Chaos/ Complexity Theory: The Impact of Sensitivity to Initial Conditions on Students' Test Performance

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Abstract

The purpose of this study was to investigate empirically the application of one of the cornerstones of chaos theory, that is, sensitivity to initial conditions, to language assessment. In doing so, 20 Iranian students at masters' level participated in this study. They were majoring in nanophysics in Islamic Azad University of Bushehr. They were sophomores aged 23 to 30. In order to ensure homogeneity, they were administered a test of reading comprehension called PET. Then, another test of reading comprehension was administered to them based on "English for the Students of Physics". Having taken that test, the students took the same test after two weeks in different versions. The versions were created by changing the order of items. The analysis of the data showed that 75.83% of students performed better in the second version of the test. This showed the effect of changing the order of items on the students' performance which is consistent with the principle of

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sensitivity to initial conditions in chaos theory. The implications of the findings will be discussed at the end of the study.

1. Introduction

Several research fields have been influenced by chaos theory among which linguistics is applied. Chaos theory is grounded in the Big Bang theory when the systematic nature of the world was created based on a chaotic act of God. The notion of chaos/complexity dates back to 1960s, when Lorenz, a meteorologist, found out that a very small difference could bring about large changes in weather that make weather forecasts almost impossible to predict. One of the cornerstones of chaos theory is known as *sensitivity to initial conditions*. It states that a small change in the initial conditions may lead to a dramatic change in the long-term behavior of a system (de Bot, 2008 cited in Larsen-Freeman & Cameron, 2008). However, the concept of chaos complexity has been used in other fields of study like mathematics, physics, chemistry, etc. McAndrew (1997) believes that reality cannot be found without chaos.

Chaos theory is a paradoxical concept. Larsen-Freeman (1997) implies that this theory has a contradictory paradoxical concept. The characteristics of the concept of complexity are as follows: a) it involves interconnectivity; b) it is not always random; c) it is not predictable; d) it is non-arbitrary; e) it involves sensitivity to initial conditions; and f) it is dynamic. Figure 1 depicts the features of complexity.

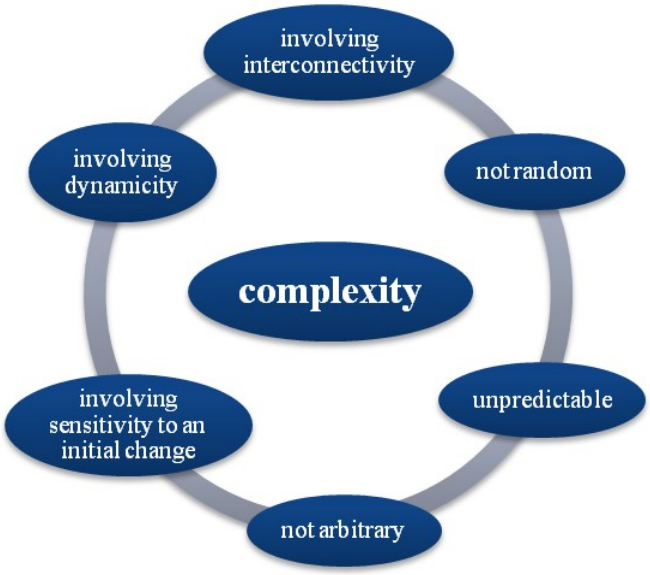

Figure 1. Features of complexity

According to Larsen-Freeman (2000), complexity is a metaphorical notion. In order to shed light on this concept, a distinction must be drawn between the term complexity and complicatedness. The former implies a system which is not independent, whereas the latter means not being simple. Something is complex provided that several independent agents have an interaction with each other. Therefore, the agents in a system are its components. They interact with each other in an unpredictable manner. Out of these interactions a pattern emerges which informs the interactions occurring among agents.

1.1. Chaos Theory and Language

Larson-Freeman (1997) maintains that language is a complex and nonlinear system. It is dynamic since it changes with the passage of time, or it changes with the passage of time because it is dynamic. In fact, dynamicity is equal to growth and change. It involves non-linearity. Since

there is no one-to-one correspondence between form and function, it is nonlinear. Similarly, since there is no difference between the current use of language and its growth or change, it is dynamic. Another reason for the dynamicity of language refers to the creativity of human beings in using the language. This feature makes humans distinguishable from other creatures. Considering the fact that humans and languages are dynamic, this will yield a dynamic system which is chaotic.

It was believed that exposure to the forms of a given language will trigger the linguistic competence and that language is acquired with ease. However, since language is a dynamic phenomenon, other aspects of language must be taken into consideration as well. Therefore, the term *nurture* which includes the social and strategic competences can play a compensatory role when there is deficiency in performance. Figure 2 indicates the variable influencing a chaotic phenomenon.

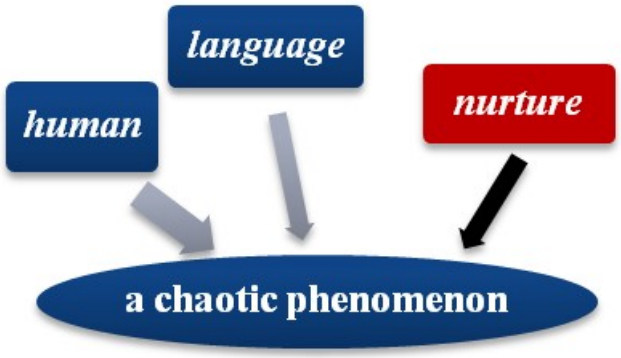

Figure 2. Variables influencing a chaotic phenomenon

Thietart & Forgues (1995) show that the state of a system changes from stable to periodic and vice versa when the strength of the relationship among variables changes. In other words, the time-dependent variables in a dynamic system are non-linear.

1.2. Sensitivity to Initial Conditions

One of the cornerstones of chaos/complexity theory is *sensitivity to initial conditions*. Chaos theory was first introduced in physical sciences in order to explicate the process of complex dynamic systems. Such systems usually have many elements which interact with others and bring about a change of order of complexity at higher levels. Researchers investigate such changes in order to understand how these changes occur. Such changes are usually non-linear meaning that there is no proportion between the effect and the cause. The reason for such nonlinearity lies in the fact that such systems are sensitive to initial conditions. This feature of chaos/complexity theory is also known as *butterfly effect,* by which, the flapping of a butterfly's wings in a country can influence a weather system in another country. This sensitivity to initial conditions can make complex systems chaotic.

1.3. Chaos/Complexity Theory and Language Learning

According to chaos/complexity theory, language is an accumulation of static units which are combined in speech dynamically (Mallows, 2002). He further adds that the dynamic patterns of complex systems indicate feedback loops. Nothing controls that system because the dynamics emerge from within the system itself, and the system benefits from that feedback to move forward, and to develop. These systems are adaptive and change their internal organization to make use of the new conditions. Such feedback loops provide the chance of having a dynamic system. In the field of language learning, such loops have not been designed because of

the large number of changing factors which influence them or are influenced by them. The factors are illustrated in Figure 3.

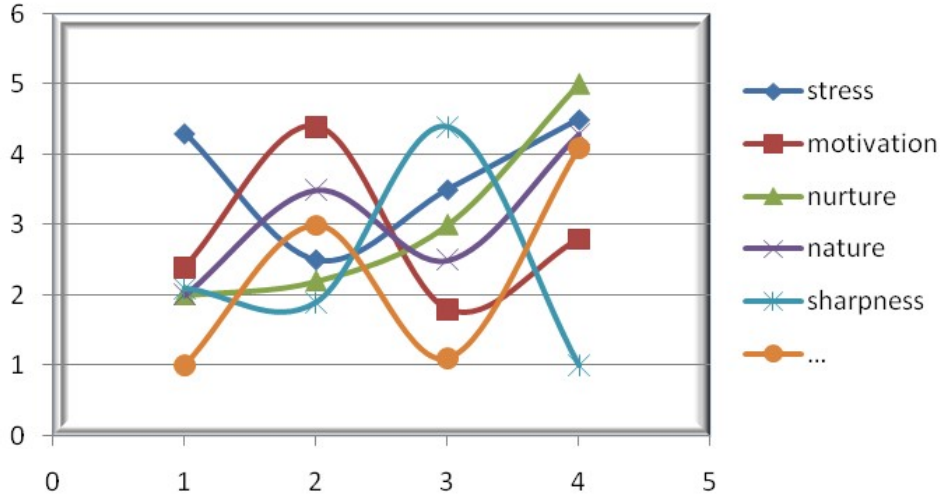

Figure 3. Factors influencing language learning

Since all facets in any segment are somehow connected with one another, any change in one would lead to a change in the representation of the output. Larsen-Freeman (1997) claims that feedback loops can be applied to learning.

Van Lier (1996) believes that learning is not caused by environmental stimuli, nor is it genetically determined as nativists believe. He states that learning is the result of complex interactions between order and chaos which has been called by Waldrop (1994) as "the edge of chaos". Undoubtedly, there is much in common between language and complex non-linear systems. Languages undergo a lot of chaos and order throughout their development and they pass through linear diachronic changes. New forms occur in a language in an unpredictable manner (Tamjid, 2007). Different forms are used with the same meanings.

2. Method

2.1. Participants

Twenty students participated in this study. They were the students of nanophysics at master's level. Of the total twenty students, there were 8 male students and 12 female students aged 23 to 30. They were sophomore majoring in nanophysics at Islamic Azad University of Bushehr, Iran. Almost all of the students had taken some English classes before at some English language institutes.

2.2. Instruments

The instrument utilized in this study was PET proficiency test (Cambridge ESOL Examinations, 2003) which was used to make sure about the homogeneity of the participants. It was used as a screening test at the beginning of this study. This test was comprised of some sections among which only the reading section was selected. The reading section included 35 multiple choice items. The researchers used only the reading section since it was relevant to the purpose of this research study.

Having made sure about the homogeneity of the participants with regard to their reading comprehension ability, the researchers administered the students a test of reading comprehension based on their English course book named "English for the Students of Physics" written by Rahimi & Fathollahi (2016).

2.3. Data collection procedure

All the students took the test in one session. It took them about 15 minutes to answer the questions. After two weeks, all the students took the same test again. However, in the second test, the order of the items was changed. In other words, there were 40 different versions of the same test. In fact, in each version, the first item was changed to another position. Thus, two different versions of the same test were administered to each student in two different sessions. One version was the same for all students and one was different for each student with regard to the order of the items.

2.4. Data analysis

The data were analyzed at two levels: in group and individually. At the group level, the researchers conducted a paired-samples t-test to find out whether the results of the two versions of the exam were significantly different or not. Actually, this was done to see whether sensitivity to initial conditions of the chaos theory had any impact on the students' performance on reading comprehension exams. Having done that, the researchers analyzed the data individually. In fact, the researchers compared the scores of the students to see whether changing the order of the items had any effects on their performance.

3. Results

Table 1 provides the descriptive statistics of the students' performance on the two version of the test. As it can be observed in Table 1, the mean of the students in the second administration of the test is higher than that of the first administration.

Table 1. Descriptive Statistics of Students' Performance on the Two Reading Comprehension Exams

	Mean	Std. Deviation	Std. Error Mean
First administration	**12.41**	**3.21**	**0.72**
Second administration	**16.04**	**2.98**	**0.63**

In Table 2, however, the results of a paired-samples t-test show that the difference was not statistically significant (Sig (2-tailed) = .35) (See Table 2).

Table 2. Results of Paired-Samples T-test for the Students' Performance on the Two Reading Comprehension Exams

T	df	Sig (2-tailed)
-1.47	**19**	**0.35**

According to Table 2, the students' performance was not statistically significant on the two different versions of the exams. However, this does not clarify whether their scores had a statistically significant relationship with one another or not. Therefore, Pearson Correlation Coefficient was conducted. Table 3 shows the result.

Table 3. Pearson Correlation Coefficient for the Students' Performance on the two Reading Comprehension Exams

Scores on the two administrations	**N**	**Correlation Coefficient**	**Sig.**
	20	**0.52**	**0.24**

According to Table 3, there is no statistically significant relationship between students' scores on the two versions of the exam. This means that despite the fact that the overall performances of the students were nearly the same; this similarity is related to the group performance rather than performance of each individual. Therefore, data were analyzed to find out whether there was any difference in scores due to the change in order of test items or not. Table 4 shows the results.

Table 4. Changes in scores on the first and second administration of the exams

No change	Increase in scores	Decrease in scores	Total change
31.57	**50.12**	**25.71**	**75.83**

According to Table 4, the total change in scores was 75.83%. As it can be seen, 31.57% of scores had no changes.

4. Discussion and conclusion

This study aimed at investigating the empirical application of one of the tenets of chaos theory, namely, sensitivity to initial conditions. For this purpose, 20 students participated in this study. The researchers examined the effect of changing the first item that the students received in a reading comprehension exam. The results of the paired-samples t-test showed no significant effect in terms of the group performance. However, regarding the individual differences, the findings indicated 75.83% of students performed better in the second administration of the exam compared to their performance on the first administration of the exam.

According to the concept of sensitivity to initial conditions this effect could be attributed to the first item. It can be claimed that the first item can play a significant role in the students' performance on the subsequent items. For example, if the students know the answer to the first item, it could affect them emotionally and, therefore, this could affect their performance on the following items and their overall test performance would change. That is probably why many tests start with easy items to prevent any negative emotional effect on the test takers. This is especially true in power tests the purpose of which is to measure the test takers' ability level (Bachman, 1990). The finding of this study is in line with that of Ahmadi (2011) who investigated the effect of sensitivity to initial conditions. He concluded that an unimportant initial condition might bring about an unexpected outcome.

It seems that when the order of items is changed, the cognitive load for the test takers will change as well, and consequently it will have positive or negative impacts on their performance. That is to say, since each item demands a certain cognitive functioning, changing the order of items makes the items interact differently leading to the increase or decrease in the difficulty level of the test items. For this reason, the first item can play a significant role in helping the test takers perform better or worse on the whole test. This is in line with the principle of sensitivity to initial conditions according to which slight changes ingrained in a complicated system at a given point can bring about big differences (Harshbarger, 2007).

Test developers can benefit from the findings of this study. They should pay close attention to the order of presenting items in a test. Based on *sensitivity to initial conditions,* a trivial initial condition might lead to a big and unprecedented outcome. Teachers, on the other hand, can make use of this information, so that they are more careful about using the test results. Students, too, can benefit from this fact because such an effect can help them utilize effective strategies in coping with the affective impact of the initial conditions.

5. Limitations of the study

This study like other studies suffers from some limitations. One of the limitations of this study is that the sample size was small, and that is why the independent-samples t-test did not

show a statistically significant difference in the test takers' performance on the two tests. The reason for selecting such a small sample was the unavailability of the participants. Therefore, a similar study could be conducted on a larger sample. Moreover, this study just investigated the effect of sensitivity to initial conditions on students' reading comprehension performance and other skills remained unexplored. Therefore, more studies can be done on other language skills.

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