A dynamical framework for graphematic feature emergence: Evidence from error patterns in children's handwriting

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The present work, part of a broader research program on a dynamical framework for graphematics, extends Anderson's Structural Analogy Hypothesis, focusing on distinctive graphematic features. Phonology and graphematics share the same structure-building operations within parallel production–perception loop architectures exhibiting common functional dynamics. The overall architecture draws on Kröger et al.'s (2022) speech production–perception model. We suggest that, throughout development, this network shapes a graphematic solution space (GSS) structured as a self-organizing map (SOM). Within this framework, abstract graphematic categories emerge from reciprocal interactions between graphomotor and visual state maps. Sensorimotor integration links motor plans—formalized in Task Dynamics—to their visual traces, yielding featural and "suprasegmental" graphematic structures. Given the interdependence of writing systems with other linguistic modules, the resulting GSS bidirectionally interacts with the phonological mental syllabary and mental lexicon. Through this interface, graphematic representations continually co-evolve with phonological counterparts—Kröger's mental syllabary and lexical networks—so that each system persistently recalibrates the other. We propose a dynamic extension of Dresher's (2009) Successive Division Algorithm. The GSS starts as a uniform landscape; the first visual-motor cue to become contrastive splits it into two attractor basins. Each additional cue triggers further bifurcations, successively multiplying these basins until every grapheme settles into its own stable state. The theoretical framework was employed to analyze handwriting errors produced during a copying task performed by 62 Italian children (Grades 1–7; mean age = 9.1 years) on a Wacom digitizing tablet. Error patterns were examined in relation to the developmental trajectory with respect to the progressive crystallization of the GSS. The model helps disambiguate errors arising from (i) confusion between graphemes occupying adjacent positions in the distinctive feature space, (ii) phonological interference, and (iii) gestural dynamics.

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