Available online at www.sciencedirect.com

ScienceDirect

Cognitive Systems Research 27 (2014) 11–24

Cognitive Systems RESEARCH

www.elsevier.com/locate/cogsys

A computational model explaining language phenomena on Korean visual word recognition

Kinam Park [a], Heuiseok Lim [b,*]

[a] Department of Computer Software Engineering, Soonchunhyang University, Shinchang-myeon, Asan-si, Chungcheongnam-do, Republic of Korea
[b] Department of Computer Education, Korea University, Anam-dong 5-ga, Seongbuk-gu, Seoul, Republic of Korea

Received 3 December 2012; accepted 6 March 2013
Available online 10 April 2013

Abstract

How do we understand the meaning of written word? Until recently, the basic mechanisms underlying visual word recognition have remained controversial. To explore the basic mechanisms underlying the human recognition processes, we propose the computational model of visual word recognition which reflects the theoretically presented linguistic processing mechanisms of Korean's visual word processing. In applying the computational model, sets of orthographic units, hidden units, context units and semantic units, were constructed. During the training phase, the weight on the connections between the units were modified using the back-propagation learning algorithm. The model using a lexical decision response time was substituted by a cross entropy values. To evaluate the model, we also conducted behavioral experiments to compare the results of the model performance with human performances. The results show that the proposed model closely simulates Korean visual word processing characteristics such as the word frequency effect, the lexical status effect, the word similarity effect and the semantic priming effect. The model suggests that the computational models should be a valuable tool that can explain the lexical information processing characteristics of the Korean visual word recognition.

Keywords: Connectionist model; Visual word recognition; Lexical decision task

1. Introduction

One of the main tasks the human brain performs is to accept external information which may be experienced or observed easily in a single environment, represent it internally, and then match the mentally represented information with existing information in the brain. Among these processes, the visual word recognition refers to the process that allows one to accept a certain word from visual stimuli, make a mental representation of the word, and recognize its meaning (Rayner and Pollatsek, 1989; Maclennan, 1993; Freeman, 2000). However, because normal adults can perform such processes very rapidly, unconsciously and automatically, it is not easy to identify these processes (Coltheart, 2000). Therefore to the relative simplicity of the processing mechanisms, many cognitive psychologists and psycholinguists have focused on the processes involved in visual word recognition, which is the main focus of this paper. To explain various phenomena associated with the visual recognition processes, cognitive psychologists have suggested various information processing models. The first suggested model was the verbal model which enabled us to explain many language phenomena in terms of information processing. The model contain serially represented mental lexicon concepts, such as a mental lexicon derived by 19th century neurologists (Coltheart et al., 2001). However, the computational models have also attracted much attention recently mainly due to technological developments and the emergence of computational cognitive neuroscience, which is a multidisciplinary study

* Corresponding author. Tel./fax: +82 2 3290 2396.
E-mail addresses: spknn@sch.ac.kr (K. Park), limhseok@korea.ac.kr (H. Lim).

1389-0417/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.cogsys.2013.04.001

integrating computer science, cognitive science and neuroscience. In the computational cognitive neuroscience, the computational model has been designed and implemented using the abstract information and structural processing of cognitive functions in the brain. Thus, the computational model defined that as multidisciplinary study, it can be applied to the efficient and intelligent computer system based on the principle of neuro-cognitive process. Various computational model such as the interactive activation model, the symbolic model and the connectionist model have been developed to simulate the cognitive function of the brain. The computational models based on the principle of the neuro-cognitive process have been used to simulated and predict human visual word processing, due to their advantages over alternative models. The computational modeling has many advantages over the alternative way of expressing theories about cognition (Jacobs and Grainger, 1994). First, an attempt to express any theory about cognition as a computational model immediately reveals many ways in which that theory is incomplete or underspecified, some of which the theorist will not have suspected. Second, once this process has compelled the theorist to fill in the gaps in the theory and an executable model has been created, the adequacy of the theory can be rigorously assessed by simulation. Third, prediction about phenomena regarding experiment of computational model are as of yet, undisclosed (Plunkett et al., 1992). For example, a phenomenon, which is not identified experimentally in the research related with word learning of an infant, was suggested through the computational model. Afterwards, there is a case that it was identified in the research through a real infant. Finally, we can perform an experiment that is difficult to enforce directly on human beings through the computational model (Plunkett et al., 1992). In case of the brain damaged patient, it is impossible or it will be to ask the patient to perform specific tasks which require regions of the brain that are damaged. However, presentation of those conditions is possible through the computational model.

The purpose of this study is to present a descriptive computational model of Korean visual word recognition. While various computational models for low level processes such as vision and the attention mechanism might be directly adapted to those mechanisms in most human beings, models explaining higher cognitive processes like language cannot be directly transformed from one linguistic group (e.g. English speakers) to another linguistic group (e.g. Korean speakers). This is because there are too many phenomena that are presented in one language but are not presented in another. Phenomena associated with one language cannot be explained by models reflecting phenomena associated with another language. Therefore, it is essential to establish a computational model for a particular language, and the model presented in this study is the first computational model reflecting the Korean visual word recognition mechanism explained by cognitive psychologists and psycholinguists. In this model, we presented sets of orthographic units reflecting the Korean orthographic system as inputs, and the semantic outputs were designed after the training phase by using the back-propagation learning algorithm. The organization of this paper is as follows: We briefly introduce the major language phenomena which our model must be able to explain to be a persuasive lexical process model, and describe the related work. We will describe input/output pairs which is used to train the model, model architecture, training procedure. Then, we will show experimental results of whether or not the proposed model can account for the basic findings aimed to simulation. We compared and analyzed the results, and will show behavioral experimental results. Finally, We will present the conclusion and plans for future works.

2. Major language phenomena in lexical decision task

Word recognition can be considered as a kind of mapping process; therefore, the visual word recognition would be a process corresponding the visual orthography with semantics or a process of corresponding the visual orthography with the semantic through phonology information from the perspective. Experimental psychologists have used various paradigm (tachistoscope, naming task, lexical decision task, etc.) to identify the corresponding process. Among them, a research using the lexical decision task (LDT) would be typical. The LDT is a procedure which involves measuring how quickly human classify stimuli as words or non-words. Generally, half of the string sequentially presented is a word, the other half is non-word. A response variable capable of being observed from a participant is response time and a correct response ratio. Researchers have identified a process that visual information is corresponded with a meaning as well as several elements participating in the processes by using the lexical decision task. LDT has been used to investigate word recognition and lexical access, a proper method in the research of the lexical access process through various researches (Taft, 1981). Language phenomena observed by LDT are frequency effect, word lexical status effect, word similarity effect, semantic priming effect, neighborhood effect and so on. The following is the description of typical language phenomena in LDT.

- *The effect of word frequency*: A phenomenon that where more frequent words are recognized faster than less frequent words is called the word frequency effect. Word frequency effect is possibly the most reliable finding in experimental psycholinguistics. It is believed that the effect occurs at the lexical access level and implicates that words are directly represented in the mental lexicon by the number of experienced words in real language usage. The relationship between word frequency and reaction time (RT) measures has been studied extensively (Forster and Chambers, 1973; Carroll and White, 1973; Monsell et al., 1989; Oldfield and Wingfield, 1965; Whaley, 1978).