DISCUSSION

THE EMERGENCE OF A DOUBLE DISSOCIATION IN THE MODULATION OF A SINGLE CONTROL PARAMETER IN A NONLINEAR DYNAMICAL SYSTEM

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If the functions of two independent modules are transparently reflected in behavior, then a double dissociation can be observed when one or the other module is selectively damaged. This fact does not imply that double dissociations are generated *exclusively* by independent and transparent modules (Shallice, 1988). Nevertheless, double dissociations are often interpreted as unequivocal evidence for independent modules. There are at least three reasons why modular interpretations are so attractive: 1) the human nervous system has anatomically distinct parts, 2) modular explanations are straightforward given observed double dissociations, and 3) alternative interpretations have been difficult to formulate.

In this commentary, an alternative to the modular interpretation is proposed in the context of surface and phonological dyslexia. Surface dyslexia is characterized by a selective impairment in reading aloud exception words such as HAVE that do not adhere to spelling-sound correspondences compared with regular words such as HATE and nonwords such as HABE (Castles and Coltheart, 1993). Phonological dyslexia is a selective impairment in reading aloud nonwords relative to regular and exception words (Patterson, 1981).

These complementary impairments constitute a double dissociation: impaired naming of exception words coupled with preserved naming of nonwords in surface dyslexia, and the reverse condition in phonological dyslexia. The widely-accepted interpretation of this double dissociation is modular: surface dyslexia is the result of selective damage to lexical processes or representations (word-specific knowledge is necessary to pronounce exception words), whereas phonological dyslexia is the result of selective damage to sub-lexical processes or representations (knowledge of spelling-sound correspondences is necessary to pronounce unknown letter strings). This modular framework appears in both dual-route (Coltheart et al., 2001) and connectionist models (Plaut et al., 1996) of word reading. An alternate, but no less modular, interpretation is that surface dyslexia is a result of damage to semantic representations, whereas phonological dyslexia is a result of damage to phonological representations (Patterson and Ralph, 1999).

A non-modular interpretation can be formulated on the basis of the *integrated pathway* (IP) model of word reading that was introduced by Kello and Plaut (in press; see also Farrar and Van Orden, 2001; Plaut, 1995). In the IP model, surface and phonological dyslexia can be interpreted as two distinct dynamic modes in a single processing pathway from orthography into the spoken language system. The IP model was inspired by a fact of development, that spoken language skills

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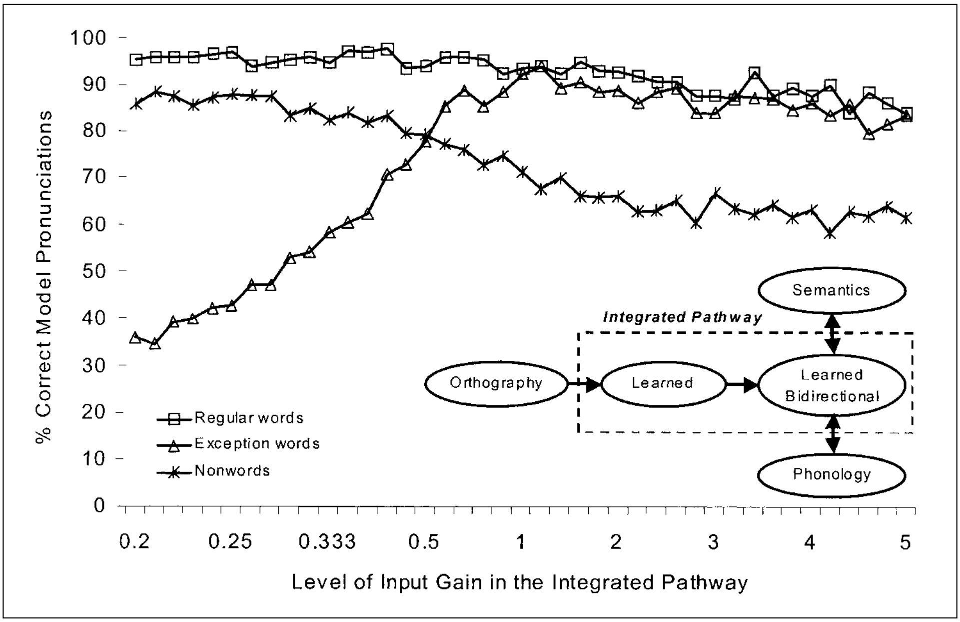

Fig. 1 – *The effect of input gain on error rates in the IP model of word reading.*

provide the foundation for reading acquisition. Spoken language acquisition requires that a child "solve" the mapping from sound to meaning (comprehension) and meaning to sound (production). In the model, spoken language acquisition was simplified as the process of learning a single distributed level of representation that mediates the bi-directional mapping between the phonological (sound) and semantic (meaning) attributes of words (see Figure 1, inset).

Reading acquisition was modeled as building upon spoken language acquisition by mapping orthography into the mediating representations between phonology and semantics. This mapping constituted the *integrated pathway*. Reading acquisition requires a connection between letter strings and their sounds and meanings. Extant models make this connection using at least two pathways from orthography into the spoken language system, one into phonology and one into semantics. By contrast, the IP model uses only the integrated pathway, thereby capitalizing on the pre-learned mappings into both phonology and semantics.

Given only the integrated pathway, the IP model appears to preclude a lexical/sub-lexical interpretation of surface/phonological dyslexia. Although a semantic/phonological interpretation appears more amenable, any modular interpretation will be difficult to defend in the IP model because the component levels of representation interact on multiple time scales (e.g., in scales of processing time and learning time). These interactions make it prohibitively difficult to assign independent effects to modular components (causes), which is a necessary step in modular interpretations (Van Orden et al., 2001). Nevertheless, the very dynamics that pose this difficulty for a modular interpretation provide the basis for a *dynamics* account of surface and phonological dyslexia.

In nonlinear dynamical systems, quantitative changes in scalar *control parameters* can result in qualitative changes (i.e., bifurcations or phase transitions) in the behavior of a system. This property of dynamical systems may allow a single control parameter to simulate both surface and phonological dyslexia as qualitatively different “modes” of behavior. The difficulty of such an approach lies in determining what kind of system, under what control parameters, could possibly generate these particular modes of behavior.

In Figure 1, simulation results are shown as evidence that *input gain* may be a control parameter that shifts the IP model between surface and phonological dyslexic modes of behavior. Input gain is a multiplicative scalar on the net inputs to connectionist processing units that, under continuous-time dynamics, can be controlled to modulate the *rate of processing* (Kello and Plaut, in press). In a model very similar to the one used in Kello and Plaut’s Simulation 3, input gain was modulated between abnormally low and high levels (normal = 1) within the integrated pathway. The resulting errors in the model’s “pronunciations” of nonwords and exception words resembled a surface dyslexic pattern at low levels, and a phonological dyslexic pattern at high levels. In addition, the model produced very high rates of regularization errors (e.g., pronouncing PINT to rhyme with MINT) at low levels (mean rate of 52% between levels of 0.2 and 0.5), a pattern that is characteristic of surface dyslexia (Patterson, 1981).

As with any simulation results, questions remain about how well the current approach will handle additional empirical findings. Further investigation is also motivated to explore in greater detail how and why this particular manipulation of input gain had the desired effects. Even with these caveats, the results stand as proof that non-modular, dynamical simulations of double dissociations are at least possible. Time will tell whether the dynamics interpretation of double dissociations can contribute to our understanding of normal and impaired cognitive systems.

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