with respect to phoneme markedness.

In our research on phonological and articulatory impairment (Buchwald, 2009; Buchwald, Gagnon, & Miozzo, 2017; Buchwald & Miozzo, 2011, 2012; Buchwald, Rapp, & Stone, 2007; Miozzo & Buchwald, 2013), my colleagues and I have focused on participants who appear to have both articulatory and phonological impairment, and we have used articulatory and acoustic analyses to identify the nature of errors that may be difficult to perceive. This approach developed in response to findings that transcription and perceptual accuracy are limited in identifying articulatory versus phonological errors. For example, Wood and Hardcastle (2000) reported that some apraxic errors that may sound like simple substitutions (e.g., tick → kick) actually arise from simultaneous /t/ and /k/ closures in the oral vocal tract, and the /k/ is perceived in error because of the order in which the consonants are released. These simultaneous gestures are the clear result of an error of motor planning, and yet would be identified as phonological errors using transcription. In Buchwald et al. (2007), we used ultrasound imaging of speech and acoustic analyses to identify that an error that is often taken as a sign of apraxic impairment (schwa insertion in consonant clusters; e.g., bleed → [bəlɪd]) was not distinguishable from the same speaker's lexical schwa in the same position (e.g., believe). This indicates that errors that are often perceived as motoric may also have a phonological locus. We have taken these two findings to reflect the limits of transcription in characterizing the productions we are analysing, as using perception/transcription can identify apparent motor errors as having a phonological locus and also can identify apparent phonological errors as having a motor locus.

Working within a similar spoken production framework to that of Romani, Galluzzi, Guariglia, and Golsin (2017), we have been exploring what we can learn if we identify error types based on their acoustics. In a series of related papers (Buchwald et al., 2017; Buchwald & Miozzo, 2011, 2012), we have proposed that phonetic/motor errors leave traces of the target motor plan, whereas phonological errors occur prior to this plan, and thus the resulting production is based on the new form. To illustrate, consider /s/-deletion errors in /s/-stop clusters (e.g., speech). If this deletion error occurs before any motor planning, then the speaker should try to produce a word with a singleton /p/, and that should be produced with aspiration ([p^h] as in peach). In contrast, if the deletion occurs after the speaker has begun phonetic encoding/motor planning, then the resulting error may reflect the fact that the target word had a cluster and thus contains the unaspirated /p/ (the sound at the beginning of beach). We have used this approach to determine the predominant error type in individuals who simultaneously present with both aphasia and apraxia of speech.

As Romani, Galluzzi, Guariglia, and Golsin (2017) mention (p. 449–471), our approach also uses properties of the errors to identify aspects of the deficit. However, we additionally demonstrated that a participant's predominant type of error (phonetic/motor or phonological) predicts their response to various experimental manipulations, including the response to a motor learning training programme (Buchwald et al., 2017; Buchwald & Miozzo, 2012), demonstrating that our approach to classification based on the acoustics of deletion errors has implications beyond the errors themselves. With respect to the present

issues, we note that all but one of the six patients we studied across these papers fitted Romani et al.'s phonetic error criterion, but we demonstrated that there were critical differences among these participants where some primarily made errors that arise in the phonological processing component (at least according to our operational definition of deletion errors in clusters being produced with the timing of a singleton) despite the presence of a high rate of phonetic errors. This would appear to suggest that Romani et al.'s classification approach may include participants of each type as we have defined them. However, it is also worth noting that while we found differences in learning rates among individuals who made predominantly motor versus phonological errors (Buchwald et al., 2017; Buchwald & Miozzo, 2012), in Miozzo and Buchwald (2013) we found no differences among these participants (who fit Romani et al.'s (2017) criteria) with respect to the effects of sonority on their error rates or error types. While on the surface this finding differs from Romani et al.'s claims (participants with predominantly phonological errors and participants with predominantly motor errors both show an effect of markedness), it may merely reflect the differences in the two approaches to identifying deficit types and that Romani et al.'s classification simply captures something different from ours.

This section has raised two specific issues that could be addressed in future work. First, if phonetic errors are to be used as an index of complexity, and we know that many participants have multiple deficits, then we should replicate the Romani, Galluzzi, Guariglia, and Golsin (2017) findings based on phonetic errors alone, as those are the errors that are most uncontroversially localized to articulatory processing. Second, given the possibility that there may be systematic differences among individuals with both articulatory and phonological impairment (with our work suggesting the possibility that error type predicts responsiveness to a basic motor learning training), future work could consider whether using different approaches to identifying participants with articulatory impairment would yield the same patterns.

Caveats to using segmental accuracy to reflect articulatory complexity

The segmental accuracy rates reported by Romani et al. (2017) are the number of incorrect productions of each sound divided by the total number of productions of that sound. However, to demonstrate that differences in phoneme accuracy come from properties of the phonemes, it is critical to control for other properties that could affect production accuracy. In particular, syllable position (onset vs. coda) and whether the sound appears in a syllable-internal consonant cluster are factors that have been shown to affect production in impaired speakers (Goldrick & Rapp, 2007; Miozzo & Buchwald, 2013). In addition, for sounds that do appear in clusters, the composition of the cluster may affect the accuracy of each of the components (Miozzo & Buchwald, 2013). From the description in the Romani, Galluzzi, Guariglia, and Golsin (2017) (as well as Galluzzi et al., 2015; Romani et al., 2011, both reporting on the same dataset), it appears that the stimuli were controlled for a number of critical lexical properties, but that the contexts in which the sounds occurred were not part of the stimulus design. By not controlling for the position a sound appears in, or whether it appears in a cluster, it is problematic to compare overall performance on different segments. (Also see Ziegler, 2018 for distinct but related issues with the segmental approach—as opposed to a featural, gestural, or prosodic approach—to defining articulatory complexity

for individuals with articulatory impairment.) This issue is compounded by the difficulty of using perception alone to identify error types for some errors in the absence of acoustic or articulatory measurement, as noted in the previous section.

While many of the issues laid out here regarding the participant population under investigation and the comparisons that are being made can be empirically investigated, there is a more complex issue that unites these topics but is less straightforwardly addressed. That is the challenge of developing a consistent and clear definition of articulatory complexity, particularly when using segments as the object of study. In the generative tradition, linguists have used the cross-linguistic typological distribution to define the notion of markedness, and there it is widely considered accurate that fricatives are marked relative to stops and that coronals are unmarked relative to labials (Greenberg, 1978; Prince & Smolensky, 1993/2004). However, this does not necessitate that, for example, /t/ (requiring complete closure at the alveolar ridge with a tongue tip gesture) is less articulatory complex than /p/ (requiring complete labial closure); from a purely biomechanical standpoint, there would be no reason to prefer /t/ over /p/. From the argument put forth by Romani, Galluzzi, Guariglia, and Golsin (2017), we may conclude that their claim is that the speakers with articulatory impairment help us see that /p/ is more complex than /t/, as more errors are produced for the former than the latter (see their Table 3). However, it will be critical to augment this type of research with additional work addressing the nature of articulatory complexity from additional perspectives such as understanding speech motor control (see papers in Maassen, Kent, Peters, & van Lieshout, 2007; Maassen & Van Lieshout, 2010). Until then, to the extent that the patterns from acquisition, loss, frequency, and typology do line up as argued by Jakobson (1941/1968) and by Romani, Galluzzi, Guariglia, and Golsin (2017), we still have the difficulty of determining the root source of these similarities.

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