Chaos Theory: An introduction for TESOL practitioners

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'Chaos theory' is a new set of theories from the hard sciences which have many implications for the humanities and social sciences, including the various forms of study of language, in linguistics in general and the field of ESL in particular. This paper offers readers of EAJ a brief introduction to some key concepts from Chaos theory, and illustrates these concepts with issues and materials of interest to workers on aspects of teaching and research in TESOL.

Introduction

Chaos Theory (hereinafter 'CT') is a name for a new development or tendency in science which has many implications for social sciences and the humanities, including the practical study of language which is a main focus for readers of EAJ. My central point is a contentious claim, which I hope to show is plausible and productive: current forms of linguistics and sociology which TESOL practices perforce rest on are all problematic, because they are all formed excessively by the linear, binary logic of traditional science. Language and the social processes surrounding language in use, including the dynamics of language teaching, learning and evaluation, are all to some degree non-linear and chaotic. Yet there are many practices in TESOL teaching and research which have implicitly discovered and used chaos principles. Chaos theory as I will describe it does not come to sweep away the old and replace it with yet another new. Its impact is likely to be less dramatic, but deeper: it connects with many existing practices, and shapes them into new configurations, developing them in new, more powerful directions, with outcomes that at this moment are impossible to predict.

CT now flourishes in science, where it is triggering or expressing a revolution that has already impacted on humanities and social sciences, which previously defined themselves against a 500-year old paradigm of science. The 'social sciences' aimed in one way or another to apply the principles of 'science' to language and social life, and gain some of the prestige of science in the process. 'Humanities' have studied similar matters in a way that is deliberately less 'scientific', therefore seeming an inferior, dubious form of knowledge compared to its 'scientific' counterparts.

CT disrupts this classification, because it is fully scientific—its practitioners win Nobel Prizes—yet radically challenges the core premises of the enterprise-formerly-known-as-Science. It does not deny or renounce the achievements or methods of classical science as Kuhn's (1970) theory implies a revolutionary paradigm should do, but it sees limits in the

scope of that model. It insists that science must tackle the chaos, complexity and interdependence of reality, not seek to reduce everything to a compartmentalized predictable linearity as the definitional form of scientific explanation: to balance rigour with openness, to be content to understand where prediction and control are inherently difficult or impossible.

Paradoxically, this means that the most dogmatically scientistic of the social sciences, including theoretical linguistics, are locked into a now out-moded model of science, and some 'humanist' approaches are, if not yet scientific, at least more compatible with new directions in science. CT drew inspiration from humanistic approaches and is well positioned to return the favour, not discrediting the social sciences (that would be a foolish way to continue a polemic that has been too divisive for too long) but pointing new ways in which all forms can aspire to be more truly 'scientific', so that TESOL practitioners can draw easily on all traditions, in all aspects of their work, whether as teachers, students or researchers.

Concepts from CT

Historically a critical moment in the emergence of CT was Poincaré's work in the 19th century on what was called the 'Three Body Problem' (Poincaré 1963). The 'three body problem' he addressed was the mathematics of the Sun, Earth and Moon, whose relations were almost perfectly described by Newton's equations, in work which was taken as the definitive achievement of his paradigm. Almost, but not quite perfectly described. Mathematicians attempted in vain to find the maths to solve this problem and put the seal on Newton's paradigm. Poincaré proved that the search was in principle vain. Three body systems are never predictable by Newtonian mathematics. They are non-linear and non-deterministic. They can be understood, modeled and explained, but not reduced to a single formula.

Following Poincaré's insights, three body analysis resists the powerful dichotomizing tendency in Western thought, in the humanities as in science, recognizing the normal state of reality as a many-body system, which can conveniently be modeled as a 3 body system, the simplest system that retains the openness and unpredictability of many-bodied reality. Instead of the binaries that are imposed on complex realities it is always possible, and illuminating, to identify other elements that are active in a situation that are simplified out of the picture by binary models (eg teacher and taught, versus teacher-society-taught, or teacher-language-taught: or L1 and L2, versus both L1 and L2 as many-body systems).

Ilya Prigogine, Nobel prize-winner in chemistry often called 'Father of Chaos Theory', provides a useful map, which accommodates and makes sense of different brands of science, linear and non-linear (Prigogine and Stengers 1984). Where phenomena are close to equilibrium, he says, classic linear science works well. Far from equilibrium, near the edge of chaos, linear science breaks down, and new kinds of phenomena appear. Causes no longer form single chains with inevitable effects, precisely predictable by devices such as the parallelogram of forces. Small differences in initial conditions can have huge, unexpected consequences, (the 'Butterfly Effect': see Gleick 1988). Positives can turn into negatives, connections can form across great distances. Yet this chaos, which disrupts the classical drive of science for certainty, has a huge pay-off. Prigogine says that close-to-equilibrium order is limited and static. The patterns that make the universe a fascinating place, home to life, society and language, all emerge in far-from-equilibrium space.

Prigogine's insights are complemented and operationalised for students of language by the work of Lotfi Zadeh on fuzzy logic (see Dimitrov and Hodge 2002). Zadeh, an engineer, proposed a new form of logic which avoided the binary, either-or logics that have dominated western thought since Aristotle, installed in the heart of science. In fuzzy logic, a category can be both A and not-A, in different ways to different degrees. This apparently simple proposal has enormous consequences, tied to the new world opened up by far-from-equilibrium science. Zadeh spelt out the connection in his Principle of Incompatibility:

> As the complexity of a system increases, human ability to make precise and relevant (meaningful) statements about its behaviour diminishes until a threshold is reached beyond which the precision and the relevance become mutually exclusive characteristics. It is then that fuzzy statements become the only bearers of meaning and relevance. (Zadeh 1973, quoted Dimitrov and Hodge 2002:20)

It is important to recognize that Zadeh is an engineer, not an artist. His principle (similar in form and basis to Heisenberg's more famous Uncertainty principle) is a rigorous law stating that the further from equilibrium, the more the scientific drive for precision will necessarily break down, in one of two ways, becoming either meaningless, or irrelevant.

There is a salutary lesson here for theoretical linguistics, especially in its most rigorous forms, such as Chomskyan linguistics, and sociological research on language and teaching, especially in its more rigorous forms, where hypotheses are made as precise as possible, tested out on carefully controlled data. If it is the case, as I argue, that language and social life are inherently 'chaotic' and non-linear, then linear linguistics will only be able to describe instances where there is a low level of complexity and dynamism, and linear modes of research will only be able to speak with the requisite precision about simple instances. But the world of second-language users and the contexts and class-rooms they must live and thrive or suffer in are inherently chaotic, and applications to this world from linguistics or classic social research will not only be merely approximate, as all class room practitioners recognize. They will be meaningless, or irrelevant.

Instead, linguistics and research methods for TESOL must incorporate the principles of CT, including Fuzziology. To describe how this can be done is a large topic. I will illustrate with one aspect of language in use that occupies much attention for TESOL teachers: the problems of explaining the common items of grammar of English, as of other languages. In his seminal Syntactic Structures Chomsky (1957) tried to connect semantics with syntax, and concluded that although intuitively there was obviously some connection, it could not be adequately formalized (in the highly linear terms he proposed for his grammar) so he reluctantly separated semantics from syntax. In 50 years since then, linguistics has tried without success to put the two back together. And meanwhile back in the classroom, teachers try to make the seemingly arbitrary forms of English seem rational and meaningful to second language learners, aware that most of what is contained in grammars is unhelpful: meaningless or irrelevant, as Zadeh would predict.

I propose that all grammatical items, which are the most common in the language and whose distribution follows Zipf's law (Zipf 1949) should be understood as meaningful, but always to some degree fuzzy in the way they mean. Words like 'the', 'it' or morphemes like –s or –ed should not be supposed to have a single crisp meaning, but a set of disparate, shifting

meanings. The rules which explain how they behave must be based on these fuzzy (inconsistent, sometimes contradictory) meanings, matching chaotic conditions of use, not any ideal model predicated on close-to-equilibrium conditions which do not exist across the range of language and behaviour.

As Prigogine says, CT does not mean the end of order and pattern but the contrary, the possibility of new, richer and more complex patterns and orders. Mandelbrot's (1982) theory of fractals is a case in point. Fractals are an order that forms in chaos: irregular, non-Euclidean shapes that are self-similar across different scales, often produced by repeated applications of a simple formula whose results are not identical. The similar pattern of leaves, small and large branches, trunks and roots is one example of fractality.

Jakobson's classic discovery of the structure of phonological systems in language is another, yet to be fully explored in terms of CT (see Hodge 1991). The branching structure of a phonological system, understood as a fractal, accounts for the relationship of similarity yet never identity between the many different language systems throughout the world, which all start from minutely different starting points ('butterfly effect') and never converge into identity. The power of fractal analysis is that it can see the same principle producing analogous (but never identical) phenomena at lower scales, of dialect, accent, idiolect, expressive registers, allowing a language teacher to lead a learner in an endless but meaningful journey up and down the scale of the target language, never lapsing into a simple identity between L1 and L2, or any other language on the globe. Chomsky's tree-diagrams of phrase structure grammars also have the tell-tale sign of fractality, with the same qualities, to make it teachable yet not reductive.

Researching TESOL

As a short cut to grounding these ideas in TESOL related issues, I will use articles in EAJ 20:1 as point of departure. The 5 articles in this issue can be categorized as linear (Bitchener, Puleo and Hird), non-linear (Zeegers, Walker) and humanist (Davies). All are solid articles of their kind, and the diversity of approaches signifies to me a healthy state, in the field and journal, where apparent contradictions co-exist. When I talk about CT I am often understood to be declaring war on all linear thinking, but that is not the case at all. On the contrary, I seek far-from-equilibrium conditions in which contradictions co-exist, within the space of area (like TESOL) a journal (EAJ 20:1) and even an individual and a project. To try to exclude linear thinking in the name of non-linearity is to be caught with Zadeh's Principle: condemned to irrelevance or lack of meaning. The rewards, as Prigogine points out, are to be able to see new patterns and connections across a divided space (in the case of EAJ 20:2, separated into articles, and orientations) which may be surprising, not predicted by the authors of the works, and more powerful and open than the specific conclusions of the separate authors.

As one instance: Davies reflects philosophically on the 'Whorfian hypothesis' in relation to language programs that teach thinking across languages and cultures. This connects with the 2 'linear' articles, both concerned with Asian learners of English and the effects of cultural differences on their learning. For many readers of EAJ Davies' article may seem insufficiently grounded in their experience, yet the issues he raises can bring out into the open some assumptions that Bitchener and Puleo and Hird do not find time to discuss. Different readers may make different uses of issues raised by each article. It may not be the stated aim

of the article that triggers new thinking in such readers: according to the Butterfly Effect principle, it may be a sentence or implication that had not been central for the writers, and what readers do with it may be different in each case. Yet this effect is not without its causes. EAJ's editorial policy has the effect of folding disciplinary divisions into a common space, creating far-from-equilibrium conditions in which such multiple and unintended connections may take place.

Both Zeegers and Walker advocate the use of focus groups in research, emphasizing that this method can produce surprising new insights: a sign of non-linearity in their design. For both, this method has its origins in business (not in CT), drawing on experience as administrators as well as teachers of TESOL, which leads them to introduce that dimension as a third body in their understanding of TESOL as an enterprise (instead of the more usual linear focus on pedagogy and language). Walker is conscious of this, drawing a 3-body model to describe what he is doing (p 46). His notion of milieu (the institutional context of TESOL) is a product both of 3 body analysis, and fractal thinking. It is the next level up from the class room.

In pointing out that CT is already implicit, to some extent, in current research I may seem to shoot myself in the foot. How could CT be a revolution, as I claim, if it is already being done? Yet this is the paradox of all revolutions, which must fuzzily both exist and not yet exist throughout their most generative epoch. Innumerable growth points must prepare the way, or the revolution will not be comprehensible or practical, yet the new configurations and developments may still be new, powerful and unexpected.

I have described the other two papers as primarily linear, yet again there is more to be said. Non-linearity is present in the way problems are framed and hypotheses generated, before a rigorous linearity is applied: definite research questions, with quantifiable or yes/no answers, directed at a managed body of data and binary categories to use in analysis. In terms of Zadeh's principle, there is a danger that the linear research instrument will not be able to contribute meaningful or relevant statements about the situation. In practice there is a strong tendency for linear research to construct a parallel linear world as source of data and object of research, depriving the conclusions of much of their meaning or relevance. This is to some degree the case with both Bitchener and Puleo and Hird. Bitchener is concerned with interaction across different ethnicities, so he constructs the discourse he analyses. Sets of mono-ethnic dyads (Japanese or Korean) and sets of cross-ethnic dyads speak for 10 minutes on two tasks (decision making, free conversation). The result is a standardized data set which he can describe precisely, at the cost of its resemblance to a real world that is not divided into such neat packages.

Yet though Bitchener is marginally more linear in his research design than Puleo and Hird, in other aspects he breaks more extensively out of his linear frame, partly because he includes so many factors that it quickly becomes too complex for him (or his readers, perhaps) to notice that he has wandered into chaos. He includes Japanese and Korean speakers, with English language making up the third body, though he does not present it in those terms. Puleo and Hird limit themselves to Japanese speakers at a specified and controlled level of understanding of English. Bitchener asks two research questions, (about effects of ethnicity on whether Korean and Japanese learners respond to communication difficulties with modified feedback, whether this ethnicity affects how they respond to this feedback), but much of his article explores a different issue: whether mono-ethnic dyads (whether Japanese or Korean) do so more than interethnic dyads. He concludes that they do. This is not less

interesting a conclusion for the fact that he did not know, or state, in the beginning that he was going to ask it. That is, he is able to produce unexpected knowledge with a linear research method by being inconsistent (non-linear) in his method. He would be a less interesting researcher if he were as rigorously linear as he seems to wish. This paradox has as many positive as negative implications for researchers in linear paradigms.

Nor is his data as uninteresting as he tries to make it. The tasks he sets may be artificial, more closely related to ESL class rooms than the real world, but the speakers are still real, and so is the text they produce: 8 hours of audiotape, all carefully transcribed. Bitchener makes the text amenable to quantitative analysis by coding it for sequences of trigger utterances (causing problems for the hearer) and feedback, either as modification or repetition. What this is doing is potentially very interesting: he is using fuzzy terms for syntactic analysis of stretches of discourse across dialogue. In terms of the tradition he uses, those categories are meant to be crisply defined, so that other researchers (though not speakers in the situation) can give them a single, repeatable meaning. The terms can then be reliably counted and processed through statistics, as he has done. However, fuzzy categories can be processed through statistics as well, though with more difficulty. CT is not at all hostile to quantitative thinking—if Poetry is its mother, its father is Maths. The point is for the generalizations to be more meaningful and relevant, not unquantified. Fuzzy descriptors would allow the numbers to correspond better to decisions language users ongoingly make in the course of interactions. That is the point of the study.

By another paradox, Bitchener is describing syntax without realizing it is syntax, and moreover using terms which come from natural (fuzzy) language and could as easily remain connected to it. He is thus able to discover and describe structures which are not named by theoretical linguistics, whose terms all aspire to maximum crispness and do not easily apply to the complexities of language in use. Although I have described his work as linear, linearity is a matter of degree. Bitchener is, in some aspects and to some degree, less linear than theoretical linguistics: that is, he is fuzzily non-linear (and linear), fuzzily a linguist (and not a linguist). Because of this contradiction his work has more potential, not less, though that potential will be reduced insofar as he tries to increase rigour, and remove contradictions.

Conclusion

CT as sketched in this paper is many things, some still in process, not a single theory to accept or reject. As a mindset, it recognizes that the world that needs to be explained is irreducibly complex, unpredictable and chaotic, and is only getting more so. The same is true of the dynamic multicultural world outside the ESL classroom, throwing ever more complex challenges to students, teachers and researchers alike. CT does not reject linear analyses, if they work. On the contrary, it seeks to give them a rationale and place, alongside and interacting with a richer set of practices based in different ways on non-linear proposals. But CT needs to be introduced to the TESOL world in non-linear ways. It cannot be the faithful application of concepts developed elsewhere to TESOL practice. Those concepts need to be exposed to problems and insights of TESOL practitioners, as a unique site of complexity and chaos, with its own unpredictable potential contribution to the evolution and spread of CT.

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