Learning with Locality Across Speech and Sign

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Overview What is the computational nature of phonological mappings, and how does it enable learners across modalities to infer phonological grammars? A vast majority of phonological mappings are restricted to a computationally simple class of functions, which are sensitive to a notion of locality and a limited memory. Many sign language mappings exhibit the exact same complexity as their spoken counterparts, despite different articulatory systems. These functions are provably and efficiently learnable, suggesting a shared learning strategy across modalities. We propose that unified, amodal locality and a restricted memory are representationally salient for and therefore exploited by phonological learners.

Local Maps Across Speech and Sign It is well-known that phonological transformations only require the computational power of finite-state (regular) machines (Johnson 1972; Kaplan and Kay 1981; Karttunen 1993), meaning the memory required to compute the mapping does not grow with the size of the input. However, full finite-state power typologically overgenerates the range of phonologically attested mappings, leading to the *Subregular Hypothesis*: phonological mappings fall within subclasses of the regular mappings (Heinz 2018). Figure 1 shows a hierarchy of several such function classes.

Recent work has shown that a vast majority of phonological processes require the simplest of these subclasses, the *Input Strictly Local (ISL)* functions (Chandlee 2014; Chandlee and Heinz 2018). A phonological mapping is ISL if the target and triggering environment comprise a contiguous substring of the input of bounded length. For example, the process of intervocalic voicing acts on input substrings of the form VTV, which are bounded by length 3. This process can then be modeled with a 3-ISL function that only needs to keep track of 3 segments at a time in order to correctly determine when to apply.

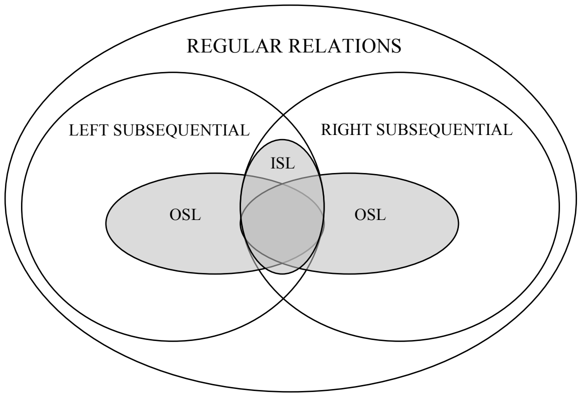

Figure 1: Subregular Hierarchy of Functions

In sign languages, Rawski (2017) showed that several widely attested processes — final-syllable reduplication, location metathesis, and compound reduction — are ISL functions, like Chandlee (2014)'s analysis of their spoken counterparts. This analysis represented signs as strings of location and movement segments (monosyllabic signs have the form LML) which contain other phonetic features, like in Liddell and Johnson (1989). Follow-up work (Rawski 2018) used model-theoretic techniques to enrich the sign representation to graph structures, encompassing the autosegmental simultaneity and feature geometry of Sandler (1989)'s Hand Tier Model. Despite this increase in representational power, these processes were captured by quantifier-free logical transductions, which Chandlee and Lindell (2016) showed are equivalent to ISL functions, coinciding with Chandlee and Jardine (2018)'s ISL analysis of autosegmental tone processes. These results collectively suggest that this mathematically restricted notion of locality is cross-modally salient for phonological computation.

Learning Local Mappings While full regular languages and relations are not learnable in the limit from positive data (Gold 1967), Chandlee et al. (2014) showed that ISL functions are efficiently learnable under these conditions when the locality k is fixed. Their finite-state-based learning algorithm works by constructing a prefix tree representation of the data and generalizing by merging states. The grammar's state merging relies on ISL locality as an inductive principle to generalize from a finite amount of data to a possibly infinite function. The algorithm provably identifies any ISL function, and is efficient in both time and data. In this way, phonological learnability depends on the nature of the grammar's representations and computations.

Cognitive Implications We propose that phonological learning across modalities is driven by learners' sensitivity to both particular locality representations (e.g. substrings/graphs) and memory restrictions (e.g. *bounded* substrings). The Subregular Hypothesis makes concrete claims about the cognitive saliency of the computational representations characteristic of the grammars that humans acquire (Rogers et al. 2013), which is also reflected experimentally (Finley 2011; Lai 2015). This has led some to posit a cognitive learning divide in the computations of phonological modules and syntactic modules (Heinz and Idsardi 2013). More generally, learning systems are necessarily structured by the representational and computational nature of their domains (Rawski and Heinz 2019).

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