Learning Behaviour of Artificial Neural Networks and Their Relationship to Human Language Education

人工ニューラルネットワークの学習行動と人間の言語学習の関係

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Abstract

This research investigates relationships between the learning behaviour of ANNs（artificial neural networks）and that of humans, in terms of learning patterns, troughs and peaks when following a course of language study. Similarities are used to predict human behaviour, based on observed characteristics of ANNs.

Learning patterns of children from a Japanese elementary school are compared with that of an ANN. The ANN was trained on language pairs for recognition, while the children used English recognition based vocabulary software（listening, reading, writing）in school and at home.

ANNs are shown to be useful models for human educational planning and can make the curriculum more efficient while keeping interest in the learning course.

Keywords：Artificial Neural Networks in Second Language Education／English Language Software／Learning Behaviour Prediction and Stimuli

1. Introduction

Artificial neural networks are mathematical or computational models that are created to be like, or simulate, biological neural networks, with an ideal ANN being expected to produce the same output as the brain of an animal even in the case of unclear or unfamiliar input, using past experience (learning) and reasoning. Researchers have had this in mind while building ANNs based on biological models and have used the output of biological models as benchmarks against which the output of the ANNs are compared.

ANNs are useful in situations where inputs are not entirely predictable such as areas where general robotic or computer systems have not been able to take the place of humans. Major advantages of using ANNs are their ability to learn from observed data, to be used as a function approximation mechanism, and to be able to do work at high speeds without fatigue. Once built and trained, they can be replicated easily and can be used in parallel, as input to other ANNs, as learning coordinators for other systems, etc. Real life applications include function approximation or regression analysis, classification and pattern recognition, directing robotic manipulators and data processing.

Human language learning is a process that begins at birth for most people. However, second language learning often does not begin until one goes to school, generally at four, six or seven years old for elementary school, or about twelve for junior high school. This study was conducted with children from a private school in Japan where students learn English from six years old.

English language software, based on the CEFR and Cambridge Young Learner Examinations wordlists, was introduced to children aged 10-11 years old. The

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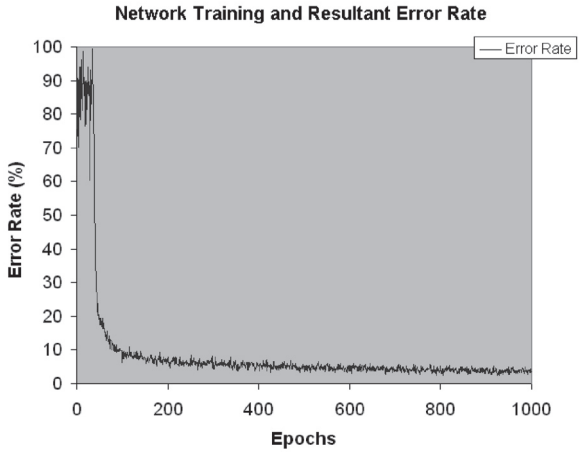
children's usage patterns were observed via automatic database collection, and combined before being compared to the learning pattern of ANNs. At planned intervals, children were stimulated by letters home to parents and surveys, while the ANNs were stimulated by introduction of new or unfamiliar trends as input. Similarities between the children and ANNs were found both during standard learning and at "excitement points", the output produced as a response to an event or stimulus.

Based on observed similarities and on long-term running of ANNs, changes to the children's learning curriculum aimed at increasing effectiveness and efficiency are proposed. The relationship in the case of language learning is the focus of this paper, but it is expected that such relationships are general in education and could be reproduced in other fields.

2. Artificial Neural Network Learning Pattern

A back-feed forward-propagation ANN was created using a reduced version of one put forward by Xu and Rudnicky [1], and was taught a language model using a limited vocabulary set equivalent to CEFR level A0 [2], to A2 using a list available from the Cambridge Young Learners Test preparation software, Wordready [3]. A software based neural network platform, Brainmaker[4], was used to run the ANN, with management dore by an author-coded program in C and C++. No hidden units or bias weights were used in the network, the output was the linear sum of the output units, batch updating was used, and the target value of the j^{th} output unit was set to 1, with other outputs set to 0 when presenting the network with a word pair (i,j). A limitation of the above setup was that overfitting may have occurred, although this can also happen in humans when learning L2 given a limited list [5]. One epoch took less than 20 seconds on a Pentium 4, 3GHz processor with 1.25GB RAM.

The ANN training rate was as below, in Graph 1.

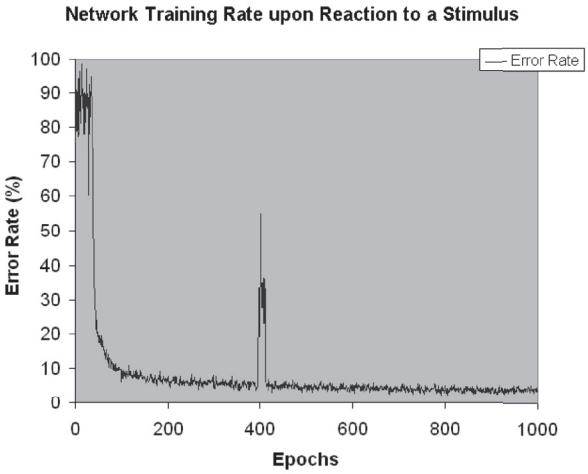


Graph 1　Network Training and Resulting Error Rate (rate of learning activity)

The above is a typical training rate of ANNs, with the error rate approaching about 2％ after initial training and stabilisation (i.e., having learned the input set).

2.1 Introduction of Stimulus to the Network

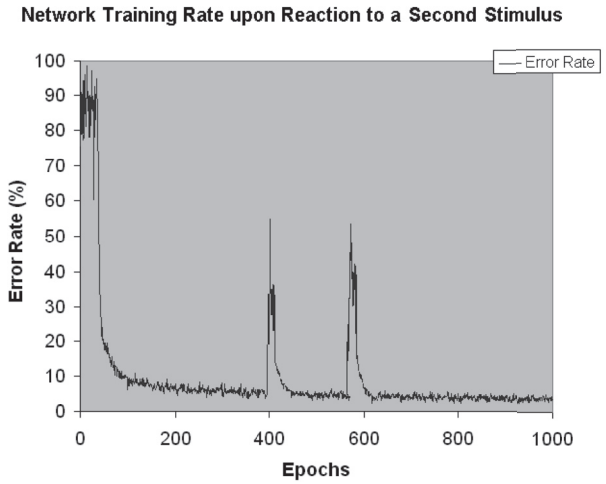
The ANN was rerun and groups of language pairs outside of the word pairs in the initial training were added to the network as input once stability had been reached. The network reacted to these events in an expected fashion, the error rate (or rate of learning activity) increased momentarily before settling again. This stimulation can be seen in Graph 2.



Graph 2　Network Training Rate upon Reaction to a Stimulus

It can be seen that when the ANN is stimulated through a new set of input data, learning activity increases. Stimulation was repeated producing a predictable result of another burst of learning as seen in

Graph 3.



Graph 3　Network Training Rate upon Reaction to a Second Stimulus

It can be concluded that, upon changing the conditions the ANN is used to, learning occurs until the new condition becomes understood. Therefore, the introduction of an event induces learning in the ANN.

3. Human (Child) Learning Pattern

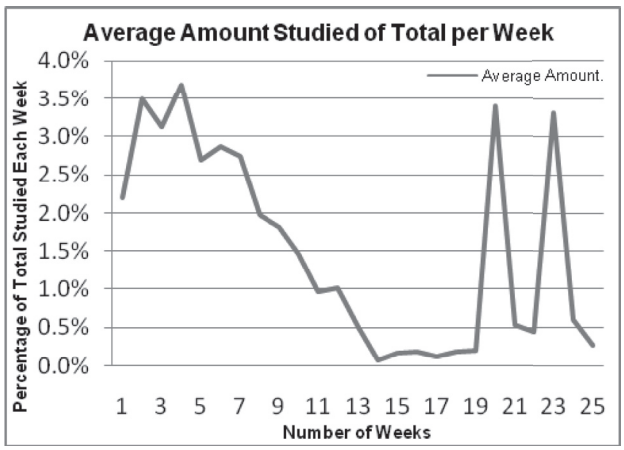
The group of children consisted of 35 boys and girls of average age between 10 and 11, from a private elementary school in Kanazawa, Japan. They were observed (via database updates) for 25 weeks.

All members of the group were given access to the language software, which was an online database of vocabulary based on the Cambridge YLE at CEFR levels A0 to A2. The software presented the data as a game, asking the children to complete a number of levels for each set of words, including typing, click-and-drag, listening, multiple-choice and a card-like layout. Each child had their own user name and password, and data was automatically saved and sent back to the database as they progressed. Learning could take place on any Internet connected computer, and all the content was online, requiring nothing to be installed, reducing potential problems caused by lack of computer know-how in the home. The data could be accessed at any time by the teachers/ researchers, including information such as the date children logged in and how much progress was made. The words were presented to the children in level order, beginning at A0. In this way, children who were not strong at English could work slowly through the A0 words, while more able children could finish the A0 words quickly and move on to A1 and A2.

3.1 Observations of the Elementary School Children Group

The elementary school children used the language software about once a week in the school computer room for 40 minutes. They each had their own computer, and headphone equipment. A letter was sent home to the children's parents with details of the software, and how to use it at home. The children started off well, studying both in school and continuing at home. However, after a few weeks, their pace of learning began to decrease, with almost all of the students having stopped by the 14th week, a holiday period from school, with no increase in at home study shown even after they returned to school.

Stimulation was needed to make the learners study at home again. On the 19th week, a bill was sent to each child's parent for the software subscription fee (of 900 yen). This is a relatively small amount of money but it managed to catch the attention of the parents. The usage of the software increased due to this first "stimulation". On the 22nd week, a questionnaire, in Japanese, was sent to parents asking for their opinions regarding usage of the software. (English version of the questionnaire can be found in Appendix A). Once again, this acted as a stimulus and learning increased. This data is shown in Graph 4, below.



Graph 4　Average Amount Studied of Total per Week

4. Results

i. ANNs and children follow the same learning patterns.

We observed that both the ANN and children have an initial burst of learning, followed by a rapid decrease. The initial high and the subsequent drop are magnified in the ANN, but the trend is the same. The difference between the groups is that ANN become stable at a low after having learned the material, but children become stable at a low even when there is material remaining to be learned.

ii. ANNs and children both react positively to stimuli.

It can be seen that the behaviour of the ANN and the children are similar when reacting to stimuli. This shows us that stimuli are important in the learning process.

iii. The ANN and children both try to return to resting (non-learning) state.

Both sets of data result in a state of non-learning after experiencing a learning phase following stimulation.

5. Conclusions and Discussion

Patterns of learning seen in ANNs have also been shown in children during language learning. This leads us to conclude that ANNs may be used to predict children's learning behaviour and aid planning when designing a curriculum. Stimuli should be built into the curriculum to enable children to get back into the learning phase, especially once they have settled into a class and have gotten used to the contents. It appears that the quality of the curriculum is not the only factor to be considered when planning education, but the existence of stimuli is also important for renewing interest in learning.

Involving the parents of the children is useful as a way to stimulate learning, as has been shown here. Parents need to be informed of what is happening in schools in order to develop a successful learning environment.

6. Limitations of the Research

The language model learned by the ANN and the word list learned by the pupils were not exactly the same. Furthermore, students were learning in three skills of reading, writing and listening, while the ANN was learning in two skills, a reading pattern as an input and a writing pattern as an output.

The children had a school holiday from the beginning of August to September, with another week holiday at the third week of September. This lack of teacher-student contact may have affected their study pattern, although they were asked to keep working during their holiday.

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Appendix

Appendix A. Questionnaire Given to Parents of Elementary School Students

1. Did your child use the software at home?
    a. Yes (How often?) _____
    b. No (Why not?) _____
2. Do you think it is a good idea to use software to teach English in class?
    a. Yes (Why?) _____
    b. No (Why not?) _____
3. Do you think it is a good idea to ask children to use this software at home?
    a. Yes (Why?) _____
    b. No (Why not?) _____
4. Please give your opinion about the 5th grade English program.

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