Quantum Leaps in Language Learning

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This paper looks at how principles in physics, cognitive science or neuroscience combined with psycholinguistic theories can offer new ways of looking at what language teachers teach. Chaos and Complexity Theory has particularly been used as a metaphor for the processes that occur in the classroom. Though linguistic theory remains notoriously inaccessible and inapplicable to many teachers this paper for the most part nonetheless persists in staying mainly theoretical the aim being to assist in making science and metaphoric language use natural areas of language teaching. In particular, three problems areas in language teaching are set out (i.e., syllabus design, focus on form and the zone of proximal development) and three solutions are suggested for each respective problem (i.e., connectionism, perspective taking and the introduction of a new approach to language teaching, socio-cognitive learning).

量子言語学(Quantum Linguistics)という用語が造られたのは、いかに物理学の理論が言語機能にふさわしいメタファーとしての働きをなしうるかということを類比的に言及するためである。この論文では、いかにして心理言語学（たとえば社会文化的理論）の理論と結びついた物理学、認知科学、あるいは神経科学の原理が、語学教師の教授内容に新しい見方を提供できるかを見ようとするものである。特にカオス・複雑系理論(C＆CTheory)には、教室で起こるプロセスのメタファーとして用いうる可能性がある。主として理論的な域をでないけれども、この論文の目的は、特にカオス・複雑系理論、発達の最接近領域(ZPD)、そして結合説において、科学の諸領域を言語教育の分野、特にシラバス・デザインと言語形式の焦点化(FonF)の領域にできる限り適応できるようにし、その結果として言語教育に新しいアプローチを導入することにある。すなわち社会認知的方法(SCL)である。

When naming new terms for theories or discoveries in physics, scientists once used Latin-based language. More recently, to name the newly created object or theory many of the words in physics are invented and quite often figurative (e.g., the big bang). It is interesting to see how easily these neologisms can then be metaphorically applied to other concepts, in this paper's case, linguistic. Indeed, this cognitive mapping ability of scientific neologisms might initially appear to be another small unique function

of language. Time, however, among other abstract concepts, is quite often expressed using concrete objects (Lakoff & Johnson 1980). Consequently, coining new scientific terms and metaphorically applying them to non-scientific concepts is not a unique function of language but rather a natural ability it has to embody and restructure our existence in thought.

The term *Quantum Linguistics* is a good example. I coined it to analogically refer to how theories in physics can act as suitable metaphors for the functions of language and language teaching. This paper looks at how principles in physics, cognitive science or neuroscience combined with theories in psycholinguistics can offer new ways of looking at what we teach—in hopes of possibly furthering to inform the language-teaching process.

Chaos and Complexity Theory [1] (Hill 2003; Mallows 2002; Larsen-Freeman 1997), henceforth C & C Theory, especially has been applied as a metaphor for the processes that occur in the classroom. Unfortunately, however this does not represent a trend. The truth is linguistic theory remains notoriously inaccessible and inapplicable to many teachers (McCarthy 2001; Ellis 1997). Nonetheless, though persisting in remaining mostly theoretical this paper takes a soft or weak approach to theory (cf. mainstream or "pulp linguistics" publications such as Pinker 1994) in hopes of making other areas of science metaphorically applicable to the field of language teaching. It is also hoped that by reading this paper teachers might consider the cognitive benefits of shifting students' thought towards metaphoric mapping. In particular, three problems areas of language teaching are pointed out (i.e., syllabus design, focus on form[2] and the zone of proximal development[3]) and three respective solutions are suggested (i.e., connectionism, perspective taking and the introduction of a new approach to language teaching, socio-cognitive learning).

Syllabus design

Linguistic learning is not a linear process yet in many syllabi it is presented this way, especially with structural-based ones (e.g., the sequence of tenses). In fact, most structural syllabuses present language in a linear cognitively naïve fashion. As is well known however learners progress at their own pace, they do not learn one form and then move on to the next more difficult one in a step-by-step, linear manner (Ellis 1994; p. 35 - 37). Perhaps it might be more appropriate to suggest that learners learn one form and then apply it metaphorically to their language use. Thus, by moving away from a linear—or for that matter literal—grammatical model of syllabus design towards a more figurative one (Katz, Cacciari, Gibbs & Turner 1998), we would also be leading students to progress from naïve cognitive models of language towards more expert ones.[4]

It might be argued that low-level students do not have a use for expert cognitive models, that they are too complex, but the truth is that mapping may be an even more basic cognitive function than grammar and hence awareness of this ability would also increase students' language acquisition. In a certain sense, first language science classes might also be thought of as having always been trying to achieve this heightened shift in cognitive models. Indeed, if thought or cognition remains at a naïve or basic level then cognition does not advance and progress may not occur. If we encourage students to attain expert, super-ordinate or metaphoric levels of thought then cognition will advance and their problem-solving skills will improve. Of note, recently this trend is being seen in EFL where more technological or scientific-based textbooks are being published (see, for example, *Tech Talk,* Hollett 2003; *Talking Science,* Widdows & Stoke 2004).

In any case, life, like C & C theory, is by no means linear and is also very complex. Consequently, rather than presenting a straight-line socio-cultural understanding of time recorded in seconds, minutes, hours, days, months, and years, (as if everything has its place upon a single objective daily routine; Harvey 1990) and having students recite their daily schedules using the present tense, teachers might do well to remove such predictability from their lessons. In our daily routine, there is always the probability of chaos (e.g., missing a train or waiting for a late one) and this unpredictability should be represented in syllabuses (e.g., the possibility of one grammatical form unpredictably emerging before or after another).

A more productive alternative approach to syllabus design is probability-based grammars (McCarthy 1998: p. 85). Part of the meaning of choosing any grammatical term is the probability with which that term is chosen. Thus each instance of language use redefines the linguistic system, however infinitesimally, maintaining its present state or shifting its probabilities this way or the other (Halliday 1991), and it is this kind of shifting and redefining of probability that is needed in syllabi. Probabilistic grammar is certainly a step in the right direction, that is, away from linearity, but it is doubtful if the ratio of probability alone adequately reflects the true complexity of the relationship at hand. A possibly more promising approach, one that more accurately reflects the complexity of the relationship between grammatical and learning development, is a *connectionist* approach to syllabus design.

Connectionism and neural networks

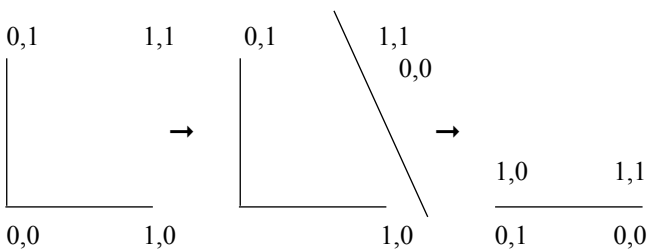
Connectionism is the name for neural network modeling systems, which can simulate learning processes and interactions of language in the mind (Elman et al. 2001). Along with advances in neuroscience, connectionism represents another contribution to quantum linguistics, or metaphorical application of scientific theories to language learning. For instance, connectionism offers new ways of looking at the emergence of grammar as the natural process of brain development. It also exhibits relations similar to those of other-, self- and object-regulation, thereby functioning in a way that could be described as a *neural ZPD*. In this way, it also has potential applications to group dynamics.

It is no small achievement that neural networks can successfully describe the possible brain interactions below the word level (see Figure 1). Additionally, neural networks reveal that the connection between language development and associative learning is very strong (Elman et al. 1996). In actuality, grammar might best be thought of as the associative connections developed between neurons as the brain develops to form concepts, and language is learned epiphenomenally (without distinction between L1 and L2 at this point). If we apply this to syllabus design, rather than to present language in a textual-based sequential syllabus, it might prove more productive to conceptually and metaphorically re-structure syllabi to that of a connectionist one similar to those undertaken by neural networks.

XOR is a formula that can solve AND/OR questions. Basically, there is a set of inputs, usually 1s and 0s (i.e., binary) that decide whether a given input falls into a positive or negative category. XOR is difficult because the pairs of patterns that are furthest apart 0,0 and 1,1 are those that need to be grouped together by the function. As seen in the above figure, this is relatively easy to solve with hidden units. Hidden units have the

effect of folding distant patterns (0,0 and 1,1). It is too complex to go into detail here but it is certainly worth pointing how XOR can successfully explain the weighting of inflecting a word as regular or irregular past tense. It is also not unreasonable to compare the four XOR quadrant relations to the triad of other-, self- and object-regulation in the ZPD. Combined they could also have applications to the dynamics of group work.

Figure 1: Representation of the four input patterns for XOR



In support of this position, the division of grammar and lexis in the brain has yet to be proven. First language acquisition studies do not find any difference between semantic and function words in children up to the age of approximately 3 years (Bates, Dale & Thal 1995). This finding can be easily misinterpreted, however, because function words in actuality do not represent grammar. Function words remain a part of lexis. Rather, the evolution of grammar involves the condensation of lexis and function words to increase meaning or form "grammar" (Bybee, Perkins & Pagliuca 1994). This condensation of meaning is very similar to the natural function of neural networks to make often made associations in the brain as connected and effective as possible. The basis of grammar, then, is the development of thought. As soon as a neural network makes an association, for example, to contract or inflect when assigning phonology to a word or thought, both language and cognition has become connected, hence taking on an association of more meaning and functioning as grammar.

In actuality, present grammatical terminology was created by the Greeks to explain the outer textual functions of language rather than the inner cognitive workings of thought and there is obvious reason to believe grammatical terminology does not reflect meta-cognitive processes. An alternative to creating terminology to describe the product of language (i.e., developing grammatical terms from the analysis of text) is to begin at the cause (i.e., with cognitive processes such as comprehension and production or visual and action-related processing) and then develop neural or cognitive grammatical constructions to describe how thought is constrained to have meaning in language and the meaning is consequently condensed by grammar according to these relations. In other words, another goal of quantum linguistics is to replace Greek grammatical terminology (or for that matter grammar) with terms that represent the internal cognitive equivalences of language. To illustrate, previously we did not distinguish between written and spoken grammatical forms but recently this has become the norm. Rather than being thought of as embedded and hierarchical, spoken language's structure is more connected and perspective taking (Brazil 1995; McCarthy 1998). Only the analysis of written language can be considered as hierarchical or embedded.

There have been three relationships found between language and brain processes. A relationship between words and

phonology has been found in the brain (Pulvermuller 2002). Thus, there is a relation between thought and the phonological unit. A separation between production and comprehension has also been found. Possibly this separation exists because comprehended language is stored in short-term memory but words for production are drawn from long-term memory or the conceptual system. Comprehension might best be thought of as more of a top-down process, and production bottom-up. Both activate different neural networks.

Another separation exists between action words and visually related words. The brain and language are divided according to the cognitive demands of vision and action. Pulvermuller (2002) explains that these neurons group together into functional webs. These functional webs map cognitive domains together to initially create thought through metaphoric mappings. From these findings, then, the following are important to describe how the internal workings of functional webs result in the external result of grammar and they could also form the basis of a connectionist syllabus:

- To make the connections between production and comprehension as effective as possible.
- To create an associative perspective between action and visually related words (i.e. perspective-taking and perspective-changing).
- To add the necessary phonology to words for speech.

Not to diminish these important findings in any sense, but it is worth noting that neural networks still remain far from being biological. They are computer simulations of the complex interactions of functional neuronal units. So far they have been successful in simulating the complex interactions of language but they have yet to incorporate a view with details of neuroanatomical connections. Nevertheless, Pulvermuller (2002) postulates that binding neurons hold functional webs together in ensembles, and these binding neurons may be the neuroanatomical reality of "grammar."

Focus on form

Mallows (2002) favors the reactive function of focus on form (FonF), which allows for the learning of form to be led by the student. In this way, he uses the complexity of fractals[5] as a reason to avoid the use of any order in the classroom. While I agree with Mallows' assessment of the reactive approach, there are grounds to reject the avoidance of the use of order in the classroom—as well as Krashen's (1985) Input Hypothesis—for one reason: simply because chaos does manifest some order. C & C theory developed out of this observed fact, and it implies that some specific FonF can be effective. The manifestation of some order in the classroom is not equivalent to a return to linearity. It simply means that probabilistically disorder will occasionally exhibit order and at the times it does, using a connectionist FonF approach may encourage language acquisition. Additionally, simple reactive FonF is probably not sufficient. Other variables to consider include the frequency of the form, the natural emergence of the form in learners, as well as the grammatical evolution of the form.

The necessity of probability also reveals at least one more difficulty with the current FonF construct. Except in rare cases when order manifests in the classroom, the chance that an entire class of students will be simultaneously focusing on the same form is remotely small. Therefore, to increase the probability of order occurring in the classroom a cognitive

framework that reflects the universe(als) and the organization of the mind is required. This cognitive focusing can be achieved with a perspective-taking (MacWhinney 1999, in-press) socio-cognitive approach, which allows students rather than FonF to focus on condensing meaning.

Perspective-taking

As soon as learners enter the classroom, they should feel a sense of heightened conceptual awareness. Metaphoric and figurative use of language in the classroom can help facilitate this awareness. Just as C&C Theory can act as a metaphor for the processes that occur in the classroom, the classroom itself can act as a metaphor for society, culture, communication, the world, and the universe. The idea is to get each student consistently thinking in terms of prototypical and basic-level universals so that they are prepared and anticipating their spontaneous naïve cognitive models to interact with non-spontaneous expert ones. Furthermore, it is important for each student to share the same cognitive perspective relating to the position from which an activity is viewed and the same level of abstraction at which a situation is portrayed. By doing so, development will occur and when development occurs meaningful use of language coincides. When language use coincides with development, condensation of meaning or the reactive use of grammar is a natural result.

A perspective-taking approach to cognition orients students according to at least four levels of comprehension: (1) affordances (i.e., an embodied form of prototype), (2) spatio-temporal reference frames (e.g., deictic or frequency), (3) action chains (i.e., causation), and (4) social roles (e.g., mammalian). The hypothesis is that these four perspective systems are grounded on specific brain structures that have evolved to solve major adaptive challenges (MacWhinney 1999). Each of these systems establishes a partial cognitive reflection of the entire human being.

Similar to the visual and action areas of the brain, the affordance system internalizes and changes words to the ways in which humans use sensation and action to act upon the world. Spatio-temporal frames internalize our mental models of positions, moments, and movements in the world. Causal action chains allow the activities of the world to be coded in terms of meaning and causative perspective. Social frames allow actions to be viewed in terms of their personal consequences and implications (MacWhinney 1999, p. 244). Each level requires an increasing level of metacognitive awareness and the development of each can occur in the zone of "embodied" development (ZED) through self-, other- and object-regulation. Once a thought has been formulated and limited to these four levels of comprehension, meaning is once again constrained in the production process through grammar and phonology.

The zone of proximal development

One drawback socio-cultural theory (Lantolf & Appel 1994; Lantolf 2000) has had, since it deals primarily with behavior and the development of speech, is that the application of it, specifically the ZPD, has been only to language teaching methodology and subsequently remains to some extent an "unfinished concept" (Kinginger 2002). Vygotsky's (1986) original theory, in other words, has been reduced through a process of simplification to serve and justify institutionalized practices while reinforcing traditional views of the language classroom. Stripped of its original meanings, the ZPD has been

inserted into a conventional pedagogical scheme, providing nothing new for reflection on theory or practice.

Regrettable as these circumstances may be, by providing a syllabus beyond the socio-cultural methodology, C & C Theory, connectionism and perspective taking help to restore some of the ZPD's original intent as well as "complete" the construct. The ZPD is a supportive social environment, where teachers "other-regulate" the productive language of students until the students are able to "self-regulate" their own output, eventually resulting in their becoming socially competent language users.

Socio-cultural theory (SCT) maintains that human beings view their environment as a social construction (Lantolf 2000) and the theory does not extend the use of language beyond social interaction. Chaos is the disorder caused by the expansion of the universe. It is also the necessary condition for intelligent life. Logically, it is the need to put disorder into order that requires intelligent problem solving. If we apply this principle to the classroom, it suggests that learners need to be guided by teachers to construct order from disorder (i.e., be other-regulated until achieving self-regulation), thereby enhancing their natural role as intelligent beings.

If intelligent action requires creating order from disorder, then this also has a considerable impact on the use of language and on language learning. Thus it may prove beneficial to extend the language learner's role from just the socio-cultural sphere to include a macro problem-solving focus. Of note, C & C theory can also be metaphorically mapped to that of another chaotic micro-process below the socio-cultural level, namely, brain and concept development. Connectionism or "grammar" is another form of order found in that particular development.

Apart from these areas of psycholinguistics and neuroscience, another very complimentary approach to socio-cultural methodology is pairing it with a cognitive grammar syllabus (CG, Langacker 1987, 1991). In the next and final section we look at combining SCT and CG to form a new approach to language teaching: socio-cognitive learning (SCL).

Socio-cognitive learning

In brief, SCT and CG are compatible because CG takes grammar from its conventional role of textual analysis of linguistic forms to that of sharing a conceptual relationship with psychology and thought. SCT further expands on this psychological and cognitive basis with its reasoning that language is a social and cultural construct. Most important, as is now commonly accepted, both approaches share the principle that thought and language are to a large degree conceptual. Within the classroom there is also a consequent need for language learners to develop conceptually in order to become proficient in language and metaphorically embody their reality with thought. To this end, by combining the ZPD with cognitive perspective-taking tasks, thought and the classroom are simultaneously placed into a grammatical-conceptual context. SCL takes a connectionist perspective-taking approach to language learning. It holds that brain development has a three-fold effect on grammar: connected, perspective taking and goal-oriented. First, neural networks connect the production and comprehension functions of language through a condensation process. Second, the neural activity interacting between the visual and action-related and the comprehension and production areas of the brain create the ability for cognitive perspective taking or figurative perspective changing. Finally, grammar is shaped by the goal or problem-solving intent of the utterance.

Conclusion

By applying areas of physics and neuroscience to language teaching, it is hoped this paper has been somewhat successful in introducing a new alternative to language teaching, SCL. SCL also has direct applications to the four skills as well as with the areas of grammar, vocabulary and pronunciation. For instance, perspective taking could be directly applied to both essay writing and speech making. With vocabulary, rather than grouping words according to their grammatical function, it seems words, which have a cognitive basic level category are easiest to learn, while super- or sub-ordinate words might be more difficult. Finally, SCL views much of pronunciation as a form of grammaticization as well as a socio-cultural process. These applications are future areas of research and development for SCL.

Quantum language learning helps to prepare learners for the super-complexity of the future. Connectionism, perspective taking, and socio-cognitive learning are complementary levels to describe thought, language and the world, and therefore each has applications to language teaching. Together they could constitute quantum leaps in language learning.

Endnotes

[1] Larsen-Freeman (1997: 142) states that chaos and complexity theory is concerned with the behavior of dynamic systems that can be characterized to varying degrees by the following features: they are dynamic, complex, non-linear, chaotic, unpredictable, sensitive to initial conditions, open, self-organizing, feedback sensitive, and adaptive. Chaos refers simply to the period of complete randomness that complex non-linear systems enter into irregularly and unpredictably.

[2] Focus on form overtly draws students' attention to linguistic elements as they arise incidentally in lessons whose overriding focus is on meaning or communication (Long 1991).

[3] The zone of proximal development is a condition by which an individual who could not attain solutions can attain them through the help of others (Vygotsky 1986).

[4] Naïve cultural models are held by the majority of people and need not be, and often are not, in line with the objectively verifiable scientific knowledge available in expert models. Cultural models are based on the collective experience of a society or social group. To get through everyday life, laypersons do not need scientifically correct models but can function with a model that enables them to make correct predictions (Ungerer & Schmid 1996).

[5] Fractals are geometric figures produced through the repetition of certain equations with the results plotted on a computer screen.

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