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Language as a Dynamical System: Sensitive Dependence on Error Conditions

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This paper considers second language (L2) as a separate and qualitatively different system from first language (L1). Dynamical systems theory is used to develop the notion of interlanguage in support of this proposition. L2 is contrasted with L1, which, in adults, is posited as a largely deterministic or stable-state form of language in that it is used in more regular and predictable ways. L2, by contrast, is used with a relatively high degree of unpredictability. Results of PET and fMRI scans are also offered, tentatively, to support consideration of L1 and L2 as discrete

systems. A practical consequence of considering L2 as a nonlinear dynamical system involves exploration, rather than simple correction, of learner errors. This entails the broader goal of identifying individual/group “attractors” in language usage and sensitising L2 curricula to students’ interlanguage profile.

第二言語の性質およびその習得過程に注目し、カオス、複雑系、あるいはシステム理論等のコンセプトを引用しながら、GassとSelinkerが提唱する“interlanguage”に関する研究の発展を目的としている。第二言語は動的システムとして認識され、成人対象の場合、決定的あるいは安定的な言語と認識される第一言語とは対照的である。また、PETとfMRIの結果は、暫定的に、第一言語と第二言語が個別の独立したシステムであるという認識を後押しする。この第二言語の認識に基づき、より広い意味での間違い訂正が授業活動に取り入れられることを薦める。間違い訂正は、これまで一般的な、誤りの指摘、正解の伝達とその理解という流れから、教師と生徒がダブルラーニングに沿って「なぜ間違えたのか?」という疑問を幅広く探索することにより、より効果的な指導法に変わる。性質が将来、いかに実証的に検証されるかという点について提案をする。

Sensitive dependence on initial conditions: The butterfly effect

“Traditionally, when physicists saw complex results, they looked for complex causes”, until a few realized that quite “simple mathematical equations could model complex systems”, and that tiny differences in input could have dramatic differences in output (Gleick, 1987, p. 8). This now

almost legendary realization has come to be known as “sensitive dependence on initial conditions” and has been dubbed, only half-jokingly, *the butterfly effect* (Gleick, 1987). This insight can be mapped metaphorically on to one of the key concerns in second language acquisition (2LA) concerning the way educators can sensitise input target language (TL) to enhance learners’ output language.

In the past fifteen years or so, complexity science and chaos theory have filtered through in various ways from mathematics, physics, meteorology, population studies, and biology to more social, philosophical, and psychological human endeavours. The most notable successes have been in information and communications theory, organisational learning, change management, and professional development, where they have served to balance an important tension between the holism of general systems theory and the reductionism of Newtonian science (Karseras, 2000; Phelan, 2001). These so-called new sciences emerged in an environment that supported experiments with new educational philosophies. I would like to suggest that the field of second language acquisition also stands to benefit from integrating some of these still emerging concepts and perspectives into its epistemology. Phenomena that interest new scientists are emergent, self-organizing, relational, adaptive, and characterised by *strange* and *periodic attractors*. Such attractors, I will argue, are also characteristic of second language (L2).

Language as a system

Language has been characterised as a system at least since Ferdinand de Saussure (1966) published his seminal *Course in General Linguistics*. Saussure talked of the way words generate meaning, suggesting that, “concepts are surely differential and

defined not by their positive content but negatively by their relations with the other terms of the system” (p. 117). The continuity between his relational, systemic view of the way meaning is made through language and new science’s emphasis on the interconnectedness of a system can be sensed here. Moreover, as Gordon Globus (1995) points out, “We are used to thinking that words *have* their own meaning, so Saussure’s claim that meaning is embedded in a system of relationships is disruptive” (p. 53). In other words, Saussure broke the tradition of isolating and defining discrete parts and instead demonstrated the holistic operation of language as a system of meaning-making. This rupture is comparable to the shift from linear to nonlinear scientific inquiry (Horgan, 1997; Kosko, 1994; Wolpert, 1993). Saussure disrupted certain foundational assumptions that existed in linguistics prior to his exposition.

L1 as a stable-state system

Linguistic science has also sought to extrapolate grammatical structures and rules that govern what might be legally said. Although languages are subject to diachronic change, over an individual’s lifetime, L1 grammar is characterized by certain internal regularities in the way it is used. The science of linguistics can be said to exist as a result of the predictable nature of native adult language. After the rapid change during the language development of childhood, native language stabilizes. There are no dramatic changes in its use during the adult life of a native speaker.

L1 is a hugely complex phenomenon. The relational character of semantics referred to above, combined with sociopragmatics of usage, has meant that even with the computational power developed in the last few decades, we are still not able to

model it adequately. That said, the nature of L1 can be seen to be equivalent with the nature of the phenomenon which has interested traditional scientific inquiry. In the sense that it is predictable, rule-governed, and not subject to change, L1 can be understood as a stable-state or *deterministic* system.

L2 as a nonlinear dynamical system

Second language (L2) as spoken by learners who are still developing language skills, including non-fluent bilinguals, is far from stable. Learners lack internal consistency in the way they use the L2. Of course many errors are due to the fact that learning is *in progress*. The students are not yet accomplished. They are still *making mistakes*; still climbing the learning curve. Memory retention could perhaps be figured as a function of exposure combined with opportunities for use. Something similar could equally be said of anything that can be learned. This is not at issue. Many of the inter-relating factors involved in *error* production in L2 speakers do link directly to the learning process. However, the curious thing about L2 learning, as will be discussed below, is that it occupies a distinctly different location in the brain as compared to L1.

The question raised in this paper is whether there are other factors that have traditionally been considered as errors or deviations from the target language (TL) that stem from the distinctive nature of L2 as a dynamical system. The suggestion is that L2 has different system characteristics from L1, and these characteristics are reminiscent of emerging, self-organising phenomenon. The characteristics of dynamical systems will also be discussed further below. For now, we might speculate that the kinds of conscious and subconscious processes; the metacognitive and cognitive skills associated

with formal learning and acquisition (Krashen, 1981) might be significant in shaping the differences in the underlying characteristics of these two postulated language systems. The main point is that the more accurately we are able to model an L2 system, the closer we can expect to come to understanding it and to finding activities that are better suited to the way the L2 part of the brain is actually programmed (Pinker, 1994).

The functional organisation of L1/L2 in the brain

Neurolinguistic studies that provide evidence of two separate storage areas in the brain for L1 and L2 lend support to the argument that L2 is a different kind of language system (Abdulla, 1999; Chee, Soon & Lee, 2003; Chee, Hon, Lee & Soon, 2001; Chee et al., 2000; Frost, 2003; Rodriguez-Fornells et al., 2002). If L2 were directly equivalent to L1, it could be argued that there would be less need for the brain to route processing differently.

Although not conclusive, a range of positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) studies point to age of acquisition as a determinant of the functional organisation of languages in the brain (Cook, 2000). Typically these studies show that if a second language was acquired after a certain childhood age, the operational functionality of the two languages occurs in totally separate regions of the cortex, supporting a *two-store* model. If both languages were acquired prior to the age threshold, functionality of both languages appears in the same location. In the latter case, for the purposes of this paper, the languages would more properly be considered L1a and L1b, with no priority given to one over the other either in terms of linguistic or sociopragmatic competence; whereas, in the two-store case,

the languages could clearly be identified as L1 and L2 to any speaker fluent in either of the languages in question.

More recent studies suggest that functional location is dependent on a degree of bilingual proficiency, which in turn may or may not be linked to age of acquisition. Thus less fluent speakers have two functional locations, whereas the *one-store* model applies for fluent bilingual speakers. However, in the last couple of years there has been some suggestion that even if evidence shows the same location for fluent bilinguals, there may be separate neuronal networks in use for at least some part of the language processes for the respective languages (Chee et al., 2000). This will be referred to here as the *split-store* model.

The important issue for the purposes of this paper is not so much the location of language function, as the underlying *system* in use to process and produce language. In the case of the split-store and one-store models, the language systems would still be considered L1 stable-state language systems as both are related to high fluency. The different routings of the split-store model could be accounted for in terms of the different features of the respective languages used in the studies, such as the differences in orthography between English and Mandarin or a pre-semantic level of processing responsible for the differential routing (Chee et al., 2000).

Neurolinguistic findings that demonstrate different locations for L1 and L2 provide support for the idea that there are qualitative differences in the *mechanics* of the two language systems. If the brain *houses* languages in different places it is likely that they are processed differently and that different cognitive mechanisms are used.

Interlanguage

Interlanguage has been described as a combination of elements from the target language (TL) and elements *borrowed* from the speaker's first language (Selinker, 1974; Gass & Selinker, 1994). Their ideas provide a good stepping-stone for the notion of L2 as a nonlinear dynamical system. They note that sometimes newly acquired elements of the target language may be used correctly, whilst others may be overgeneralised (e.g., walk, walked; run, runned; cold, more colder). However, in the author's experience, as the TL is being internalised, it is not always overgeneralised by students. Sometimes the TL is used *correctly*, sometimes not. This can also be said for L1 during childhood acquisition. Cook (2000) has indicated that children's language should be considered as a different system from adults, rather than as a partial version of it. She also makes the point that whereas children's L1 learning always results in mastery, L2 learning rarely does. L2 is not stable. Rather, in complexity terms, it is a system in a state of flux.

In addition to overgeneralization, interlanguage has also been characterized by interference from the speaker's first language (e.g., in the case of L1 Japanese and L2 English: I saw a dream; I met an accident; it's up to the project) (Selinker, 1974; Selinker & Gass, 1992; Gass & Selinker, 1994). Again, sometimes the TL is used correctly, but sometimes there is interference. The interlanguage speaker takes what we might venture to call *periodic excursions into chaotic behaviour*. There is a certain amount of unpredictability in usage, or at least there are no obvious causal reasons why interference may occur on one occasion but not on another. A third characteristic of interlanguage is the presence of *noise* in terms of language structures that do not belong in either L1 or L2.

Chaotic behaviour in language is understood here as L2 that is far from the TL or language that is incomprehensible in a pragmatic context. (The increasing amount of literature being dedicated to English as an international language highlights the absence of an explicit *standard language* in many situations and raises important questions about the appropriateness of a given TL. Such questions are entirely appropriate for the current discussion but remain beyond the scope of the present paper.) Until TL has been perfectly internalized (perhaps until it is processed via L1 regions of the brain), there will be problems in what we might call *long-term system predictability*. Indeed, brain-based research suggests that it is exceedingly rare that native-like control is ever achieved if L2 is acquired post-puberty (Abdulla, 1999; Chee, Soon & Lee, 2003; Chee, Hon, Lee & Soon, 2001; Chee et al., 2000; Frost, 2003; Rodriguez-Fornells et al., 2002). In other words, L2 remains as interlanguage. It is in a constant state of emergence. It only exceptionally ever reaches a stable state. Grammar is not used as consistently as a first language speaker would use it and expressions lack some degree of sociopragmatic alignment. In the author's experience, there is a high degree of randomly correct and incorrect usage.

The developmental issue here might be framed in terms of focusing on input language that has a higher probability of adapting towards TL. Dynamical systems theory may offer 2LA a way of mapping periodicity of errors to show their frequency over time in relation to TL usage to this end. This possibility is picked up again below.

L2 errors as strange attractors

The errors of overgeneralization and interference that are typically made by second language learners, as well as TL that comes to be used correctly might, in the language of dynamical systems, usefully be characterised in terms of attractors. In dynamical systems, such attractors act as focal points of convergence for system behaviour, in that they appear as identifiable patterns in the sea of otherwise chaotic unpredictability (Gleick 1993; Lewin 1993; Stewart, 1997). In 2LA, a TL attractor might be understood as related to a student's interlanguage *readiness* to absorb certain TL structures over others.

In nonlinear dynamics, attractors are known as *strange attractors* if behaviour is continually drawn towards them, but never to the point where equilibrium is achieved. These might be the aspects of language that a learner has repeatedly studied, the grammar point they *know about* all too well, that they can reproduce in textbook grammar exercises, but which continue to *slip* towards incorrect usage in free writing or conversational exchange. Students may have heard and shadowed "Have you ever...?" and "I've never..." many times in listening practice, "solved" numerous grammar book examples, played substitution drills to repetitive delirium, but still, it doesn't *stick*; still, when caught off guard in free conversation, they slip back to, "I have ever done a bungee jump."

As counter-intuitive as it might first seem, strange attractors are the engines of information. In this strange, upside-down world, order is death and rules signal the absence of creative, generative self-organisation. In nonlinear dynamical systems noise is the bringer of possibility. Without vocabulary

there is no possibility of linguistic communication. With vocabulary comes the possibility of error. This is the start of L2 communication, from the thorny bed of chaos and errors. A greater understanding of the system characteristics perpetuating such errors may add a string to 2LA bows, especially at lower levels.

Just as the butterfly effect magnifies small uncertainties into large effects, so strange attractors act as a channel that magnifies initial randomness. In terms of 2LA, this could translate into a greater or lesser number of a certain type of error becoming manifest over time. A central question for chaos theoreticians is, “Where is this random motion coming from?” As language teachers we read *random deviation from TL*.

The appropriateness of linguistics for 2LA

The central thesis of this paper is that L2 is a qualitatively different language system from L1. It may share certain learning and memory processes, yet there is something qualitatively different also. If this is so, is it appropriate that the main informing body of knowledge for 2LA is a science that cut its teeth on L1, namely linguistics? Are we using hammers with screws?

There is a strong tendency on the part of both teachers and students simply to repetitively, patiently, and persistently correct errors back to TL standards. In the author’s experience, there is far less effort focussed on why and how certain errors keep manifesting. There is almost an unspoken assumption that *they just do*. They are accepted as *common* mistakes for Japanese learners and often blamed solely on *poor memorization*. Perhaps we, as teachers and learners, could benefit by asking the question posed by the new sciences in relation to dynamical

systems, “Where is random deviation coming from?” Rather than assuming errors are meaningless noise to be eliminated, perhaps it is worth first trying to listen for patterns within the noise to better understand their nature.

Error identification

Many methods have been used for error identification (Mizuno & Haramitsu, 1991; Farooq, 1998; Richards, 1974). Selinker and Gass (1992) have suggested an error identification process entailing tape-recording conversational exchanges between student/s and teacher/s. The recording is replayed and the teacher identifies errors for the student to correct with the teacher’s assistance. This approach enables uninterrupted conversational exchange, and error work is subsequently based on language which has personalized meaning for the student. Both of these factors have merits. However, in practice, replaying the tape in full to reveal the errors can be time consuming. Furthermore, the method is heavily teacher-centred. Apparent also, is the suggestion to jump directly from error identification to correction.

An alternative is for the teacher to selectively note error phrases during conversation, discussion, etc. with one or a group of students. This requires multi-tasking (talking/listening/noting) on the teacher’s part, which is difficult for some. However, if the note-taker is able to record enough of the original context to enable sense making, this method has the value that errors are in a condensed form and therefore more accessible for evaluation. Again, the practice language has personal value. The following example is from a lesson warm up in which three students and a teacher talk about their weekends. The following phrases/sentences were noted by the teacher during the conversation:

- I had first time in Gero.
- We were very relaxing.
- ...very hot than usual.
- I am worry but I want to challenge to go in.
- My friend was born baby.
- Last week I'm having a party, no the former last week.
- They like sing a song.
- I was walk with my dog around the house.
- They didn't understand the heavy snow.
- My hometown area it has few snow.
- I saw a car slipped into the river.
- Three cars crashed each other, we passed away.

The teacher then has the choice of whether to *play back* the error phrases by reading them aloud as listening input or alternatively to present the notes in written form either during class time or as homework. Either way, students themselves are required:

- 1) to identify *where* in the sentence/phrase the error exists
- 2) to identify the *type* of the error.

Dependent on individual pride levels and group dynamics, students either work individually or together with peers. The degree to which students define grammatical error types depends upon their existing ability in this area. It is not suggested that new grammatical terms be introduced for this purpose. At the most basic level it has been useful to introduce this exercise by differentiating simply between:

- grammar (e.g., I am worry) and
- expression (e.g., I want to challenge) type errors.

The consciousness-raising aspect of this activity has value in itself (Willis & Willis, 1996). The personalized value, in terms of working with language that has direct meaning for students, tends to be strongest whilst the memory and sense of engagement is still fresh. A drawback of both this and the former method, however, is that both are teacher-centred in that the teacher is required to monitor error identification, whether in the tape-recording or during the conversation. Another criticism might be that the analytic aspects of these methods detract from real-time processing and production.

Shadowing

A third option, which is more suitable for peer work amongst students (subject to appropriate level pairing), involves a shadowing exercise, use of transcripts, and a pre-recording. In addition to highlighting *problem areas* in students' language, this activity also encourages students to chunk their spoken utterances and can act as a preparatory activity leading to selective and/or interactional shadowing activities in free conversational exchanges (Murphy, 1995). Paradoxically, what is lost in terms of practice using personalized language is gained in the fact that as the language of the transcript is less personal, students are likely to feel less threatened by corrections generated in "listening" as opposed to "speaking" practice. The potential negative effect of raising students' awareness to errors is discussed further below.

This option is based on the assumption that L2 learners are least able to repeat language unfamiliar to them. The recording should be selected to ensure that students are comfortable with overall comprehension. In practice, the ability of some students to mimic without actually understanding the content does not seem to

interfere with their partner's ability to distinguish meaningful from non-meaningful shadowing. What is noticeable is the i+1 effect (Krashen, 1985); even though students might be able to relay the meaning of the conversation in some detail, their control over the language structures used is significantly less than their comprehension, even when shadowing. Very often, if a student is able to reproduce what s/he hears exactly, that ability suggests that production mirrors comprehension and indicates language that has been well internalized and that can be used with a predictable degree of proficiency. Occasionally, the student will be able to reproduce some part of the phrase and/or may reproduce it imperfectly. This interference or "noise" potentially contains valuable information about the kind of errors the students is making and gives us cues about their interlanguage profile.

The assumption is that the language content of these noise sections is either new or less familiar and therefore a relevant focus for input language and subsequent study. Building a portfolio of marked transcripts (see Figure 1) to cross-reference is useful for differentiating language errors from simple mistakes.

Method

Typically in this kind of exercise students are paired. Student A listens and shadows. Student B plays the recording in chunks and marks up the transcript according to A's utterances. This is done twice through. Pairing students so that their levels are compatible is important. Use of the transcript enables the activity to be more student-centred, taking the onus off the teacher in terms of error identification. Even where pairing is good, lower levels may have difficulty apprehending pronunciation problems. The support of the written text, however, does seem to enable students to pick up structural mismatches. An exemplar of a marked transcript, useful for students to see, appears in Figure 1.

Figure 1. Marked transcript¹

A: Good afternoon. Rothchild Hotel. How may I help you?
 B: Yes, I'd like to speak to Dr. Banforth. / I'm not sure what his room number is.
 A: One moment. May I ask who's calling?
 B: Yes, this is Hiro Fujiita.
 A: Ah, Mr Fujiita. There is a message here for you from Mr Banforth. / It says that he would like to meet you / at six o'clock in the lobby here at the hotel. / It also says that he'll be back at 5:00 in case you wish to call first. / You can reach him in room 518.
 B: Thank you. Could you leave a message for him? /
 A: Of course.
 B: Could you tell him that I won't be able to make it until 6:30 / because I'll be in a meeting until 6:00....

As suggested above, there may be benefit in this exercise in its own right. Often, students express a desire to role-play the conversation themselves after the shadowing exercises. Students may choose to focus on pronunciation, chunking, and intonation, using the transcript as a guide to focus, or they may move to improvised role-play scenarios that are more loosely based on the original. However, to build an interlanguage profile for the student, the activity needs to be done repeatedly to generate sufficient marked transcripts to cross-reference errors and to begin to identify patterns.

Error exploration

In the final sections of this paper, error exploration is suggested as an additional step in the learning process between identification and correction. This is accomplished in two ways. Firstly, in terms of taking a glimpse at advances in science that have emerged since error analysis peaked in the 1970s as a focus for attention (Richards, 1974). Secondly, the language

of dynamical systems theory is used in a more metaphorical way, as it has been in many other disciplines (Karsenas, 2000; Phelan, 2001; Schön, 1971) to encourage the use of process orientated methods, particularly double-loop learning, alongside the more traditional kinds of 2LA activities referred to above. If we are to pursue error exploration, the main value of all the activities above is not just in making errors available for correction, but going one step further and beginning to explore patterns in error making. In this paper, 2L has been characterized as a non-linear dynamical system. Over the last 20 years, computers have made advances possible in the so-called new sciences (Gleick, 1993; Globus, 1995; Kosko, 1994; Lewin, 1993; Stewart, 1997). Drawing on these developments, one method used to investigate error types in Alzheimer subjects involves layered attractor networks trained to associate semantic and phonological representations (Devlin, Anderson & Seidenberg, 1998).

Methods such as *phase space mapping* have also emerged as a way of capturing and categorising trajectories in relation to a point of equilibrium. In 2LA terms this could mean tracking the way errors and forms of interlanguage approximate or deviate from the given TL over time. The promise of complexity theory is in the simple rules that underpin the complexity, the rules that govern interactions between lower order elements. If teachers were able not just to find the errors, but to understand the ebb and flow of the currents and whorls of strange attraction, the jar and clash of L1 and L2, the turbulence of miscommunication, they may be able to find more effective leverage points and processes. The suggestion is that these and other methods that have developed in the study of nonlinear dynamical systems may be suitable for adaptation to 2LA research.

Double-loop learning in second language acquisition

Within the field of 2LA, raising students' awareness of learning processes has come to the fore in a number of ways (Farooq, 1998; Willis & Willis 1996). In the simplest terms, Ellis (1994) describes this as *noticing*:

Noticing is of considerable theoretical importance because it accounts for which features in the input are attended to and so become intake (information stored in temporary memory which may or may not be subsequently accommodated in the interlanguage system). (p. 361)

The shadowing activity described above provides a tangible basis for comparison of observed and produced language. It enables students to become aware of input at a more conscious level than their attentional system would allow if they were processing information at a purely semantic level.

Another consciousness raising strategy is *double-loop learning*. Double-loop learning is more often used along with reflection to help practitioners externalise their mental models as well as question and improve their practice (Schön, 1983; Lester 1998). I would argue, however, that it is appropriate for adult learners as well as their teachers to use a similar process for their own progress. In terms of error exploration, this would entail individual learners building a portfolio of their own errors, ideally from a variety of sources, which could include the activities detailed above. The teacher, as facilitator, would then be able to work with the student/s to encourage them not

to jump simply to correcting errors, but first to look at the range of errors they have made and begin to elucidate patterns in the type of error. With this knowledge, the student can go back to the core curriculum and sample units in a way that is more relevant to the characteristics of their own interlanguage.

Teachers and students should be aware that there can be negative effects of consciousness raising. Sometimes, depending on students' personality or the sheer extent to which error work is done as opposed to more communicative activities, it can act to inhibit production, particularly where confidence and/or face is at issue.

Summary and conclusion

This paper has discussed language in terms of dynamical systems, with the suggestion that the unpredictability of second language (L2) makes it suitable for description and analysis in terms of a nonlinear dynamical system. Results of brain studies seem to support a two-store model, which in turn adds support to the conceptualisation of L2 as a discrete language system from that of L1. In beginning to describe L2 as a nonlinear dynamical system, the kinds of errors typically identified in interlanguage have been described in terms of attractors in interlanguage that tend to slip towards particular kinds of correct or incorrect usage. The suggestion is that sensitivity to errors and error type, as an indicator of interlanguage stage, can then be used to tailor input and attune the medium of input to meet students' strongest learning styles and most immediate learning needs with subsequent benefits for language development (Pinker, 1994).

While methods that utilize attractor networks and phase space mapping are currently beyond the scope of most language

teachers, greater emphasis on exploring errors is advocated in preference to jumping directly to correction. Activities that enable students to compare input language with their own production were offered with the aim of raising consciousness to error-making through reflective strategies such as double-loop learning. Future research might usefully explore the way students are able to identify certain kinds of errors over others.

Footnote

¹ Slashes indicate chunking.

Outline box indicates student was unable to repeat once.

Shaded box indicates student was unable to repeat both times.

Notes above transcript indicate distorted/partial reproduction.

Bubbles are exclamations/questions from the listener.

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