

Theoretical Exploration of Grammar Perceptron

– Focusing on the Korean ‘-었-’ Perceptron –

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1. Introduction

1.1 Research Purpose

The perspective of language research reflects the way language itself exists. ①From a structuralist perspective, language is regarded as an organic natural entity. It is seen as an observable phenomenon that exists independently of humans. ②From a functionalist perspective, language is considered a relational and dynamic phenomenon that can serve different functions depending on context or situation. It is viewed as part of socio-cultural sign systems that exist for communicative purposes, interacting with situations and socio-cultural codes to fulfill multiple functions. These two perspectives seem to correspond respectively to langue and parole as primary objects of study. ③From the perspective of an individual, language also constitutes a cognitive ability processed in the brain. As the totality of what a human brain acquires and processes, language can be approached from neurobiological or cognitive perspectives.

Human “language” can be studied from all three perspectives, which makes it a highly intriguing research subject. In particular, the third perspective has attracted increasing attention with the development of neuroscience, cognitive science, and computer science, and with the emergence of artificial intelligence. Theoretical exploration of how language is represented in the brain can itself be fascinating.

Artificial neural networks are constructed by connecting perceptrons, which model human neurons. Today, these networks are used to perform various language processing tasks. This raises the question: might the process by which the human brain acquires language resemble the process by which artificial intelligence learns language? If AI’s language learning is similar to that of the human brain, could perceptron models be used to represent linguistic phenomena? Might that even amount to grammatical description? Could we design a model that integrates neural information processing with brain structure and function to describe human linguistic ability? To what extent can traditional linguistics contribute to this?

To test this possibility, I attempt to design a perceptron model that explains the grammatical phenomenon of the Korean element “-었-.”

1.2 Problem Statement

Human grammatical intuition is sometimes unclear. Analyzing the grammatical function of “-었-” reveals such experiences. Consider the following:

- (1) a. 지난 번에 여기서 먹었던 게 뭐였었지? 진짜 맛있었는데...
 What was-was it that I ate here last time? It was really delicious...
 b. 지난 번에 여기서 먹은 게 뭐였지? 진짜 맛있었었는데...
 What was it that I eat-Ø here last time? It was-was really delicious...

Recently, usages similar to (1) have often been encountered in everyday speech. They seem especially common in conversations among women in their twenties, but in fact (1) appears to be widely used. Attempting to analyze the grammatical function of every “-었-” in (1) quickly reveals that it is not a simple matter. This leads to three possible considerations:

- ① Grammar may fail to properly represent logic.
- ② Grammar itself may be changing.
- ③ Intuition may simply be unclear.

The second and third possibilities are likely related.

- (2) a. 진짜 예뻤는데. She **was-is** really pretty. (었느 : looks back)
 b. 진짜 예쁘던데. She **looked** really pretty. (더 : looked back)
 c. 진짜 예뻤었는데. She **had** really **been** pretty. (었었느 : have looked back)
 d. ^{??/*}진짜 예뻤던데. ^{??/*}She **had looked** really pretty. (*었더 / Adj.+ __)
 e. *진짜 예뻤었던데. She had really been pretty. (*었었더)

(2a) and (2b) are interchangeable utterances in the same situation. Then why are (2c) and (2d) not interchangeable? If the “-었-” in (2a) and (2c) is the same, why is (2d) unacceptable? Saying that (2d) is “too much pastness” does not explain why (2c) feels natural. Perhaps speakers fail to distinguish “었었느” from “(었)었느” or “었(었)느,” or perhaps they use them loosely.

Why is our intuition so imprecise? Is it simply a speech error? Or is it because the tense-aspect-modality (TAM) system is too complex to be acquired accurately? Or is the system itself changing to such an extent? If so, why can human language collapse or reorganize? Could this be similar to the probabilistic changes in weight adjustments during neural network learning? If language phenomena can be represented through perceptron connection models, might such variability also be described? These questions arise again.

Therefore, it seems useful to reconsider the concept of the perceptron, the basic unit of artificial neural networks that imitate the brain. One could attempt to

devise a preliminary method of grammatical description by applying the perceptron concept to individual grammatical elements. Next, by focusing on the Korean pre-final ending “-았-,” one could attempt to construct a perceptron model that reflects its grammatical functions and constraints. If some tentative method can be devised, perhaps the next stage of exploration will be possible.

2. Brain Representation of Language

2.1. Representation of Signifiers – Informational Representation of Visual and Auditory Stimuli

The human brain forms various concepts through the process of generalizing peripheral sensory experiences. Perceived peripheral stimuli are processed in specific regions of the brain, and the main linguistic stimuli – visual and auditory – are no exception. Auditory stimuli are processed in the temporal lobe, including Wernicke’s area, while visual stimuli are processed in the occipital lobe (the visual cortex).

The perceived peripheral stimuli are then handled in the association areas near the regions that process them, where they are transformed into more generalized (or categorized) information. The process by which visual and auditory stimuli are represented as visual and auditory information can be described as follows.

(3) Visual Information Representation

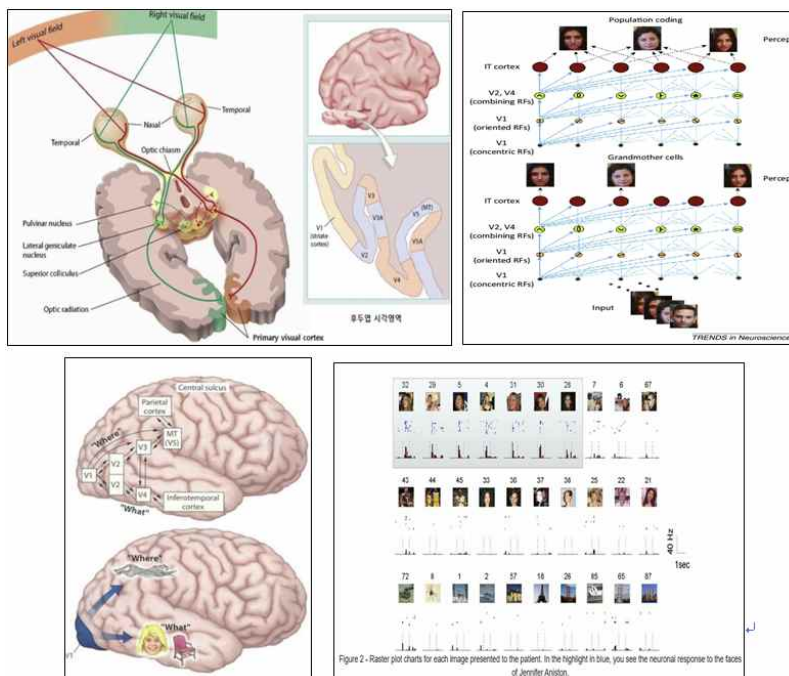
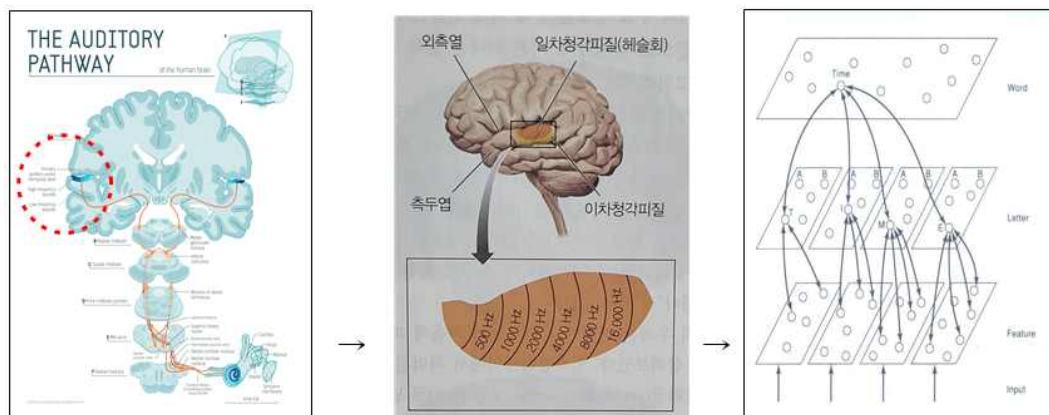


Figure 2 - Raster plot charts for each image presented to the patient. In the highlight in blue, you see the neuronal response to the faces of Jennifer Aniston.

The visual stimuli detected by the optic nerve are transmitted to the primary visual cortex (V1) at the end of the occipital lobe, where they are gradually integrated into increasingly complex visual information. This concentration of information can be understood as a processing stage in which numerous visual features—such as size, shape, and color—are combined.

The fact that there exist specific cells (so-called “Jennifer Aniston cells”) that do not respond to other people’s faces but respond only to the visual stimulus of Jennifer Aniston’s face serves as evidence of this. It shows that, in the hierarchical process of combining peripheral stimuli, certain stimuli become specialized information.

(4) Representation of Auditory Information



In the cerebral cortex of the temporal and occipital lobes, there are neurons that respond to specific acoustic stimuli (hereafter referred to as “auditory stimuli”). This characteristic distribution of neurons suggests, much like the processing of visual stimuli, that auditory stimuli may also be processed into auditory information through a hierarchical concentration of peripheral stimuli.

Phonological units recognized through hearing or graphemic forms recognized visually are, at this stage, not yet combined with any meaning or function. They appear to be limited to the signifier representation within linguistic signs, which are combinations of signifier and signified. The auditory and visual linguistic information processed in the brain’s sensory areas has not yet attained the status of full linguistic signs.

2.2 Distributed Representation of Language

When it comes to the representation of meaning (the signified) in linguistic signs, it is not possible to provide as concrete an explanation as for the representation of signifiers. What is clear is that multiple localized regions of the

brain cooperate to process language, but it is difficult to determine precisely which regions are responsible for particular concepts or grammatical functions. For the formation of minimal linguistic units such as morphemes, or larger units, there does not yet seem to be research as detailed as the hierarchical integration of visual and auditory information.

Nevertheless, there are research findings that can serve as useful design directions for conceptualizing a perceptron-based grammar model. A few points are worth considering.

2.2.1 Distribution of Signifier and Signified

The brain processes specific cognitive functions in localized regions, but each region interacts with others to perform complex cognitive tasks. Wernicke's area and Broca's area are representative localized regions related to language. Early observations suggested that Broca's area was associated with language production and Wernicke's area with language comprehension. More recently, however, diverse studies have been conducted on the functions of other localized regions. Research has accumulated that investigates which brain regions are activated in response to specific linguistic stimuli, using experiments on Brodmann's areas and even more detailed anatomical subdivisions, in order to clarify which regions are involved in particular aspects of language processing.

David W. G. (2012) argued that vocabulary functions as a distributed, parallel interface. Speech proceeds through the dorsal speech pathway, located in the inferior parietal lobe and including the supramarginal gyrus, which serves as an interface between sound and articulation. The ventral speech pathway, located in the posterior superior temporal sulcus (pSTS) and the middle temporal gyrus, is said to function as an interface between sound and meaning.

Emiliano Zaccarella et al. (2017) reported that the structural integration (merge) that forms syntactic structures occurs in the inferior frontal gyrus (IFG): phrase structures activate the BA44 region more strongly, while sentence structures activate BA45. In both types of IFG activation, the posterior superior temporal sulcus (pSTS) was also reported to be active. According to Rita C. et al. (2009: 241), the STS is primarily activated when hearing human voices, making it a region associated with voice recognition.

Taken together, these studies suggest that the representation of signifiers corresponding to specific concepts and the representation of syntactic structures are processed in separate neural networks.

2.2.2 Distributed Representation of the Signified

It is not entirely clear how to define the scope of the signified entity in

linguistic signs. Lexical meaning can be understood as representing specific concepts, while sentence meaning can be seen as representing propositions. However, beyond the functions of grammatical forms or the representation of phrase meanings—which are difficult to interpret as single concepts—there are also pragmatic functions. Traditionally, semantics in linguistics has dealt with these various kinds of meaning. From a semiotic perspective, one might consider the signified entity to encompass everything from grammatical functions to pragmatic effects.

The most straightforward signified entities to consider are the individual concepts that can be recalled in the mind. Linguistically, these are generally represented by single words. Of course, depending on the characteristics of each language, there may be complications such as case markers, but in general, a single concept tends to be represented by a single word. Yet even single concepts vary from concrete to abstract, making it difficult to assume they are represented in a specific brain region. In the visual system, for example, the ventral “what” pathway and the dorsal “where” pathway are distinguished. The way visual stimuli are integrated into perception differs depending on the direction of activation: the “what” pathway represents concepts of concrete objects, while the “where” pathway processes functional and abstract concepts such as spatial location or direction. Abstract concepts like “peace,” “God,” or “scholarship” are not originally formed on the basis of specific sensory stimuli, so it is difficult to predict or expect that their signified entities are processed in any particular visual or auditory region.

The linguistic processing that interprets the sequential arrangement of words as hierarchical structures also does not occur in a single brain region. It is already common knowledge that in the hierarchical synthesis of lexical meaning, Broca’s area is primarily involved in speech production, while Wernicke’s area is primarily involved in comprehension. Pragmatic meaning or literary meaning, beyond syntactic semantic synthesis, is processed in the dorsolateral prefrontal cortex (Ingo Hetrich et al. 2021).

Recently, it has been revealed that, in addition to the language centers of the cerebral cortex located mainly in the left hemisphere, the cerebellum is also closely related to language processing. Interestingly, the cerebellum does not become uniformly activated when the cortical language centers are functioning. Instead, certain regions of the cerebellum are reported to be more or less activated depending on their relation to specific cortical language processes.

Colton Casto et al. (2025) reported that the lobules Crus I/II and VIIb are more sensitively activated by linguistic tasks than by non-linguistic tasks. Similarly, Sabrina Turker et al. (2023) presented comparable observations, summarizing the results of a meta-analysis of 403 studies using brain imaging.

(5) Sabrina Turker et al.(2023: 709, 713 Figure 4, 5)

stimuli and memories distributed across various brain regions constitute the signified entity. However, the brain regions activated during semantic, syntactic, phonological, and prosodic processing are highly likely to be cooperating areas that enable the signified entity to correspond to the signifier entity in language processing. It can therefore be inferred that signified entities, too, are represented in a distributed manner across multiple brain regions.

From the above review, it becomes clear that the representation of signifiers and signifieds in linguistic signs is not processed independently in specific brain regions. All stimuli experienced by humans in connection with linguistic stimuli are stored in a distributed fashion within the biological neural network. Although we cannot observe neural activity at the level of individual neurons in the human brain, we can surmise that language processing occurs within localized regions—that is, within local neural networks.

3. Perceptron Model for Grammatical Description

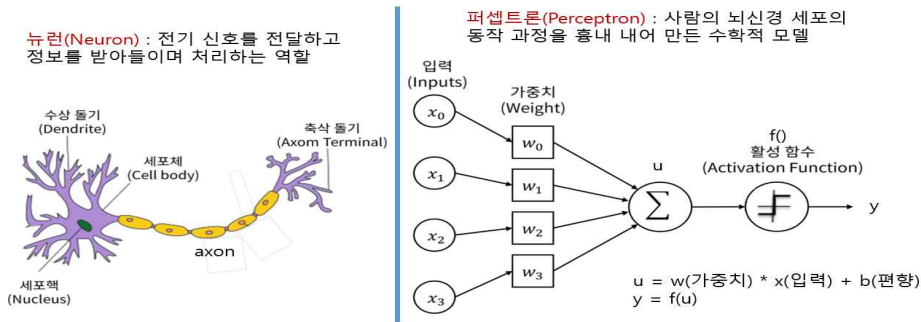
The brain or artificial neural networks are a kind of black box in which the specific information processing procedures cannot be fully identified. In artificial neural networks, the connection structure among perceptrons is designed and therefore known, but the strength of those connections—that is, the weights—are still considered impossible to determine. Likewise, in the brain, it is known that neurons located in certain regions are responsible for specific functions, but there is no way to grasp how multiple regions interact or how information operates within the network structure.

Nevertheless, it is intriguing that perceptrons and CNNs (Convolutional Neural Networks) were developed with inspiration from biological brain structures such as neurons and the visual cortex. The fact that CNN's convolutional layers or the attention layers of transformer architectures can process input information by compressing (abstracting) it hierarchically or sequentially (see Yann Le Cun et al., 1998 for CNN mechanisms; Ashish Vaswani et al., 2017 for attention mechanisms) suggests that the language processing methods of the human brain and artificial neural networks, while not identical, may be considerably similar. The rapid spread of AI usage in everyday life also makes us consider this possibility, since the outputs of artificial neural networks imitate the outputs of the human brain to a significant degree. It seems clear that artificial neural networks designed on the basis of perceptrons are able to mimic human cognitive abilities—such as understanding context and memory—to a fairly advanced level.

3.1. The Operating Mechanism of the Perceptron

The perceptron constitutes the fundamental theoretical concept underpinning artificial intelligence technologies. As an abstraction modeled after the brain's neural cells, the perceptron provides the foundational framework for computation based on weighted connections.

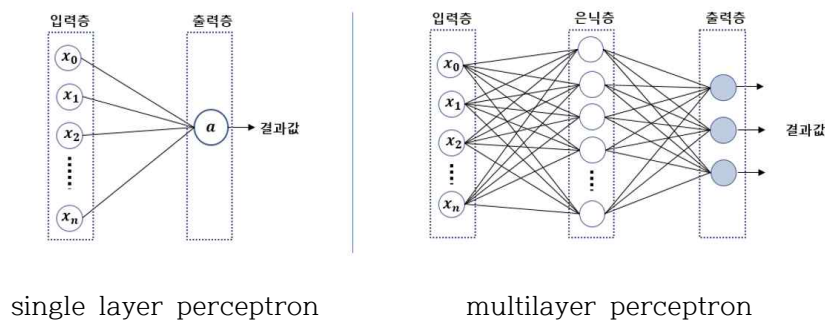
(7) Conceptual Diagram of Neurons and Perceptrons

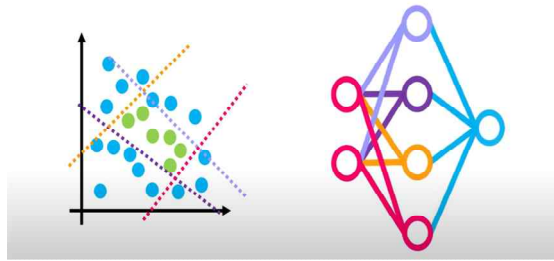


The left side of Figure (7) illustrates the structure of a biological neuron, whereas the right side presents its abstraction as a perceptron model. In the perceptron, each input value x is assigned an appropriate weight, and the weighted inputs are summed. The resulting value is then processed through an activation function, which determines the output. By employing an activation function, the perceptron is able to emulate the phenomenon whereby a biological neuron becomes activated only when the input surpasses a certain threshold.

By stacking perceptrons such as those depicted in Figure (7) in various configurations, one obtains a multilayer perceptron (MLP). As illustrated in Figure (8), the left-hand side demonstrates an example in which multiple single-layer perceptrons are combined to construct a multilayer perceptron.

(8) Multilayer Perceptron, MLP



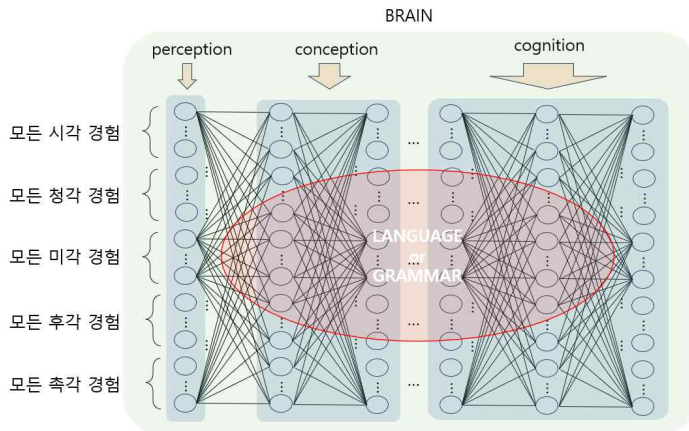


When perceptrons such as those depicted in Figure (7) are stacked in multiple layers, the resulting architecture is commonly referred to as a “hidden layer,” insofar as its internal operations are not directly observable. Each perceptron in the input, hidden, and output layers is connected by edges, each assigned a distinct weight. During the learning process, these weights are adjusted in order to minimize the error between the input and the output. Because the adjusted weights across individual nodes (perceptrons) cannot be fully identified, the intermediate layers are designated as hidden layers. All nodes (parameters, perceptrons) constituting the entire neural network (multilayer perceptron) perform operations analogous to those illustrated in Figure (7) in parallel. Even relatively simple multilayer perceptron structures, such as the one presented below Figure (8), are capable of solving the XOR logical problem and performing classification tasks (see D. E. Rumelhart et al., 1986 for detailed discussion). The ability of multilayer perceptrons to address such problems marked a rapid advancement in artificial intelligence technologies. Contemporary large language models (LLMs) based on transformer architectures likewise represent a variant of multilayer perceptrons.

3.2. Exploring the Grammatical Perceptron

In order to explore methods of representing grammar through perceptrons, it is instructive to compare the mechanisms of artificial neural networks with the process by which humans acquire language. Since the brain itself may be regarded as a network of neurons, it can be conceptualized as a form of multilayer perceptron. As illustrated below, information (percepts) detected in real time through sensory organs is integrated into concepts, which are subsequently combined into higher-order cognitive structures. Language, being one of these cognitive capacities, may thus be understood in the following manner:

(9) Language within the neural network of the brain



Within a network such as that depicted in Figure (9)—namely, the brain—linguistic symbols constitute high-frequency patterns of stimuli that combine perceptual information detected as visual and auditory signs. In this sense, the neural organization representing specific linguistic symbols appears to exist due to a meta-level necessity, insofar as it mediates brain regions responsible for other cognitive capacities. When a particular linguistic symbol is provided as input, non-linguistic inputs are simultaneously introduced. In the process of associating certain multimodal analog information, organized into concepts, with specific linguistic symbols, language acquisition takes place. A given linguistic symbol may correspond to meaning, or alternatively, the occurrence patterns (usage) of a symbol may correspond to meaning; in some cases, even abstract patterns without explicit form (such as word order or semantic roles) may correspond to meaning. At the stage of cognitive development beginning with conceptual learning, not only abstract concepts but also all thought content—including sociocultural behavioral modes that take into account given situations or contexts—are represented and mediated through language, thereby enabling communicative life. If the human brain as a whole is regarded as a single neural network, language would be distributed across the weights within that network. The rules of language and linguistic competence would, in some manner, be represented in a distributed fashion within the neural network referred to as the “brain.”

Then, how is linguistic information distributed within artificial neural networks? In such networks, linguistic information is dispersed across the weights connecting perceptrons. The iterative computational process (learning) of adjusting weights to minimize the error between input and output has been theoretically formalized mathematically. However, because the number of individual parameters corresponding to neurons in an actual artificial neural network is exceedingly large, there appears to be no technical method currently available to precisely identify all weight values. This is due to the necessity of computing complex equations involving partial differentiation of intricate matrices for each parameter

individually. Nevertheless, considering the learning process of the encoder component in transformer-based neural networks, one may gain insight into how linguistic information is connected to individual perceptrons during the process by which children acquire language.

When humans acquire language, they match pairs that combine specific linguistic forms with specific cognitive contents. For instance, when learning the lexical item “puppy,” children are simultaneously exposed to sensory input stimuli such as the puppy itself, photographs of puppies, and videos of puppies, together with the linguistic form stimulus “puppy.” The language learning process consists in distinguishing the puppy from within complex audiovisual stimuli, while simultaneously isolating the linguistic form “puppy” from within complex linguistic stimuli, and then matching the two.

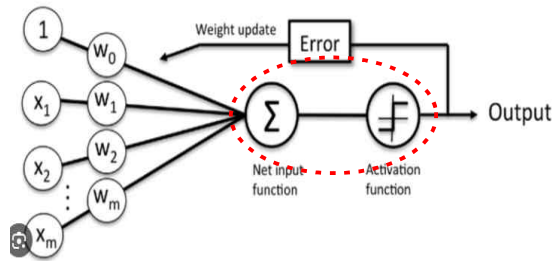
In artificial neural networks, non-linguistic input stimuli (meaning) are not provided as input values; therefore, in order to emulate the human process of meaning processing, attention is performed on masked input values. In the encoder of transformer models, the “masking” technique is employed to obscure a certain proportion of the input values, thereby enabling unsupervised learning based solely on the input information. A vast corpus of linguistic data is supplied as input to the attention process, undergoing an embedding procedure that imitates the semantic relations understood by humans. As a result, the language processing capabilities of artificial intelligence, which we utilize in everyday life, have become possible.

The vast amount of linguistic data provided as input to the encoder of the transformer represents the world of human knowledge (meaning). Based on this data, the artificial neural network undergoes a process analogous to that of children acquiring language, wherein specific linguistic symbols are associated with meaning. This is because extensive human knowledge is embedded during the attention process. Through embedding in natural language processing, semantic interpretation that considers context has become possible, and given that the culmination of this development is the attention model, such an assumption is not implausible. Although it is not possible to identify all the weights among the parameters of an artificial neural network, it is nonetheless reasonable to understand the network as a composite of models such as that depicted in Figure (7).

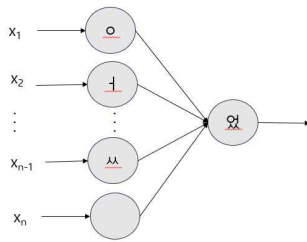
From this perspective, how might a single grammatical element be represented within the entire neural network? Let us consider, as an example, the Korean pre-final ending “았.”

Recalling once again the basic operating mechanism of the perceptron, it is as follows:

(10) Basic Operating Mechanism of the Perceptron



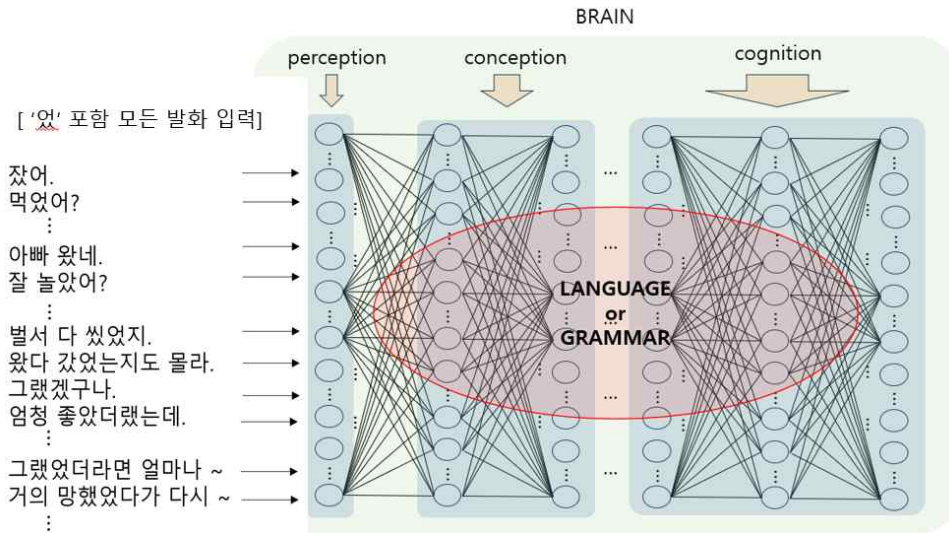
(11) Incorrect Perceptron Representation



In Figure (10), weight adjustment upon the occurrence of error is repeatedly carried out during the learning process of the neural network. The learning process consists in minimizing the error with respect to the correct output by adjusting the weights so that certain input values X_{1-n} are treated as more or less important. Considering this correspondence, representations similar to those in Figure (11), which are confined solely to signifiers, provide little explanatory power. Representing a single perceptron in this manner results merely in a chain of neurons corresponding to signifier representations, even if the entire sentence is represented. Nothing is offered that can explain the grammatical function or constraints of “으(-öss).” It is merely a set of connected nodes.

In conceptual diagrams such as Figure (9), it is therefore necessary to further specify how linguistic inputs are connected somewhere within the hidden layer to form the “-öss” perceptron. See below.

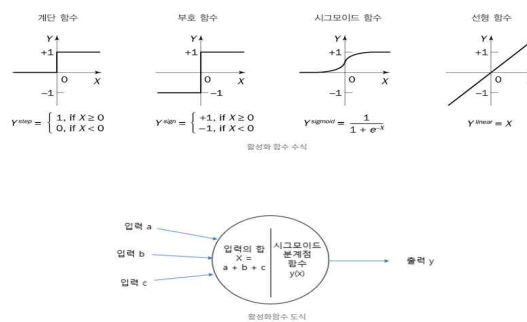
(12) A model of the process by which children acquire the “으(-öss).”



From the simplest utterances heard from parents during childhood to all utterances presented as stimuli up to adulthood that contain “-öss,” the set of such utterances constitutes the learning data (input values) for acquiring the grammar of “-öss.” Through this data, our brain learns the grammar of “-öss” and thereby acquires its grammatical functions and constraints. Accordingly, one may conceive of a perceptron model in which computations vary depending on the grammatical functions (meanings) or constraints that we have acquired.

In artificial neural networks, perceptrons apply various mathematically designed functions to produce output values. Activation functions condition the output by imposing specific constraints on the input values. Through activation functions, the threshold phenomenon of neurons is simulated. When the function of a single perceptron is schematized, it appears as follows:

(13) Activation Function of the Perceptron

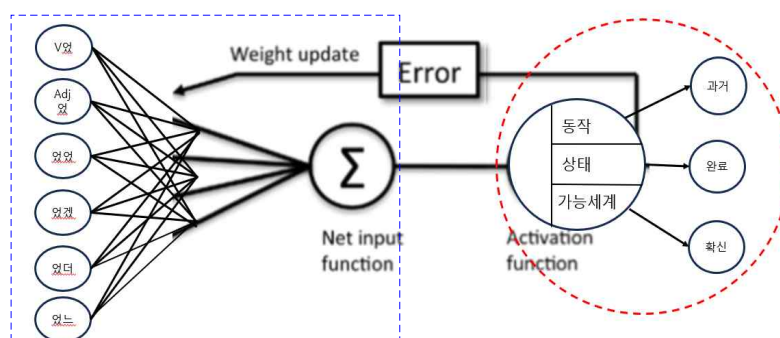


Depending on which activation function is applied to the sum of input values, the output will differ. It may produce only fixed values such as “0, 1” or “0, 1, -1,” or it may yield values within a certain range.

Conditional activation through functions appears appropriate insofar as it

reflects constraints that operate differently according to grammatical functions. Lexical elements representing fixed semantic concepts can be treated as cases in which the signifier directly corresponds to the signified. In contrast, grammatical elements generally exhibit patterned distributive characteristics within sentences with respect to their grammatical functions or associated constraints. The contents described as “rules” or “constraints” are all patterns detected on the basis of such distributive features. These patterns may be regarded as activation functions designed to output specific grammatical functions or constraints. In the case of “-öss,” one might tentatively conceptualize it as follows:

(14) Tentative Perceptron Model of a Grammatical Element



Looking at the red-marked circle in Figure (14), “action, state, possible world” functions as the activation condition, and depending on each condition, “past, perfect, certainty” is output. When the sum of the input values of “-öss” is embedded into the domain of “action,” the grammatical function “past” is produced; when embedded into the domain of “state,” the function “perfect” is produced; and when embedded into the domain of “possible world,” the function “certainty” is produced. To say that the sum of the input values of “-öss” is embedded into the domains of “action, state, possible world” means that the situation represented by the utterance is semantically interpreted as dynamicity, stativity, or modality. Let us now consider the following.

- (15) a. We arrived here yesterday. 우리는 여기 어제 도착했다.
 (Interpretation of temporal-spatial sequence: past)
- b. We have just arrived here. 우리는 여기 이제 막 도착했다.
 (Interpretation of the internal structure of action: perfect)
- c. If we had taken the plane, we would already have arrived here.
 비행기를 탔다면 우리는 여기 벌써 도착했다.
 (Interpretation of situational property: certainty)

All examples in (15) contain the expression “arrived.” The morpheme “-öss,” when

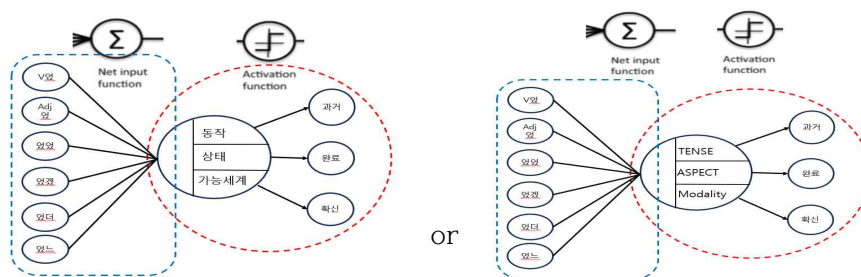
integrated with “arrive,” is analyzed respectively as a marker of “past, perfect, and certainty.” Such analysis depends entirely on the semantic properties of the utterance content. It varies according to whether the utterance concerns the spatiotemporal location of a situation, the internal structure of an action, or a hypothetical situation that could be possible. The grammatical function of “-öss” thus changes depending on the semantic conditions of the utterance content. Since most grammatical elements are analyzed in this manner with respect to their grammatical functions, **the processing represented by the perceptron in Figure (14) may reasonably be regarded as constituting part of Figures (9) or (12).**

The grammatical function of “-öss” cannot be clearly defined as a single functional marker such as tense or aspect. Historically, scholarly perspectives have shifted from the single-function marker hypothesis to the multi-function marker hypothesis. Yet, despite the consensus that a given grammatical element may possess more than one function, it remains difficult to describe this intuitively. At this point, if one employs a **model such as Figure (10), it becomes possible to intuitively grasp that “-öss” has at least three distinct grammatical functions.**

Let us now examine the input section marked in blue in Figure (10). If our brain, similar to an artificial neural network, autonomously learns abstracted patterns based on input values, certain patterns will be extracted. By organizing the information presumed to be reflected in such extracted patterns, the input section may be presented in a more simplified form.

Humans do not acquire a fully established grammar of “-öss” separately. Considering the process of acquiring the grammar of “-öss” as described in Figure (12), in order to grasp its grammar, one must analyze, at the level of word forms, all utterances containing “-öss”—namely, the “-öss” inflected forms of verbs or adjectives—as signifiers, and then extract the signified components that consistently correspond through their relation to meaning, situation, context, and utterance content. For example, the input values in (15) would also have been utilized in learning, and although the linguistic form “arrived” is indistinguishable at the level of signifier, the function of “-öss” is likely to be learned as varying depending on the utterance content and its contextualization. Such a mapping process may be likened to the learning procedure in neural networks, wherein weights are adjusted. Accordingly, organizing the patterns of input values in a way that allows the variation of outputs according to activation conditions to be grasped as intuitively as possible would be helpful. Tentatively, one might conceive of the following model:

(16) Basic Model of the Grammatical Perceptron

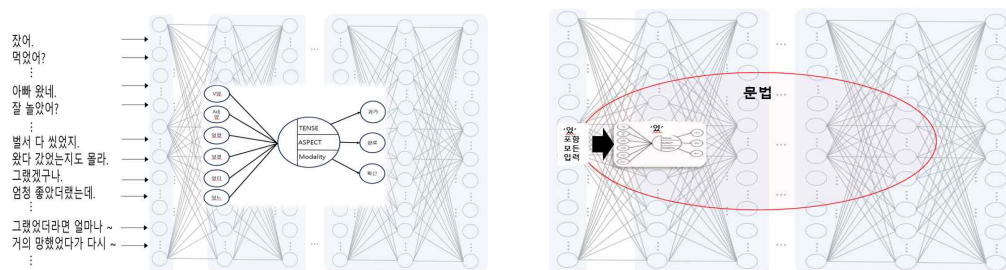


The input section marked with blue dotted lines represents the distribution containing “-öss.” As shown in Figure (16), **the perceptron model of an individual grammatical element consists of three parts: the input section, the activation condition section, and the output section.** The **input section** is described in terms of the distributional patterns in which the individual grammatical marker appears.¹⁾ The **activation condition** section organizes the multiple grammatical categories that a given grammatical element may mark in individual utterances. The conditions under which a grammatical category is activated are specified by the connecting lines between the input section and the activation condition section. The **output section** organizes the final grammatical function or meaning determined according to the activation conditions.

Consequently, models such as Figures (14) and (16) represent, through linguistic predicates, the process by which the brain or artificial neural networks abstract and generalize information while learning and processing all linguistic stimuli containing a specific grammatical element. In reality, it is not a single neuron that represents the grammatical function of “-öss,” but rather the neural network organization that performs the grammatical function, which is schematized as a single perceptron. The relationship between individual grammatical perceptrons and the overall grammar may be understood as illustrated in the following diagram:

(17) The Position of Individual Grammatical Perceptrons within the Overall Grammar

1) The distinction between “V/Adj + -öss” and the chain forms of “-öss” with other pre-final endings reflects the fact that Figure (14) remains a tentative model, and also that children are exposed to grammatical elements contained within word forms as linguistic stimuli during language acquisition. For the present, attention will be directed to the method of representing the perceptron of an individual grammatical marker.



4. The “-öss” Perceptron

Building upon the preceding discussion, let us now examine the specific grammatical phenomena of “-öss” and further elaborate the perceptron model of “-öss.”

4.1. Verb/Adjective + 았(-öss)

Consider the stage in which, based on the inflected forms of verbs and adjectives containing “-öss” at the word level, certain patterns or rules are autonomously discovered.

- | | | |
|-----------------|---------------------|--|
| (18) 아이(Child): | 엄마, 뽀빠. | Mom, Ppoppi. |
| | 엄마(Mom): 뽀빠? | Ppoppi? |
| | 아이: 응, 멍멍이. | Yeah, the doggy. |
| | 엄마: 어디 있어? | Where is it? |
| | 아이: ①{*가/갔어}. 집에. | ①{*go / went (gone)}. Home. |
| | 엄마: 멍멍이가 ②{예뻐/예뻤어}? | Was the doggy ②{pretty / was pretty}? |
| | 아이: 응, ③{예뻐/예뻤어}. | Yeah, ③{pretty / was pretty}. |

The conceptual representation of verbs is knowledge formed on the basis of changes in time and space in reality. In (18)①, the grammaticality of the verb depends on the presence or absence of the suffix -았. As in (18)①, if a past event is represented in the present tense, the result is ungrammatical. In contrast, in cases such as ② and ③, the presence or absence of -았 does not cause problems in communication and poses no grammatical issue. The conceptual representation of adjectives, by comparison, is knowledge formed on the basis of relative temporal-spatial continuity or persistence. If verbal concepts are understood as actions involving movement across time and space, adjectival concepts represent attributes or enduring states of an entity. From the child’s perspective, if the dog was perceived as pretty, then whether at the moment of conversation (present) or at the time of seeing the dog (past), the property of “cuteness” itself does not

change as a concept. This reflects our general knowledge of the world. A dog may cease to be cute, but the concept of “cuteness” itself does not alter. When the dog leaves, a change in location (a spatiotemporal change) occurs, but when the dog is cute, no such change takes place. This explains why the exchanges in (18) at ② and ③ can sound natural.²⁾

다음 예도 보자.

- (19) a. 어제는 급하게 어디 가던라(↗)? (회상)
 I saw where you are hastily going yesterday. (recollection)
 b. 어제는 급하게 어디 갔던라(↗)? (완료+회상) (perfective + recollection)
 I saw where you had gone hastily yesterday.
 c. 어제는 급하게 어디 갔지? (과거 or 완료)
 I saw where you went hastily yesterday. (past or perfective)
- (20) a. 어제는 너무 예쁘던라. (회상)
 Yesterday, (you) looked so pretty. (recollection)
 b. 어제는 너무 *예뻤던라.
 Yesterday, (you) *was looked so pretty.
 c. 어제는 너무 예뻤어. (과거)
 Yesterday, (you) was so pretty. (past)

All of the utterances in (19) presuppose that the addressee’s act of going somewhere is situated in the past, as indicated by the explicit temporal marker “yesterday.” In (19a), the utterance is possible when the speaker actually witnessed the addressee in the process of going. In (19b), the utterance is possible when the speaker did not witness the act but inferred that the addressee must have gone somewhere. In (19c), depending on the context, the utterance may be interpreted in line with either (19a) or (19b). Both (19a) and (19b) are closely tied to the addressee’s epistemic world: whether the addressee was in the process of going or had already gone, the fact is represented as part of the speaker’s consciousness. Whether framed as recollection, evidentiality, or otherwise, the utterance presupposes that the addressee’s action occurred and that the speaker was aware of it. By contrast, (19c) is an utterance that maintains a certain distance from the speaker’s subjective experiential awareness. It does not presuppose the existence of the addressee’s act of going somewhere in the same way, and thus corresponds to a more objective statement compared to (19a) and (19b). The different ways in which the speaker’s awareness intervenes in past situations reveal the two functions of the suffix -었- as realized in verbs.

2) In English, where adjectives cannot independently function as predicates, the use of the copular verb be is required, and consequently tense inevitably plays a crucial role such like *was pretty* in (18). Such differences may arise depending on the grammatical system of each individual language.

(20) likewise concerns utterances about past situations, just as in (19). The conceptual representation of adjectives differs from that of verbs in that, when functioning predicatively, adjectives generally do not take aspectual phases into account. This is because our system of knowledge is structured to reflect the world in such a way that actions are construed with reference to aspectual phases, whereas states or properties are construed without such reference. Compared with (19b), one might expect -았 in (20b) to mark an aspectual property, but in light of the general mode of representing the world, such a procedure is unnecessary. As a result, (20b) constitutes a very rare usage pattern—indeed, an ungrammatical expression. Formally, the paradigms of (19a, c) and (20a, c) are similar. In patterns resembling (19a, c), (20a) can be seen as more closely tied to the speaker’s awareness, while (20c) is less so. In this respect, (20c) is a more objective statement than (20a). The difficulty, however, is that (20b) is awkward, which makes it less straightforward to analyze the function of -았 in adjectives in the same dual manner as in verbs. Just as (19c) can be used either in a subjective recollective context or in an objective statement context, (20c) can also be used in both. Taken together, (19) and (20) show that in verb forms, -았 functions either as a tense marker or as an aspectual marker, whereas in adjective forms, -았 functions only as a tense marker. Expressions such as “방금 (다) 먹었다(I just ate)”, which naturally denote the completion of an action at the present moment, are acceptable. By contrast, expressions such as “방금 (다) *예뻤다(I just was pretty)”, which attempt to distinguish aspectual properties in adjectival concepts, are generally awkward.

4.2. ‘있었(-öss-öss)’

The integrated form -öss-öss appears to require further examination.

- (21) a. 그녀는 너무 예뻤어. ⇨ Pragmatically unmarked
 She **was** so pretty.
- b. 그녀는 너무 예뻤었어. → Pragmatically marked
 She **had been** so pretty. (implies: she is no longer as pretty at present.)

(21) is an example that allows for multiple linguistic interpretations. Compared with (21a), (21b) more strongly conveys the implicature that “she is not as pretty now.” This phenomenon is attributed to the effect of -었었. Some scholars recognize -었었 as a marker of the pluperfect (past perfect), while others interpret -었₂ as a marker of discontinuity. Both views appear to relate to the aspectual properties inherent in -었. For convenience, if we represent -었었 as -었₁었₂, the two existing views seem to treat -었₂ as bearing aspectual features. However, as the following examples suggest, a somewhat different analysis may be possible.

(22) a. 어제는 급하게 어디 갔었지?

I saw where you had gone hastily yesterday. (pluperfect)

b. 어제 그녀는 너무 예뻤었어.

I think that she had been so pretty. (recollection)

(22a) is essentially (19c) with the addition of -었₂, and (22b) is (20c) with the addition of -었₂. Apart from the explicit past marker “yesterday,” (22b) is identical to the utterance in (21b). Since -었₂ already clearly indicates a past situation, this difference does not appear to pose any problem for the analysis. In (22b), the implicature “she is not that pretty today” is also strongly perceived. However, when we look at (22a), which shares the same paradigm but has a verb as its predicate, the implicature is not perceived as strongly. This seems to be related to the way verbal and adjectival conceptual representations structure our knowledge of the world. Adjectival concepts are generally expected to persist, but when a specific spatiotemporal location is explicitly marked, such general knowledge is disrupted. Verbal concepts, by contrast, inherently involve change, so the marking of spatiotemporal location does not trigger a marked interpretation. In adjectival concepts, however, spatiotemporal delimitation does give rise to a marked interpretation. As a result, implicatures derived from logical interpretation are perceived more strongly in adjectival contexts.

By gathering the related phenomena as outlined below, it becomes possible to attempt a new interpretation.

(19) c. 어제는 급하게 어디 갔지?

I saw where you went hastily yesterday. (past or perfective)

(22) a. 어제는 급하게 어디 갔었지?

I saw where you had gone hastily yesterday. (pluperfect)

(20) b. 어제는 너무 예뻤어.

Yesterday, (you) *was looked so pretty.

(21) b. 그녀는 너무 예뻤었어.

She had been so pretty.

In (19c), -었 was noted as being interpretable either as a past tense marker or as a perfective marker. When the temporal adverb “yesterday” is absent, the likelihood of interpreting -었 as a perfective marker increases; when “yesterday” is present, the likelihood of interpreting it as a past tense marker increases. Of course, even with “yesterday” present, depending on the actual situational context, -었 may still be interpreted as a perfective marker. By contrast, in (22a), where -었₂ appears, the construction explicitly marks a past perfect situation. The interpretation of adjectival forms with -었₂ can also be understood in the same

pattern as verbal forms with -였었. Although in (20b) -였 functions as a past tense marker, the tendency in (21b) for the implicature to be strongly perceived indicates that -였었 explicitly marks the past perfect. Thus, whether in verbal or adjectival forms, -였었 consistently serves to explicitly mark a past perfect situation.

An interesting point arises here. In (22a), the utterance does not distinguish whether the addressee was “in the process of going somewhere” or “not in the process of going anywhere.” Whether the aspectual phase of gada (“to go”) was one of ongoing motion or of absence of motion depends on how the actual past situation is interpreted. By contrast, in the case of yeppeuda (“to be pretty”), such interpretive variation does not occur. Consequently, with gasseotda (“had gone”), the implicature is not strongly perceived, whereas with yeppeosseotda (“had been pretty”), the implicature is strongly perceived.

Taken together, it seems clear that -였었 functions as a marker of the past perfect, whether it is used with verbs or with adjectives. In the case of verbs, however, the interpretation of the aspectual phase of the action may vary depending on the actual past situation³⁾, and thus no implicature arises at the present moment. In the case of adjectives, by contrast, there is no room for aspectual-phase interpretation, but an implicature does arise with respect to the present situation. Accordingly, the evidence for equating either -였₁ or -였₂ in (22a) and (21b) with -였 in (19c) and (20b) becomes considerably weaker.

In relation to this issue, -였었 may be treated as an exceptional phenomenon of -였. By “exceptional phenomenon,” I mean that although -였었 functions as a marker of the past perfect, the functions of -였₁ and -였₂ cannot be analytically distinguished. This explanation also suggests that Korean speakers’ intuitions regarding the continuous integrated form of -였 are imprecise. Indeed, whether in verbal or adjectival forms, when we consider utterances containing either -였 or -였었, the situations referred to are consistently past situations. In other words, both -였 and -였었 appear in utterances describing the same type of past reality. Morphologically, -였 and -였었 are distinctly marked, which may have led to the assumption that they must serve different functions. Yet, in actual usage, many utterances with -였었 could logically be expressed with -였 alone, without any problem. The fact that utterances judged as ungrammatical in writing instruction are nevertheless frequently used in everyday speech further indicates

3) A theoretical issue arises when the interlocutor is situated in a past real-world context characterized as “being on the way somewhere,” since the perfect aspect appears to correspond to the progression of the situation. While this may be interpreted as a limitation inherent in representing knowledge of the world through language, it is also worth considering the possibility that such a phenomenon reflects an internal problem within aspectual category theory itself. If the utterance “Were you hastily going somewhere yesterday?” is taken as a precise interrogative expression, the content of the utterance ultimately refers to a past situation.

that speakers' intuitions about the function of -었었 are often inaccurate. Examples such as “그 녀석이 제때에만 도착했~~었~~더라도 이런 일은 없었을 거야(If only he was had arrived on time, this would not have happened”, where an additional -었 is employed unnecessarily, are easy to find.

These actual examples may be taken as evidence that Korean speakers' systematic intuitions are becoming destabilized.

- (23) 가. 지금은 시들었지만 수선화 꽃밭도 참 예~~뻐~~겠더라. 고택을 나오면 추사 김정희의 묘가 있는데 이 일대가 아주 고즈넉하고 차분한 느낌이 들어 힐링하기 좋은 것 같았다.⁴⁾
 나. 저 은행나무도 노랗게 물들면 예~~쁘~~겠구나 공산성에도 배롱나무가 많아 한창일 때 오면 예~~뻐~~겠더라. 끊힌 성벽길을 돌아돌아 다시 성벽길로 진입.⁵⁾
- (24) 가. 지금은 시들었지만 시들기 전에 왔더라면 수선화 꽃밭도 참 예~~뻐~~겠더라.
 나. 지금은 시들었지만 시들기 전에 왔더라면 수선화 꽃밭도 참 예~~쁘~~겠더라.
 다. 지금은 시들었지만 시들기 전에 오면 수선화 꽃밭도 참 예~~뻐~~겠더라.
 라. 지금은 시들었지만 시들기 전에 오면 수선화 꽃밭도 참 예~~쁘~~겠더라.
 마. 지금은 시들었지만 시들기 전에 왔더라면 수선화 꽃밭도 참 예~~뻐~~을 것 같더라.
 바. 지금은 시들었지만 시들기 전에 왔더라면 수선화 꽃밭도 참 예~~쁘~~ 것 같더라.

In (23), what does the -었 appearing in the inflected form of yeppeuda (“to be pretty”) signify? (24) reconstructs the assumed situation of (23a) and then modifies it, as in (23b), by replacing the present-tense condition (“if she comes”) with a past-tense condition (“if she had come”). In (24), forms both with and without the addition of -었 to yeppeugetdeora (“would have been pretty”) are listed. Is there a way to explain the reason for the realization of -었 in each case? Although these are variations of (23), they are in fact forms that are plausibly used in everyday speech. In spoken language, unlike in writing classes where strict grammatical representation is required, utterances such as those in (23), which include an apparently unnecessary -었, may actually be more frequently used.⁶⁾

The emergence of the form ‘-었었’ has rendered it difficult to distinguish the respective functions of ‘-었¹’ and ‘-었²,’ thereby introducing a certain degree of grammatical instability into the system of ‘-었.’ In terms of artificial neural networks, this could be likened to a failure of classification resulting from weight adjustment. Such instability may not be unrelated to the variation in speakers’

4) <https://blog.naver.com/pinkgreen29/223211153957>

5) <https://blog.naver.com/dmlgml76/223208503739>

6) From my perspective, it seems plausible that in the case of the conjectural inflection of 예쁘다(yeppeuda “to be pretty”), forms such as 예쁘겠다(yeppeugetda “would be pretty”) and 예쁠 것 같다(yeppeul geot gata “it seems she would be pretty”) compete within the syntactic buffer. As a result, fused forms like 예뻐을 것 같더라(yeppeosseul geot gatdeora) and 예뻐(었)겠더라(yeppeoss(eot)getdeora) may emerge as the final utterance. It may be that the weighting of -었었 has induced a shift in the system of prefinal endings, producing utterances that reflect speakers’ imprecise intuitions.

judgments regarding the acceptability of forms such as ‘-겠었.’ When enumerating the diverse inflectional patterns that incorporate ‘-었,’ one encounters forms such as ‘-였었, -였었더⁷⁾, -였었느⁸⁾, -였었겠⁹⁾, -었더, -었겠더¹⁰⁾, -었겠느, -었겠었, -었겠었느¹¹⁾, -겠었, -겠었느, -겠었더¹²⁾.’ Excluding the problematic intuitions surrounding ‘-였었’ discussed earlier, most of these integrated forms can be analyzed as marking tense or aspect depending on whether the predicate is verbal or adjectival.¹³⁾

4.3. Modal Logic and ‘-었(-öss)’

The final phenomenon to be considered in relation to the grammatical function of ‘-었’ concerns the modal-logical interpretation of propositions. Let us examine the following case.

- (25) a. 잡히면 죽**었다**. If one were caught, one was already dead.
 b. 잡히면 죽**는다**. If one is caught, one dies.

(25) constitutes an utterance in which the fulfillment of the antecedent renders the content of the consequent a presupposed fact. This raises the question of whether the pre-final endings -었 and -는 can be analyzed as direct markers of factualization. The absence of -겠 or -더 in such contexts suggests that the possibility cannot be entirely dismissed. Moreover, since -었 conveys a relatively stronger degree of certainty than -는, there is room to interpret the two as markers differing in intensity. Restricted to conditional utterances, -었 may be analyzed as “strong factualization,” whereas -는 may be understood as “weak factualization” or “prospective factualization.” Of course, the distinction could alternatively be framed in terms of “strong certainty” versus “weak certainty.”

A similar phenomenon can be observed even when the utterance does not explicitly take the form of a conditional construction. Consider the following

-
- 7) 시청자 여러분과 이야기를 나누는 것 자체가 **좋았었던** 처음 방송을 **켰던** 날처럼 다시 방송을 시작하고 싶다. (<https://www.starnewskorea.com/star/2025/06/09/2025060917423312590>)
- 8) 진태현은 "시은씨가 9개월 동안 우리 태은이를 잘 품었지 않나. 임신 준비할 때 무엇을 먹**었었**느냐"고 물**었**다. (https://www.chosun.com/entertainments/enter_general/2023/04/13/3ATRYCXA3YCKNJXJS3IS7ZUNJY/)
- 9) 맘먹고 **앵벌** 몇일하면 기본적으로 10강셋은 무난히 **맞혔**겠지. (<https://www.inven.co.kr/board/tera/2527/20949>)
- 10) 멘델스존이 이 연주를 듣는다면, 무덤에서도 신나서 춤을 **춰**겠더라. (<https://blog.naver.com/novemberagain/223932401646>)
- [출처] 2025.07] Vora 실내악단- 멘델스존 8중주작성자 노뎀버 (<https://blog.naver.com/yoons519/223967217450>)
- 11) 그럼에도 불구하고 정치적 부담을 이재명 대통령이 **물**렸**겠**었느냐. 알았을 겁니다. (https://www.ytn.co.kr/_ln/0103_202508181242185182)
- 12) 새해 다짐으로 블로그와 유튜브를 **하**겠**었던** 저는 포항 라멘 맛집을 첫 번째로 **다**뤄보**겠**다고 **했**었다죠! (https://blog.naver.com/l_duck/223534440261)
- 13) For a more detailed analysis, see 최정진(Choi Jeong-jin 2012).

examples.

(26) (While observing a colleague following behind near the mountain summit)

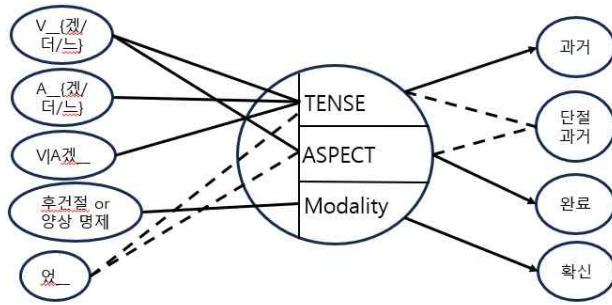
- a. 이제 도착했다.(arrived) Now, [he/she] has arrived.
- b. 이제 (곧) 도착한다.(arrives) Now, [he/she] is arriving (soon).
- c. 이제 거의 도착했다.(arrived) Now, [he/she] has almost arrived.

(26a) demonstrates that the use of -았 conveys a stronger sense of factualization compared to the present form in (26b). Consequently, an utterance such as “Now, soon [he/she] has arrived” is impossible. The present form encompasses a broad spatiotemporal domain of incompleteness or non-past, thereby expressing only a degree of “prospective factualization.” By contrast, -았 signals “factualization” in the sense of strong certainty. This raises the question of whether -았 can be regarded as a direct marker of factualization or strong certainty. Examining (26c) within the same utterance situation, the presence of 거의 (“almost”) alters the interpretation of the completeness of ‘arrival.’ From the aspectual perspective of ‘arrival,’ (26c) is less complete than (26b). However, although the interpretation of the terminal phase of ‘arrival’ changes, the degree of factualization—namely, the level of certainty—remains constant. Thus, it is not implausible to analyze -았 as functioning in this way. Strictly speaking, the utterance in (26c) does not correspond to a real-world situation that matches the completed state marked by -았. Rather, it represents a situation construed as completed, not an actual arrival but an assumed arrival. Whether or not the aspectual profile of ‘arrival’ is modified by 거의, the situation remains one of assumption—that is, a hypothetical situation. This, moreover, aligns with the semantic properties of conditional utterances. In sum, -았 may be understood as functioning to mark factualization or certainty in the apodosis of conditionals or in utterances concerning possible worlds.

4.4. Interim Conclusion

Synthesizing the foregoing discussion, the grammar of -았 may be schematized in terms of a perceptron model as follows.

(27) The ‘-았’ Perceptron



In the input layer, -었 appears in both verbal and adjectival inflectional forms. In verbal inflections, it fulfills either a tense or an aspectual function, but the determination must be made logically in relation to the connection between the utterance and the real-world situation: it cannot be resolved by purely linguistic criteria. In adjectival inflections, -었 functions as a tense marker. Whether in verbs or adjectives, when -겠었 occurs in the predicate, -었 serves as a tense marker (이병기 Yi Byung-Ki, 2006). The logical modality of a proposition is associated with -었 when it appears in conditional clauses or utterances concerning possible worlds. In the case of -었었, dashed lines are used to indicate the interpretive confusion between tense and aspect. Although this form exhibits such ambiguity, its meaning can be understood as “a past perceived as discontinuous from the moment of utterance.” The presence of dashed-line elements within a single perceptron model may be interpreted as reflecting areas of uncertainty in the speaker’s grammatical intuition. If unique or emergent usages are observed that resist patterning, additional input nodes may be added to accommodate those forms.

5. Toward a Perceptron Grammar Model

One possible line of inquiry is to consider how individual perceptrons for separate grammatical elements might be combined in order to describe expressions at the level of phrases or clauses. Among the inflectional forms containing -었 that have been observed with increasing frequency in recent usage is -었어서.

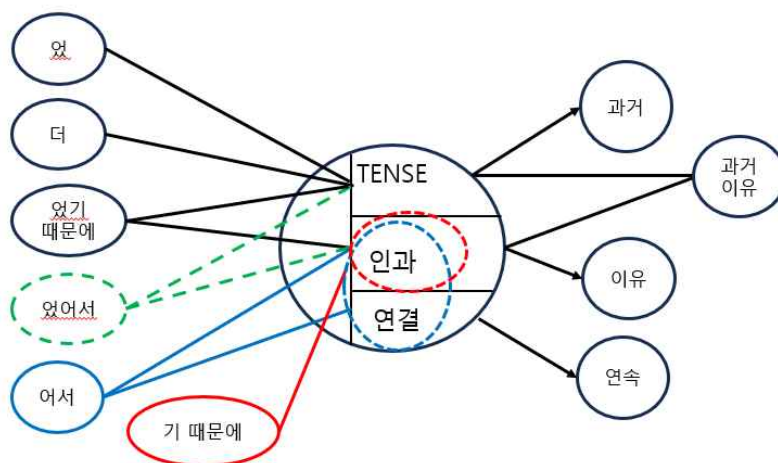
- (28) ㄱ. 저희는 우메다에 숙소를 잡았어서 우메다역 근처 야키토리 맛집인 타카토리 도야마를 가기로 했어요.¹⁴⁾
 ㄴ. 저는 낮에 갔을 때 너무 귀여웠어서 저녁에 한번 더 갔는데요. 거리가 활기차고 귀여워서 낮/밤 언제 가도 예쁘고 재밌더라고요.¹⁵⁾

14) <https://blog.naver.com/sy5316/223482612983>

15) https://blog.naver.com/strider_/224031190139

According to the author's intuition, the expression still feels awkward, yet it has recently been encountered with some frequency. Among the various functions of -어서, it appears that -였 has begun to occur in the usage that denotes causation or reason. In other functions of -어서, which are related to the continuity of situations, -였 does not readily appear. By contrast, the construction -기 때문에, which is used solely as a marker of causation or reason, imposes no restriction on the occurrence of -였. This difference can be readily captured within the perceptron model presented below.

(29) '였어서' and '였기 때문에'



This represents a consolidation of the perceptrons for -였, -어서, and -기 때문에, with only the necessary components retained. Red markings indicate the -기 때문에 perceptron, while blue markings distinguish the -어서 perceptron. When the -였 perceptron is combined with the -기 때문에 perceptron, the result may be interpreted as “past reason,” that is, a past situation presented as the cause. Methods for describing such semantic composition could also draw upon the representational techniques of formal semantics. This constitutes a natural expression. To achieve such semantic composition, however, the activation conditions marked in blue involve not only causation but also connection. The existence of the “connection” category interferes with the independent integration of the categories of causation and tense. The awkwardness of -였어서 may thus be attributed to the processing burden imposed by the “connection” component. In other words, as additional weighted connections are introduced, the computational load increases, and integrations that require more complex category-to-category calculations are grammatically constrained. Nevertheless, as illustrated in (28), if the new usage gradually becomes established, one may interpret the strengthening of the green-marked connections in (29) as an increase in weight. In the process of linguistically representing the semantic composition “past + reason → past reason,” it is possible that language reality is shifting toward a strengthening of

the causal marking function of -어서, to the point where it may be processed in a manner similar to the -기 때문에 construction.

Artificial intelligence technologies based on complex computational structures—matrix operations of such scale that they cannot be apprehended at a glance—are capable of imitating human cognitive abilities to a considerable degree. However, understanding how such imitation is possible is grounded in mathematical models, which imposes limits on intuitive comprehension. Even if one possesses the knowledge to understand the mathematical models, the sheer magnitude of the vectors employed in the matrices makes precise understanding impossible. Employing perceptron models that are more intuitively accessible is therefore highly convenient for aiding comprehension. Furthermore, as efforts accumulate to explain complex linguistic phenomena through such models, it may eventually become possible to estimate the scale of predicates employed in the input layer, activation conditions, and output layer.

Could a sentence-representation perceptron become a comprehensive descriptive model that allows an intuitive grasp of patterns of linguistic integration? What methods are available for representing the integration procedures among activation categories corresponding to semantic composition processes? Can hierarchical structures also be represented within a perceptron model? Is there a way to describe the manner or process of combining perceptrons in a more intuitive fashion? Might such an approach provide insights for the development of new algorithms in the field of language processing? How should differences in the linkage between linguistic systems and non-linguistic cognitive systems (such as agglutinative vs. inflectional structures) be handled? In languages such as inflectional or isolating types, where the internal distribution of functional load differs, how could the model be applied? Many other questions may arise as well. There remain numerous issues to be considered in the pursuit of grammatical description through perceptrons. Since this is an initial attempt, such questions are natural and will need to be addressed in the future. If answers to these questions are eventually obtained, they may provide clues for designing artificial intelligence architectures appropriate for language processing. If perceptron models differ across languages in representing sentence structures or constituent elements, such differences could also be reflected at the design stage of AI systems.

참고 문헌

307번역랩, 류광 공역(2025), 사바슈 이을드름 & 메이삼 아스 가리지헤낙홀루, 『마스터링 트랜스포머』, 위키북스.

- 김모세 역(2024), 아즈마 유키나가, 『파이토치와 구글 코랩으로 배우는 BERT 입문』, AK커뮤니케이션즈.
- 류 광 역(2019), 차루 C. 아가르왈, 『신경망과 심층학습』, 제이펍.
- 류 광 역(2021), 스투어트 러셀 & 피터 노빅, 『인공지능 현대적 접근방식』(4판), 제이펍.
- 성기철(1974), 경험의 형태 {-었-}에 대하여, 『문법연구』 1, 문법연구회, 237~269쪽.
- 이병기 Yi, Byung-Ki(2006), ‘-겠-’과 ‘-었-’의 통합에 대하여, 『국어학』 47, 국어학회, 179~206쪽.
- 임희석·고려대학교자연어처리연구실 (2020), 『자연어처리바이블: 핵심이론, 응용시스템, 딥러닝』(수정판), 휴먼사이언스.
- 전희원·정승환·김형준 역(2021), 수다르산 라비찬디란, 『구글 BERT의 정석』, 한빛미디어.
- 최정진 Choi, Jeong-Jin(2012), 「한국어 선어말 어미의 시제성과 양태성 연구」, 서울대학교대학원 박사학위논문.
- 최정진 Choi, Jeong-Jin(2020), 선어말 어미 ‘-었-’의 의미와 시상체계 연구에의 시사점, 『어문학』 148, 한국어문학회, 99~130면.
- Ashish Vaswani, Noam Shazeer, Niki Parmar, Jakob Uszkoreit, Llion Jones, Aidan N. Gomez, Lukasz Kaiser, Illia Polosukhin (2017). Attention is all you need. *Neural Information Processing Systems 30*, pp. 5998~6008. (<https://doi.org/10.48550/arXiv.1706.03762>)
- Rita Carter, Susan Aldridgeet, Martyn Page, Steve Parker, Christopher D. Frith, Uta Frith, Melanie Shulman (2009), *The human brain book*, London: Dorling Kindersley.
- David E. Rumelhart, Geoffrey E. Hinton and Ronald J. Williams (1986), Learning representations by back-propagating errors, *Nature 323*, pp. 533~536.
- David H. Hubel and Torsten N. Wiesel (1959), Receptive fields of single neurons in the cat's striate cortex, *Journal of Psychology 148*, pp. 574~591.
- David H. Hubel and Torsten N. Wiesel (2005), *Brain and Visual Perception: The Story of a 25-Year Collaboration*, Oxford University Press.
- David W. Gow Jr (2012), The cortical organization of lexical knowledge: A dual lexicon model of spoken language processing, *Brain & Language 121*, pp.273-288. (<https://doi-org.ulibx.ulsan.ac.kr/10.1016/j.bandl.2012.03.005>)
- Emiliano Zaccarella, Lars Meyer, Michiru Makuuchi and Angela D. Friederici (2017), Building by Syntax: The Neural Basis of Minimal Linguistic Structures, *Cerebral Cortex 27*, pp. 411-421.(doi:10.1093/cercor/bhv234)
- H. S. Lee (1991), *Tense, aspect, modality: a discourse-pragmatic analysis of verbal affixes in korean from a typological perspective*, Ph. D dissertation in UCLA.
- Ingo Hertrich, Susanne Dietrich, Corinna Blum & Hermann Ackermann (2021) The Role of the Dorsolateral Prefrontal Cortex for Speech and Language Processing. *Frontiers in Human Neuroscience 15:645209*. (doi: 10.3389/fnhum.2021.645209)
- Jürgen Schmidhuber (2015), Deep learning in neural networks: An overview, *Neural Networks 61*, Elsevier, pp. 85-117.

(<http://dx.doi.org/10.1016/j.neunet.2014.09.003>)

- Levelt, W. (1999) Producing spoken language: a blue print of speaker, Brown et al. eds., *The Neurocognition of Language*, Oxford UK: Oxford University Press.
- Yann Le Cun, Bernhard Boser, John S. Denker, Donnie Henderson, Richard E. Howard, Wayne Hubbard, and Lawrence D. Jackel, (1989), Handwritten Digit Recognition with a Back-Propagation Network, *NIPS'89: Proceedings of the 3rd International Conference on Neural Information Processing Systems*, MIT Press, pp. 396~404.
- Yann. Le Cun, L. Bottou, Y. Bengio and P. Haffner, (1998), Gradient-based learning applied to document recognition, *Proceedings of the IEEE, vol. 86, no. 11*, pp. 2278-2324. (doi: 10.1109/5.726791.)
- Phu Mon Htut, Kyunghyun Cho, & Samuel Bowman (2018), Grammar Induction with Neural Language Models: An Unusual Replication. In *Proceedings of the 2018 Conference on Empirical Methods in Natural Language Processing*, Association for Computational Linguistics, pp. 4998-5003.
- Yann LeCun, Yoshua Bengio, and Geoffrey Hinton(2015), Deep learning, *Nature 521*, pp.436-444. (<https://aclanthology.org/D18-1544/>)
- Yikang Shen, Zhouhan Lin, Chin wei Huang, & Aaron Courville (2018), Neural language modeling by jointly learning syntax and lexicon. In International Conference on Learning Representations. (<https://doi.org/10.48550/arXiv.1711.02013>)