Grounding Language Performance in the Anticipatory Dynamics of the Body

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Speech acts, conversations, and other language activities emerge from anticipatory dynamics that situate minds and bodies near critical states. Critical states entail a kind of symmetry in which possible actions exist simultaneously as propensities to act. To speak or understand is to break the symmetry of these possibilities and realize the utterance that is expressed. This hypothesis is derived from complexity theory and agrees with findings that concern action generally and linguistic performance in particular.

Barack Obama spoke several times at our home institution as a candidate for president. We witnessed how well he works a room, even auditorium size, effectively engaging his audience in gesture, posture, and eye contact as he moved around a large stage. To speak so engagingly requires much experience, polishing the pragmatic skills to bend meaning precisely in different contexts and to different audiences. Skillful purposeful gesture, intonation, and different wordings of the same subject matter—all to say exactly what is necessary to win support and no more.

From Obama’s perspective, he need only talk to his audience, but that intent entails a vastly complicated coordination of mind and body together, and with the audience. Skilled public speaking requires coordination across the body of the speaker. The anticipatory organization of the body pre-prepares the outline of movements in a continuous anticipatory flow. This anticipatory flow pre-engages...
words and gestures that will be enacted of limbs, torso, neck, and head as well as breath, mouth, lips, larynx, and tongue. Perpetual coordination is essential for speaking and listening—yet, except for motor coordination, it has not been a prominent topic in language sciences.

The sections that follow emphasize coordination in language. We begin with problems inherited from conventional approaches to language, most prominently the question of intentionality. We then discuss concepts from complexity science with respect to brains, bodies, and behavior. A complex system is one in which the behavior of the whole emerges in the cooperative dynamics of components. Mind and body comprise a complex system in task performance as their different components change, cycle, or oscillate through time, coupling behavior to the laboratory environment of task demands.

This complex system exploits the timing of changes as a shared currency and a source of similarity among the mind, the body, and the world. Like an Obama speech, every human activity unfolds across time. Mind and body are situated in time with respect to a changing world, and the component cycles of the mind and body all combine in the coordinated activity of the whole. Timescales of embodied changes are not the same throughout the body, however, which leads to conflicts. Global harmony is simply not possible. One name for the resulting incomplete and unsatisfiable harmony is frustration (Sherrington, 2010).

The negative connotation of the word frustration belies its actual positive consequences. In a living system the frustrated outcomes would be rigid habit on the one hand or complete chaos on the other. Either extreme would soon bring about the death of a living organism. It is a positive thing that these alternatives are frustrated and the benefits of frustration are more than prophylactic. Frustration of habit and chaos brings into existence novelty; it creates the singular behavioral trajectories that even the most mundane and practiced behaviors always enact. It is frustration that ensures a healthy mind and body, which never truly think or do the same things twice, in exactly the same ways, always making room for creativity in even the smallest of tasks.

Frustration produces human behavior in the perpetually frustrated compromises among rhythms of the mind, the body, and the world. Without frustration, behavior would be too orderly or too chaotic, unadapted to the world at hand. Creative frustration results because differently embodied mechanisms, changing on different timescales, can coordinate their activities without ever fully capitulating to a dominant rhythm of the body or of the world. Frustration thus implies a flexible emergent coordination, ready to change on a dime if need be, even as a frustrated compromise is being enacted.

Frustration is thus a key feature of complexity theory among its treasure chest of concepts, symptoms, and empirical criteria for novel emergent coordination. We use these concepts first to circumvent widely recognized dilemmas of language use. After that our goal throughout is to introduce concepts that explain
the variation in measurements from laboratory studies of language performance. Arranging all our eggs in the same basket, we hope to create a coherent picture of language performance.

INTENTIONALITY, NOVELTY, AND CONTROL

A good deal of what people do with language is about conveying intentions to one another. The intentions of authors have also been carefully studied to make sense of written language across centuries of exegesis. Intentions understood this way are also the basis of poetic discourse and determine the rhetorical sense of irony, satire, sarcasm, and metaphor. The meanings of tropes cannot be understood from their linguistic surface structure; they are understood in the way their meaning departs from it, as the speaker intends (Gibbs, 1999).

Yet at the same time that intentions appear to be crucial for ordinary language, they appear to be intractable within conventional linguistics and psycholinguistics. Intentionality suggests a capacity to bring language into existence, to cause speech. The intention to speak might cause movements of facial muscles, for example, and contraction of the diaphragm to compress lungs and exhale breath. The intention to listen might cause an attentive posture and a reduction in other cognitive activities to sustain attention. But intentions cannot be ordinary causes and still make sense scientifically.

Suppose Obama’s intention to speak was caused by his intention to persuade audiences of his goodwill. What then caused his intention to persuade? Maybe it was caused by his intention to be elected president. Still, what caused his intention to become president? Either we continue with this regressive quest, seeking the cause of the cause of the cause, or the intention to become president would need to take on the magical status of a prime mover or a mini-Obama homunculus to stop the endless regress.

Intentions also require an individual to stay open to affordances that may satisfy intended goals while ignoring affordances that might derail them. Selective attention goes to the heart of paying attention, or not paying attention, as the capacity to turn a blind eye or deaf ear to those things that are irrelevant to purposes at hand (Mack & Rock, 2000). For example, participants instructed to listen through their right ear only, while ignoring their left ear, successfully attend to the right ear’s story demonstrating selective attention despite the different voice telling a different story in their left ear (Broadbent, 1958; Deutsch & Deutsch, 1963).

If the right ear’s story switches to the left ear, however, participants’ attention switches to the left ear as well, succumbing to involuntary capture of attention. It is involuntary capture because it goes against the instruction to ignore the left ear’s story (Treisman, 1960). But which minilistener homunculus successfully
attenuated the left ear to begin with, then changed her mind, and incorrectly went to the left ear to follow the right ear’s story?

Of course dilemmas of language are not limited to questions of intentionality. How do novel uses of known words come into existence, or entirely new word forms? If a husband tells his wife that he is dog tired, and then she amplifies the expression saying she’s dinosaur tired, does this pose the same theoretical problem that is presented by a novel sentence construction? Or is it a different problem? At one time syntax, acting upon static constituents, seemed to be sufficiently generative to supply imaginable new sentences (e.g., Chomsky, 1957; Jackendoff, 1997; Williams, 2003). Yet is this the same problem as that of a word that may express indefinite variety and shadings of meanings?

In an idealized lexicon the constituents play the central role and include meanings, spellings, pronunciations, and even the possible uses in sentence constructions (e.g., Bresnan, 2001). The constituents are the elementary units and their use in grammatical rules relies upon their unchanging character. They do not possess any interesting dynamics of themselves and their entries in the lexicon do not depend on context apart from what is already specified in their representation. But how then do truly novel meanings emerge when meaning is basically given through fixed properties of the constituents?

Contemporary models of semantics that emphasize the role of constituents and neglect syntactic structure do not resolve these problems. Hyperspace Analogue to Language (HAL; Burgess & Lund, 1997) and Latent Semantic Analysis (LSA; Landauer & Dumais, 1997) are high-dimensional models of word meaning that treat sentences like “bags of words,” disregarding grammatical information. Words’ meanings are defined in terms of their co-occurrences with other words, but the co-occurrence patterns themselves are static.

The concept of meaning through co-occurrences in higher dimensional space depends on the co-occurrence structure existing in the first place, just as theories that emphasize the role of grammatical rules are dependent on the constituents being defined before the fact. Yet if novel utterances are to be explained they must, at heart, differ from rules or statistical co-occurrences. This is the problem of novelty.

Novel metaphorical extensions of meaning, like the term dog tired, tend to show up in the fault lines between words’ typical tectonics of semantic structure (Lakoff, 1987). For example, the fact that a dog may sleep a lot during the day and that being tired sometimes implies needing sleep might connect somehow in the fault line between dog and tired to generate dog tired. Yet how does the intention to exaggerate dog tired become something like dinosaur tired in the next breath?

The previous dilemmas of intentionality and novelty set the stage for a third dilemma, the problem of control. This problem is better known as the degrees-of-freedom problem (Bernstein, 1967; Turvey, 2007). For each element
or dimension of the mind and body that must be controlled in speech, a causal model must accord one controller to each degree of freedom of movement that that element allows. For example, speech entails changes in about 70 muscles and speech activities such as conversations are also variable expressions of the body, entailing very many (vast) degrees of freedom. A source of controllers to control each degree of freedom would be quickly overwhelmed (Raczsaszek-Leonardi & Kelso, 2008).

The degrees-of-freedom problem has another counterpart in abstract descriptions of languages. Languages are abstract entities consisting of multiple parts, and combinations of parts, of various sizes and on different scales. As the number of described words, described words’ meanings, and the possible ordered combinations of words’ meanings grow, their number soon becomes indefinitely large, rivaling or trumping the number of neurons in a brain.

Language performance would circumvent all these dilemmas if it included a prominent role for intentions and a capacity for novelty in self-organization, which would also skate around the degrees-of-freedom problem. In a nutshell, intentions can supply constraints to stay near critical states and contingencies collapse critical states into speech perception and overt speech (Kloos & Van Orden, 2010; Van Orden, 2010; Van Orden, Kloos, & Wallot, in press). Critical states thus form a bridge from intentions to overt communication. In this picture, language performance expresses temporary dynamical structures, emergent coordination, and the creation of information in language use.

FRUSTRATION AND CREATION

Traditional studies of language emphasize the regularities in language, such as the regular syntactic patterns of word ordering in competent speech. Regular and universal features of languages have been described and then attributed to native structures of the mind and brain (Chomsky, 1957). Sound wave perturbations of the acoustic environment on auditory sensory organs are encoded, or decoded, by these mental structures. In this way, physical forces of pressure waves on eardrums would become information.

Yet hearing speech while speaking changes the articulatory trajectories of the spoken words in the direction of the sounds that are heard (Yuen, Davis, Brysbaert, & Rastle, 2009). And no elaborate decoding of pressure waves appears to be necessary, or even possible, in such examples. Shadowing can follow the shadowed speech as closely as 150 ms (Koshevnikov & Chistovich, 1965), which is also about the minimal duration of a simple reaction time to indicate that a sound has been heard (Porter & Castellanos, 1980).

Too little time passes between ear and mouth for elaborate information processing to occur and yet the information necessary for shadowing is apparent...
Thus ambient speech must be sufficiently rich in constraints to specify articulation of speech directly (Fowler, 1986, 1996). Sufficiently constraining ambient speech would reduce degrees of freedom for perception of speech, especially if perception itself is action (Turvey, 2004).

Self-organization includes direct specification of information, which is not unusual in nature. If a predator appears, for example, an animal collective self-organizes to respond as one to the threat (e.g., Lee, Pak, & Chon, 2006). In observed flocks of starlings, the changes in each bird’s position or velocity become long range correlated with positions and velocities of birds elsewhere in the flock. Positions and flying speeds remain correlated at all spatial scales of the flock to the periphery of the flock. Scale-free long-range correlations are a hallmark of self-organized criticality documented in flocks of Italian starlings numbering over 4,000 birds (Cavagna et al., 2009).

Simultaneous actions in a collective require direct immediate specification of constraints across the entire flock of birds. Neighboring individuals directly transfer information about what to do, which is what allows the collective to act single-mindedly. Critical states of the collective make this possible. A critical state balances the tendencies of individual animals to act independently against a tendency to do exactly as their neighbors do. Individuals’ capacity to act alone is juxtaposed against a new capacity to move simultaneously with their neighbors in the balanced state. The balanced tension, or frustration, between local and global alternatives propagates changes in position and speed throughout the flock.

Evidence of frustration is also observed in the physiology of brain and body and in repeated measurements of language performance in the laboratory (Kello & Van Orden, 2009). Language activities also entail critical states of the brain and body, which are the physiological bases of intentional activity (Juarrero, 1999). Intentions are constraints self-organized as temporary dynamical patterns among faster changing processes of physiology to persist as the embodiment of intentions on timescales slower than the physiological events so organized.

Intentions as constraints have observable consequences in the anticipatory organization of a person. Embodied intentions poise a person—body and mind—in an anticipatory organization. In this anticipatory organization, apperception of the body includes “heightened tonicity of the reactive mechanisms . . . widespread contraction of skeletal muscles . . . marked changes in breathing, heart rate, and vascular processes . . . and an increased readiness of arousal for associations within a given sphere” (Bills, 1934, p. 408). The muscle tensions will vary in kind (not simply in quantity) from person to person anticipating the same task and from task to task in the same person, so information is created in the idiosyncrasies of muscle tensions.

Intentions change on slower timescales than the nervous system, just as the kinematics of articulation unfolds more slowly than changes in the nervous sys-
tem. Changes on slower timescales constrain the possibilities for change on faster timescales (Newell, 1990; Simon, 1973). The more slowly changing intentions and kinematics supply flexible limits on dynamics within the nervous system (Van Orden et al., in press). Inertia can also be exploited in the more slowly changing intentions and kinematics as a source of vertical coupling of mind and body (cf. Wijnants, Bosman, Cox, Hasselman, & Van Orden, submitted) and horizontal coupling between speaker and listener. Consequently, speaker and listener share a common organization of their bodies and nervous systems when sharing a conversation (Shockley, Santana, & Fowler, 2003; Stephens, Silbert, & Hasson, 2010).

Ongoing dynamics of mind and body supply these and other constraints to the brain, which is not usually considered. In the same vein, purposeful speech sustains and is sustained by the purpose in speaking. The circularity is characteristic of strongly emergent phenomena, and it defines the relation between phase transitions of cortical dynamics and the neurons so organized (Ito, Nikolaev, & van Leeuwen, 2007; Kelso, 1995). The phase transition constrains the activities of the neurons and the activities of the neurons sustain the different organizations of the brain, on either side of the critical state. Emergent phenomena all exhibit this strange loop control between the activities of their local elements, which compose and sustain global structures, and the global structure, which constrains the selfsame local activities. Global patterns constrain the local activity of the same elements that sustain the global pattern: constrain sustain.

ANTICIPATED SPEECH AND SELECTIVE ATTENTION

Barack Obama went on to win the U.S. presidency in November 2008 and moved with his family to the White House in Washington, DC. Crime is a severe problem in parts of Washington, especially east DC. Imagine a young couple walking at night in east DC who stumble upon a crime. The taller of the two sees it first and indicates caution by ducking down and in a whispered, “Shh . . .” while pointing toward the crime. The other partner whispers in return, “Oh my God, those vultures are stealing his boots.”

Think about the point in time just before the word “vultures” was uttered. Prior to that moment, the couple’s attention was toward a man wearing boots and other men removing those boots. Once the words are whispered, “Oh my God, those . . .” the details of the scene limit the pragmatics of what may be said next. Even so, the range of options remains quite large. The next thing said could have been “vermin” or “thieves” or “monsters” but less likely “gentlemen” or “bitches” or “senators.” And the choice of the word “vultures” hints at details in the scene that might have otherwise prompted “ghouls” or “corpse robbers.”
Self-organized criticality sheds light on how a history of utterances and subtle details of the situation surrounding a conversation specify language behavior. The relevant contextual constraints include the relations among the couple, the thieves, and the victim. Relevant anatomical and physiological constraints include the limited range of motions of the speaker’s jaw, lips, and tongue; embodied relations among joints, muscles, fasciae, and the nervous system allow our linguistic anatomy to move in some ways but not in other ways.

Yet embodied constraints are also present in the odd desires, prejudices, habits, goals, and beliefs that situate each of us, now, in our present trajectory. Details of the couple’s previous history supply these constraints, including their separate histories of well-being and idiosyncratic relations to other living beings. If a speaker’s history results in a well-known penchant for hyperbole, then the previous use of term *vultures* might have been met with skepticism. “Really, are you kidding, they are simply helping the bum get comfortable.” All the available constraints at the moment before saying “vultures” contribute constraints to self-organize critical states.

Criticality allows speech to be preselected before articulation in a specific sense of the term *preselected*. Limits on possible speech cut down the degrees of freedom for word choice. Limits, as constraints, rule out some propensities but not others. In this sense of preselected, the propensity to say a particular word is preselected if it yet remains within the set of possibilities. Constraints are generally limiting relations among a system’s components reducing the degrees of freedom for upcoming behavior; so long as a potential articulation is still possible within the reduced degrees of freedom, it is preselected (Gibbs & Van Orden, 2010).

Speech acts are anticipated in critical states and enacted by relevant contingencies. The moment before enacted speech, all emphasis is on the anticipated alternatives for speech. But relevant contingencies enact speech. The prominent role of contingencies shows up at the exact point in time that contingency is prominent empirically, when scientists do not have access to the proximal causes of enacted behavior. We cannot know the contingent details that predict the proximal causes of saying “vultures” no matter how well we know the speaker. A scientist could carefully shape the preceding context of the “vultures” utterance to create a bias in favor of saying “monsters,” but the priming would affect a priori constraints, exclusively, not the proximal articulation of “vultures.”

In theory, the indeterminacy reflects the instability of critical states, which have a hypothetical or epistemic status compared with observed speech, which is empirical and has an ontological status (Atmanspacher & Primas, 2005). Each spoken utterance is thus a singular event, which is also consistent with the consequences of frustration in self-organization. Any source of a relevant constraint, no matter how seemingly inconsequential, collapses a critical state and enacts behavior (Kloos & Van Orden, 2010; Riley & Turvey, 2002; Zbilut,
2004). The term *relevance* implies only that a constraint pertains to the content of the critical state sufficiently that it can discriminate among anticipated speech outcomes.

The relation between critical states and contingencies also includes a basis for selective attention. Selective attention is possible because critical states are selectively impervious to irrelevant contingencies. The speaker’s critical state prior to saying “vultures” can only be perturbed by contingencies favoring an anticipated speech alternative, which holds as well for enacted behavior generally (Kloos & Van Orden, 2010; Van Orden et al., in press). Imagine that you intend to stop eating junk food, from now on, that’s it. The next day, after missing lunch, you come across your favorite candy bar in the glove compartment of your car. The unexpected discovery will blow your intention for that day as you eat the candy bar.

But if you had found an electronic game there instead, you wouldn’t have eaten the game because it is not edible. Likewise, the position of the moon was probably irrelevant for enacting “vultures” instead of “monsters.” The selective constraints that create a critical state allow the actor to stay open to relevant contingencies without being misled, too often, by superficially relevant contingent events. On occasion one may find oneself driving toward work, by mistake due to the shared route to Grandma’s house (in a capture error; Norman, 1988). But usually constraints are only satisfied by contingencies relevant to the purpose at hand.

Putting all these ideas together, intentional contents constrain the limited critical state, setting limits as well on which contingencies can enact behavior. Frustration in the self-organization of critical states ensures that “all voices are heard,” in a manner of speaking, or that “no stone is left unturned” concerning the possible contributions of relevant constraints or contingencies. And this picture of language begins to make sense of how *dog tired* (with its figurative entailments of use) need only crash into the constraints toward exaggeration because superficial contingencies like starting with a phoneme /d/, plus a bigger = more kind of protologic, can emerge as *dinosaur tired* in speech (cf. Lakoff, 1987).

**CONTROL OF LANGUAGE PERFORMANCE**

We next explain the variation in measurements of linguistic activities. A single control parameter predicts the changes in the overall patterns of variation that have been observed in laboratory experiments (Van Orden et al., in press). The control parameter is illustrated as a ratio between a numerator referring to involuntary control and a denominator referring to voluntary control.

Affordances* (affordances-star) specifies the available degrees of freedom for a particular task performance. Effectivities* refers to the performance capacities
of a particular individual. They are both sources of involuntary control. These claims generalize the usual definitions of *affordance* and *effectivity* to refer now to the particulars of individuals and environments.

Affordances* and effectivities* are more or less inclusive of what the environment affords a typical member of a species or what a typical member of a species may effect within his or her environment. Affordances* refer to the degrees of freedom afforded by a particular task environment for the effective performance of a particular person. Effectivities* concern the embodiment of the person with respect to the task environment’s controllable degrees of freedom.

Concerning affordances* (hereafter, just affordances), an ambiguous task stimulus affords more than one response option. Consequently the ambiguous task stimulus presents more degrees of freedom for responding than an unambiguous stimulus. Concerning effectivities* (hereafter, just effectivities), preexisting embodied constraints of a skilled performer can control more degrees of freedom more flexibly compared with an unskilled performer.

Putting these ideas together, comparing affordances with effectivities defines the residual degrees of freedom of a task environment. The value of the numerator on a particular trial of a task performance will reflect these residual degrees of freedom. Residual degrees of freedom fluctuate as random variables, as uncontrolled variation across measured values.

The value of the denominator concerns the controllable degrees of freedom by sources of voluntary control. An experimenter’s instructions to a participant concern voluntary control. A participant takes on the experimenter’s instructions as intentions to participate by limiting response behavior to the instructed response options, by remaining vigilant, by paying attention to what he or she is told to pay attention to, by responding quickly and accurately, and by obeying whatever else the instructions say about performing each trial of the experiment.

Voluntary control adjusts online, bringing constraints into and out of existence, to control residual degrees of freedom. A change in either the denominator or the numerator will change their ratio, however. Systematic changes in the values of the ratio can walk a system through all the possible options for behavior. Between the different kinds of response options are critical values of the control parameter, which specify tipping points.

Tipping points exist between the alternative response options allowed in experiments. The kind of response that will be observed changes across the tipping point of the control parameter, like the change from a correct response to an error. Spelling the conjunction of “you” and “are” as “your” is such an error, a common error in speeded writing.

Manipulations of artificial speech have demonstrated the existence of tipping points between perceptual options (Tuller, 2005). The values of the control parameter were changed by changing the duration of a gap of silence within a synthetic spoken word. The gap of silence appeared just after the initial fricative...
/s/ in the synthetic pronunciation of “say” and was lengthened incrementally until the participant reported hearing “stay.”

Changing the gap of silence changed the affordance–effectivity numerator in small increments. Incremental changes increased the gap of silence only 10 ms at a time to move the participant’s perceptual report gradually toward the tipping point, across the tipping point, and then back again. Beginning at “say,” the silent-gap was increased until it passed 20 ms in duration, creating stimulus ambiguity. Ambiguity increases the available degrees of freedom for the perceptual report. But a sufficiently long gap duration (60–80 ms) will collapse the extra degrees of freedom into an unambiguous hearing of “stay,” which participants reported as a sudden change from “say” to “stay” (Tuller, Case, Ding, & Kelso, 1994).

The first time a participant sits through trials with increasing gap durations, a relatively longer gap duration will be necessary to change “say” to “stay.” The longer gap marks the far end of the ambiguous region. However, had the experimenter first presented “stay” and then shortened the gap duration incrementally toward “say,” then the far end of the ambiguous region is the relatively short gap, inducing a sudden change in perception from “stay” to “say.” The stable travel through the ambiguous region, to the far ends of ambiguity, is called hysteresis because the “history” of a previous trial response is sufficiently biasing to collapse the ambiguity, staying consistent with the system’s history.

Hysteresis is one of several empirical flags of the tipping points between qualitative changes in perceptual report or some other action, induced by small incremental changes in the values of a control parameter. The sudden change in perceptual report induced by a single small incremental change at the far end of ambiguity is called a sudden jump, another empirical flag. A third empirical flag reflects a contrastive effect called enhanced contrast. Enhanced contrast is the inverse of hysteresis. The perceived qualitative change from “say” to “stay” occurs at the near end of the region of ambiguity as soon as additional degrees of freedom for perception become available.

In the “say–stay” example, turning hysteresis into enhanced contrast reflects a change in effectivities of the numerator. With experience in the “say–stay” task, participants come to expect where a particular run of trials will lead. The expectation, as a change in effectivities, now resolves the ambiguity in favor of the expected change, and enhanced contrast replaces hysteresis. Participants anticipate the coming change in perception and this anticipation is sufficient to resolve ambiguity at first opportunity. Consequently, participants reported the change from “say” to “stay” at gap durations of about 30 ms and the change from “stay” to “say” at durations of about 50 ms, at the leading edges of ambiguity instead of the trailing edges (Tuller et al., 1994).

Perception along the artificial “say–stay” continuum has been examined in brain images as well, revealing simultaneous sudden jumps in brain and behavior.
The incremental “say–stay” continuum was presented while SQUID images were collected, together with behavioral measures and EEG. Participants pressed one of two keys to indicate whether “say” or “stay” was perceived. Within the ambiguous range, the brain dynamics were highly similar at vowel onset and then collapsed into one of two distinct patterns, coinciding reliably with whether the participant reported “say” or “stay” (Kelso, 1995).

The imaging results also revealed additional empirical flags of tipping points including critical fluctuations and critical slowing. Just before the sudden jump in brain and behavior, critical fluctuations were observed as exaggerated “chaotic” fluctuations in brain or behavioral measurements near the tipping point. Critical slowing was observed as an exaggerated slowdown before the perceptual report, before returning to “normal.” Chaotic dynamics facilitate the transition to the new state across the tipping point; both flags, often observed together, suggest ways that a system can “wisely” abandon one state for another when perturbed (Sherrington, 2010).

Tipping points have also been demonstrated to exist between alternative interpretations of ambiguous sentences. Artificial speech was again manipulated creating incrementally continuous changes in sentence prosody using the relative times between accented syllables. Time between accented syllables was lengthened or shortened to move perceptual reports past a tipping point and back again, between the two different prosodic interpretations. Again, hysteresis and enhanced contrast were observed (Rączaszek, Tuller, Shapiro, Case, & Kelso, 1999).

A clever, albeit subtle, and indirect investigation of tipping points, and ambiguity, looked at sentence contexts that also present category labels (Rączaszek-Leonardi, Shapiro, Tuller, & Kelso, 2008). In the sentence “The mouse was eaten by the bird even though it tried to hide,” “bird” is the category label. Listeners heard sentences that were either neutral (e.g., “The food was eaten by the bird . . .”), or biased (e.g., “The mouse was eaten by the bird . . .”) in prompting the category label (e.g., “bird”). At issue was the performance dynamics around when a participant infers that the category label “bird” of the sentence refers to an atypical bird such as “eagle” and not a more common, and more likely, exemplar like “sparrow” or “robin.”

While participants listened to the sentences, they were also presented visually with a probe word at 0 ms, 450 ms, or 750 ms after the offset of the category label. The probes were either typical exemplars of the category such as “robin” or atypical exemplars such as “eagle” that were appropriate to the sentence context. Participants made speeded lexical decisions to the probe items. Analysis of the lexical decision times to contextually relevant, atypical probes (“eagle”) showed no priming advantage until 450 ms after hearing the category label (Rączaszek-Leonardi et al., 2008).

Thus, somewhere near 450 ms, after hearing a word like “bird,” instability due to multiple available associates precipitates a rapid reorganization. Reor-
organization creates a contextually relevant interpretation for “bird” that benefits the lexical decision response to “eagle.” The reorganization occurs in a fashion reminiscent of a physical phase transition (a.k.a. bifurcation or tipping point) through a change of stability (Racaszek-Leonardi et al., 2008). After the reorganization, the “bird” context contributed additional constraints, changing the numerator effectivities of the control parameter and reducing the degrees of freedom of anticipated candidates for lexical decisions, resulting in a different or perhaps smaller set of candidates that include “eagle.”

Several additional studies have explored self-organization in online sentence processing. One research program studied participants’ grammaticality judgments and reading times to syntactically ambiguous sentences (e.g., “As the author wrote the book describing Babylon grew”). This research demonstrated “digging in effects” in which early commitments to the wrong syntax make it harder to reorganize what the ambiguous sentences mean (Tabor & Hutchins, 2004). One way to think of this effect is as a variety of critical slowing.

Presumably, sentence ambiguity entails extra degrees of freedom supporting more than one interpretation. Additional constraints will be necessary to collapse the ambiguity, and these constraints self-organize as more of the sentence is read. The extra time to self-organize the disambiguating constraints is reflected in the slower reading time. Ambiguity is thus a perturbation of sorts as critically slower and more chaotic dynamics reorganize the syntactic attachment if sufficiently perturbed. In a model, each word encountered gave rise to a set of attachment sites. Interactions among conflicting attachment sites were the source of “chaotic” dynamics that eventually yielded a state in which both syntactic and semantic constraints were sufficiently satisfied (Tabor & Hutchins, 2004).

Sentence ambiguity illustrates that context plays a direct constitutive role in language understanding, as envisioned in strong theories of situated language and cognition (e.g., Larsen-Freeman & Cameron, 2008). Also, speech errors and correct performances share a common basis (Freud, 1914), as was envisioned in subsymbolic connectionism as well (e.g., Van Orden, Pennington, & Stone, 1990). Finally, because values of control parameters refer directly to trial performances, the irreducible unit of psycholinguistic analysis becomes the perception-action cycle, as envisioned in ecological psychology (Gibson, 1979/1986).

There are also broad empirical implications. A laboratory task contributes change to measured values of behavior if the task changes in structure from trial to trial (Holden, Choi, Amazeen, & Van Orden, in press). Unsystematic changes across task trials perturb performance unsystematically, as when an experimenter randomizes the order of presented trial conditions or when a different stimulus is presented on each trial, requiring a different response. Systematic or rhythmic changes, however, may invite entrainment of a participant’s actions. Unchanging aspects of tasks are fixed constants in the control parameter, contributing to
stability as unwavering constraints on performance (Simon, 1973). Compare how unwavering constraints in our relation to the earth’s gravity situate walking or swimming (Shanon, 1993; Van Orden, Holden, Podgornik, & Aitchison, 1999).

Meaningful methodological constraints change from one generation of scientists to another; natural language phenomenology itself changes on many timescales, sometimes spanning societies and cultures, sometimes generations, and other times changing within the life spans of individuals. Even the spellings and pronunciations of words are changeable things, for instance, when the word “min” in Old English became the equivalent two-letter word “my” of contemporary English (Wiktionary, 2010) and when the spellings of Dutch words were recently regularized to facilitate reading acquisition (Bosman, van Hell, & Verhoeven, 2006; Wenzel, 1997). Ambiguous morphology is also always present at any given time (Feldman & Andjelković, 1992), which can contribute to colloquial spellings, such as an English word written with a substitute “z” for “s” as in “guyz.” The colloquial variation is not in line with any official dictionary, but “guyz” can have a psychological salience nevertheless (e.g., Bosman & Van Orden, 1997; Buchanan, Hildebrandt, & MacKinnon, 1994; Lukatela & Turvey, 1994a, 1994b; Van Orden, Johnston, & Hale, 1988; however, cf. Vanhoy & Van Orden, 2002).

Other characteristics of language change, too, such as the relative frequency with which a word or phrase is heard around town or in the new way in which it is used. Consider the word cell versus the terms cell phone or handy (in Germany), r simply cell. Martin Cooper invented an early functioning cell phone in 1973 (The New York Times Company, 2010), although it took several decades before cell phones were both available and affordable. Subsequently, between 1997 and 2007 the subscriber rate for cell phone service soared from 4% of the world population to 49% (International Telecommunication Union, 2009). Within a decade, cell phone use dramatically changed the relative use of words that refer to cell phones in all the impacted languages and also the relative frequencies of their cell-phone meanings.

The numerator and denominator of the control parameter synthesize the myriad changes in the mind and body of the participant with respect to the specifics of the task at hand. Meaningful changes can occur at all available spatial and temporal scales, from local rapid changes in a neuron versus slower traveling waves across the neuropil, or fast coordination of articulation in speech versus slowly changing vigilance, or linguistic changes due to development or aging or the most recent conversation. And these examples encompass only a fraction of the factors that contribute changes to measured values in language experiments.

At most, repeated measurements will reveal changes that unfold more slowly than the trial pace of actual measurement taking (and that occur within the duration of the experiment). Thus, the estimated timescales will always be those
basketed by practical details of method and design. Practical details bracket rates of change that align along a somewhat intermediate range of timescales compared with the full spectrum of possible timescales. These practical details concern every case of measurement taking. What we need to complete this picture, however, is knowledge of how the factors on different timescales interact.

PARAMETER DYNAMICS IN SPACE AND TIME

How do the myriad factors combine their contributions? Arguably, this is the first question that should be asked in the analysis of any system because the answer dictates the kinds of theory and method that a scientist proceeds with from that point onward. The answer to how factors interact is found in how the changes across repeated measurements disperse. Dispersion can be observed from two independent perspectives: aggregate dispersion or dispersion over time (e.g., compare Holden, Van Orden, & Turvey, 2009, with Van Orden, Holden, & Turvey, 2003). Because these perspectives are independent, they provide independent evidence about interactions.

The shape of a data probability density function and other aggregate data distributions provide a picture of the interaction in space. For example, if a familiar Gaussian distribution is observed, it suggests that the factors affecting behavior interact additively, concatenating their effects one on top of the other. The fact of additive interactions can even be inferred without necessarily knowing about the details of the interacting factors (although no theoretical conclusions are ironclad).

Familiar Gaussian distributions come from systems whose components affect each other through relatively weak, additive, and independent perturbations. Weak interactions among components disperse effects along local lines of interaction, allowing effects to be localized in the individual components. Weak additive interactions are called component-dominant dynamics because the dynamics within each component are stronger than its interactions with other components, ensuring the dynamic integrity of the components (Van Orden et al., 2003).

Other kinds of interactions among components produce different patterns of dispersion. Multiplicative interactions govern many physical, chemical, and biological systems (Furusawa, Suzuki, Kashiwagi, Yomo, & Kaneko, 2005; Limpert, Stahel, & Abbt, 2001). Multiplicative interactions among independent components yield lognormal dispersion in aggregate data. The term lognormal comes from the fact that a logarithmic transformation of the measured values produces dispersion in a Gaussian “normal” pattern. The log transformation redistributes a heavy tail of extreme values to become the symmetric dispersion of the Gaussian. The implication this time is that weak but multiplicative
interactions disperse effects along local lines of interaction. And once again the dynamics within components are stronger than those among components, encapsulating component effects.

To stop now, with the proposed control parameter, plus multiplicative interactions among its factors, would already yield several far-reaching positive implications. For instance, multiplicative interactions would account for both cooperative (amplifying, overadditive) and competitive (dampening, underadditive) interaction effects in addition to the qualitative effects that span tipping points.

The idea of a control parameter also generalizes the older and narrower idea of independent variables. A control parameter is a synthesis of factors that might otherwise be examined analytically and mistaken for a set of independent variables because the synthesis of factors in a control parameter can mimic factorial changes in measured values. This is true despite the fact that multiplicative interactions are what are found generally in experiments that use factorial designs (cf. Van Orden, Pennington, & Stone, 2001).

Multiplicative interactions can stretch and extend dispersion to extreme values (e.g., multiplying by values > 1), compress and shrink dispersion (e.g., multiplying by values < 1), or leave dispersion unchanged (e.g., multiplying by 1). Extending this idea to include interactions among interdependent components greatly stretches and extends dispersion to extreme values because effects are amplified through recurrent multiplication (e.g., like a number times itself, times itself again, times itself again ...).

The result is dispersion in the shape of a power law. A power law shape on logarithmic axes is a straight line. The magnitudes of the X and Y values change together in orders of magnitude. Extreme values are rare (orders of magnitude more rare); intermediate values common; and small values are far more common (orders of magnitude more common), occurring with (log) frequencies of change inversely proportional to the (log) size of changes.

Repeatedly measured word naming times (the time that passes after each word becomes visible until a participant’s pronunciation triggers a voice key) appear to be mixes of lognormal and power-law behavior (Holden et al., 2009). The observed shapes of naming time distributions will change from one person to the next, however. One person’s naming times will disperse in a shape almost exactly like a lognormal. Another person’s naming times will disperse in shapes that emphasize a power law.

Simulated mixes of lognormal and power-law behavior do this as well, and they pass a stringent hazard-function-test of generality (see Figure 1), which suggests they would adequately mimic each participant’s response time distribution in almost every laboratory task. Aggregate word naming times emphasize a spatial perspective, but power-law behavior in naming times is observed from the alternative temporal perspective as well (Holden et al., 2009;
FIGURE 1 Three characteristic hazard functions found generally in response time data and the distributions of pronunciation times from which they were approximated on linear (Panels A, B, and C) and log–log scales (Panels D, E, and F). Panels A, B, and C correspond to distributions of pronunciation times to 1,100 words by each of three individual participants. The heavy black line in each panel is the participant’s empirical pronunciation-time distribution. The white points surrounding each black line in each panel represent simulation mixtures of ideal lognormal and inverse power-law distributions, using fixed parameters of synthetic distributions in a resampling or bootstrap technique (cf. Efron & Tibshirani, 1993). The boundaries established by the white clouds of the simulated distributions circumscribe a 90% confidence interval around each empirical probability density and hazard function.

Van Orden et al., 2003). Details of power-law variation across time are illustrated in Figure 2.

The data in Figure 2 come from a self-paced reading task. The data in the figure come from one participant who read a story presented word by word on a computer screen. The reader revealed each word in succession by pressing the space bar on the computer’s keyboard. The Y-axis of the data graph, in the upper right quadrant of the figure, indicates the normalized time intervals between the
key presses (shorter interval times are nearer to the origin). The X-axis, left to right, portrays the order in which each key press occurred.

The figure includes the results of a spectral analysis, which is one way to examine interactions among factors across time. In a spectral analysis, sine waves of different amplitudes are combined to mimic the aperiodic pattern of the changes in measured values from one trial to the next. The power-law scaling relation that results is between the amplitudes (power) of the sine waves, the magnitude of change $S(f)$, and their frequencies or how often changes of that magnitude occur.

In the illustrated scaling relation, the size of change $S(f)$ is inversely proportional to its frequency $f$: $S(f) = 1/f^\alpha$, with scaling exponent $\alpha \approx 1$. This scaling relation is sometimes called pink noise because visible light with the same spectral slope would have a pinkish cast due to power concentrated in lower, redder frequencies. There are other numerical and geometric analyses to portray this scaling relation although each comes with its own vulnerabilities and caveats (Holden, 2005).

The scaling relation is a linear relation (on logarithmic axes) between how often changes of a particular magnitude are observed and the magnitude of the observed changes. Large changes are rare whereas intermediate are more common, and small changes are the most common, appearing with frequencies
inversely proportional to their magnitude (power). Notice the parallel. The power laws of dispersion in space and time are both scaling relations between the magnitude of observed values and how often values of a particular magnitude are observed (on logarithmic scales).

In the data pattern of Figure 2, each change in measured values fits into a statistically self-similar fractal pattern. Fractal data have counterintuitive properties. For instance, in the fractal pattern, longer data sets gain access to rare but much larger magnitude changes. This counterintuitive idea is illustrated in Figure 3.

Figure 3 uses the same data as Figure 2 analyzed piecemeal, one quarter of the data at a time, as though we had run several experiments of different length, with 1,024, 2,048, 4,096, and 8,192 trials, respectively. The different data lengths reveals gross changes in the magnitude of variability as a data series gets longer, contradicting the bedrock assumption of uniform variability.

FIGURE 3 Trial-ordered series of reading times (left) and the resulting spectral plot (right). The bottom panel includes the leftmost 1,024 trials of the data presented in Figure 2, and each panel above increases the length of the data series taken from the data in Figure 2. The scaling relation remains close to the same value of a for each increasingly longer data series. However, the extent of variation grows upward along the Y-axis in the log units of orders of magnitude.
upon which standard statistics rely. Moving from shorter to longer trial series, variation grows in orders of magnitude.

Conventional theories would have difficulty accounting for the fact that more data equal more extreme variability (Van Orden, Holden, & Turvey, 2005). The assumption of uniform variability allows larger data sets to yield more reliably stable estimates of average performance in standard analyses, meaning that error variance should not increase as more data points are collected. Conventional theories, methods, and analyses of variance are simply wrong on this point, however, their most fundamental assumption.

Power-law behavior in fractal data implies that longer data series include more extreme variation. No stable mean values exist, which topples the center pole of conventional empirical thinking, bringing down the whole tent. Repeated measures of linguistic behavior are not well represented by their mean.

Measured values of human performance, linguistic and otherwise, by individuals or in aggregate populations, commonly disperse as power laws (Kello, 2004; Kello et al., 2010). Power-law dispersion implies that the stronger multiplicative interactions disperse effects along global lines of interaction. The dynamics between components are now stronger than the dynamics within components, so local lines of interaction no longer encapsulate component effects.

Interdependent components change each other’s dynamics as they interact, which is called interaction-dominant dynamics (Van Orden et al., 2003). The source of creativity in frustration originates in interaction-dominant dynamics among components. Components retain enough independence to frustrate being completely dominated by other components yet succumb at the same time to a perpetually frustrated compromise that never fully takes hold.

COORDINATION DYNAMICS

Interaction-dominant dynamics across the body support a coupling in time between task and participant and the evidence of interaction-dominant dynamics is ubiquitous in language performance (Kello, Anderson, Holden, & Van Orden, 2008). The strongest corroboration at present has been found in reanalyzed data series revealing multifractal patterns (Ihlen & Vereijken, 2010).

Multifractal data are not fully characterized by a single scaling exponent or equivalently by a single fractal dimension. The data show a dispersion of fractal dimensions around a central tendency (loosely speaking). The central tendency is estimated by the value of the monofractal scaling exponent α, derived as in Figure 2.

Multifractal data entail a degree of complexity never considered outside of complexity science. But multifractal dispersion has not yet been explored systematically in human performance. Many studies do exist, nevertheless, demon-
strating reliable manipulations of monofractal $\alpha$. Although multifractal dispersion will no doubt add much to this picture, once explored, we can currently describe only the systematic changes in task–participant coordination dynamics from studies that examined change in the monofractal $\alpha$ parameter.

When the relation between a task and a participant changes sufficiently, the change in coordination is estimated by changes in the $\alpha$ parameter. A change that results in more uncontrolled degrees of freedom in the numerator of the control parameter, for example, contributes disorder to variation across trials, pulling the estimated $\alpha$ toward the $\alpha \approx 0$ of random white noise. A change to extremely rigid control, increasing the denominator of the control parameter, becomes tightly ordered and overrigid. It pulls the estimated close to the $\alpha \approx 2$ of overregular brown noise (compared with white or pink noise, that is; see Van Orden et al., in press).

Thus, the outcome for the coordination parameter $\alpha$ reflects a trade-off between order versus disorder in performance, predicted by changes in the control parameter of task performance. The control parameter comprises a numerator summarizing sources of disorder and involuntary control versus a denominator summarizing sources of order in voluntary control. The value of the coordination parameter when $\alpha \approx 1$ is a kind of “frustrated ideal” or “frustrated optimum” of coupling between a task and a participant and order and disorder.

The coordination parameter pertains to the coupling, exclusively. For instance, it is possible that Barack Obama finds the task of being president a kind of ideal match between the job to be done and his interests and skills, but that is not exactly the kind of ideal we intend. The coordination parameter evaluates variation in the online coupling of task and person and although some couplings may feel better than others, the coordination parameter doesn’t tell us that precisely.

For example, repeated measures of the relaxed treadmill gaits that adults prefer do not yield $\alpha \approx 1$. Preferred gait sits at a value somewhat less than one, toward the $\alpha \approx 0$ of white noise (Hausdorff et al., 1996). One way to interpret this comfort gait is that it requires less voluntary control, perhaps because a treadmill supplies uniform constraints (compared with natural terrain) sufficient to reduce the need for voluntary control. This may allow a kind of least effort in control and a reduced denominator in the control parameter (Kloos & Van Orden, 2010). Not a bad thing despite $\alpha \neq 1$.

If comfort gait requires less voluntary control, then forced departures from the comfort gait would require more voluntary control, increasing the denominator and moving $\alpha$ away from $\alpha \approx 0$ and toward $\alpha \approx 1$. Gaits slightly faster or slower than the preferred pace do indeed yield values of $\alpha$ closer to $\alpha \approx 1$ (Hausdorff et al., 1996), and the effect is observed for wide-ranging deviations from preferred pace in both walking and running and across a variety of repeated measurements (stride interval, stride length, step interval, step length, and im-

Adults’ preferred gaits center on a coordination that includes reduced voluntary control, possibly due to highly constrained treadmill conditions. If so then we may reduce voluntary control further. Supplying more task constraints on gait via the task environment increases sources of involuntary control (relative to voluntary control). For instance, walking to a metronome beat cedes control to the task environment, moving the \( \alpha \) value of the entrained gait even closer to \( \alpha \approx 0 \) (Hausdorff et al., 1996). Relaxation of voluntary control also reduces muscle tensions generally, which at the same time increases subtle overrandom muscle tremor (Woodworth & Schlosberg, 1954).

Human gait reveals a wide range of \( \alpha \) values. For example, a toddler taking her first steps will lock out degrees of freedom in her legs and torso, which overcontrols balance so as not to fall down. Consequently, the toddler’s gait reveals a pattern not unlike a drunkard’s walk, which is actually another name for the brown noise variation when \( \alpha \approx 2 \). Slightly older children’s gaits disperse \( \alpha \) values widely, including values close to \( \alpha \approx 2 \), but as children approach puberty the measures of preferred gait trend toward the narrowly dispersed adult gait, near \( \alpha \approx 1 \) but slightly in the direction of \( \alpha \approx 0 \) (Hausdorff, Zemany, Peng, & Goldberger, 1999).

Gait is not a special case. Changes in sources of involuntary control versus voluntary control have been manipulated in many cognitive and motor experiments (Van Orden et al., in press, is a review). In all cases known to us, the direction of change in the a coordination parameter is correctly predicted by the direction of change in the ratio of voluntary to involuntary control (Kloos & Van Orden, 2010). The wider implications of this control parameter for language performance, however, remain mostly untested.

**LANGUAGE PERFORMANCE**

The data in Figures 2 and 3 came from participants who read a short story, advancing the story by pressing the space bar of a keyboard. One group of participants advanced the story one word at a time, so the reading times estimated the times to read single words. Another group of readers advanced the story one sentence at a time, so reading times estimated the times to read sentences. Coordination parameters were estimated in each case from spectral analyses and other methods.

Reading the story word by word yielded a coordination parameter close to \( \alpha \approx 1 \), whereas reading the story sentence by sentence yielded a parameter reliably closer to \( \alpha \approx 0 \) of random white noise (Wallot & Van Orden, in press). This result can illustrate once again how we are beginning to think of
language performance as the coupling of person and language task. We chose it here because the result is ambiguous, which illustrates the issues at play when conducting research using coordination parameters.

The magnitude of variation of reading times, word by word, is much less pronounced than variation of sentence reading times. Widely varying sentence lengths may exaggerate sources of unsystematic change in the numerator. Unsystematic changes from one measurement to the next, all else equal, are unsystematic perturbations and sources of disorder in the coordination. They push the coordination parameter in the direction of the $\alpha \approx 0$ of random white noise.

But there is another way to look at the same outcome, which we hope can make clear why one requires multifaceted changes, and counterintuitive changes, to motivate control hypotheses. A nagging question becomes, Do observed changes stem from a manipulation that changed the numerator or that changed the denominator, or both? A single change in the coordination parameter, by itself, cannot answer this question (Van Orden et al., in press).

For instance, sentences entail more linguistic complexity than single words, and syntax and semantics may constrain reading performance. If reading performance entrains to these additional sources of constraint (which originate in the intentions of the author) then as when the metronome entrains gait, voluntary control will be reduced. If voluntary control is reduced, then so are sources of order and the coordination parameter will move closer to $\alpha \approx 0$ of random white noise.

Each such manipulation of a task changes idiosyncratic relations between text and reader—the linchpin of reading. This will be the case as well for the additional dimension of coordination that multifractal analysis will reveal. Observed changes in multifractal dispersion of a coordination parameter, within an experiment, imply variation in the values of its control parameter, and the control parameter refers directly to emergent coordination between text and reader.

Thus, we now confront exclusively ecological questions about language performances. All empirical questions can be asked with respect to the relation between task and participant. This turns the research program of psycholinguistics into a program that confronts direct perception and perception–action measurement trials, necessitated by the interaction-dominant dynamics of mind and body (see also Van Orden et al., 2003).

CONCLUSIONS

We conclude with additional thoughts about the Obama speech that we saw. The coordination between Obama and his listeners is in some sense reflective of persuasion and agreement, to the extent that the listener stays in phase with
the speaker, for example. A listener who supplies covert or overt perturbations to Obama’s intended message will be less in phase than a rapt listener who finds nothing to disagree with. The implied focus on the interactions between a speaker and a listener, or between a text and a reader, illustrates a good entry point empirically and theoretically at which to broach language performance.

This entry point is not concerned with underlying causes of language performance, however. The proximal causes of any particular utterance or interpretation are contingencies, which are too much the products of idiosyncrasy in history, disposition, and situation—whereas constraints are readily manipulated and, we suggest, have been the manipulated factors in psycholinguistics all along (Hollis, Kloos, & Van Orden, 2009). This claim reinstates the goal that we took on when we set about writing this essay. It should be possible to build a bridge between the historical literature of psycholinguistics and the complexity science that we practice.

It should be possible to translate historical findings into a new theoretical language. That was our belief when we began writing this essay and our experience since has only strengthened that belief (see also Gibbs & Van Orden, 2010; in press). The control parameter is a generalization of familiar independent variables after all. It is not the same thing as independent variables and should not be equated with independent variables. Factors are no longer conceived as being independent in the way they interact. The control parameter is a synthesis of the factors that would traditionally have been treated as independent variables.

Dramatic changes in theory and method, then, are not always about the empirical factors that can be manipulated. The changes we have focused on here are about what can be concluded from a successful manipulation. Each examined factor is expressed empirically in an interaction among all other available factors of mind and body, irrespective of what each factor might correspond to as an embodied aspect of performance.

In that light, it no longer appears credible to pick out selected factors and tasks as special or elite representatives of cognitive structure to be favored above others. No factor has yet accrued the kind of evidence to justify such conjecture and perhaps no factor ever will (though the future is uncertain as always). What appears certain, today, however is this: No factor stands alone to produce language performance. Language performance is the product of interaction-dominant dynamics, which anticipate the future as embodied propensities to speak or listen with understanding.

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