Complex dynamic systems in students of interpreting training

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Students of interpreting training may go through drastic cognitive changes, but current empirical findings are disparate and isolated. To integrate these findings and to obtain a better understanding of interpreting training, the present article tries to reinterpret students of interpreting training as complex dynamic systems. Relying primarily on longitudinal empirical data from several existing studies, the article illustrates how the initial state of some key parameters influences the progress of the systems, how the parameters themselves evolve, and how interpreting competence develops as a result of self-organization. The hope is that a metatheoretical framework such as Dynamic Systems Theory will allow specific findings and particularistic models for interpreting training to be integrated. Moreover, this approach may allow false dichotomies in the field to be overcome and seemingly contradictory data in empirical reports to be better understood, thereby providing guidelines for future research.

Keywords: complex dynamic systems, Dynamic Systems Theory, interpreting students, interpreting training, self-organization

1. Introduction

Interpreting, as probably the most demanding language task, requires interpreters and in particular, student interpreters, to use all their relevant cognitive resources and abilities so as to fulfill satisfactorily the involved task demands. This assumption seems to have been taken as a common sense with little research on how resources and abilities are mobilized in the interpreting task or interpreting training as well as how these resources interact to produce the intended results or progress. Although a few studies have been conducted on how individual differences change during or after interpreting training (e.g., Yudes, Macizo, and Bajo 2011; Dong and Liu 2016), further research is needed to provide an integrated account of these changes.

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To account for developmental changes, there seem to be more theories or models than we would have liked. The proliferation of incompatible theories is difficult not only for practitioners but also for theoretical researchers. As Lewis (2000: 36) notes: “A scientific discipline can profit from radically different claims and vigorously competing theories, but it needs some body of shared insights or a general framework for reconciling different positions.”

Interpreting training aims at progress in interpreting competence, just as general language training aims at progress in general language competence. The traditional view of language processing or acquisition is often associated with an information processing model, the key feature of which is a somewhat linear path of development. This ideal model is perhaps overly simplistic with the development of interpreting competence being much more complex. Among all the non-linear theories that recognize the crucial role of interactions of variables such as the acquisition theory of emergentism and the processing theory of the competition model, the Dynamic Systems Theory (DST) seems more promising as a metatheory that not only allows for non-linear behavior and sometimes unpredictable outcomes but also allows for messy facts that happen in real time in real life. DST, originally an area of mathematics, has recently been applied to research on language acquisition (e.g., Larsen-Freeman 1997; De Bot, Lowie, and Verspoor 2007; Van Geert 2008; Baba and Nitta 2014), and is welcome as a metatheory in general human development (e.g., Lewis 2000; Witherington 2007). And despite unanswered questions regarding this metatheory, DST is potentially the most appropriate theory for an integrated account of the changes going on during interpreting training, or more accurately, an integrated account of the cognitive development in students of interpreting training.

The present article therefore intends to treat students of interpreting training as complex dynamic systems and reinterpret relevant empirical findings from a DST perspective. In what follows, we will first briefly review the main features of the DST, illustrate the possible main components of the complex systems, and then focus on a DST reinterpretation of previous relevant findings followed by a brief discussion of the significance of the DST perspective.

2. Dynamic Systems Theory (DST)

Simple systems that contain two interacting variables are complex and demonstrate this characteristic when considering their evolution over time. This complexity is heightened and decidedly non-linear for complex systems, particularly if we consider the case of human beings as being complex systems. Dynamic Systems Theory was originally developed as a theory for simple systems such as
the two coupled variables in a double pendulum and has since been applied to research on complex systems such as human development.

Since DST is about the evolving trajectory of either a simple system or complex systems, the major feature of a dynamic system is its change over time. Research on “change over time” may focus on either short-term or long-term changes and micro- or macro-evolvement. Van Geert (2008) illustrates this concept of the timescale using an example from Lewis Carroll’s story Through the Looking Glass. In the story, Alice walks on a chessboard. The long-term dynamics of walking on the chessboard is walking from place A to B, with each step being a dynamic constituent. In contrast, the short-term dynamics of walking is more akin to one leg moving forward at a time, and the movements of body and limbs are dynamic constituents. The observation of short-term dynamics may help to predict long-term dynamics. For instance, if Alice were to walk only with one leg, perhaps as the result of an injury or any other impediment, then Alice would likely avoid certain rough terrains. In turn, the observation of long-term dynamics, such as the path taken by Alice, may help uncover the nature of the underlying short-term dynamics.

The second key concept in DST is termed self-organization. In Van Geert’s (2008) example, before Alice walks to the Queen who is on the other side of the chessboard, there are numerous paths that Alice can take. But since there are rules on chessboard movements, the number of possible paths is reduced. As Van Geert (2008:182) explains: “...the (chessboard) landscape gets organized into a limited number of endpoints and a limited number of paths. Thus, after a while, the landscape becomes more orderly, more structured or organized, in terms of how it relates to Alice’s walking.” The critical idea is that this organization of the system is a direct consequence of the dynamics itself (the chessboard landscape and Alice’s walking), not a pattern that Alice is born with or brings to the chessboard. If the landscape changes, self-organization may produce a different pattern.

The third key concept is often coined the butterfly effect. That is, the evolving trajectory of a system is sensitive to its initial state or condition; a minor difference at the beginning may produce dramatic consequences in the long run. Moreover, this sensitivity to the system’s initial state may depend on one or more critical parameters, and one parameter may play a more significant role than another. A related concept is that of non-linearity, “a non-linear relation between the size of an initial perturbation of a system and the effects it may have in the long run” (de Bot et al. 2007:8). Some of the initial perturbations may be absorbed at some point along the way and the effects become smaller than what can be predicted from a linear relation.

The fourth concept is termed attractor state, which refers to a situation in which the system gets “stuck” or becomes stable at some point of development,
thereby requiring repellors or extra resources to move it out of the stable state. One example is fossilization in second language acquisition (de Bot et al. 2007; Larsen-Freeman 2005). Rather than viewing fossilization as an end state, a DST perspective on this phenomenon can be advantageous since it views fossilization as a reflection of the constant and changing interaction between variables and the individual learner.

While researchers using DST in their work may differ in their emphasis or focus, they maintain the same basic features described above. For example, Van Geert (1996) uses DST as a tool for analyzing developmental profiles. Fogel (1993) sees DST as an alternative to psychological reductionism. Work by Lewis (1995) focuses on the concept of self-organization in an effort to build his own theoretical models. This range of research demonstrates how this conceptual toolkit can be used to address different time scales of development and can provide opportunities to start dialogues among researchers typically working in different theoretical traditions. As such, DST provides a way to account for the cognitive changes in students of interpreting training.

3. The complex dynamic systems in students of interpreting training

To account for the cognitive changes in students of interpreting training from a DST perspective, we must first determine the complex systems in such students. Based on previous research in the literature, we believe that language proficiency, working memory (WM), executive control, and psychological factors are four complex constructs that may interact with each other and affect how students progress differently during interpreting training.¹

Language proficiency

Language proficiency is critical to students of interpreting training as interpreting requires immediate processing of the two languages under time pressure. For most interpreting trainees, their first language (L1) proficiency is not problematic, with their second language (L2) proficiency being more of a challenge. There is research suggesting that L2 proficiency is important in simultaneous

¹ Other factors such as syllabus design and faculty qualification are important too, but we would focus on the cognitive and psychological factors because it is not yet very clear how differences in these factors would lead to differences in interpreting performance and development. In addition, external factors such as syllabus design mostly function through internal factors such as the cognitive and psychological factors here.
interpreting performance (Tzou et al. 2012). In addition, Christoffels, de Groot and Waldorp (2003) found that lexical retrieval efficiency (i.e., the speed and accuracy in accessing words) directly affected interpreting performance. According to the verbal efficiency theory (Perfetti 1985), lexical processing abilities such as word naming efficiency significantly correlates with language comprehension skill. Lexical retrieval efficiency is thus frequently used as an index of language proficiency in studies of interpreting (e.g., Christoffels et al. 2003; Cai et al. 2015).

Working memory

The task of interpreting is demanding in the aspect of memory processes, regardless of whether it is a consecutive interpreting (CI) task or a simultaneous interpreting (SI) task. In a typical CI task, interpreters often need to comprehend a long segment of speech before reproducing it in the target language (TL). Even with the help of notes, interpreters have to memorize many details. As Gile (2009) argues, the demanding nature of interpreting often saturates the interpreter’s cognitive resources, thereby leading to errors or failures in interpreting performance.

Short-term memory (STM) and working memory (WM) are often measured in studies of interpreting (e.g., Köpke and Nespoulous 2006). Although the exact nature of STM and WM is still controversial in cognitive psychology (for a review, see Aben, Stapert, and Blokland 2012), STM generally refers to the system that temporarily stores information and is frequently assessed by simple spans such as the digit span or the L1/L2 word span, while WM refers to the system that both temporarily stores and manipulates information, and is assessed by complex spans such as the L1/L2 reading/listening/speaking span or the operation span. Christoffels et al. (2003) found that STM (indexed by digit span) was indirectly related to SI performance, while WM (indexed by reading span) was directly related to SI performance. The emphasis is thus placed on the relationship between WM and interpreting, although STM is often measured at the same time.

The result of an empirical test of the relationship between interpreting and WM may depend on the specific WM measurements employed, because each measurement may reveal a different aspect of WM. There may be measurements of different spans or of coordinating ability or updating ability (also considered part of cognitive control, e.g., Miyake et al. 2000). For interpreting research, it is probably better to use a combination of those that are not so obviously related to the language processing aspect of the interpreting task itself (e.g., updating), and those that are more directly related (SL listening and TL speaking spans).
Cognitive control

Cognitive control or executive control/functioning is an umbrella term for the management of cognitive processes. Specifically, cognitive control includes the ability to manage a complex set of task demands, to inhibit irrelevant or competing information, and to switch attention to goal-relevant information. Cognitive control thus mainly consists of three relevant, but independent, components or functions: inhibition, shifting, and updating (Miyake et al. 2000). Apart from these three components, monitoring is another component that is frequently discussed (e.g., Hilchey and Klein 2011; Dong and Li 2015), and the participant that is supposedly advantageous in monitoring is said to be better at monitoring the task at hand (frequently tasks containing interference or requiring switching).

Since the task of interpreting is cognitively demanding, we believe that cognitive control is essential to its successful performance, but there is limited direct evidence for this belief to this point (Timarová et al. 2014 is a notable exception). Almost all research on the relationship between interpreting and cognitive control in the literature concerns whether interpreting training can produce an interpreter advantage in domain-general cognitive control (i.e., cognitive control measured in tasks that do not directly involve language processing). Except for one study (Woumans et al. 2015), all the other studies (e.g., Yudes, Macizo, and Bajo 2011; Dong and Xie 2014; Morales et al. 2015; Becker et al. 2016; Dong and Liu 2016; Babcock and Vallesi 2017; Dong and Zhong 2017) have found an interpreter advantage in one or two functions of cognitive control. Since interpreting training can produce an interpreter advantage in cognitive control, cognitive control must be an essential construct exercised during interpreting training, and thus part of interpreting competence.

There are standardized measurements of cognitive control (for a review, see Dong and Li 2015). The three typical measurements of inhibitory ability are: the Flanker task, the Simon task and the Stroop task (with probably different versions in each task). For the function of shifting, there are two typical measurements: the color-shape task and the Wisconsin Cart Sorting Test. And the n-back task is frequently considered a task measuring the function of updating, which is also considered a function in WM (e.g., Anguera et al. 2013).

Psychological factors

Anxiety and motivation, or in broader terms, psychological stress and attitudes, are the two major psychological factors that may significantly affect interpreting performance and development. It is understandable that anxiety is related to interpreting performance (Brisau, Godijns, and Meuleman 1994; Ivars and Calatayud 2001),
which is especially true for students of interpreting who do not yet have the language proficiency or necessary skills to perform well. Measurements include the State and Trait Anxiety Inventory (e.g., Ivars and Calatayud 2001) or physiological tools that record heart rate and skin conductance level (e.g., Kurz, 2003). Based on relevant anxiety scales in the literature, Dong, Chen, and Yu (2013) developed a state anxiety scale of 20 items all specifically aimed at interpreting trainees. The scale was validated by a series of tests, indicating that the scale has good internal reliability (Cronbach’s $\alpha = 0.92$), good construct validity (correlated with and also different from four criterion-related scales: trait anxiety, self-efficacy, foreign language listening and speaking anxiety), good predictive validity (correlation coefficient $r = -0.434$), and good test-retest reliability (Cronbach’s $\alpha = 0.84$). This is probably the first interpreting anxiety scale that is tested in validity and reliability. The predictive validity in Dong et al. (2013) suggests that anxiety is negatively correlated with interpreting performance.

Motivation helps instigate and sustain goal-directed activities. In the last 40 years or so, a large body of literature has highlighted the importance of motivation in successful second language learning (e.g., Dörnyei 1998). The proposition of this relationship is based on the argument that attainment of proficiency in a second language entails long-term effort on the part of the learner. Based on similar arguments, attainment of interpreting competence entails hard effort on the part of the student interpreter, who needs a strong motivation to persist in difficulties and frustration. Cai and Dong (2017) developed a motivation scale for interpreting training that consists of 12 items in four dimensions: intrinsic motivation; instrumental motivation; performance goals and intended efforts. With a group of student interpreters, the study found that scores on the motivation scale significantly predicted their performance on an interpreting test.

In sum, the four constructs of language proficiency, working memory, cognitive control, and psychological factors are important factors influencing how different students in the same class make different progress in interpreting training. From a DST perspective, these constructs may interact with each other, and students’ progress is therefore complex and non-linear. For example, language proficiency may interact with anxiety and motivation, while working memory may interact with both language proficiency and cognitive control. It is not easy and perhaps impractical to investigate every aspect of the complex systems (at the start or at the same time), but a DST perspective enables us to see the larger picture when we are investigating a specific aspect of the systems and enables researchers to identify areas that require further inquiry.
4. Evolution of dynamic systems in students of interpreting training

Since the task of interpreting is cognitively demanding, students of interpreting go through drastic cognitive changes during the training process. To identify these changes (or the evolution of the systems, in DST terms), longitudinal data are needed and therefore must be collected. Little research has been conducted to date on the cognitive changes of students of interpreting training with even fewer longitudinal research projects on the topic. Most relevant research (e.g., Christoffels, de Groot, and Kroll 2006; Liu, Schallert, and Carrill 2004) employs a cross-sectional design, mostly comparing professional interpreters with student interpreters or general bilinguals. Only a few relevant longitudinal studies (e.g., Cai et al. 2015; Dong et al. 2013; Dong and Liu 2016; Zhang 2008) have been conducted. Regardless of whether these studies are cross-sectional or longitudinal, they seem isolated and independent (despite many of the latter coming from the same lab). DST offers an opportunity to integrate them into a whole. In the section that follow, we will reinterpret previous relevant findings from a DST perspective, hoping to see whether this umbrella account will add to our current understanding of interpreting training or students receiving such training.

4.1 Different predictive powers of initial parameters

As described in Section 2, the butterfly effect generally refers to the phenomenon that a small change at the beginning may produce large changes in the end. A typical case in human development is the relationship between a small change in a certain gene and dramatic consequences in later development. For a relationship between cognitive factors, a small change in a certain factor (e.g., L2 proficiency) may not be able to produce such huge consequences in later development, and therefore it may not be so appropriate to use the term without considerable scrutiny. However, it is definitely worthwhile to explore how later development in interpreting is sensitive to its initial state and the initial state of related parameters; this approach is certainly akin to the butterfly effect even if it is not precisely the same concept.

Perhaps the most relevant study that investigated the question of how later development in interpreting competence depended on its initial state and the initial states of critical factors is Cai et al. (2015). The study recruited 61 native speakers of Chinese who had just started interpreting training in year three of the university as an English major. The participants were tested on interpreting performance (inverse CI from English to Chinese) in the second month (Time 1) and tenth month (Time 2) of interpreting training. Based on pilot studies, L2 proficiency (general test like TOEFL), memory capacity (English listening and
speaking spans, Chinese speaking span, and digit span), and word translation efficiency (English-Chinese and Chinese-English word translation recognition) were selected as the critical factors, and tests were conducted at Time 1. The students then received formal training for the intervening eight months that was designed to enhance their CI competence, especially interpreting from English to Chinese (including four courses of interpreting and four courses of translation, apart from other courses such as literature; 80 minutes’ class time x 18 weeks for each course).

As illustrated in Figure 1, the findings can be summarized as follows (with key findings listed in points 4 and 5): (1) English listening and speaking spans, and Chinese speaking span (as WM measures) significantly correlated with CI performance at Time 1, and explained respectively 8.3%, 10.2%, and 7.5% of the variances in CI performance; (2) The digit span (as short-term memory) and lexical retrieval efficiency had no statistically meaningful relationship with CI performance at Time 1. (3) English proficiency significantly correlated with CI performance at Time 1, and explained 15% of the variances in CI performance. (4) CI performance at Time 1 accounted for almost half (46.6%) of the variance of CI performance at Time 2. (5) After excluding the contribution of CI performance at Time 1, only L2 proficiency made a significant contribution (3.6%) in accounting for the variances in the development of CI competence.

The data suggest that after excluding the contributions of CI performance at Time 1, L2 proficiency is probably the most important predictor of the development of CI competence (in unbalanced bilinguals as students of interpreting). In addition, Mayor and Jesus (2015) found that, among factors of L2 listening

![Figure 1. Design and results in Cai et al. (2015)](image-url)
comprehension, L2 reading comprehension and L2 grammar, proficiency in L2 listening comprehension had a significant effect on undergraduate students' interpreting ability and was a predictor for interpreting aptitude. In DST terms, later development in interpreting is sensitive to its initial state and the initial state of the parameter of L2 proficiency (especially L2 listening comprehension).

This line of research has rich implications for CI training. Factors (e.g., L2 proficiency) that could predict later development (of interpreting) are important factors that should be taken into consideration at admission tests and at initial training after admission. The best candidates for interpreter training are those who have mastered their L2, which is easy to understand partly because it is consistent with our intuition. What is not easy is striking a balance among all the factors. For example, an interpreting program admissions test might have to weigh the factors of language proficiency (especially L2 proficiency) and interpreting strategy skills. Some candidates may have been trained on interpreting strategies prior to sitting for the exam, resulting in a better performance on the test than those who have not yet received any training but who have stronger language proficiency. The former candidates may get higher performance scores, however the latter may develop better in the long run. As de Bot et al. (2007:8) states: “a non-linear relation between the size of an initial perturbation of a system and the effects it may have in the long run.” In order to make more informed decisions during admissions testing and subsequent training, more research is needed involving a DST perspective.

4.2 Evolution of parameters

Parameters of a complex system also evolve along the timescale. How each parameter evolves may be influenced by the interaction of parameters or variables, or by the general pattern that is emerging. In the complex systems of students of interpreting training, there may be classes of parameters in L2 proficiency, working memory, cognitive control, and psychological factors.

L2 proficiency

There seems little doubt as to whether L2 proficiency evolves or progresses in interpreting training. In fact, interpreting training is frequently taken as a way to improve L2 proficiency. However, a closer examination of L2 proficiency may require us to challenge these assumptions. There may be differences in the developments of typical language skills such as reading, listening, speaking and writing, and these differences may be related to the initial state of the complex system of a student receiving interpreting training. That is to say, although receiving identical interpreting training, a student of minimal L2 proficiency and a student of higher
L2 proficiency would be expected to develop differently in L2 proficiency, especially when specific language skills are taken into consideration. Since a search of the literature did not yield any systematic empirical research in this regard, specific claims cannot be made at this time.

**Working memory**

The situation with WM in interpreting is quite different. Researchers are very much concerned with whether WM is strengthened during interpreting training, or whether there is an interpreter advantage in WM. The measurements of reading/listening/speaking spans (together with STM digit/word span) have been explored, but the results in the literature are mixed. There has been research supporting an interpreter advantage in WM (Christoffels, de Groot, and Kroll 2006; Köpke and Nespoulous 2006; Tzou et al. 2012; Signorelli, Haarmann, and Obler 2012), but there has also been research that failed to find such an advantage (Chincotta and Underwood 1998; Liu, Schallert, and Carroll 2004). Nevertheless, these studies were all cross-sectional in nature that generally compared interpreters of different amount of interpreting experience with bilinguals of little interpreting experience. Most of these comparisons may suffer from a lack of control in factors such as participants’ backgrounds (e.g., age, L2 proficiency), and may also suffer from a small participant sample size (see Dong and Cai 2015 for a comprehensive review, see Brysbaert and Stevens 2018 for recommendations of participant size). And yet, these innovative studies have contributed substantially to the literature, particularly in regard to the idea of an interpreter advantage in WM.

Zhang (2008) conducted a longitudinal study on how six months’ interpreting training or experience may improve participants’ reading span and coordinating ability in interpreting (relevant to WM executive control). Three groups of Chinese-English bilinguals were measured in a pretest and in a posttest six months later: 35 beginning student interpreters, 35 advanced student interpreters and 13 professional interpreters. Data were collected on their L1 reading span and on their ability to coordinate in situations of difficulty in interpreting. The results indicated that six months’ interpreting experience improved the first group’s reading span and the second group’s coordinating ability. The latter two groups did not show any improvement in reading span probably because the span had potentially reached a ceiling. The first group did not show any improvement in coordinating ability probably because six month’s training at this initial stage was not good enough to produce such an effect. In short, various WM components may evolve differently, depending on the complex systems of the student of interpreting training.
Cognitive control

As with L2 proficiency and WM, cognitive control is indispensable to accomplish an interpreting task. Interpreters have to switch efficiently between two languages, and update relevant information in WM. The question is: how do cognitive control abilities evolve during the process of interpreting training? Researchers seem more interested in the domain-general concept of cognitive control, that is, cognitive control abilities tested in tasks that do not involve language processing (e.g., the color-shape task, the n-back task, the Flanker task). Several recent studies (Yudes, Macizo and Bajo 2011; Dong and Xie 2014; Morales et al. 2015; Woumans et al. 2015; Becker et al. 2016; Dong and Liu 2016; Babcock and Vallesi 2017) have explored how interpreting experience brings cognitive control advantages, a question similar to the question of cognitive control ability evolution. Interpreting experience has been found beneficial to general-domain switching ability (Yudes, Macizo, and Bajo 2011; Dong and Xie 2014; Dong and Liu 2016), updating ability (Morales et al. 2015; Dong and Liu 2016), and monitoring (Becker et al. 2016; Babcock and Vallesi 2017). Behavioral data showed little evidence for an interpreter advantage in interference tasks (e.g., Yudes, Macizo, and Bajo 2011; Dong and Xie 2014; Dong and Liu 2016), but a recent ERP study showed robust evidence for such an advantage (Dong and Zhong 2017). In other words, there is evidence indicating that domain-general cognitive control abilities do get strengthened during the process of interpreting training.

In addition, Dong and Liu (2016) found evidence for the uniqueness of an interpreting training experience. As a longitudinal study exploring the evolution of cognitive control abilities during interpreting training, Dong and Liu (2016) compared three groups of Chinese-English young adult bilinguals in a pretest and in a posttest. During the interval of the two tests (i.e., one semester with 32 class hours), the three groups of participants received either (oral) interpreting training or (written) translation training or general L2 training. The group of participants receiving general L2 training served as the control or baseline. Interpreting training and translation training were compared because the former is cognitively more demanding than the latter although both involve frequent switching between two languages. The results showed that, with the general L2 training as the control, the interpreting training produced significant cognitive advantages in switching ability and updating efficiency, while the translation training only produced marginally significant improvements in updating efficiency. The results suggest that the fact of an interpreter frequently switching between two languages under time pressure has its impact on the complex systems of the student interpreter, producing unique progress in cognitive control abilities like switching and updating.
Psychological factors

Anxiety and motivation are two important psychological factors for the development of interpreting competence. But as to the question of how these two factors develop or change during the process of interpreting training, little empirical research has been reported in the literature. The doctoral thesis of Wu (2015) is an exception, in which Wu conducted a cross-sectional study and found that students’ motivation to study interpreting fluctuated considerably during the first year or two. These fluctuations were related to the students’ experience with their social context (including factors like the prospect of a career in interpreting), their learning context (including teachers, classes and classmates) and other psychological factors like confidence. To achieve good results in interpreting training, one has to monitor students’ level of motivation so as to maintain or raise it. More research is certainly needed to make further claims.

To sum up, in the complex dynamic systems of students of interpreting training, parameters in both the linguistic and non-linguistic domains may evolve together with the systems. Certainly not all parameters evolve in the same way. And during the process of interpreting training, a certain parameter or a set of parameters (e.g., L2 proficiency, WM) may stop evolving, and the evolution of the complex dynamic systems may then mainly depend on the interaction or coordination of the parameters. Fossilization or an attractor state may set in if all parameters and their interactions stop evolving. In that case, a push on a critical parameter such as L2 proficiency or motivation may get the system re-started. However, the relationship between the evolvement of parameters and the evolvement of the systems needs more empirical research.

4.3 Self-organization

Under the previously-described concept of “change over time” in a dynamic system, self-organization is potentially the most important concept illustrating how changes happen over time. Briefly, self-organization refers to a process in which some form of an overall pattern or coordination arises out of local interactions between component parts of an initially disordered system. Self-organization may occur in various complex systems such as biological, social, and cognitive systems.

To the author’s knowledge, Dong et al. (2013) is the sole study to date that depicted how self-organization occurs in interpreting training. In total, 19 tests were conducted to measure L2 proficiency, WM, cognitive control, anxiety, and interpreting performance, and these tests were administered to 52 participants at two stages of interpreting training – i.e., the second and tenth month of interpreting training during their third academic year as English majors. At Time 1, there
were two tests of consecutive interpreting in the L2–L1 and L1–L2 directions, five tests of language skills (English proficiency, comprehension of source language, summary writing for source language, L1–L2 and L2–L1 word translation), eight different measures of WM span (listening, reading and speaking spans in both languages, digit and spatial spans) and two cognitive control tasks (Stroop and Flanker tasks). At Time 2, two more tests (trait and interpreting anxiety) were administered. Results from Time 2 were reported in detail in Dong et al. (2013), but those from Time 1 were not reported for considerations of space and because only results from Time 2 could fit in a valid model (via structural equation modeling, see below for details).

There were three main findings, which are summarized in Table 1. First, for the L1–L2 direction in which participants received little training, none of the 15 tests administered at Time 1 significantly correlated with interpreting performance, while at Time 2, only interpreting anxiety correlated with interpreting performance. Second, for the L2–L1 direction in which participants received most of their training, six of the 15 tests (English proficiency, source language comprehension, source language summary, English listening and speaking spans, Chinese speaking span) administered at Time 1 significantly correlated with interpreting performance, but no valid model via structural equation modeling can be built. Third, for the L2–L1 direction, six of the 17 tests administered at Time 2 significantly correlated with interpreting performance, and among the six possible structural models, the one depicted in Figure 2 was valid.

Table 1. Number of variables correlated with interpreting performance, and valid model established

<table>
<thead>
<tr>
<th>Task</th>
<th>Test time</th>
<th>Number of variables</th>
<th>Valid model</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1–L2 CI</td>
<td>Time 1</td>
<td>0</td>
<td>n/a</td>
</tr>
<tr>
<td></td>
<td>Time 2</td>
<td>1 (Interpreting anxiety)</td>
<td>n/a</td>
</tr>
<tr>
<td>L2–L1 CI</td>
<td>Time 1</td>
<td>6 (Eng Prof, Eng Comp, Eng Summ, Eng lst and spk span, Chn spk span)</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Time 2</td>
<td>6 (Eng Prof, Eng Comp, Eng Summ, Eng lst span, Chn spk span, Intp anx)</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Notes. (1) Time 1 and 2: 2nd and 10th month of interpreting training. (2) Full spellings for abbreviations: English proficiency, English (SI) comprehension, English (SL) summary, English listening and speaking spans, Chinese speaking span, Interpreting anxiety. (3) Anxiety was not tested at Time 1. (4) Dong et al. (2013) only reported data from Time 2.

2. Cai and Dong (2015) was not precise in their review of Dong et al. (2013) when they said that none of the tests at Time 1 correlated with interpreting performance. They forgot to qualify the direction of interpreting. Specific quantitative data and statistical analysis can be provided if requested.
As shown in Figure 2, the six tests that correlated with interpreting performance can be categorized into two factors: language competence (source language summary, source language comprehension, and English proficiency) and psychological competence (interpreting anxiety, English listening span, and Chinese speaking span). Altogether, the results indicate that, for students of interpreting, both language skills and psychological competence are important for L2–L1 CI performance, and that psychological competence is especially important because language skills mostly function through the mediation of psychological competence.

![Figure 2. Structural equation model for L2–L1 CI at Time 2 (Dong et al. 2013).](image)

However, the most important finding is illustrated by the contrast between Time 1 and Time 2 – i.e., the process of an initially disordered system becoming gradually coordinated. At Time 1, although six tests correlated with interpreting performance in the L2–L1 direction, no valid structural model can be built for these variables. After about 8 months’ interpreting training, six of the tests that correlated with interpreting performance in the L2–L1 direction became component

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3. An umbrella term was needed to cover the three tests of interpreting anxiety, English listening span and Chinese speaking span because assigning the three tests to two or three subcategories would not result in a valid model that fitted the data. For simplicity, the term “psychological competence” was used.

4. A rectangular box in a structural equation model represents a variable measured. A large circle represents an underlying construct which the variables have measured, and the number on each connection line between the two indicates their relationship, with larger numbers (absolute value) indicating stronger connections.
parts of a valid structural model. In short, the complex system of interpreting competence was gradually coordinated after interpreting training.

In sum, Table 1 and Figure 2 illustrate how the complex dynamic systems of students of interpreting got gradually organized during the process of interpreting training. Both the contrast between the two test times and the contrast between the two directions are evidence for the process of self-organization. The factors that were related to interpreting performance after training were probably factors that mattered most in interpreting performance for the students at this stage of development. Interpreting training is thus a process that mobilizes and coordinates trainees’ component abilities, at least for the first year of training for unbalanced bilinguals.

5. Benefits of a DST perspective in interpreting studies

First, viewing students of interpreting training as complex and dynamic systems, a DST perspective avoids psychological reductionism to a certain extent and perhaps more closely approximates “the truth” than traditional approaches. In traditional approaches that are frequently associated with an information processing model, the development of interpreting competence is generally simplified, with many variables and especially interactions between variables ignored. In the DST perspective, students of interpreting training are complex organisms of growth with many known and unknown parameters that are always functioning. Interpreting training enhances some parameters and triggers their interaction or self-organization in a certain way that is consistent with the purpose of interpreting training. Interpreting competence seems dependent on an optimal structure of self-organization, although the structure may change more or less at different training stages and in different interpreting tasks.

Second, as a metatheoretical framework, DST offers insights into future research. When we try to integrate individual studies within a DST framework (as we did in the above sections), we may find gaps and contradictions, which can precisely serve as topics for future research. In fact, the analyses in Sections 4.1, 4.2, 4.3 have produced specific suggestions, such as research into “the non-linear relation between the size of an initial perturbation of a system and the effects it may have in the long run” (de Bot et al. 2007:8), research into the relationship between the evolvement of parameters and the evolvement of the systems, and research into self-organization at different stages of development. None of the previously-mentioned empirical studies are perfect, with the variable of motivation, for example, missing in most of them (e.g., Cai et al. 2015; Dong et al. 2013). More longitudinal studies are needed along with replication of previously-conducted
studies. Only with a thorough understanding of students of interpreting can we make claims about interpreting training with confidence.

Third, as a metatheoretical framework, a DST perspective provides an overarching way of thinking when we address dichotomies on a certain topic. For example, there has been a debate as to whether the target language (TL) is processed in parallel with source language (SL) comprehension in consecutive interpreting (Macizo and Bajo 2004; 2006; Ruiz et al. 2008). The serial processing view postulates that TL processing will not start until SL comprehension is complete, while the parallel processing view postulates that TL processing is conducted while SL comprehension is still in progress. Instead of taking one or the other side, Dong and Lin (2013) asked the question of when the TL was processed in parallel with SL comprehension, i.e., when TL words or structures were activated and processed while the SL was in progress. Their results suggest that it was probably determined by two interacting factors: (1) mental correspondence strength of a processing unit from SL to TL (e.g., L2–L1 correspondence strength of a word is generally stronger than the word’s L1–L2 correspondence strength); and (2) an interpreter’s capacity surplus in SL comprehension to coordinate TL processing (e.g., generally more surplus in students of better L2 proficiency and more interpreting skills than students otherwise). If we use C to represent the first factor, and S to represent the second one, and if we take the sigmoid function as the tool, Figure 3 may roughly depict the answer to the question of when the TL is processed in parallel with SL comprehension, transcending the dichotomy of whether the TL is processed in parallel.\(^5\) The model depicts the idea that the probability (P) of TL parallel processing during SL compression depends on the two united effects (U) of the two variables of C and S. In the function of U, a and b are the relative weights for the two factors of C and S, and \(\lambda\) is a constant which decides how steep the slope is in Figure 3 (with steeper slope representing faster learning). Specific values for a, b and \(\lambda\) are not determined, and there may be no way to determine them at the current stage of research. Again, more research is needed to make further claims.

\(^5\) This function, frequently used to simulate cognitive processing, was described by McLeod, Plunkett and Rolls (1998:18) as follows: “[The function] effectively combines a threshold, below which net input has little effect, a region in which the activity grows roughly in proportion to the net input, and then a region where further input has little effect as the unit approaches its maximum activity.”
Figure 3. CS model of parallel processing during SL comprehension. The probability ($P$) of TL parallel processing during SL compression depends on the two united effects ($U$) of the two variables of $C$ (mental correspondence strength of a processing unit from SL to TL) and $S$ (interpreters’ capacity surplus in SL comprehension to coordinate TL processing).

6. Conclusion

Frustrated by the unsatisfactory situation of empirical research in interpreting studies, and inspired by the enthusiasm to apply DST to explain human cognitive development (e.g., Lewis 1995, 2000; Geert 1996, 2008; Vallacher, Van Geert, and Nowak 2015), the present article tries to show how a DST perspective can integrate previous empirical research and provide guidelines for future research. In the complex dynamic systems of students of interpreting training, language proficiency (especially L2 proficiency), memory capacity (especially working memory), executive control (especially switching, updating and inhibition abilities), and psychological factors (especially anxiety and motivation) are probably four of the major constructs that may interact and affect how different students of interpreting develop differently their interpreting competence. Longitudinal empirical data from a few existing studies on students of interpreting illustrate how the initial state of some key parameters influences the progress of the systems, how parameters evolve themselves, and how interpreting competence develops as a result of self-organization. When integrating previous research, we find gaps and contradictions which are topics for future research.
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