

# **Researching Complex Dynamic Systems: Retrodictive Qualitative Modelling to Understand Motivation in the Japanese EFL Classroom**

Hamish GILLIES

## **Abstract**

While the application of concepts from both complexity theory and dynamic system theory to the social sciences is becoming increasingly attractive in principle, attempts to achieve this in practice have mainly reached an impasse. In this vein, the current paper seeks to first justify their application to the social sciences, and in particular the area of language learning motivation. While the paper acknowledges the potential difficulties of such an approach, it proceeds to respond to these by proposing a technique entitled Retrodictive Qualitative System Modelling, providing a detailed outline of the application of the five phases of this technique. The paper concludes with a recognition of the need to validate this technique by applying it to an actual research context.

## **Introduction**

'Complexity is an idea whose time has come.' (Byrne, 2005: 98)

The study of complex dynamic systems is most definitely 'in fashion' across the disciplines. As Byrne (2005: 97) points out, 'There are complexity institutes, complexity journals, complexity popular science books, complexity management, complexity art', all seeking to either explain how complex dynamic systems underlie every aspect of the universe, both animate and inanimate, or exploit its potential. Indeed, we are seeing the increasing application of our understanding of complex dynamic systems to further technological development, for example in medicine and engineering, and even the internet (Strogatz, 2003).

The application of the overlapping theories of Complexity and Dynamic Systems is a relatively recent direction in SLA research and is designed to account for the complex and dynamic nature of situated behaviour over time (Dornyei, 2009; De Bot et al, 2007). To provide a brief history of these theories, Complexity Theory (CT) can be seen as

emerging from the field of biology, while Dynamic Systems Theory (DST) has its origins in the study of mathematics and physics (Larsen-Freeman & Cameron, 2008: 2-3). While Newton, in the 1600s, is famous for his study of dynamics and his three laws of motion, it was not until Poincare, in the latter years of the 19th Century, that the seeds of the modern subject of dynamics were sewn; Poincare introduced a qualitative, geometric approach to the understanding dynamic systems. After that, the next major leap came with the invention of the computer, which enabled nonlinear equations to be put through thousands and thousands of iterations at one time. This technological advancement allowed the mathematician Lorenz, in the early 1960s, to break open the field of Chaos Theory by understanding chaotic attractor states and the importance of initial conditions (Strogatz, 1994).

Since Lorenz, both theories have been progressively applied to, and at the same time developed in, a range of disciplines and fields, including within the social sciences: for example, in psychology, Lewis (e.g. Lewis, 2005) has applied DST to the study of emotions; Spivey & Dale (2004) have likewise looked at the dynamics of cognition. In education, Thelen & Smith (1994, 1998) have pioneered the application of DST to the understanding of child development. More recently, DST has entered applied linguistics research: for example, as well as Larsen-Freeman & Cameron's (2008) comprehensive text on how CT could advance the study of SLA, a special issue of the *Applied Linguistics* journal (volume 27, no. 4, 2006) was devoted to a discussion of the implications of Emergence, a feature of CT, for the study of SLA.

While CT emphasises the interconnectedness of systems, DST focuses on how systems change over time, such changes being neither completely predictable nor completely random (De Bot, 2008; Larsen-Freeman & Cameron, 2008). Put simply, DST is Complexity Theory viewed from a perspective which emphasises the dynamic aspects of that complexity. For our purposes, I will refer to the overall combination of these two theories as Complex Dynamic Systems Theory (CDST).

## **Researchability of a Complex Dynamic System Theory (CDST) framework**

### **Relevance of CDST to social sciences**

There are various reasons why a CDST framework can be extremely usefully applied to the realm of social sciences, especially the area of learning and education. First of all, social contexts can easily be recognised as complex systems, containing sub-systems and contained within super-systems; and these systems are governed by lots of interrelated factors. Take a classroom for example: it contains students and teachers, while itself being contained within a department and a school; what happens in the

classroom is governed by a wide range of different factors including the attitudes and behaviour of the teacher and the students, the nature of the learning materials being used, the policies of the school, the facilities in the room, the time of day, and even the state of the weather outside the building. These factors also influence *each other* : a prime example is the relationship between the teacher and the students. This brings us to the second reason why CDST is applicable: there is constant development in social contexts; in other words, as well as being complex, they are always in a dynamic process of change, and over different time-scales. To return to the educational context, the aforementioned teacher-student relationship is one in which each agent continuously acts and reacts in relation to the other. And this development can happen at the scale of task completion - for instance, the teacher sets up a task, but the students find it too difficult, so the teacher then pauses the task in order to explain it more clearly, etc. - or more broadly at the scale of semester - for instance, the students' test performance over the semester causes the teacher to incorporate more review lessons at the end of the semester, and the students achieve better end of semester test scores.

Human society and behaviour, then, is a complex dynamic system by every definition of the term. Indeed, the lack of convincing results shows that simple paradigms cannot do justice to the reality of the situation. This is amply illustrated by the recent history of research into language learning motivation, which can be represented by four distinct periods: the *social psychological* period, the *cognitive-situated* period, the *process-oriented* period. As the labels suggest, each period has attempted to grapple with the complex dynamic nature of language learning motivation by recognising different aspects of it, rather like the well-known Indian fable of the group of blind men who each touch a different part of the elephant, each claiming to have discovered the elephant. However, each attempt has ultimately failed to fully capture both its complex and its dynamic aspects. The *social psychological* period, mainly driven by the work of Gardner and his Canadian colleagues, established the influential concepts of integrative and instrumental motivation. However, it eventually came under criticism from other researchers in the early 1990s for ignoring the contextual realities of the language classroom, especially in non-Canadian, EFL settings. Crookes & Schmidt's (1991) article, which turned out to be the most ground-shifting critique of Gardner et al.'s theories, led the way to a more *education-friendly* (Dörnyei, 2001) approach to language learning motivation research, and marked the inception of the *cognitive-situated* period. The various conceptual frameworks which appeared during the *cognitive-situated* period (cf. Dörnyei, 1994; Tremblay & Gardner, 1995; Williams & Burden, 1997) recognised the influence of environmental factors (e.g. the learning situation), but lacked any temporal dimension. As Dörnyei himself observed of his own framework: it 'lacks an indication of any

relationships between the components and hence cannot be seen as a motivation model proper' (Dörnyei, 1998: 126). Recognition of the need to take the dimension of time into account led Dörnyei, and later Dörnyei & Ottó, to devise a process-oriented model complete with pre-actional, actional, and post-actional phases aiming to show the development of motivated behaviour over a period of time (Dörnyei 2000, 2001; Dörnyei and Ottó, 1998). While acknowledging their model was 'a good starting point in understanding motivational evolution' (Dörnyei, 2005: 86), Dörnyei has also admitted that, because it views the action process (in this context a learning process) as a discrete event, ignores its embeddedness within a wider personal agenda, and essentially presents a linear view of causality, 'the process model of L2 motivation cannot do justice to the dynamic and situated complexity of the learning process or the multiple goals and agendas shaping learner behaviour' (Dörnyei, in press: 79-80). It is against this background, or rather a perhaps inevitable development of this dynamic history of language learning motivation research, that CDST can offer a framework which is able to handle the complex and dynamic reality of motivated behaviour.

#### **Recognised difficulties of researching complex dynamic systems**

However, while researchers in the social sciences can accept this applicability in principle, they reach an impasse when it comes to putting into practice. Due to the multiple interrelated influences, the almost indefinite number of determinants of a system, and the non-linear relationships between components of a system, no one has managed to achieve empirical data on complex dynamic systems in the social sciences. Indeed, in the field of applied linguistics, virtually every scholar who has tried to adopt a CDST approach (e.g. Larsen-Freeman & Cameron, 2008; Ellis, 2007; De Bot, 2008) has admitted failure. In other words, they have acknowledged that CDST offers the best way forward in research design, but are unable to take the next step and apply the theory. Larsen-Freeman & Cameron (2008), for example, admit that adapting to a CDST approach has been problematic for them as it is 'easy to fall back into old ways of thinking, and requires continual monitoring to ensure that ways of talking (or writing) reflect complex dynamic ways of thinking' (2008: x). De Bot et al. (2007) have even made the claim that it is simply impossible to research complex dynamic systems: 'it is a matter of fact that it is very difficult to get a grip on complex interactions' (2007: 18). In fact, this claim holds true if we consider using quantitative statistical research tools, because such tools can only handle linear relationships, which are only a partial constituent of complex dynamic systems. And as we noted earlier, human behaviour consists of both linear and non-linear relationships. As yet, no computer program is capable of simulating the human agent, embedded in a wider human society. So where do we go from here? Can qualitative tools offer a way into a broader CDST approach?

### The reality of given situations

I believe a way forward lies in the recognition that even though the world around us is complex and dynamic, we know from everyday experience that there is a significant amount of predictability in people's behaviour. Underlying this predictability is the overriding influence of certain powerful attractors which act to mitigate against the multiple random influences on a given system and guide its trajectory even if temporarily. Some systems are actually governed by a relatively small number of attractor states and so we can observe predictable behaviour in these systems. To take an extreme example of a powerful attractor state, if a gun-wielding maniac were to enter a crowded room, we can safely predict that 99% of the people in the room would soon be on their stomachs, at least for a while. Even in more mundane situations, for example the language learning classroom in a given country, the behaviour of students tends to follow regular patterns; for example, research shows that silence is a key attractor state in the Japanese university language classroom (King, unpublished PhD thesis). Therefore, the key question in any research setting is whether the system of interest is governed by powerful attractor states, and, especially in the case of a learner, what kind of complex conglomerate makes up the attractor.

Having discovered the good news that powerful attractors do actually exist in everyday life, we need not look much further to discover a second piece of good news. The curious fact is that when we consider various dynamic situations of diverse sorts, we almost always find a relatively small number of well-recognizable archetypes of phenomena, and these are usually even generalisable. For example, if we look at the language classroom, we will soon recognize three or four types of language learning outcomes: e.g. the outgoing, talkative type of student who is very confident but makes mistakes; or the shy, studious type of student who performs well on written, grammar-based tests but lacks confidence in oral communication. Even in personality psychology, which concerns the ultimate variety of human nature, established tests such as the Myers-Briggs Type Indicator (Myers-Briggs, 1976) show that a surprisingly great deal of variation can be captured by a surprisingly small number of types. Indeed, Plato's theory of forms, as well as the ancient Middle-Eastern Enneagram (Ouspensky, 1949), are evidence that the idea of a limited number of archetypes has been around for thousands of years. While I do not claim to know the reason for this phenomenon, nor have I found any explanation in the research literature, a CDST approach suggests that the self-organization of dynamic situations produces a limited number of different outcomes which can only happen if the self-organization is dominated by some key attractor influences. These outcomes are permutations of those attractors and they override many other potential variants. This does not mean that there are no variants. If we look beyond these major types we do find many exceptions and grey areas, yet the salience of these major types is surprising and again offers a promising way forward for the researcher.

Were these two insights not enough to convince us of the researchability of complex dynamic systems, there is one final piece of good news: when we talk about attractor states, these usually involve powerful conglomerations of components which seem to be recognizable by the man on the Clapham omnibus, such is their salience. That is, the fact that our focus is on the most important factors which override the myriad of other potentially influencing factors can be utilized in the sense that these are recognized by the agents themselves. In practical terms, as Dörnyei & Ushioda (in press: 109) point out, this means we can rely on qualitative self-report tools, to obtain a sufficiently detailed picture of the situation and the salient factors or components underlying it, so that it is very unlikely that a component is there but it has not come up in the interviews. Nor do we have to worry about potentially subconscious or elusive factors because if those are elusive then they are unlikely to be able to exert the kind of overriding power which is necessary to produce an attractor state. An attractor state is a very salient state which people are aware of because the system behaviour shows such remarkable consistency. Evidence of this is how non-specialists fully understand concepts such as 'interest' and 'vision', and are able to describe how they were 'in the zone', for example, whilst engaging in an activity.

The above observations and considerations lead to a possible way of achieving what seemed impossible up to now, that is, researching complex dynamic systems: by first trying to identify some salient attractor states of the system, and if there are some, that is, if the system behaviour is to some extent predictable, then identify the various outcome options, that is, typical attractor states, and then work backwards, i.e. retrodictively to apply Byrne's (2002) coinage of the term, to investigate what leads to these states.

'What [Gould (1991: 283)] describes is a process of interpretation of the past so as to construct a model of development towards the present in which the actual form of that development is often the product of contingent factors at key points of transition/transformation...Gould's approach might be called *retrodition* (emphasis added) – the explanation of what has happened by the use of models that fit the data.' (Byrne, 2002: 25)

Let us look at this process in more detail now.

## Towards retrodictive qualitative system modelling

### Quantitative and qualitative modelling

Recognising the fact that complex dynamic systems are constantly changing, for example via feedback loops, co-adaptation and self-organization, we need a research tool which can accommodate such dynamism. Modelling is the main tool which has been applied to complex dynamic systems to do them justice because it can illustrate movement and change; in fact there is simply no alternative. To quote Van Gelder & Port (1995: 15): 'Precise, quantitative modelling of some aspect of cognitive performance is always the ultimate goal of dynamical theorizing in cognitive science'. In natural scientific research, complex quantitative dynamic models have been created using computer programs to investigate such areas as meteorology and population change, or to understand how people react in given situations such as when evacuating a building. Indeed even in cinematic science, such computer-driven models have been created to bring to life realistic CG scenes of crowds of characters in motion (for example, the battle scenes in 'Lord of the Rings'). In the social sciences, however, there has been a certain wariness of the applicability of quantitative modelling because of the need for absolute precision, which cannot yet be achieved in the study of human behaviour, as Van Gelder & Port (1995) explain:

'Human cognitive performance is extraordinarily diverse, subtle, complex, and interactive. Every human behaves in a somewhat different way, and is embedded in a rich, constantly changing environment. For these kinds of reasons (among others), science has been slow in coming to be able to apply to cognition the kinds of explanatory techniques that have worked so successfully elsewhere. Even now, only a relatively small number of cognitive phenomena have been demonstrated to be amenable to precise, quantitative dynamical modeling. Fortunately, however, there are other ways in which dynamics can be used to shed light on cognitive phenomena.' (Van Gelder & Port, 1995: 16)

Therefore, proponents of the CDST approach, especially Larsen-Freeman & Cameron, have been arguing that the main focus should be on creating qualitative models of human behaviour. 'In qualitative modelling, a complex dynamic model is used as an analogical model for the system under investigation' (Larsen-Freeman & Cameron, 2008: 40). The most developed proposal of a strategy for creating a model has in fact been Larsen-Freeman & Cameron's (2008) *complexity thought modeling*:

- Identify the different components of the system, including agents, processes, and subsystems.

- For each component, identify the timescales and levels of social and human organization on which it operates.
- Describe the relations between and among components.
- Describe how the system and context adapt to each other.
- Describe the dynamics of the system:
- How do the components change over time?
- How do the relations among components change over time?
- Describe the kinds of change that can be observed in the system: steady change or discontinuous leaps from one state or mode of action, to another in phase shifts or bifurcations.
- Identify the contextual factors that are working as part of the system.
- Identify processes of co-adaptation with other systems.
- Identify candidate control parameters, i.e. the motors of change that seem to lead to phase shifts.
- Identify candidate collective variables that can be used to describe the system, before and after phase shifts.
- Identify possible fractals in the system.
- Describe the state space landscape of the system:
- Where are the attractor states in the state space (i.e. stabilities in the changing system)?
- How deep and steep are they? (i.e. How stable are the attractor states?)
- Describe the trajectory of the system in its state space. (i.e. What are common patterns of activity?)
- Identify regions of the state space that are most used by the system, and those which are seldom visited. (i.e. What does the system do out of all it could possibly do?)
- Describe what happens around attractors. (i.e. What kind of variability is there around stabilities?)
- Identify possible emergence and/or self-organization across timescales and/or levels of human organization.

(2008: 70-1)

Such models can at least provide a sufficiently dynamic representation of a complex dynamic system. My approach draws on Larsen-Freeman & Cameron's ideas, but adds a further twist in the light of the discussions above, resulting in a retrodictive model.

#### Creating a retrodictive qualitative model

- Phase 1: Establishing the units of analysis

In the social world, everything is dynamic, and embedded – a never-ending progression of nested and interconnected dynamic systems. To take the example of a school,

first there are the staff systems: for example subject departments, levels of seniority, full-timers and part-timers, assigned classrooms. Then there are the student systems: for example year groupings, class memberships, family backgrounds, clique memberships. And amidst this nesting of systems, we can observe how the individual student is connected to all the other systems in the school; indeed, not simply connected but both sensitive and responsive to all the other systems, whether it be the teachers, the classrooms, the subjects, even the school budget system.

Bearing in mind this interrelatedness and nesting feature of complex dynamic systems, the first step of a CDST approach is to choose the most appropriate level of abstraction and the relevant units of analysis. This would help to do our research due justice. Therefore we must decide exactly what the purpose of our research is, answering such questions as ‘What exactly is it that we are interested in?’ and ‘What is interesting about the research situation?’; and then ‘What are we hoping to do with the research findings?’ and ‘To who is the research designed to be of benefit?’. The answers to some of these questions, especially what we are interested in, may change as we discover what is salient within the research setting.

- **Phase 2: Establishing the salient attractor states**

Next, we need to ascertain whether the target system shows any obvious patterns (i.e. is governed by an attractor state), and then proceed to identify, using a range of possible external sources of evidence, the most salient behavioural archetypes. Observation alone is not sufficient to capture such contextually embedded processes; rather one needs to draw upon the implicit knowledge of people who have spent a long time in the system. For example, in the system of a school one might ask teachers or students via interviews or focus group discussions. In this way we can identify the system behaviour outcomes.

- **Phase 3: Anchoring the qualitative system model**

Having established the outcomes, we can use them to anchor our model; to borrow the metaphor of completing a maze, it is always easier to find one’s way out of the maze from the centre than to find one’s way in. From a qualitative modelling perspective, this would mean that we actually have some fixed model outcomes, and therefore something to build on.

- **Phase 4: Establishing the salient system components**

Having established some firm outcome points in our qualitative model, we actually have one more source of potential information for the model, and this is the range of constituent components. As we argued earlier, salient attractors are perceivable for participants, therefore if we conduct a well-designed series of in-depth interviews

within the research context, and then analyse the data appropriately, we can elicit all the important details. It is simply inconceivable that there is a powerful attractor there which was not mentioned by any of our participants. That means that we can actually list a relatively finite set of components that might play an active role in the system. However, at this stage the model still lacks dynamism: it does not tell us about processes.

• **Phase 5: Establishing the signature dynamics of each system**

If indeed the established outcome pattern signifies distinct operational modes of the larger system, then a closer inspection of examples of each outcome pattern will inevitably show some robust distinction from a qualitative system modelling perspective. Therefore, by means of further analysis of the interview data, and further interviewing if necessary, the next step is to identify the signature dynamics of the model: the kind of patterns which led the components to one particular outcome as opposed to the other outcomes. From a qualitative system modelling perspective, the key issue is identifying different movement or change patterns, which I am going to call signature dynamics, amongst the already identified components, and leading to the already identified outcomes. From the perspective of the whole research project, it is these signature dynamics which will be seen as the main results of the study, as they on the one hand fully capture the dynamic character of the system, and yet offer on the other hand observations which go beyond the specific situations; that is, they are generalisable to some extent. An example of a signature dynamic within the classroom context, and one easily recognizable by a teacher, might be the following downward spiral: a student gets a bad score in a test > She loses self-worth > Her motivation decreases > She studies less before the next test > She gets a worse score in the next test – and so the spiral continues.

**Research implications**

**Validating Retrodictive Qualitative System Modelling within an actual language classroom context**

The next step, then, is to validate this technique by applying it to a specific research context. Once validated, it is hoped that the data obtained from such modelling can benefit the learning experiences of less successful and motivated students. In terms of CDST, this would involve an intervention into the learning situation (i.e. the classroom) which would attempt to restructure the learning landscape and move the learner system from its current detrimental attractor state into a more productive and more motivated attractor state. For this to happen, it would require the cooperation of not only the students but also the teachers, as prime agents in the situation. In addition,

such research could be extended by investigating the range of attractor states that govern the teachers as complex dynamic systems. This would richly complement and further illuminate the data regarding the students.

**Applying this research model to other contexts where we can recognise a limited set of archetypes/attractor states (e.g. learning outcomes)**

Finally, having devised and successfully implemented a research design based on CDST, it is proposed that the design could be employed in any field where the number of attractor states governing system behaviour outcomes is relatively small and identifiable.

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