Chinese and Spanish readers: Are there cultural differences?

A comparative study performed with Chinese and Spanish university students on syntactic and semantic processing in the native language and the perception of scenes by an eye-tracking procedure

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Tesis doctoral

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Junio de 2019

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经过大海的一番磨砺，卵石才变得更加美丽光滑。

Después de las olas del mar, la piedra se vuelve más hermosa y suave.

After sea waves, the pebble becomes more beautiful and smooth.

Appreciations

Este trabajo no hubiera sido posible sin la ayuda de muchas personas que directamente o indirectamente estuvieron implicados en le desarrollo del mismo.

En primer lugar, quisiera agradecer a mi **directo**r de tesis, el **Dr. José Antonio León** por su apoyo, tanto personal como académico. Gracias por sus valiosos comentarios, siempre acertados, puntuales y expeditos, y por su gran paciencia que me han alentado desde el inicio a seguir adelante y a hacer las cosas de la mejor manera posible. ¡Muchas gracias!

En segundo lugar, también quiero extender este agradecimiento a **José Manuel Igoa** y **Ricardo Olmos,** que no sólo me han apoyado en todo, dentro y fuera de la tesis, sino que, además, con sus sugerencias siempre han conseguido sembrar la semilla y encauzar mis experimentos de forma que se han convertido en ideas brillantes e innovadoras. ¡Gracias!

A **Inmaculada Escudero, Marcos Ruiz, Lorena Alicia M. Arnal, José Ángel Martínez** y **José David Moreno**, cuyos ánimos durante todo el proceso, críticas constructivas e ideas diferentes les han dado un aire nuevo a las investigaciones y los procesos de la tesis. ¡Gracias!

Finalmente, quiero hacer un agradecimiento especial a **mis padres**, **Yunkun Zheng** y **Huimin Zhang,** que *siempre* han estado ahí. Infatigables e incansables, siempre están allí. Son y han sido siempre mis mejores amigos. Desde que era pequeña hasta ahora, siempre me han apoyado en todas las decisiones que he tomado, incluso en las más raras o extravagantes, siempre me han defendido, me han ayudado y me han dado fuerzas para seguir adelante, para conseguir mis metas y para luchar por mis sueños, sin dudar de mí una sola vez, sin desfallecer, ni siquiera en los momentos más difíciles. Ahora, por fin, he llegado a eso que quiero ser de mayor. Mucha gente me ha ayudado en el camino, pero sin ellos, sus apoyos y sus esfuerzos durante toda mi vida, especialmente estos años tan lejos de ellos, esto no habría sido posible. Ahora, por fin, estoy en ese paso, en ese punto en el que miro hacia atrás y solamente os puedo decir: ¡Gracias, y os quiero mucho, mucho!

我要特别感谢一下我的父母，这些年，从小到大，他们一直都在我身边，不知疲倦地永远支持我，帮助我，对我不离不弃。 他们一直都是我最好的朋友，我们无话不谈。十几年来，一直在国外的我，也没有陪在他们身边，但他们还是一直支持我做出的所有决定，即使是那些奇怪的，不着边际的，他们也都支持我。他们总是给予我前进的力量，让我去实现我的理想，为我的梦想而奋斗，他们就是我最坚强的后盾。现在，我终于长大了，也达到了我想要的状态，我只想说，如果没有他们这一生的努力和支持，我不可能是现在的我，最好的我。最后，当我回头看这一切的时候，我只想说：谢谢你们，我永远爱你们！

郑昫燃

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Resumen

La comprensión lectora implica diferentes niveles de procesos cognitivos complejos. Además de la ortografía, el procesamiento fonológico y semántico de palabras individuales, los lectores también tienen que construir una representación del significado coherente mediante la integración de las propiedades semánticas de cada palabra, de acuerdo con ciertas reglas sintácticas. Reconocer una palabra no significa entenderla. En ciertas ocasiones, escuchamos o leemos palabras que son familiares para nosotros, sabemos que son palabras reales o que hemos escuchado en otras ocasiones, pero no podemos recordar sus significados. Esto sucede especialmente con palabras de muy baja frecuencia.

En el presente estudio, realizamos tres experimentos entre estudiantes universitarios chinos y españoles de la Universidad Autónoma de Madrid (UAM) sobre las oraciones experimentales en su idioma nativo y sobre la percepción de escenas a través de imágenes. Tratamos de analizar las posibles diferencias en el patrón de movimientos oculares entre los lectores chinos y españoles, para después cuestionarnos si estas diferencias se deben a diferencias culturales o a las diferencias lingüísticas y de escritura del idioma como, por ejemplo, las diferentes reglas sintácticas, los diferentes sistemas de escritura (caracteres chinos y letras), etc.

En un primer experimento se analizó el curso temporal del procesamiento sintáctico y semántico cuando estudiantes chinos leían frases en su idioma nativo. Los movimientos oculares de los lectores fueron registrados siguiendo el paradigma utilizado por Yang, Wang, Chen & Rayner (2009), donde se examinó la relación entre una palabra crítica de un solo carácter (Critical Word, CW en lo sucesivo) y el contexto de la oración. Se desarrollaron tres tipos de condiciones: congruente (CON), alteración semántica (SEM) y alteración semántica y sintáctica (SEM + SYN). Treinta y cinco estudiantes universitarios nativos chinos de la UAM participaron en este estudio. Se llevaron a cabo dos conjuntos de análisis: análisis basado en caracteres y análisis basado en regiones. Los datos de movimiento ocular no mostraron diferencias en el factor de condición en el procesamiento de primer paso, solo se registraron en la CW con respecto a CW-2 (dos palabras antes de la palabra crítica) y CW-1 (una palabra antes de la palabra crítica) en la duración de la primera fijación, así como las medidas de *Gaze duration*. Sin embargo, hubo un efecto significativo sobre la condiciósn en

el procesamiento posterior, en regresiones en la condición de alteración semántica + sintáctica en comparación con la condición congruente. Estos resultados sugieren que los lectores chinos pueden detectar los efectos de una alteración semántica + sintáctica y que el procesamiento de la información semántica y sintáctica es distinto tanto en la lectura de primer paso como en la de segundo paso.

En un segundo experimento aplicamos este mismo patrón del experimento anterior, traduciendo las oraciones al español. Todas las reglas y el procedimiento del experimento fueron idénticos al anterior, donde se examinó la relación entre una sola palabra crítica y el contexto de la oración. Treinta y tres estudiantes universitarios nativos españoles de la UAM participaron en este estudio. Los datos de los movimientos oculares mostraron que los tiempos de la lectura de primer paso fueron significativamente más largos para la región objetivo (Target Region) en las dos condiciones de alteración (SEM y SEM + SYN) que en la condición congruente (CON). Además, la alteración semántica + sintáctica causó una interrupción más intensa que la alteración semántica pura, como se refleja en *first-pass reading time* fueron más largos para la región objetivo (Target Region) y en *go-past times* que fueron más largos para la región objetivo y la posterior de la región objetivo en la primera condición que en la última condición. Estos resultados sugieren que los lectores españoles pueden detectar inmediatamente los efectos de, al menos, una alteración semántica y que el procesamiento de la información semántica y sintáctica es distinto tanto en la lectura de primer paso como en la de segundo paso.

En un tercer experimento se examinó las posibles diferencias culturales entre el español y el chino en cuanto a la rapidez con que realizaban los movimientos oculares ante la presentación de imágenes fotográficas. Los participantes, chinos y españoles, examinaron escenas fotográficas mientras realizaban una tarea de calificación de preferencias. Para cada escena, a los participantes se les presentaron dos imágenes en el mismo monitor: una versión normal y otra inusual / extraña. No solo hubo diferencias entre las versiones normales y extrañas de las escenas, según el tiempo inicial de fijación en la región de interés (ROI) y el tiempo posterior de fijación de la ROI, sino que también hubo evidencia de diferencias culturales al ver cualquier tipo de escena entre participantes chinos y españoles.

En general, la presente investigación indica que, a pesar de las grandes diferencias entre los sistemas de escritura alfabéticos y los caracteres chinos, hay importantes similitudes en el procesamiento de oraciones entre los españoles y los chinos. Primero, las infracciones semánticas y sintácticas pueden detectarse de inmediato, aunque el chino se considera un lenguaje altamente dependiente del contexto. En segundo lugar, aunque una alteración sintáctica siempre va acompañada de una alteración semántica, la evidencia de los datos de eye tracking confirma que las alteraciones sintácticas producen una interrupción más grave que las violaciones semánticas puras. Se necesitarán más estudios para dilucidar el procesamiento más fino de la información semántica y sintáctica en la lectura del chino. El presente estudio al menos indica que estos dos tipos de procesamiento pueden iniciarse inmediatamente y disociarse entre sí en ciertas condiciones tanto en la lectura del chino como en el español. Los datos de la visualización de la escena muestran que (i) las regiones extrañas atraen las fijaciones un poco antes que las regiones normales y (ii) los participantes observan más las regiones extrañas que las regiones normales. Más importante aún, nuestros resultados no son consistentes con los reportados por Rayner et al. (2007), Evan et al. (2009) y Yang et al. (2009) puesto que en estos estudios no encuentran diferencias culturales importantes en el control oculomotor durante la percepción de la escena.

Abstract

Reading comprehension involves different levels of complex cognitive processes. Besides orthographic, phonological, and semantic processing of individual words, readers also have to build up a coherent meaning representation by integrating the semantic properties of each word according to certain syntactic rules. Recognizing a word does not mean understanding it. In certain occasions, we hear or read words that are familiar to us, that we know they are real words we have heard in other occasions, but we cannot remember their meanings. This happens especially with very low frequency words.

In the present study, we ran three experiments with Chinese and Spanish university students of Universidad Autónoma de Madrid (UAM) on the processing of experimental sentences in their native language and the scene perception with the same sets of images. Our aim was to find out whether there are any differences in the eye movement pattern between Chinese and Spanish readers, and to assess whether these differences are due to cultural differences or to linguistic differences such as the different syntactic rules, the different writing systems (characters and letters), etc.

In the first experiment, we analyzed the time course of syntactic and semantic processing when Chinese is read. Readers' eye movements were monitored followed the paradigm used by Yang, Wang, Chen & Rayner (2009), where they examined the relation between a single-character critical word and the sentence context. Three kinds of conditions were used: congruent (CON), semantic violation (SEM), and semantic and syntactic violation (SEM + SYN). Thirty-five native Chinese speaking university students at the UAM took part in this study. Two sets of analyses were carried out: character-based analysis and region-based analysis. The eye movement data showed no differences in the condition factor in the first-pass processing, only in the Critical Word (hereafter CW) respect to CW-2 (i.e. two words ahead of the CW) and CW-1 (i.e. one word ahead of the CW) in First fixation duration, as well as Gaze duration measures. However, there was a significant effect of condition in later processing, in regressions out in the semantic + syntactic violation compared to the congruent condition. These results suggest that the effects of a semantic + syntactic violation can be detected by Chinese readers and that the processing of syntactic and semantic information is different in both first-pass and second-pass reading.

In the second experiment we used the same pattern as in the Chinese experiment, by traslating the sentences into Spanish. All the rules and procedure were the same, and here we also examined the relation between a single critical word and the sentence context. Thirty-three native Spanish-speaking university students of the UAM took part in this study. The eye movement data showed that the first-pass reading times were significantly longer for the target region in the two violation conditions than in the congruent condition. Moreover, the semantic + syntactic violation caused more severe disruption than did the pure semantic violation, as reflected by longer first-pass reading times for the target region and by longer go-past times for the target region and post target region in the former (SEM + SYN) than in the latter condition (SEM). These results suggest that the effects of, at least, a semantic violation can be detected immediately by Spanish readers and that the processing of syntactic and semantic information is different in both first-pass and second-pass reading.

In the third study we examined whether there are cultural differences between Spanish and Chinese in how quickly eye movements are drawn to highly unusual aspects of a scene. The viewers examined photographic scenes while performing a preference-rating task. For each scene, participants were presented with two pictures in the same monitor either a normal or an unusual/weird version. Not only were there differences between the normal and weird versions of the scenes, according to the time of initial examination of the region of interest (ROI) and the subsequent examination of the ROI, but there was also some evidence of cultural differences while viewing either scene type between Chinese and Spanish viewers.

Overall, the current research indicates that despite substantial differences between Chinese and alphabetic writing systems, there are still many similarities in sentence processing between Spanish and Chinese. First, both semantic and syntactic violations can be detected immediately, although Chinese is considered a highly context-dependent language. Second, although a syntactic violation is always accompanied by a semantic violation, evidence from eye tracking data confirms that syntactic violations yield more severe disruptions than do pure semantic violations. Further studies will be needed to elucidate the finer processing of semantic and syntactic information in the reading of Chinese. The present study at least indicates that these two types of processing can be initiated immediately and dissociated from each other under certain conditions in both reading Chinese and Spanish. The data of the scene viewing show that (a) weird regions attract fixations slightly sooner than do normal regions and (b) viewers look longer at weird regions than at normal regions. More importantly, our results are not consistent with those reported by Rayner et al. (2007), Evan et al. (2009) and Yang et al. (2009) where cultural differences have little influence on oculomotor control during scene perception.

Chapter I

General introduction

The main objective of this thesis is to find out whether there are cultural diffferences between Chinese and Spanish readers in reading in the native language and in the perception of scenes by means of an eye-tracking procedure. The following introduction is divided into three parts: First, I will provide some general notions of grammatical and semantic processing in language comprehension. Following this, I will give a general overview of relevant aspects of modern Chinese grammar. Finally, a brief description of the main measures and characteristics of eye movements in the domains of reading and scene perception will ne advanced.

The information provided in this introduction is intended to help the reader to become familiar with the processes of grammatical analysis and semantic interpretation in language comprehension, to understand some general features of modern Chinese grammar, and to compare the methods and procedures of the eyetracking methodology as applied to reading and to the perception of visual scenes. As regards the Chinese grammar, it should be borne in mind that the structure of words, phrases and sentences in modern Chinese is clearly different from Spanish and English languages. Therefore, in this review we will focus on some salient features of the phonetic structure, the morphological arrangement of words, and the syntacrtic structure of basic sentences in Mandarin Chinese. However, we will begin by developing a general description of language comprehension processes that are common to every language, in order to focus on the Chinese language in a subsequent chapter.

1. Grammatical and semantic processing in language comprehension

In terms of linguistic processing, the dissociation between form and meaning can be found at all levels of linguistic representation, and particularly at the level of words and sentences. In the former case, we must bear in mind that recognizing a word and accessing its meaning are different processes. One thing is to recognize the word, which is done by consulting the mental lexicon, and another thing is to understand or access its meaning, which is an additional step subsequent to its recognition. This is the reason why we can recognize a word although we might not remember its meaning; nevertheless, we cannot understand a word without having recognized it. However, the goal of readers and listeners concerning words is to access their meaning. Rarely (except when we perform some psycholinguistic task) we settle for recognizing the words without any concern about their meaning. I will address tjhis issue in the next subsection.

1.1 Semantic processing

Recognizing a word does not mean understanding it. In fact, there is no exact parallelism between the form of words and the meanings or the concepts which constitute the basis of our knowledge of words. There are concepts that are represented by several different words (synonymy); for example, the words "burro" (donkey), "asno" (donkey) and "pollino" (colt) refer to the same concept, and there are words that express several different concepts (homonymy), for example "banco (bank)". On the other hand, there are objects and events, even in our everyday experience that have no name. In English or Spanish, there is no word that designates the pile of toothpaste that you put on the brush every day (example from Jay, 2003). There is also no single word that refers to a dead tree, although there is a specific word for a dead body: "cadáver (corpse)." Languages differ in the way of classifying and naming many objects; for instance, foreigners are surprised by the amount of Spanish terms to identify the different results that can be obtained by cutting an edible material with a knife: "rodaja, rebanada, loncha, tajada, lonja"; all these Spanish words mean "slice" in English; "cortada, corte" mean "cut"; "filete" means "steak", etc. (Crystal, 1994).

Following the distinction proposed by the British philosopher Locke (1632-1704), it is possible to differentiate between intension of a word, which refers to its meaning and specifies the properties that an object must meet to be included as a member of that class or concept (e.g., the concept "perrez" or properties that an object must meet to be considered a dog), and the extension or set of objects that have those properties (all the dogs of the world, real or imaginary). Semantics also distinguishes between the denotation of a term, that is, its objective meaning, which a dictionary specifies about it (definition of dog), and its connotations, or set of emotional and subjective implications that we associate with the term ("pretty", "threatening", "smelly"). People share the denotation, but the connotations differ from one person to another.

But what is meaning? If we ask someone in the street for the meaning of the word "狗

(gǒu), perro, dog", he or she will immediately indicate one which is in sight. Thus, this puts us in touch with the referential theory of meaning; according to this theory, the meaning of a word consists of the object (referent) to which the word refers. This was one of the first philosophical conceptions about meaning, but the issue is not so simple. In the case of proper names, it is possible to think that they refer to an individual object or entity (person, place, etc.): "Paris" means a specific city crossed by the Seine River and, among its properties, it's the capital of a country called France; "Elvis Presley" refers to a unique person who was a rock singer. However, to what objects do words such as "justice", "evil" or "comfort" refer? We can believe that it is only a problem of abstract words, but let's go back to the concrete word "dog". Actually, this word does not refer to an individual subject, since it can be applied to hundreds of animals, very different from each other, distributed throughout the planet (from a chihuahua to a mastiff) or imaginary; neither does it refer exactly to a group or a collection of those objects (for that is the word "pack" or "dogs" in the plural), but to something common to all of them: the concept of a dog.

1.2 Organization of the semantic system

How are concepts organized in our semantic system and how do we access them when we understand or produce the words? An astonishing fact is the ease and the speed with which we retrieve the meanings of words, despite the large amount of information that we store in our conceptual system. This suggests that the conceptual system must be very well organized, with the concepts very accessible and, apparently, the organizational form is by grouping them into semantic categories, which are formed according to the common characteristics. There are very general categories, such as those of living beings and inanimate objects, and others more specific, such as reptiles, fruits or tools. On the other hand, there are hierarchies within the categories, since the smaller ones are the parts of more general ones (Izura, Hernández-Muñoz & Ellis, 2005). For instance, the category "birds", constituted by many different specimens, is part of the more general category of "animals", which also includes fish, mammals, reptiles, etc., and, in turn, the category of animals along with plants is part of the category "living beings".

Each concept is an abstraction of many concrete stimuli. Thus, the concept "cat" refers to all cats in the world, regardless of their size, shape or color. There are many different types of chairs, some classic, others with avant-garde designs, some made of wood, another made of iron, plastic, etc., and in all possible colors. However, we all group them under the concept of "chair" (Izura et al., 2005). This grouping represents a huge saving in cognitive terms, because we do not have to form a representation for each specific instance of the category, which would imply hundreds of representations of chairs, tables, cats, etc. On the other hand, when we find a new exemplar, for example a different chair, we will have no problem to know what it is, although we have not seen it before.

These categories, formed by abstraction of many different specimens, belong to the so-called basic level, because it is the level at which we usually think and which we refer to constantly. Unless you want to specify certain information, we usually talk about the dog, the cat, the tree or the table, without referring to a specific breed of dog, a specific tree or a specific type of table. Eleanor Rosch (1978) claimed that the basic level is of great relevance for the organization of the concepts in our memory, since it groups specific concepts with common characteristics (all dogs, regardless of race, have a great resemblance, all the tables they have much in common, etc.), and they are clearly different from the other basic concepts (any dog differs from cats, horses or cows, and any table differs from chairs or closets). In fact, it is the type of category most used in our conversations, and the basic concepts are the first ones that children acquire during language development.

We also have other categories above and below the basic level that are very useful. On the lower side is the subordinate level, which allows specifying the members of the category (very useful for specialists in a given field). Thus, within the "table" category we distinguish many types of table: kitchen table, dining table, armchair table, study table, etc., each with its specific characteristics, and within the category "tree" we distinguish the fir tree, the oak, the willow, the cherry tree, and so on.

As mentioned above, demanding greater abstraction is the superordinate level, to which belong the most general and abstract categories, for example, animals, furniture or plants (Izura et al., 2005). The superordinate categories are made up of very diverse specimens that often have little in common with each other, which requires a great exercise in abstraction. What functions do a table, a closet, a bed, etc. share to form the furniture category? Or the dog, the octopus, the sardine and the butterfly to form the animal category? However, this level also entails a great cognitive saving, because it allows referring to all animals or all furniture with a single word.

According to Cuetos, González & De Vega (2015), some categories are closed, such as the days of the week or months of the year, while others, the majority, are relatively open and consist of many members, especially natural categories (animals, flowers, etc.) and many artificial ones (furniture, tools, etc.).

On the other hand, our conceptual knowledge is quite similar to that of people in our environment. Unlike what happens with episodic knowledge, which is very different in each person, since each one has his or her own experiences, semantic knowledge is shared mostly by all the members of the society in which we live. This knowledge includes all the information about the objects, people, facts, etc. in our world. We know that giraffes have long necks, they are mammals, they live in the savanna, they feed on the branches of trees, etc., and Dublin is the capital of Ireland or Alexander the Great was a famous king and general.

Every time we learn a new concept, we not only learn its essential characteristics, but also the category to which it belongs, which is most important. In this way, we put that concept in the right place in our conceptual system, which facilitates its search and determines the system, which has a certain organization. Likewise, whenever an object or event is classified under a given category, it inherits all the characteristics of that category. At the moment we become acquainted with a new type of bird we automatically incorporate all the features of the category "bird" (it has beaks and feathers, it lays eggs, nests, flies, etc.). If it did not fulfill any of those characteristics, for example, if it did not fly, we would include it as a characteristic feature.

Given the important role of typicality / availability in semantic processing, it is essential to have normative studies about what people in a linguistic and cultural field consider as members of a semantic category and which are more representative of it. In English, one of the first works in this regard was that of Battig & Montague (1969) on natural categories, which was carried out with a group of 422 students from the universities of Maryland and Illinois who were asked to write instances of a good number of categories.

In Spain, in addition to the norms by Izura et al. (2005), we have the work of Pilar Soto et al., initially published by the Universidad Autónoma de Madrid and then reissued by the publisher Visor (Soto et al., 1994). This normative study focuses on 45 natural categories extracted from Battig & Montague, such as geographical features, animals, trees, birds, buildings, diseases, atmospheric phenomena, flowers, fruits, tools, insects, musical instruments, mammals, seafood, materials, metals , furniture, parts of the human body, fish, precious stones, clothing, dog breeds, reptiles, among others. More recently, Marful, Díez & Fernández (2014) collected data from 284 participants for the 56 categories of Battig & Montague. Cognitive psychologists and psycholinguists have made an effort to organize the meanings of words in terms that can be managed with programs designed to process natural language, within the enormous limitations that still exist in this field. WordNet is one of the most notable examples of this. It is an electronic word base created initially by Fellbaum (1998) and under the direction of George A. Miller at Princeton University.

1.3 Sentence comprehension

See the following example,

El niño asustó a la gata amarilla y ésta salió corriendo.

The words "la gata amarilla" constitute a grammatical phrase, as shown by the fact that the three words share gender, number and constitute a unit of meaning.

Cuetos et al. (2015) claimed that word order is a syntactic element of utmost importance, since it helps the reader establish the functions of each of the concepts in that specific sentence. For example, "el niño" appears as the subject of the sentence and, therefore, is the agent of the action, while "la gata" is the object or recipient of the action. If the order of some words were altered, the interpretation would be different (eg, "la gata amarilla asustó al niño y [éste] salió corriendo"), or even the sentence could be very incoherent (eg, "el amarilla asustó ésta a la y niño corriendo salió gata"). In sum, the reader or listener must show some linguistic competences that allow him or her to categorize different kinds of words (names, verbs, adjectives, etc.), segment the text into grammatical components (phrases, clauses, sentences) and establish correlation links between words located at different constituents. These competencies are intuitive and pragmatic, very different from the formal knowledge of having studied grammar (it is virtually the same for illiterate people as well), amnd absolutely necessary to correctly apply subtle syntactic operations during the comprehension of the language. In addition, these operations are executed at a high speed, and unconsciously.

The psychological reality of segmentation in grammatical units is supported by an important fact: the units of prosodic intonation in speech coincide with grammatical units. Likewise, during silent reading, readers also spontaneously pause at the end of clauses and sentences, as shown by the studies that record eye movements (Just & Carpenter, 1980). Finally, the prosodic intonation units (phrases and clauses) provided in adult speech could serve as a cue for babies to start learning syntax (e.g., Pinker, 1992). All this clearly indicates that language users spontaneously segment language into grammatical constituents.

The psychology of language has tried to unveil the understanding of sentences (Cuetos et al. 2015), by carefully studying the underlying processes, emphasizing syntactic processes, and explaining them through theoretical models. Syntax is an emergent phenomenon at the level of sentences and, for many, constitutes the most extraordinary aspect of human language, which is unparalleled in any other species. There are two different approaches in the psychological study of syntactic processes in sentences. First, structural theories, derived from the linguistics of Noam Chomsky, assume that the syntactic processing is executed in a "module" that operates independently of other processes. Second, functionalist theories, related to functional and cognitive linguistics, generally assume an interactive architecture of language, that is, propose a mutual influence between syntactic, semantic and pragmatic processes. We will address both models of sentence processing and will also review some aspects of the interpretation of sentences, which have to do with the connection of meaning with the pragmatics of language, such as the embodiment of meaning, the understanding of metaphors and the processing of negation and counterfactual statements.

The three perspectives just mentioned reflect equally important psychological processes in the understanding of sentences, but emphasize different aspects. The structural perspective is interested, above all, in how the reader or listener intends to segment the sentences into hierarchically organized syntactic components, starting from the linear input of the sentence.

Although these theories consider the possible interactions between syntax and semantics, this latter aspect is relatively secondary for them, since they do not intend to be theories of meaning. The functionalist perspective, on the other hand, analyzes how some grammatical terms (e.g., pronouns, conjunctions) regulate the activation of the concepts and the correlation between them during comprehension. This approach assumes a close functional relationship between syntax and meaning, so that sometimes both processes are not easily separable.

Finally, the pragmatic perspective is interested in the semantic complexity of some types of sentences, whose understanding involves processes that are not strictly linguistic. For example, the theories belonging to this perspective postulate that in some sentences sensorimotor or bodily processes, metaphorical concepts or pragmatic assumptions are activated. The three perspectives are valid and complementary, but they follow different theoretical approaches and experimental procedures.

1.4 Functional perspective of grammar

As mentioned previously, the theories of syntactic parsing, heirs to Chomsky's generative linguistics emphasize the central role of syntactic representation, neglecting or leaving semantics in the background. However, there are also linguists with a functionalist and cognitive approach to grammar, interested in the processes of construction of meaning and in the cognitive mechanisms that underlie the understanding of sentences. From this perspective, the boundaries between syntax and semantics are blurred, since the grammatical elements actively contribute to the construction of meaning and at the same time are influenced by it (Cuetos et al. 2015).

Although functionalist and cognitive linguists offer quite heterogeneous ideas, we will mention some of them of special relevance for the psychological investigation of language.

1.4.1 Grammar as processing instructions. According to the linguist Talmy Givón (1992), grammatical markers (prepositions, pronouns, conjunctions, morphemes, etc.) can be considered processing instructions that guide the reader in the execution of certain mental operations, mainly the regulation of the attentional focus, the search of information in memory and conceptual integration. For example, pronouns often function as anaphora that tell the reader or listener what concept, previously mentioned, should be kept activated in the focus of attention. Consider the sentence: "When Juan finished reading the book, he threw it in the bin." In the second clause, two pronominal anaphora tell the reader to keep the previously mentioned referents activated: he = John, it = the book. Just like road signs are instructions that tell the driver how to behave when driving, grammatical markers tell the reader or listener how to operate with words and concepts in sentences. Note that in both cases these instructions must be executed - with greater or lesser success - by the driver or the reader or listener, respectively.

1.4.2 There is a close correspondence between linguistic form and meaning. For example, the grammatical subject is in most cases an animate entity, usually human, conscious, active and volitional (Givón, 1990). Although in some cases the grammatical subject can be any noun phrase (including an inanimate object), the truth is that many more meaningful predicates can be constructed referring to animate entities and especially to people. The parallelism between linguistic form and meaning is also manifest in the fact that some structures or grammatical "constructions" express relevant events of human experience, such as spatial location, causal relations or transfer actions (Goldberg, 1995). For example, the constructions of double object structures "subject-verb-object 1-object 2", present in sentences such as "the colonel handed the book to the old woman" or "the girl told a story to her mother", carry the idea general transfer, that is, an agent transfers an object (or information) to a receiver.

1.4.3 Figure and background. In many predicative structures, a figure / background relationship is postulated (e.g., Landau & Jackendoff, 1993, Talmy, 2001). The figure is the relatively unknown entity that receives the attentional focus, and the background is the most familiar entity that is used as a frame of reference (Talmy, 2001). For example, consider the locative sentence: "The red book is on the desk in my office." The figure is the object whose position we wish to establish (the red book), and the background is the best-known object that serves as the frame of reference (the table in my office). A feature of the predicate pattern figure / background is asymmetry. Thus, in the locative sentences the figure is usually more dynamic, smaller and less salient than the background. Consequently, the inversion of the terms determines strange phrases or with a different meaning. Thus, when inverting the figure and the background of the previous example, one gets: "The desk in my office is under the red book". Predictive symmetry is also observed in predicates that indicate similarity, in which the properties shared by the figure and the background must be especially salient in the background (Tversky, 1977). For example, in the phrase "my dog is like a lion", the similarity that the speaker wants to emphasize resides in certain outstanding properties of the lion (fierceness, strength, etc.) that are transferred to his dog. Again, the inversion of the terms produces colorful phrases such as "a lion is like my dog".

1.4.4 Perspective. When language users decide to communicate, they necessarily frame the description of an event or scenario using a particular point of view. In a way, language users cannot help but include themselves in what they say, establishing a spatial, temporal or conversational framework centered on the here-now-self. Consider the sentences "the bull is behind the fence" or "the bull is in front of the fence". Both sentences describe an analogous situation but from a different speaker's perspective: the first implies that the fence is between the bull and the speaker. In other words, the spatial relationship between the bull and the fence is the same, and what changes is the position of the speaker. In general, the description of spatial relationships assumes a given perspective of the speaker. Thus, the deictic terms "in front of", "behind", "to the right", "to the left", "here" or "there" implies a particular point of view that is altered when the interlocutors move. On the other hand, linguistic messages in Spanish and in many other languages imply a temporal perspective. It is not possible to generate a sentence without establishing a dating of events regarding the moment of speech (present, past, or future). For this, there are various verbal resources, such as morphemes that give rise to verb tenses or adverbs of time. Some languages, such as Spanish, also establish other features like verbal aspect, indicating whether the action is considered completed (escribió una carta; perfective aspect) or in progress (escribía una carta; imperfective aspect). Finally, other elements of perspective are the deictic pronouns ("yo", "tú", él/ella) that imply the perspective of the speaker, the perspective of the listener or the perspective of another person outside the communicative context, respectively.

In this section, we have addressed general aspects of sentence comprehension with examples from Cuetos et al. (2015), in Spanish. These processes are intended to be generally applicable to different languages. However, since part of the research that will be reported in this thesis was carried out in Chinese, we will need to specify certain particular features of the script and the grammar of this language that might have implications for processing. In the following section, we will address a few aspects of Chinese phonetics and phonology, as well as information about morphology and morpheme changes, and word order in sentences. The specific features associated to the written script in Chinese and other aspects of the syntax of modern Chinese will be seen in Chapter II.

2. The characteristics of modern Chinese grammar

In the folloing section, the basic rules of modern Chinese, from Pinyin (the phonemic transcription of Chinese pronounciation), and other characteristics of the grammar of Chinese will be disscussed.

2.1 The phonetics of modern Chinese: *Pinyin* (the letters are the basic phoneme of the pronunciation of Chinese characters).

To read in Chinese is to read the characters and the first step is to know how to pronounce them. A useful tool to learn the pronunciation of Chinese characters is *Pinyin* (a sound transcrption system; every Chinese character has its own Pinyin). In the Chinese phonetic system, there are 23 consonants (at syllable initial position), and 24 vowels (syllable final). Thery are given with their phonetic transcription between brackets:

23 consonants: b [p] p [p‘] m [m] f [f‘] d [t] t [t‘] n [n] l [l]
g [k] k [k‘] h [x] j [tɕ] q [tɕ ‘] x [ɕ]
zh [tʂ] ch [tʂ‘] sh [ʂ‘] r [ʐ] z [ts] c [ts‘] s [s]
y [j] w [w]
24 vowels divided into: 6 single vowels: a [Ą] o [o] e [ɤ] i [i] u [u] ü [y]
18 compond final: ai [ai] ei [ei] ui [uei] ao [ɑu] ou [ou] iu [iou]
ie [iɛ] üe [yɛ] er [ɐ]
(5 front nasal vowels): an [an] en [ən] in [in] un [uən] ün [yn]
(4 post nasal vowels): ang [ɑŋ] eng [əŋ] ing [iŋ] ong [uŋ]

The syllables of modern Chinese (Mandarin) result from the combination of a consonant and a vowel or two, such as, a syllable "ma" = consonant "m" + vowel "a" or "guan" = consonant "g" + vowels "u" and "an". But in Chinese, the same syllable can be represented in script by different characters with the different tones. To complete a Chinese spoken syllable, the tone is a very important component (it it shared among different syllables); the tone is thus an integral part of the syllable and the vowels occupy a dominant position in it (there is a large measure of musical sound component). There are no composite consonants (the syllables are unmistakable, the forms and structures are well ordered, they are uniform). The syllables are short and clear, as in the examples mentioned above: the syllable "ma" can be given four different tones: "mā", "má", "mǎ" and "mà", and each of them is written with a different character and bears a different meaning; e.g.: "妈" ("mā") means "mom", "麻" ("má") means "linen", "马" ("mǎ") significants "horse" and "骂" ("mà") means "abuse"; in the character "关", the pronunciation is "guān", meaning "close"; in the character "罐", the pronunciation is " guàn", and it means "tank". Therefore, in Chinese the tone is very important for a syllable, for if it changes, the meaning of the word/sentence will be changed totally.

A popular grammar book of modern Chinese (Liu et al., 2001). Practical Modern Chinese Grammar (updated), shows the basic grammar of Chinese. In the following paragraphs, we are going to address some important grammatical rules of Chinese. (For more information, the reader is referred to https://wenku.baidu.com/view/0039d1ce050876323112128b.html).

2.2 Lack of strict morphological changes

Compared with Indo-European languages (such as English and Spanish), the most obvious feature of Chinese is that there are no strict morphological changes.

a. A morphological change is a change in the form of a word, when the word is embedded in a sentence, due to the different grammatical meanings that the word may take. Indo-European languages such as English and Spanish have rich morphological changes, and different forms are used to express corresponding grammatical meanings.

b. Chinese does not have the same morphological changes as the Indo-European languages, and does not use different word forms to express different grammatical meanings. In Chinese, when the same word is located on a different position, indicating different grammatical meanings, the form itself does not change. For example,

---

	Chinese & English		Spanish
(1) yìběnshū 一本书 one classifier book		liǎng běnshū 两本书 two classifier books	un libro / dos libros
(2) wǒshuō 我说 I speak		tāshuō 他说 he speaks	yo hablo / él habla

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2.3 Word order and function words are the main grammatical markers in Chinese

Since Chinese does not rely on rigorous morphological changes, the main means of expressing grammatical and semantic relations in Chinese are word order (see 2.3.1) and function words (see 2.3.2).

2.3.1 Word order refers to the order of the syntactic constituents in the sentence. In the case of Chinese, different orders yield very different meanings.

a. If word order is different, syntactic structure and sentence meaning are different.

(3) 洗衣服 xǐ yīfu (verb + noun)
wash clothes
(wash clothes)

衣服 洗 了 yīfu xǐle (noun + verb)
clothes wash (be done)
(clothes was washed)

(4) 下来 坐 xiàlái zuò (direction + verb)
come downstairs sit
(come downstairs and sit)

坐 下来 zuò xiàlái (verb + direction)
sit down
(sit down)

(5) 来早 了 lái zǎo le (verb + adv.)
come early (symbol of past time)
(I came early)

早来了 zǎo lái le (adv. + v.)
early come (past time)
(I have been here for a while)

(6) 一会儿 再 谈 yíhuìr zài tán
later (will) talk
(I will talk about it later)

再 谈 一会儿 zài tán yìhuìr
more talk a while
(talk for a while more)

(7) 不 很 清楚 bù hěn qīngchǔ   很 不清楚 hěn bù qīngchǔ

not very clear   very unclear

(not very clear)   (very unclear)   (indicates different degrees)

b. If word order is different, there is a difference in pragmatics and also a change in the center of gravity of the expression. Consider the following examples:

(8) 你 能 今天 晚上 来 吗? Nǐ néng jīntiān wǎnshang lái ma?

you can today night come (modal particle)

(Tonight, can you come?) The main question is the time

(9) 你 今天 晚上 能 来 吗？Nǐ jīntiān wǎnshang néng lái ma?

you today night can come (modal particle)

(Can you come tonight?) The main question is whether you can come.

(10) 屡 战 屡 败 lǚzhàn lǚbài

always fight again fail (fight and defeat)

(11) 屡 败 屡 战 lǚbài lǚzhàn

always fail again fight (defeat but keep fighting)

Example (10) has its focus on "always fails", which means that they fight, but are defeated in every battle; example (11) means "always defeats but fight again and again"; it focuses on "keep fighting", which means that although they fail, they are not discouraged and continue fighting.

2.3.2 Function words: The notion of function word refers to a word that has no complete meaning by itself, but has a grammatical meaning or function. It has the characteristics of being attached to a word or a sentence, in order to convey grammatical meaning. These words cannot form a sentence alone, nor become a grammatical component by themselves. For example:

The presence or absence of a function word causes a change in meaning.

(12) 孩子 脾气 háizi píqì
child temper
(childish, can mean naughty, spoiled, etc)

(13) 孩子 的 脾气 háizi de píqì
child (function word) temper
(child's temper: good or bad)

(14) 湖南 大学 húnán dàxué
Hunan university
(Hunan University: a proper noun)

(15) 湖南 的 大学 húnán de dàxué
Hunan (function word) university
(all the universities in Hunan: a collective noun)

2.4 The structure of words, phrases and sentences in Chinese is basically the same

Chinese consists of morphemes that form words, words that form phrases, words and phrases that form sentences, and their construction is basically the same. E.g.:

(16) 水 — water; 喝 水 — drink water; 我 要 喝水。 — I want drink water (I want to drink water.)

(17) 马 — horse; 骑 马 — ride horse; 她 喜欢 骑马。 — she like ride a horse (She likes to ride a horse.)

The above examples are intended to illustrate a general grammatical rule of Chinese. In these examples it is shown that Chinese sentences have a subject-verb-object (SVO) structure like othe languages. More details about this will be given in Chapter II.

In the following section, we will address the major features of the eye-tracking procedure as used in reading and scene perception.

3. Eye movements in reading, scene perception and visual search

In this section, I will first provide a cursory review of the issue of eye movements in reading focusing on the major differences betweent English readers and Chinese readers. Following that, I will address in more depth the issue of eye movements in scene perception and visual search.

3.1 Eye movements in reading

In general, practically all the measures that are typically used in eyetracking studies involving texts, such as average fixation duration, average saccade length, regressions (saccades that move backwards in the text), etc., are usually influenced by factors such as text difficulty, reading skill, and characteristics of the writing system for all kinds of readers (see Rayner, 2009, for a thorough review).

As far as writing system is concerned, the one that is most different from alphabetical systems, like that of English and Spanish, is Chinese script. Rayner (2009) showed that Chinese readers tend to have average fixations durations that are quite similar to readers of English (225-250 ms), and their regression rate does not differ dramatically. Where they do differ is that average saccade length in Chinese readers is much shorter than that of readers of English, since the former typically move their eyes only 2-3 characters.

For English and other alphabetic languages, the decision of where to move the eyes next is strongly influenced by low-level cues provided by word length and space information. Thus, saccade length is influenced by the length of the fixated word and the word to the right of fixation (Inhoff, Radach, Eiter, & Juhasz, 2003; Juhasz et al., 2008; O'Regan, 1979, 1980; Rayner, 1979; White et al., 2005b). As far as space information is concerned, for Chinese, in general, there is no space between words and characters. In a recent study, Bai, Yan, Liversedge, Zang, & Rayner (2008) inserted spaces between Chinese words or between Chinese characters. Whereas inserting spaces between characters interfered with reading, inserting spaces between words did not (recall that many Chinese words are composed of two characters). Actually, it is quite surprising that the insertion of spaces between words did not interfere, given that the Chinese readers have a lifetime of experience reading without spaces. Moreover, even when interword spaces are orthographically illegal, Chinese readers find it beneficial to reading.

3.2 The perceptual span in scene perception

Fixation durations during scene perception tend to be longer than those in reading, and saccade size tends to be larger. The average fixation duration tends to be closer to 300 ms (but varies as a function of the task and the characteristics of the scene). Average saccade size tends to be 4-5 deg (though it too can vary as a function of task and the exact nature of the scene - more densely packed scenes lead to longer fixations and shorter saccades). Whereas there is a well-defined task for readers, exactly what participants should do in a scene perception task is more variable. Sometimes participants are asked to look at the scene in anticipation of a memory test while other times they may be asked to indicate if a certain object is present in the scene. Under the latter instructions, scene perception becomes very much a visual search task.

Examination of the eye movement pattern (or the scan path) of a viewer on a scene demonstrates that viewers do not fixate every part of the scene. Most fixations tend to fall on the informative parts of the scene. Thus, viewers tend to not fixate on the sky or the road in front of a house. Furthermore, viewers are able to obtain the first of the scene in a single glance. That is, the gist is understood so quickly that it is obtained even before the eyes begin to move (De Graef, 2005). Castelhano and Henderson (2008) found that when viewers are shown a scene for as little as 40 ms, they are able to extract enough information to understand the scene gist. Thus, the gist is thought to be acquired during the first fixation in order to orient subsequent fixations to appropriate/interesting regions in the scene.

While the gist of the scene can pretty much be obtained on the first fixation, how much information do viewers obtain on each fixation as they look around a scene? It is clear that information is acquired over a wider range of the visual field in scene perception than is the case for reading. As with reading, the best way to address this issue is via gaze-contingent paradigms. Yet surprisingly few such studies have been reported.

Henderson, McClure, Pierce, & Schrock (1997) used a moving-mask procedure, while Saida & Ikeda (1979) used a moving-window paradigm. It appears that the answer to the question of how large the perceptual span in scene perception is has not been answered as conclusively as it has in reading. Viewers typically gain useful information from a fairly wide region of the scene, which also probably varies as a function of the scene and the task. For instance, the ease with which an object is identified has been linked to its orientation (De Graef, 2005), frequency within a scene context (Hollingworth & Henderson, 1998), and how well camouflaged it is (De Graef, Christiaens, & d'Ydewalle, 1990). As has been shown in reading (Henderson & Ferreira, 1990), it is likely that the ease of identifying a fixated object has an effect on the extent of processing in eccentric vision.

3.2.1 *Eye movement control in scene perception*

Where do viewers look in scene? Since the pioneering work of Buswell (1935) & Yarbus (1967), it has been widely recognized that viewers' eyes are drawn toward important aspects of the visual scene and that their goals in looking at the scene influence very much their eye movements. Quite a bit of early research demonstrated that the eyes are quickly drawn to informative areas in a scene (Antes, 1974; Mackworth & Morandi, 1967). It is also clear that the saliency of different parts of the scene influence what part of the scene is fixated (Mannan, Ruddock, & Wooding, 1995, 1996; Parkhurst & Niebur, 2003). A large amount of empirical and computational research has recently been devoted to understanding the factors that govern fixation position in scenes (Foulsham, Kingstone, & Underwood, 2008; Henderson, 2003; Itti & Koch, 2000; Melcher & Kowler, 2001; Parkhurst, Law, & Niebur, 2002; Rutishauser & Koch, 2007; Tatler, Baddeley, & Vincent, 2006; Underwood, Foulsham, van Loon, Humphreys, & Bloyce,2006), and much of this work revolves around how saliency (which is typically defined in terms of low-level components of the scene, such as contrast, color, intensity, brightness, spatial frequency, etc.), influences where viewers look.

Saliency is not the only factor involved in determining where to look, and there are questions about how important it is (Foulsham & Underwood, 2008; Henderson, Brockmole, Castelhano, & Mack, 2007). It has also become increasingly clear that there are strong cognitive influences on where viewers look as well (see Henderson, 2007; Torralba, Oliva, Castelhano, & Henderson, 2006). Henderson (1993) found that viewers tended to fixate near the center of an object and that there was a greater tendency to undershoot the center than to overshoot. Furthermore, landing position influenced fixation time as the duration of the first fixation on an object decreased, and probability of refixations the object increased. In addition, Mannan et al. (1995, 1996) found that viewers tend to look in pretty much the same locations across three viewings of a scene even though the scenes had been either high-pass or low-pass filtered. Thus, low-level visual information must be critical in deciding where to look next.

Are the eyes drawn to unusual parts of a scene? A somewhat contentious issue concerns the extent to which the eyes are drawn to highly informative unusual or emotional aspects of a scene; the evidence is somewhat uneven as some experiments indicate that they are, while others suggest they are not. Early experiments found that the eyes move quickly to an object that is out of place in a scene (Friedman, 1979; Loftus & Mackworth, 1978). Unfortunately, these studies did not control physical distinctiveness very well (Rayner & Pollatsek, 1992), and, when it was controlled, studies (Brockmole & Henderson, 2008; De Graef, 1998; De Graef et al., 1990; Henderson, Weeks, & Hollingwouth, 1999) failed to replicate the finding that semantically inconsistent objects were fixated earlier than consistent objects (but see Underwood & Foulsham, 2006; Underwood, Humphreys, & Cross, 2007).

More recently, Becker, Pashler, & Lubin (2007) & Harris, Kaplan, & Pashler (2008) renewed interest in the extent to which semantically incongruent objects in scenes attract the eyes. For instance, Harris et al. (2008) introduced emotional, yet somewhat unusual, aspects into scenes; for example, in a control scene people are tossing a beach ball at a beach, while in the emotional scene the beach ball is replaced by a baby. They found that viewers looked earlier at the emotional aspect of the scene. A number of other recent studies (Calvo & Lang, 2005; Calvo & Nummenmaa, 2007; Kirchner & Thorpe, 2006) have likewise reported that the eyes quickly move to emotional objects or scenes (though in these studies, the object/scene is usually presented in parafoveal vision, and the latency of a saccade from a central fixation point is measured for an emotional scene/object versus a neutral scene/object).

Rayner, Castelhano, & Yang (2009a) used the scenes from Harris et al. (2008) as well as a large number of other scenes with weird or unusual aspects. Like Becher et al. (2007) & Harris et al. (2008), they found that the eyes were drawn to the weird parts of the scene earlier than when the weird aspect was missing. Yet, the eyes being drawn to the weird part of the scene was not instantaneous; it was fixated within 3 fixations (in comparison to the same part of the scene being fixated within 3.5 fixations in the control condition). Underwood, Templeman, Lamming, & Foulsham (2008) likewise reported that the incongruous objects attract attention earlier than congruous objects, but the effect was not apparent until the picture has been displayed for several seconds.

Are there cultural influences on where to look in scenes? It has recently been suggested that Asian (Chinese) participants look at scenes differently than English-speaking participants. Specifically, Chua, Boland, & Nisbett (2005) reported that Chinese viewers spent less time looking at the focal objects in a scene and more time looking at the scene background than their English-speaking counterparts. These results were discussed in the wider context of a general theory of cultural differences in cognition (Nisbett, 2003) whereby Asian cultures lead people to not place as much value on the individual as on the group, while the American culture places more emphasis on the individual. According to Chua et al., this underlying cultural difference in thinking led the Chinese viewers to look more at the background and spend relatively less time (in comparison to the Americans) looking at the focal objects.

However, three recent reports have raised some questions about the validity of Chua et al.'s (2005) findings. Rayner, Li et al. (2007) reported no differences in the looking patterns of Chinese and American participants, with both groups looking more at focal objects than the background information. Boland, Chua, & Nisbett (2008) noted that the study was not a direct replication of Chua et al. given that the same materials were not used (and the focal objects were more apparent in their study than in the Rayner et al. study), and the task varied between the two studies (expectation of a memory test in Rayner et al. and a rating task for scene likeability in Chua et al.). However, Evans, Rotello, Li, & Rayner (2009) used the original scenes from Chua et al. (as well as additional scenes for increased power) & Chua et al.'s task, and also found no differences between the two groups (either with the entire set of stimuli or with the subset that had been preciously used by Chua et al.). Furthermore, Rayner et al. (2009a) argued that if Chinese viewers paid more attention to the background information in a scene it might take them longer to notice the weird object in the scene. Nevertheless, there was no difference between the Chinese and American viewers in their study.

When do viewers move their eyes when looking at scenes? Given that attention precedes an eye movement to a new location within a scene (Henderson, 1992; van Diepen & d'Ydewalle, 2003), it follows that the eyes will move once information at the center of vision has been processed, and a new fixation location has been chosen. When this shift in attention (from the center of fixation to the periphery) takes place in the course of a fixation was investigated by van Diepen & d'Ydewalle (2003). Their results suggest that the extraction of information at the fovea occurs rapidly, and attention is then directed to the periphery to choose a viable saccade target almost immediately following the extraction of foveal information. The general timing of the switch between central and peripheral information processing needs further investigation, but it is likely that the variability of information across scenes will make it more difficult to delineate a specific period as has been done in reading.

Previous studies by Henderson & Pierce (2008) & Rayner, Smith, Malcolm, & Henderson (2009) are quite informative with respect to issues related to the timing of eye movements in scene perception. Henderson & Pierce (2008) adapted the paradigm used by Rayner & Pollatsek (1981; Morrison, 1984) to create a scene onset delay paradigm. The results support a mixed model of eye movement control and indicate that the durations of some fixations are determined regardless of scene presence while others are under direct moment-to-moment control of scene analysis. Interestingly, the percentage of fixations under direct control was much greater in reading than in scene perception.

Rayner et al. (2009b) adapted the disappearing text/masked text paradigm (Rayner et al. 1981, 2003, 2006) discussed above to create a situation in which a scene was masked at certain points after the onset of each new fixation. Interestingly, they found that viewers ne 150 ms to view the scene before the mask was not disruptive. Obviously, this is longer than the 50-60 ms that was needed in reading for the mask to not cause disruption and longer than one might predict given that viewers can obtain the gist of a scenes on the first fixation.

Models of eye movement control in scene perception. A number of models of eye movement control in scene perception have recently appeared. For the most part, these models focus on where to move the eyes next and little effort has been made to specify when the eyes move (or what influences the decision to move the eyes). A fair number of computational models (Baddeley & Tatler, 2006; Itti & Koch, 2000, 2001; Parkhurst et al., 2002) use the concept of a saliency map (following from Findlay & Walker, 1999) to model eye fixation locations in scenes. In this approach, bottom-up properties in a scene make explicit the locations of the most visually prominent regions of the scene. The models are basically used to derive predictions about the distribution of fixations on a given scene.

While these models can account for some of the variability in where viewers fixate in a scene, they are limited in that the assumption is that fixation locations are driven primarily by bottom-up factors, and it is clear that higher level factors also come into play in determining where to look next in a scene (Castelhano & Henderson, 2007). A model that includes more in the way of top-down and cognitive strategies was recently presented by Torralba et al. (2006). Indeed, as noted previously, while there has been a lot of research to localize where viewers move their eyes while looking at scenes, there has been previous little in the way of research attempting to determine what controls when the eyes move. This is in contrast with reading where the issues of where to move the eyes and when to move the eyes have both received considerable attention. Models of eye movement control in scene perception need to better explain the factors influencing when to move the eyes.

3.2.2 *Eye movements and visual search*

Visual search has received considerable attention over the past 40 years. However, the majority of this research has been done without measuring eye movements (Findlay & Gilchrist, 1998), and it has often been assumed that they are not particularly important in understanding search. However, this attitude seems to be largely changing as many recent experiments have utilized eye movements to understand the process. Many of these studies deal with very low-level aspects of search and often focus on using the search task to uncover properties of the saccadic eye movement system (see Findlay & Gilchrist, 2003). However, it is becoming very clear that eye movement studies of visual search, like reading and scene perception, can provide important information on moment-to-moment processing in search (Trukenbrod & Engbert, 2007; Williams & Pollatsek, 2007; Zelinsky, Rao, Hayhoe, & Ballard, 1997).

Here the focus is primarily on research using eye movements to examine how viewers search through arrays to find specific targets. As noted at the outset, fixation durations in search tend to be highly variable. Some studies report average fixation times as short as 180 ms while others report averages on the order of 275 ms. This wide variability is undoubtedly due to the fact that how difficult the search array is (or how dense or cluttered it is) and the exact nature of the search task strongly influence how long viewers pause on average.

Typically, saccade size is a bit larger than that in reading (though saccades can be quite short with dense arrays) and a bit shorter than that in scene perception. Two important points regarding eye movements during search are first discussed.

3.2.3 *Eye movement control in visual search*

Where and when to move the eyes. While there have been considerable efforts undertaken to determine the factors involved in deciding where and when to move the eyes in visual search (Greene, 2006; Greene & Rayner, 2001a, 2001b; Hooge & Erkelens, 1996, 1998; Hooge, Vlaskamp, & Over, 2007; Jacobs, 1986; Pomplun, Reingold, & Shen, 2003; Vaughan, 1982), a clear answer to the issue has not emerged. Some have concluded that fixation durations in search are the result of a combination of preprogrammed saccades and fixations that are influenced by the fixated information (Hooge et al., 2007; Vaughan, 1982). Others have suggested that the completion of foveal analysis is not necessarily the trigger for an eye movement (Hooge & Erkelens, 1996, 1998) while others have suggested that it is (Greene & Rayner, 2001b). Still others (Trukenbrod & Engbert, 2007) have demonstrated that fixation position is an important predictor of the next saccade and influences both the fixation duration and selection of the next saccade target. Rayner (1995) suggested that the trigger to move the eyes in a search task is something like: Is the target present in the decision area of the perceptual span? If it is not, a new saccade is programmed to move the eyes to a location that has not been examined (see also Motter & Belky, 1998a, 1998b; Najemnik & Geisler, 2005, for similar arguments). As with reading and scene perception, attention would move to the region targeted for the next saccade.

The decisions about where and when to move the eyes is undoubtedly strongly influenced by the characteristics of the specific search task and the density of the visual array, as well as viewer strategies (van Zoest, Donk, & Theeuwes, 2004). It seems that parallels between visual search and scene perception are greater than with reading, in that visual saliency plays a greater role in directing fixations. Also, search for targets in visual search displays and scenes have different dimensions that are more variable than reading. For instance, with respect to search tasks, there are many different types of targets that people may be asked to search for. Searching for a certain product in a grocery store shelf or searching for a particular person in a large group picture or for a word in a dictionary may well yield very different strategies than skimming text for a word (and hence influence eye movements in different ways). Although the task is generally much better defined in visual search than in scene perception, it typically is not as well specified as in reading.

3.2.4 *Eye movements and visual cognition*

Although there are obviously many differences between reading, scene perception, and visual search, some important generalizations can be made. First, how much information is processed on any fixation (the perceptual span or functional field of view) varies as a function of the task. The perceptual span is obviously smaller in reading than in scene perception and visual search. Thus, for example, fixations in scene perception tend to be longer, and saccades are longer because more information is being processed on a fixation. Second, the difficulty of the stimulus influences eye movements: In reading, when the text becomes more difficult, eye fixations get longer, and saccades get shorter; likewise, in scene perception and visual search, when the array is more difficult (crowded, cluttered, dense), fixation get longer, and saccades get shorter. Third, the difficulty of the task (reading for comprehension vs. looking at the scene for a memory test, and so on) clearly influences eye movements. Finally, in all three tasks it seems that viewers integrate visual information somewhat poorly across saccades (Najemnik & Geisler, 2005; Rayner, 1998), and that what is most critical is that there is efficient processing of information on each fixation.

4. General Objectives

The general objective of this thesis was to examine cultural differences between Chinese and Spanish readers when processing sentences and viewing images by an eye-tracking procedure. This general objective was divided into three studies. In the first study, we examined the time course of semantic and syntactic processing when Chinese is read. Readers' eye movements were monitored, and the relation between a single-character critical word and the sentence context was manipulated such that three kinds of sentences were developed: (1) congruent, (2) those with a semantic violation, and (3) those with both a semantic and a syntactic violation. In the second study, we used the same pattern of the Chinese study, but using sentences in Spanish. Based on these two studies, we wanted to discover an easy way to help foreigners (especially Spanish native speakers) to study Chinese. Chen (1999) suggested that it is better to use a semantic + syntactic violation condition to study Chinese, because syntax and semantics are closely interrelated in Chinese and, thus, most syntactic violations will always severely disrupt semantic processing. In the present study, we will continue to investigate whether there is a difference between Chinese and Spanish to read texts from different cultural background.

Finally, in the third study, we replicated the study carried out by Yang, Wang, Chen & Rayner (2009). The current study examined whether there are cultural differences in how quickly eye movements are drawn to highly unusual aspects of a scene. Spanish and Chinese viewers examined photographic scenes while performing a preference-rating task. For each scene, participants were presented with either a normal or an unusual/weird version. Not only were there differences between the normal and weird versions of the scenes, but there was also evidence of cultural differences while viewing either scene type between Chinese and Spanish viewers. The present study, along with other recent reports, raises doubts about the notion that cultural differences can influence oculomotor control in scene perception.

If there are differences between Spanish and Chinese readers only in the first and second studies, but not in the third, we can conclude that those differences are due to the form of the writing and the linguistic rules of each language; but if there are differences also in the third study, then the conclusion will be between Chinese and Spanish exist cultural differences.

5. Overview of the experiments

First study: We analyzed the time course of semantic and syntactic processing when Chinese is read. Reader's eye movements were monitored followed the paradigm used by Yang et al., (2009), where we examined the relation between a single-character critical word and the sentence context. Three kinds of conditions were developed: congruent, semantic violation, and semantic + syntactic violation. Thirty-five native Chinese speaking university students at the Universidad Autónoma of Madrid took part in this study. Two sets of analyses were carried out: character-based analysis and region-based analysis followed an eye-tracking experiment.

Second study: We analyzed the time course of semantic and syntactic processing when Spanish is read. Reader's eye movements were monitored followed the paradigm used by the previous Chinese study, where we examined the relation between a single-character critical word and the sentence context. Three kinds of conditions were developed: congruent, semantic violation, and semantic + syntactic violation. Thirty-three native Spanish speaking university students at the Universidad Autónoma of Madrid took part in this study. Two sets of analyses were carried out: word-based analysis and region-based analysis.

Hypothesis: If there are differences in eye movement patterns between Chinese and Spanish readers, then we should find out whether these differences are due to cultural differences or due to linguistic differences such as verb conjugation (present, past, future, etc.), number (singular and plural), or other linguistic features.

Third study: We intended to find cultural differences between Chinese and Spanish when they are viewing pictures depicting a normal scene or an unusual/weird scene by means of an eye-tracking experiment. Unlike the two previous studies, in the third study we compared both groups (Chinese and Spanish) in the same task, and with the same stimuli. In this case, we did not use sentences, but only images. If there are differences between Spanish and Chinese readers also in the present study, then the differences may be attributable to cultural factors.

Chapter II

Experiment I

The time course of syntactic and semantic processing in Chinese character/sentence comprehension: an eye-tracking study of integration processes during language comprehension

Abstract

In the current research, we analyzed the time course of semantic and syntactic processing when reading Chinese sentences. Reader's eye movements were monitored following the paradigm used by Yang et al., (2009), focusing on the relation between a single-character critical word and the sentence context. Three different conditions were used in the study: congruent, semantic violation, and semantic and syntactic violation. Thirty-five native Chinese speaking university students at the Universidad Autónoma of Madrid took part in this study. Two sets of analyses were carried out: character-based analysis and region-based analysis. The eye movement data showed no differences in the condition factor in the first-pass processing, and longer First fixations and Gaze durations in CW with respect to CW-2 and CW-1. However, there was a significant effect on condition in later processing, particularly in regressions out in the semantic + syntactic violation compared to the congruent condition. These results suggest that the effects of a semantic + syntactic violation can be detected at later processing stages by Chinese readers and that the processing of syntactic and semantic information is distinct in both first-pass and second-pass reading.

Keywords: Chinese; time course; semantic and syntactic processing; sentence comprehension; eye-tracking; integration process; language comprehension

Introduction

Reading comprehension involves complex cognitive processes at different levels. Besides orthographic, phonological and semantic processing of individual words, readers also have to build up a coherent meaning representation by integrating the semantic properties of each word on the basis of syntactic rules. So far, most evidence from studies of alphabetic languages appears to support the view that readers start all levels of processing in an immediate manner, including the higher order processes of syntactic analysis and semantic integration (Just & Carpenter, 1980). For example, studies in which ambiguous words were used have shown that context exerts an immediate influence on word recognition (Duffy, Morris, & Rayner, 1988; Kambe, Rayner, & Duffy, 2001; Rayner, Cook, Juhasz, & Frazier, 2006; Rayner & Duffy, 1986; Rayner & Frazier, 1989; Sereno, O'Donnell, & Rayner, 2006). Moreover, evidence from behavioral and event-related potential (ERP) studies has suggested that readers detect immediately whether a word is semantically congruent with the context or not (Braze, Shankweiler, Ni, & Palumbo, 2002; Rayner, Warren, Juhasz, & Liversedge, 2004; Rösler, Pütz, Friederici, & Hahne, 1993; Van Berkum, Hagoort, & Brown, 1999). In addition, garden path effects, which strongly support the notion that syntactic analysis begins very rapidly, have been observed in many studies (Bader & Lasser, 1994; Crocker, 1994; Frazier & Rayner, 1982; Sturt & Crocker, 1996).

Although the results of a number of studies have suggested that the processing of both syntactic and semantic information occurs quickly and online, the relative time course of such processes and their interplay within the language processor remains unclear. To investigate this issue, the violation paradigm has often been used. The basic manipulation in this paradigm is to change a critical word in a sentence/ text to introduce an anomaly. By observing and comparing the normal reading patterns and the patterns of disruptions caused by different types of anomalies on word viewing times, researchers can infer how and when the information that caused the anomaly was processed by readers (Chen, 1992, 1999; Danks, Bohn, & Fears, 1983; Rayner et al., 2004). With this paradigm, studies from alphabetic languages have demonstrated that syntactic and semantic processing differ from each other in their time course, with the former being initiated earlier than the latter (Braze et al., 2002; McElree & Griffith, 1995). For example, Braze et al. (2002) recorded eye movements while readers read sentences that differed by a single word, making the sentence syntactically anomalous (but understandable), pragmatically anomalous, or non-anomalous (control sentences). Results showed that syntactic anomalies manifested their effects right at the target verb, whereas for pragmatic anomaly, the effects were not apparent until the word after the target verb. Moreover, evidence from some ERP research has also supported the view that syntactic processing may be initiated very early, independently of semantic constraints and task requirements (Friederici, Pfeifer, & Hahne, 1993; Gunter, Stowe, & Mulder, 1997; Hahne & Friederici, 2002).

In our current study, we will analyze and compare Chinese and Spanish in this regard. Chinese people and Spanish people have widely different languages and cultures, which might eventually lead to different reading patterns and strategies. On the other hand, it might be the case that Chinese and Spanish readers detect semantic violations immediately and are able to differentiate the processing of syntactic and semantic information in both first-pass and second-pass reading stages.

Alphabetic languages like English and Spanish generally have explicit markers or inflectional indicators, such as specific lexical classes, number, tense, or other grammatical morphemes, in order to specify different types of syntactic information. However, in Chinese, a non-alphabetic (logographic) language, there are no morphological markers to signal the difference between, for instance, the present and the past. The Chinese language does not have tense morphemes, it only depends on the context of the sentence to determine its tense. This is shown in the following sentences,

----

1a. 他(he/él) 准备(is going to/irá)下课后(after class/después de la clase)去打篮球(play basketball/jugar al baloncesto) [he is going to play basketball after the class]

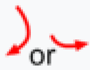
1b. 他(he/él) 昨天(yesterday/ayer)下课后(after class/después de la clase)去打篮球了(play basketball/jugar al baloncesto) [he played basketball after the class yesterday]

In order to better understand the materials used in our study in Chinese, I will offer a description of the main characteristics of Chinese script, the sound system of Chinese, the pictographs and ideographs that support the Chinese writing system, some basic notions of word representation and structure, and a few comments on sentence structure in Chinese. The information provided in the following sections has been partly taken from Chapter 2 of Rumjahn Hoosain's book *Psycholinguistic implications for linguistic relativity: A case study of Chinese* (pp. 5-22).

1. Written Chinese

The basic unit of script in written Chinese is the character. Chinese characters are made up of configurations of eight major types of strokes, each with a label of its own. They are 一 (*Héng*), 丨 (*Shù*), 丿 (*Piě*), 丶 (*Diǎn*), ㇏ (*Nà*), ㇀(*Tí*), ㇇(*Zhé*), 亅(*Gōu*) [see Table1] Finer discrimination can produce about 20 distinct strokes (see W. S.-Y. Wang, 1973). The number of strokes in a character can vary from 1 to well over 20. In the simplified script adopted on the mainland after the establishment of the People's Republic of China - as distinct from the traditional script used in Taiwan, Hong Kong, and other overseas communities - the number of strokes is often significantly smaller. For example, "son": 儿 (simplified), 兒 (traditional); "sports meeting": 运动会 (simplified), 運動會 (traditional).

Table 1: Table of the basic strokes of Chinese

Direction	 or	 or						 or		 90° turn
Chinese	点	钩	横	捺	撇	竖	提	弯	斜	折
Pronunciation	*Diǎn*	*Gōu*	*Héng*	*Nà*	*Piě*	*Shù*	*Tí*	*Wān*	*Xié*	*Zhé*

The average number of strokes of the 14 most frequently occurring characters written in the traditional script, according to a corpus of more than a million characters surveyed by C. M. Cheng (1982), is 6.5 strokes. In a corpus of simplified script of more than 50,000 characters, with 3,317 different characters identified, M. Y. Chan (1982) found that the 14 characters with the highest frequency of occurrence had an average of 5.6 strokes. In addition, the average stroke number of 2,000 commonly used characters was reduced from 11.2 to 9.0. There is an inverse relationship between frequency of usage and number of strokes in characters (M. Y. Chan, 1982). This would correspond to a similar relationship between frequency and word length in alphabetic languages, and both can be taken as indication of the principle of least effort expounded by Zipf (1949).

2. Sound of Chinese

Nearly all characters are pronounced monosyllabically in Chinese. However, there is a small number of Chinese characters that can be pronounced subsyllabically. For example, a frequently used character is the character 儿 (-r/*er*), pronounced as /-r/ in Putonghua (the Mandarin)[1]. This character is attached to other nouns to indicate the diminutive or as a form of endearment, although it can also be pronounced as /er/; as a full syllable it means "son". Likewise, some characters have two or three pronunciations with distinct meanings, e.g. 处 ①*chǔ* (verb) 处罚(*chǔfá,* punish) 处置(*chǔzhì,* handle; deal with) ②*chù* (noun) 处所 (*chùsuǒ,* place) 长处(cháng*chù*, advantage).

As mentioned in Chapter I, in Chinese, tonal differences affect meaning just as change in consonants and vowels does. There are four tones in Putonghua, which yields as many as 420 different syllables in Chinese. In C. M. Cheng's (1982) survey of a corpus of more than a million characters, he identified 401 syllables. With these 400-odd syllables, the permutation of tonal variation in Putonghua in effect results in more than a thousand different pronunciations, with some syllables not realizing all the possible tonal permutations. This number corresponds to tens of thousands of characters. Naturally, homophones abound. C. M. Cheng (1982) found that the 12 highest frequency syllables and their tonal variations made up 25% of the distribution of sounds in his corpus of characters, and the 45 highest frequency syllables made up 50%. As mentioned, the tone of syllables alters meaning as much as changing a consonant or a vowel.

3. Pictographs and ideographs

A small percentage of characters convey meaning by pictograph representation, either iconic or abstract. The former are more direct, such as the character for *bird* (鸟, niǎo). Whereas these pictograph characters have an etymology related to pictures, this relation is unlikely to have psychological reality in present day usage. It is not possible for the

[1] While *Putonghua* is the term used for the official dialect in the People's Republic of China, *Mandarin*, an older name for the same dialect, remains the term used in Taiwan and some overseas communities. In this study, we will always refer to Mandarin.

uninitiated Chinese reader or indeed the nonreader of Chinese to discern or guess the meaning of such symbols. The confusion between having a pictograph etymology and having a psychologically real pictograph function can lead to misunderstanding.

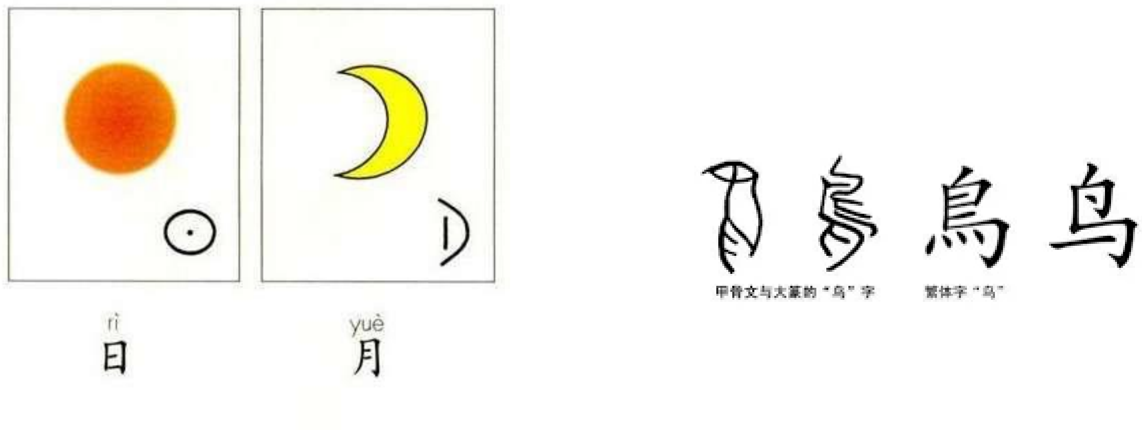


Figure 1: The pictograph of Chinese characters (sun, moon and bird)

The phonological system of Chinese has many different syllables, each character having different meanings. A Chinese written word can be made up of only one or several characters. A character can thus make a single-character word or be a morpheme of a multiple-character word, with a very different meaning in these two situations. Some representations are abstract rather than iconic. An example would be the character meaning *wood* (木, the vertical line above the horizontal line represents the trunk stemming of the earth, while the strokes below the horizontal line represent the development of the root system.), made up of a repetition of the pictograph for *grove* (林, where the height of the trees is almost the same), *forest* (森, where the trees can be high and low, or old trees and also young trees; bviously, an iconic representation of a wood would require many more trees). Such characters do not need to represent always concrete things. An example is the character meaning both "*to trust*" or "*letter*" (the same character "信 (xìn)", which is made up of the characters for *man* (亻,人) and for *word* (言). Such abstract representations have been called ideographs. Only relatively few characters fit the label in this sense. However, the label "ideograph" is also being loosely applied to all Chinese characters (Besner, Daniels, & Slade, 1982; Huang & Jones, 1980), as graph symbols representing meaning directly. In addition, there are no explicit markers between words in written Chinese (the spaces between characters and words are identical).

4. The bisyllabic word in modern Chinese

The Chinese character was usually a free form, that is, words were usually monomorphemic. For example, a single character was used as a word in classical Chinese to mean teacher. Nevertheless, the same character is now used together with another meaning "old" to mean "teacher". "师" and "老师" both mean "teacher", in classical and modern Chinese, respectively. It should be noted though that written language has not just become more redundant, it has equipped itself with a means of productive combination of characters to form a richer vocabulary of words, just as the productive combination of radicals have been used to form new characters.

Although words in modern Chinese tend to be two characters long, the most frequently used ones tend to be monosyllabic (Suen & Ary, 1986); among the 60 words ranked highest in usage only two are two characters long. Many of the single-character words are function words or auxiliaries. This is a manifestation of the principle of least effort, whereby more frequently used word tends to be shorter.

The difference in the frequency distribution pattern of individual characters, compared with the frequency distribution of words (which can be one, two or more characters), is demonstrated by statistical data provided by C. M. Cheng (1982). Frequency of occurrence of Chinese words shows a lognormal distribution similar to that of English words. Higher frequency words tend to constitute a more unevenly large cumulative percentage of occurrence. However, frequency distribution for individual Chinese characters shows less of such a pattern, because "common" characters can occur in common as well as rare multicharacter words. In this way, they are like English morphemes. In the sample of C. M. Cheng (1982), he found the same extent of variety of Chinese words as was found in the corpus of English words by Kučera and Francis (1967), both with a type-token ratio of about 1:20. This means that each word occurs an average of 20 times in the samples surveyed. Thus, Chinese words (but not characters) have distribution patterns like that of English words.

Nevertheless, characters used to function mostly as words in classical Chinese. The difference between characters as free forms in classical Chinese and as bound morphemes in modern Chinese is blurred by the fact that an educated Chinese person is familiar with classical literature and literary style usage. Classical Chinese texts are commonly assigned in high school, and therefore the usage is much more familiar than the language of Chaucer would be to the average English speaker. Hence, it is sometimes difficult to determine whether a certain character in isolation is a free form (e.g., a word) or just a bound morpheme waiting to be combined with other characters to form words. It could function as one or the other depending on context, usage, and the user's competence.

The tendency for multisyllabicity goes hand in hand with the attrition of the repertoire of sounds in the history of Chinese (see Kalgren, 1949). In any natural language, there are always many more meanings to be conveyed than there are units of sounds. Without the general device of having multisyllabic morphemes, as in alphabetic or syllabic languages, the words. In this context, two is the smallest number and therefore the most economical. Hence, the tendency for bisyllabic words in modern Chinese. The need for disambiguation is of greater importance in oral language. Otherwise, the visual nature of the written script tolerates more homophones, because homophonic characters have more freedom to assume different visual shapes than homophones in alphabetic languages.

5. Syntax of modern Chinese

Chinese is usually classified as a subject-verb-object (SVO) language. In addition, a dialect difference can make the Chinese speaker to be exposed to variations in word order. Word order, or rather character order, is an important aspect of meaning at the sentence level and at the lexical level. There are some bisyllabic words where the constituent characters form different words if their order is reversed. For example, "story" (故事) becomes "incident" (事故) when the two constituent characters are reversed; "蜜蜂" (bee) changes to " 蜂蜜" (honey) when they change the word order.

Grammar as such is not taught in Chinese schools. Instead, what is attended to are the interrelations of meanings of individual characters and the emergent meanings derived from their combinations. For example, Kalgren (1949) wrote: "A Chinese grammar in actual fact becomes very meager; mainly rules for the relative position of the words in the sentence, and, in addition, the functions of a number of auxiliary grammatical words"(p. 68; cited in Hoosain, 1991, p. 22). Of course, we do not imply that there are no rules of grammar in the

Chinese language; there are good analyses of Chinese grammar (e.g., Chao, 1968a). However, the legacy of the structure of Chinese is that the reader has to monitor the semantic relations of character sequence, more so than in alphabetic languages, particularly in the absence of word boundaries. The lack of inflections in Chinese is another reason to pay attention to semantic relations. One needs to figure out, for example, the intended tense of verbs and whether nouns are in the singular or plural. Unlike Spanish, in Chinese do not have an explicit marker for number. There is no change of the singular or plural, only distinct with the number before the noun. Similarly, in Chinese there is no difference in nouns between feminine and masculine. In the Chinese written system, all are the same, occasionally adding an adjective to distinguish the gender. In the extreme case of some classical texts, there are no punctuations to mark phrase or sentence boundaries. Segmentation depends on the only available cue of meaning and semantic relations between characters.

Although many Chinese words are bimorphemic, the character retains its individuality, versatility, and salience as a unit of language. In the case of Chinese texts, the interrelations among and the ordering of characters are important indicators of lexical and grammatical relations.

Objectives

In the current study, we followed the pattern used by Yang et al. (2009), with the aim of examining the time course of semantic and syntactic processing when Chinese is read. Readers' eye movements were monitored, and the relation between a single-character critical word and the sentence context was manipulated such that three kinds of sentences were developed: (1) congruent, (2) those with a semantic violation, and (3) those with both a semantic and a syntactic violation. We wanted to discover an easy way to help foreigners (especially Spanish people) to study Chinese. Chen (1999) suggested that it is better to use a semantic + syntactic violation condition to study Chinese, because syntax and semantics are closely interrelated in Chinese and, thus, most syntactic violations will always severely disrupt semantic processing. In this study, we will continue to investigate whether there is a difference between Chinese and Spanish to read sentences in languages from a widely different cultural background.

Method

1. Participants

Thirty-five university students at the Universidad Autónoma of Madrid participated in this experiment. All participants were native Chinese speakers, born in China and some of them started their first year in Spain to study Spanish. They all had normal or corrected-to-normal vision. The average age of the subjects is 23 years old, the eldest was 36 and the youngest was 19.

2. Design

The design of this experiment was a within subject design, 3x6. The independent variables were “condition”, with three levels (CON, SEM and SEM+SYN), “region”, with five levels (T-1, T, T+1, T+2 and LR) and "CW" (critical word), with six levels (CW-2, CW-1, CW, CW+1, CW+2 and CW+3). We will explain all of them in the following section. The dependent variable was Reading Comprehension. This variable was operative by several eye tracking measures that will be explained in subsequent sections.

3. Materials

There were 39 experimental sentence frames; each sentence frame contained a single-character CW. By manipulating the relation between the CW and the sentence context, three kinds of sentences were developed: CON, SEM, and SEM + SYN. Two sets of analyses were carried out to analyze the eye movement data for the experimental sentences. The first set was based on individual Chinese characters and included the CW, two characters before it (CW-2 and CW-1) and three characters after it (CW+1, CW+2, and CW+3). The second set was based on regions wherein every two characters of interest were combined. Specifically, the sentences were divided into seven regions: a pre-target region T-1 (including CW-4, CW-3 and CW-2), a target region T (including CW-1 and CW), a first post-target region T+1 (including CW+1 and CW+2), a second post-target region T+2 (including CW+3 and CW+4), a third post-target region T+3, a fourth post-target region T+4, and a last region LR (including the last two characters and the period). Examples are shown in Table 2, and the full set of sentences is provided in Appendix I. For example, the CW 酒 (a noun that means "wine") in the CON Sentence A was both semantically and syntactically appropriate for the sentence context. In the SEM Sentence B, the CW 枪 (a noun that means "gun") maintained the syntactic property of the CON CW as being a noun but was semantically inappropriate for the context. Finally, in the SEM + SYN Sentence C, the CW 挂 (a verb that means "hang") yielded both a syntactic and a semantic violation in the sentence context. Note that all of the CWs in this condition can be used as verbs only when they are presented in isolation. Given that context plays an important role in determining word category, two norming studies (presented below) were used to ensure that this condition really introduced a syntactic violation. For each sentence frame, the three kinds of CWs were located at the same position in the sentence: They were in the middle of the sentence, at least 3 characters away from the beginning and 10 characters away from the end of the sentence; so that we could examine to how many characters would the effect of violation spill over.

Three material sets were created for this experiment, each containing 39 experimental sentences and 57 filler sentences. The experimental stimuli in each set included 13 sentences in the CON version, 13 in the SEM version, and 13 in the SEM + SYN version. Each version of the experimental sentences appeared once across each of the three sets (see Table 2).

Table 2: Examples of a Stimulus Sentence in Chinese Used in the Experiment

Congruent (CON):

A. 小李/ (1) 经常/ (2)饮酒/ (3)因此/ (4)容易/ (5)换上/ (6)胃炎/ (7)等疾病。
Xiao Li / (1) always / (2) drinks wine / (3) so / (4) easily / (5) get / (6) stomach / (7) illness.
Xiao Li drinks a lot of wine so he could easily get stomach illness.

Semantic violation (SEM):

B. 小李/ (1) 经常/ (2)饮枪/ (3)因此/ (4)容易/ (5)换上/ (6)胃炎/ (7)等疾病。
Xiao Li / (1) always / (2) drinks gun / (3) so / (4) easily / (5) get / (6) stomach / (7) illness.
Xiao Li drinks a lot of gun so he could easily get stomach illness.

Semantic + syntactic violation (SEM + SYN):

C. 小李/ (1) 经常/ (2)饮挂/ (3)因此/ (4)容易/ (5)换上/ (6)胃炎/ (7)等疾病。
Xiao Li / (1) always / (2) drinks hang / (3) so / (4) easily / (5) get / (6) stomach / (7 illness.
Xiao Li drinks a lot of hang so he could easily get stomach illness.

Note—*The critical word; (1) the region T - 1; (2) the target region T; (3) the first post-target region T + 1; (4) the second post-target region T + 2; (5) the third post-target region T + 3; (6) the fourth post-target region T + 4; (7) the last region of the sentence.

4. Apparatus

An SR Eyelink 1000 Plus eye-tracking system was used to track eye movements at the rate of 1000 Hz. The eye tracker monitored movements of both eyes and viewing was binocular. A NEC 21-in. MultiSync EA221WM monitor was used to display the stimuli. All the stimuli were presented in white on a black background on the computer monitor. All the characters were printed in Kai-Ti font. The size of each character was 20 points (0.71 × 0.71 cm2, with 0.2 cm between individual characters). Each character subtended approximately 0.8° of visual angle with the participant's eyes being 71 cm away from the monitor. For each experimental trial, the sentence always appeared in the center of the screen, and the CW also appeared in the middle of the sentence.

5. Procedure

A similar procedure to that in Yang et al. (2009) experiment was used. Prior to beginning the experiment, the participants received the experimental instructions. They were randomly assigned to one of the three stimuli sets and they were tested individually. The experiment consisted on a calibration phase and an experimental phase. In the calibration phase, each participant performed a 6-point calibration procedure to make sure that the eye-tracker recordings were accurate. Then, the experimental phase followed.

At the beginning of the experimental phase, the participants were told to read each sentence carefully for comprehension. Before reading each sentence, they were asked to fixate on a dot on the middle left end of the computer screen that indicated the position of the first character of the sentence. Once they fixated on the dot, the sentence was displayed. The participants read each sentence at their own pace and then pressed a button to terminate the end of the trial. One third of the sentences were immediately followed by a true/false comprehension question to ensure that the participants were not merely skimming the sentences. The participants answered the question based on the information from the previous sentence by pressing an appropriate button. The answer to a question of an experimental sentence was identical in the CON, SEM, and SEM + SYN conditions. Each participant read the 39 experimental and 57 filler sentences in a random order; the whole experiment lasted about 30 min. Six practice sentences were presented at the beginning of the experiment to familiarize the participants with the procedure. The participants were informed that they could take a break whenever they needed one.

6. Data analysis

An illustration of the combination of characters is shown in Table 2. We included the regions prior to and following the CW in order to examine so-called parafoveal-on-foveal effects (Starr & Rayner, 2001) and spillover effects of the violations, respectively. We will return to these two kinds of effects in reporting the results.

In each set of analyses, a number of eye movement measures reflecting first-pass processing (i.e., initial skipping probability, first-fixation duration, gaze duration for character based analysis/first-pass reading time for region based analysis) and later processing (i.e., second-pass reading time, go-past time, regressions in, regressions out, and total reading time) were computed as a function of the violation (Rayner, 1998). Analyses were performed using Repeated-Measures ANOVAs (R-M ANOVAs) in IBM SPSS Statistics 19.

Results

All the participants scored 80 % or better in response to the questions, averaging 95%. Fixations with a duration lower than 250 msec were removed from the analyses. Thus, 14.3% of the data were lost, including track losses. This percentage does not represent a problem for the data analysis.

The major issues were the following: (1) Can Chinese readers detect semantic and/or syntactic violations immediately?, and (2) can syntactic and semantic processing be separated from each other? In order to address these issues, three comparisons were drawn: (1) CON versus SEM, (2) CON versus SEM+SYN and (3) SEM versus SEM+SYN. Then, the eye movement measures reflecting the character-based analysis and the region-based analysis in the first-pass and later processing were reported separately below. Means and standard deviations are also reported in Tables 3 and 4, as follows:

i. Character-Based Analysis

Skipping probability is the probability of skipping a word when you are reading; **first-fixation duration** reflects the time that the eyes initially fixate on the character, regardless of the number of total fixations on it; and **gaze duration** is the sum of the time of all fixations on a character before the eyes move to another character. The three of them are sensitive online measures of processing (Birch & Rayner, 1997; Ehrlich & Rayner, 1983; Rayner, 1998). The probability of **regressions in** and **regressions out** indicate where the readers encountered anomalies or processing difficulties, and where they looked back to try to integrate the anomalies or overcome processing difficulties in the sentence. We will report these two measures only for the character-based analysis, because some regressions from one word to another word within a region would not be counted in the region-based analysis. For example, in the T region with CW-1 and CW, when readers regressed back from CW to CW-1, it would be considered a refixation of the same region, rather than a regression.

The first-pass processing including skipping probability and first-fixation duration, other three measures: gaze duration, regressions in and regressions out will be reported in detail as measures of later processing stages.

Although the pattern in the character-based analysis was similar to that in the region-based analysis, both reports will be reported in detail. The character-based reading time analysis is informative because there was considerable missing data, due to the high skipping probability for individual Chinese characters (about .40, for a similar finding; see Chen, Song, Lau, Wong, & Tang, 2003; Wong & Chen, 1999; or Wang, Chen, Yang, & Mo, 2008).

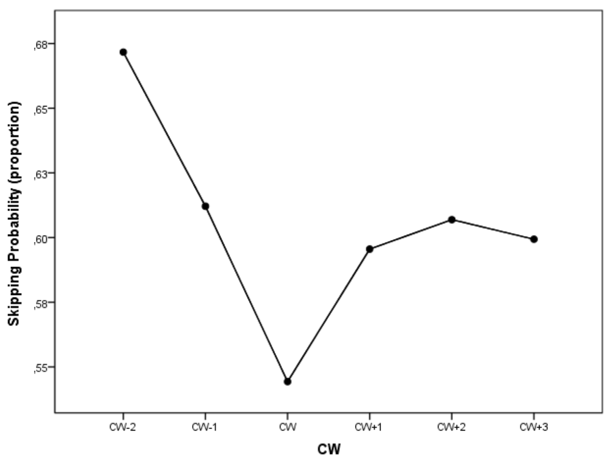
Table 3: Participant Means (With Standard Deviations) of Initial Skipping Probability (SP), First-Fixation Duration (FFD), Gaze Duration (GD), and Percentages of Regressions-Out (Reg. Out) and Regressions-In (Reg. In), as a Function of Congruency at Different Characters of the Experimental Sentences

		SP		FFD (msec)		GD (msec)		Reg. Out		Reg. In	
Position	Alteración	M	SD	M	SD	M	SD	M	SD	M	SD
CW-2	CON	.68	.17	195.97	44.22	198.69	42.58	18.99	14.53	50.21	24.93
	SEM	.66	.18	182.66	36.34	187.79	38.72	23.01	15.40	57.20	17.22
	SEM+SYN	.67	.17	189.78	30.50	196.66	42.79	22.57	14.48	61.17	20.18
CW-1	CON	.66	.16	194.02	46.97	197.83	47.99	17.43	13.30	47.76	21.89
	SEM	.62	.22	208.89	40.46	221.32	52.65	18.13	13.49	63.59	20.12
	SEM+SYN	.56	.25	200.66	49.95	207.69	58.43	20.66	15.37	65.47	15.59
CW	CON	.57	.24	207.87	44.68	213.43	46.76	19.88	16.12	38.75	22.56
	SEM	.53	.21	234.68	63.78	246.02	64.12	22.70	16.72	48.07	18.42
	SEM+SYN	.53	.23	225.15	65.76	244.73	74.28	30.84	21.80	53.55	25.93
CW+1	CON	.63	.16	190.58	51.45	193.70	53.04	16.88	15.87	31.60	18.55
	SEM	.60	.19	199.81	49.92	214.42	61.18	24.24	18.06	31.70	20.64
	SEM+SYN	.56	.20	216.96	51.88	227.35	59.12	24.76	16.63	35.78	20.21
CW+2	CON	.64	.17	199.37	45.42	201.63	46.21	14.18	12.89	28.68	18.16
	SEM	.61	.22	205.11	31.25	210.17	33.82	20.32	15.88	32.54	18.00
	SEM+SYN	.57	.20	223.21	62.73	228.38	63.95	21.17	17.45	29.30	19.11
CW+3	CON	.63	.17	199.05	33.98	199.05	33.98	12.26	13.73	25.47	17.50
	SEM	.59	.16	201.00	41.26	204.44	42.73	13.32	12.81	33.36	18.45
	SEM+SYN	.57	.19	201.02	26.42	206.39	30.57	13.41	12.47	21.88	18.58

Note--CON, congruent; **SEM**, semantic violation; **SEM+SYN**, semantic + syntactic violation.

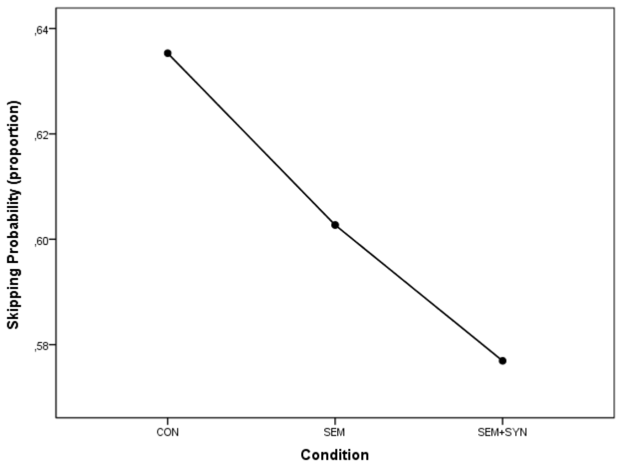
First-Pass Processing

Skipping probability. The interaction between the CW and condition was not statistically significant [F (10.290) =.514, p=.880, MSE=.009, η2=.017]. Instead of this, there was a significant effect of the CW [F (5,145) =4.034, p<.001, MSE=.149, η2=.150], but no significant effect of the condition [F (2, 58) =10.833, p<.001, MSE=.154, η2=.272]. This result can be observed in the following graphs:



Graph 1: *Proportion of skipping probability for the CW variable.*

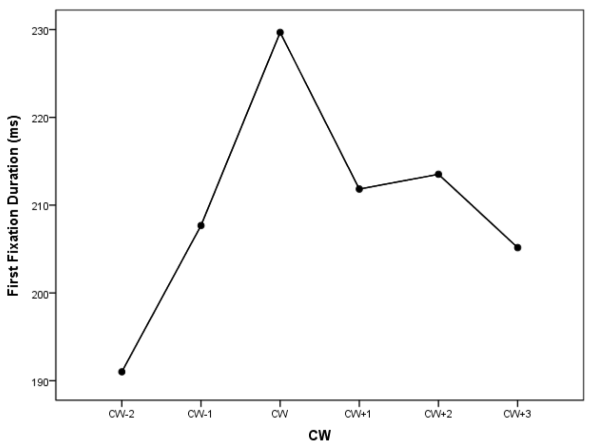
The skipping probability is more likely to occur on the CW-2 words, while it is less probable for characters that are closer to the CW. Moreover, the CW has the lowest probability for skipping, that is, readers focused on the CW.



The probability of skipping a character in the sentence is gradually decreased depending on the conditions, that is, the readers skipped in a lowest proportion in the SEM+SYN condition than in the CON and SEM conditions. However, as mentioned above, these differences among conditions did not reach statistical significance.

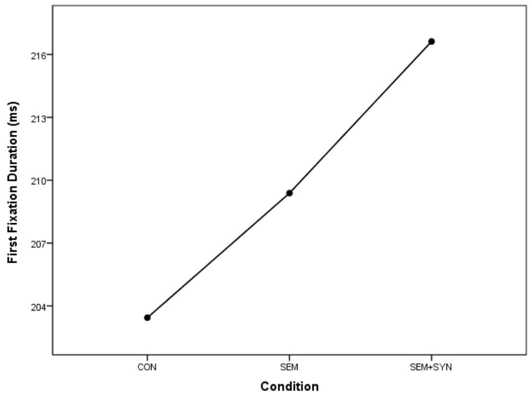
Graph 2: *Proportion of skipping probability for the condition variable.*

First fixation duration. No statistically significant interaction effect between the CW and the conditions was found [F (10,220) = 1.271, p=.248, MSE=1981.750, η2=.055]. Instead of this, there was a significant effect of the CW [F (5,110) =6.356, p<.001, MSE=10927.056, η2=.224] and of condition [F (2, 44) =6.264, p<.01, MSE=6012.383, η2=.222]. This result can be seen in the following graphs:



Graph 3: *First fixation duration for the CW variable.*

The CW presented the highest value for the first fixation duration. Then, the first fixation duration decreases with the shifting to the front or the back of the CW characters (the only exception is the CW+2 characters, whose duration is higher than those of both adjacent sites). The results emphasize the importance of two characters (CW and CW+2) because of the grammar or the sentence structure in Chinese.

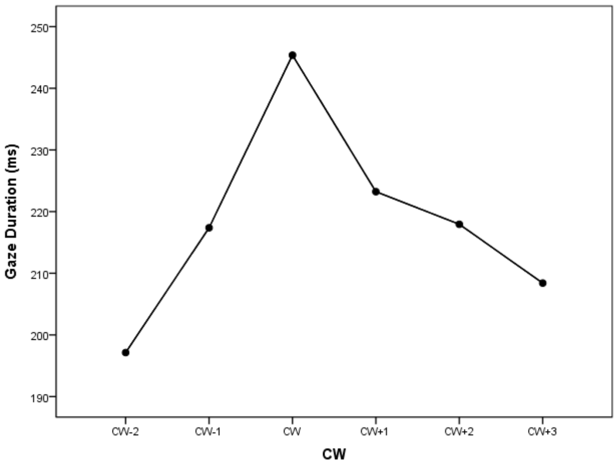


The time of the first fixation duration gradually increased by the conditions. The SEM and SEM+SYN conditions were longer than in the CON condition, but the SEM+SYN condition got the highest duration.

Graph 4: *First fixation duration for the condition variable.*

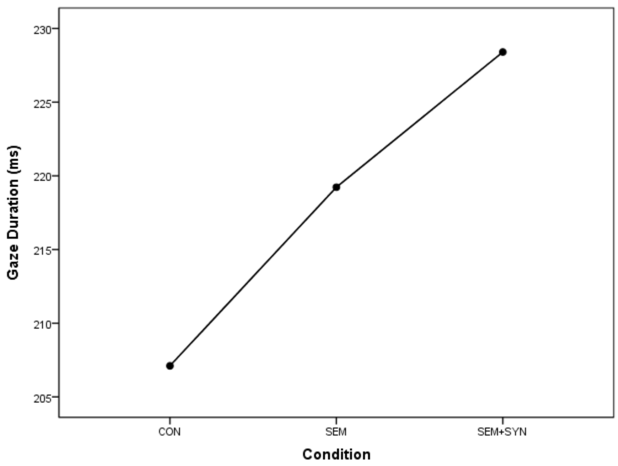
Later Processing

Gaze Duration. The interaction between the CW and the conditions was not statistically significant [F (10,220) =1.858, p=.052, MSE=3185.086, η2=.078]. There was a significant effect of the CW [F (5,110) =8.504, p<.001, MSE=17999.862, η2=.279], and also a significant effect was found of condition [F (2, 44) =11.646, p<.001, MSE=15742.304, η2=.346]. This result can be seen in the following graphs:



The CW presented the highest value in gaze duration, while the characters that were farther away from the CW obtained the lower gaze duration. Attention is thus focused on the CW characters, while the non-critical characters (especially the characters farther from the CW characters) received shorter fixations.

Graph 5: *Gaze duration for the CW variable.*

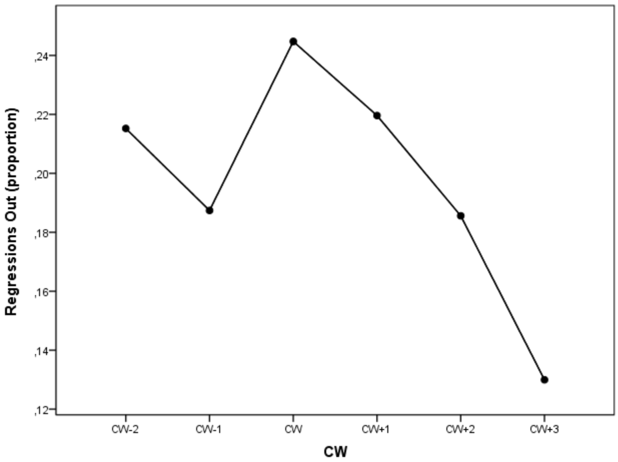


The time of the gaze duration gradually increased by conditions, that is, the readers fixated longer in the SEM and SEM+SYN conditions than in the CON condition.

Graph 6: *Gaze duration for the condition variable.*

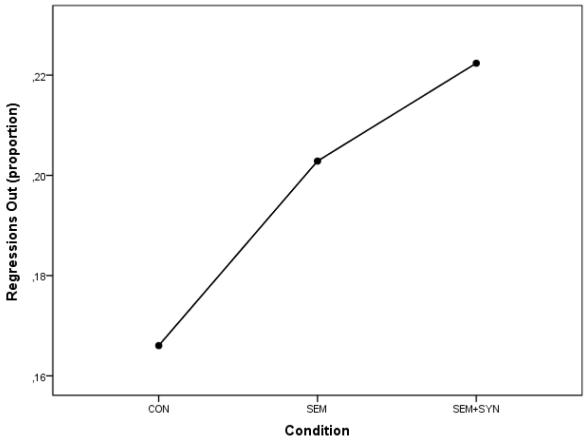
In the character-based analysis, no significant differences were found in gaze duration between the SEM condition and the CON condition (p>.14), and between the SEM and the SEM+SYN conditions (p>.79)]. This may suggest that the characteristics of the character to the right of fixation exerted an influence on the processing of the currently fixated character (a parafoveal-on-foveal effect). Although there is controversy concerning the validity of lexical parafoveal-on-foveal effects in reading English (see Rayner & Juhasz, 2004; Rayner, White, Kambe, Miller, & Liversedge, 2003; Starr & Rayner, 2001), there is some evidence for this effect in Chinese (see Yang, Wang, Chen, & Rayner, 2009). The effect of a violation on CW-1 in the present study seems to suggest that there are lexical parafoveal-on-foveal effects in reading Chinese. However, it is difficult to determine whether this effect was due to semantic processing or occurred because of mis-localized fixations. In alphabetic writing systems, it was demonstrated (Drieghe, Rayner, & Pollatsek, 2008; Nuthmann, Engbert, & Kliegl, 2005) that mis-localized fixations occurred when the reader intended to fixate on word n but the saccade fell short of the target and the eyes landed on word n-1 instead. In such situations, the reader's eyes would be fixating word n-1, but word n would be the processing target. Further research specifically aimed at examining parafoveal-on-foveal effects (which the present study was not designed to explore) is needed before we can conclude that the effects observed in the present experiment were due to semantic processing. This is also the result found by Yang et al. (2009).

Regressions out. The interaction between CW and condition was not statistically significant [F (10,290) =.735, p=.691, MSE=.015, η2=.025] Instead of this, there was a significant effect of the CW [F (5,145) =4.637, p<.01, MSE=.141, η2=.138], and also of the conditions [F (5,145) =4.637, p<.01, MSE=.141, η2=.138]. This result can be observed in the following graphs:



Graph 7: *Proportion of regressions out for the variables CW and condition.*

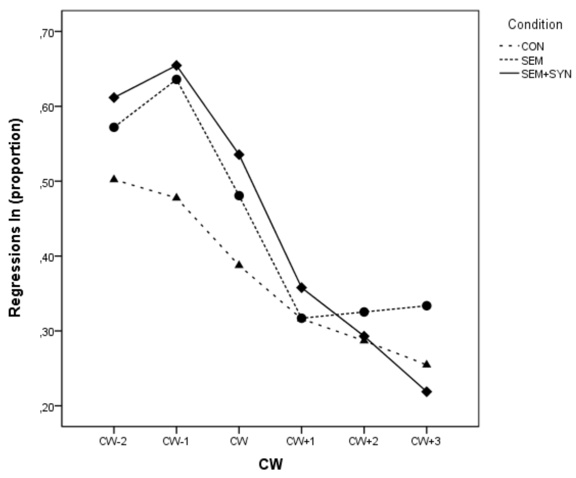
The CW character gets the highest value, while the character CW+3 gets the lowest value in regression out. The decrement trend of regression out starts from the CW character, which indicates that the characters beyond the CW seems to be unworthy to be paid attention. A possible reason for this is that these characters do not provide enough information for readers or that they are just used for the completion of one sentence.



Graph 8: *Proportion of regressions out for the variables CW and condition.*

The proportion of regression out increased gradually across conditions, that is, readers were more likely to regress to an earlier portion of the sentence in the SEM and SEM+SYN conditions than in the CON condition.

Regressions In. The interaction between the CW and the conditions showed a significant effect [F (10,290) =2.930, p<.01, MSE=.070, η2=.092]. The readers were more likely to regress to CW-1 [MD=-.158, p<.01] in the SEM condition than in the CON condition (see Table 3). Moreover, readers also regress between the three different conditions [F (2, 58) =12.558, p<.001, MSE=.327, η2=.302] and the six different characters [F (5,145) =50.249, p<.001, MSE=1.727, η2 =.634]. However, the readers were more likely to regress to CW-1 [MD=-.177, p<.001] and CW [MD=-.148, p<.05] in the SEM+SYN condition than in the CON condition, and to regress to CW+3 [MD=.115, p<.05] in the SEM+SYN condition than in the SYN condition. This result can be seen in the following graph:



The higher regressions were present in CW-2 and CW-1 in all the conditions. In the following words, a progressive decrease was observed. CON condition obtained fewer regressions in than the other two conditions between CW-2 and CW. Some differences were observed in the last words because the regressions in the SEM+SYN condition decreased more than in the other two conditions.

Graph 9: *Proportion of regressions in for the variables CW and condition.*

In the following section, a more detailed analysis of the results about each measures will be reported: **First fixation duration** and **gaze duration** data revealed a significant effect in the characters and the conditions. Readers' attention is kept on the CW characters, while the non-critical characters, especially the character CW-1 (the verb) are really fixed by readers in the violation SEM. Moreover, readers fixated longer in the SEM and SEM+SYN conditions than in the CON condition. Also, in the SEM condition there is more influence of characters CW-1 and CW, but after the CW, from CW+1 to CW+3, the SEM+SYN condition exerts more influence than the SEM condition. In turn, Yang. & Rayner (2009) found significant effects from CW to CW+3.

Skipping probability, the CW is the character that the readers did not skip much; on the contrary, CW-2, CW-1, and CW+2 were the most skipped characters. Moreover, the readers tended to skip characters less in the SEM+SYN condition than in the CON and SEM conditions. That means that when the sentences are congruent, readers skipped more than in sentences with semantic or semantic and syntactic errors. Yang et al. (2009) found a significant effect in skipping probability in CW+1.

Regressions out. Readers were more likely to regress to an earlier portion in the SEM and SEM+SYN conditions than in the CON condition. Furthermore, regressions out only revealed significant effects in the characters and the conditions factors, but not in their interaction.

Regressions in. As in the case of regressions out, readers were more likely to regress to a particular character in the SEM and SEM+SYN conditions than in the CON condition. There were significant differences between the SEM+SYN and the CON conditions for characters CW-1 and CW, and only the verb (CW-1) showed a significant effect between the SEM and CON conditions. Furthermore, there was a notable difference between the results of Yang et al., 2009 and ours, for they found significant differences at CW and CW+1 between the SEM+SYN and SEM conditions, but we only did at CW+3.

Taken together, the results of regressions suggest that the violation caused at the CW was evident early on and spilled over to the next three characters, and that the readers were trying to use contextual information prior to the CW (CW-1) to resolve the anomalies. In other words, when an anomaly is encountered, readers are more likely to reread the character (the verb) before the critical word. Moreover, these effects were larger at CW+3 in the SEM+SYN condition than in the SEM condition, suggesting that the readers encountered more difficulties in integrating the anomalies with the context.

ii. Region-based Analysis

We computed two standard measures typically used in region-based eye movement analyses (Rayner, 1998): the probability of initially skipping the region and **first pass reading time** (i.e., the sum of all fixations on a region prior to moving to another region, similar to the gaze duration in the word-based analysis). In addition, other eye-tracking measures were also computed. The means of the different measures across the regions of the sentence are shown in Table 4.

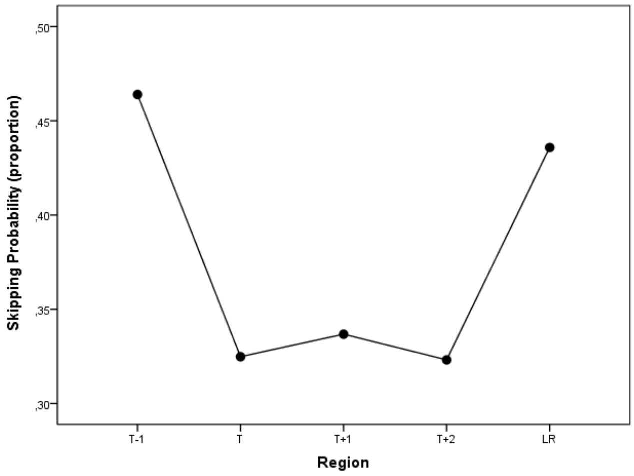
Table 4: Participant Means of Initial Skipping probability (SP), First-Pass Reading Time (FPRT), Go-Past Time (GP), and Total Reading Times (TRT) as a Function of Congruency at Different Regions of the Experimental Sentences (With Standard Deviations)

		SP		FPRT		GP		TRT	
Region	Violation	M	SD	M	SD	M	SD	M	SD
T-1	CON	.48	.21	230.12	61.20	388.98	98.39	507.73	213.67
	SEM	.46	.24	216.23	48.66	401.09	165.17	564.80	268.79
	SEM+SYN	.45	.20	215.42	87.88	428.07	162.68	581.23	211.84
T	CON	.35	.23	233.98	66.80	453.15	170.19	566.40	249.60
	SEM	.33	.23	278.48	96.90	536.94	205.05	847.11	348.25
	SEM+SYN	.30	.24	286.48	126.99	665.90	308.80	954.06	379.56
T+1	CON	.37	.19	216.64	56.35	453.86	244.12	484.41	179.08
	SEM	.36	.25	238.70	63.29	597.13	300.87	646.95	280.35
	SEM+SYN	.28	.20	264.91	79.66	604.35	285.80	654.39	239.81
T+2	CON	.35	.21	225.83	53.56	358.34	163.08	445.70	157.04
	SEM	.31	.19	241.70	60.66	438.52	208.58	478.69	139.44
	SEM+SYN	.31	.19	225.81	46.07	397.24	148.81	493.82	149.29
LR	CON	.45	.17	242.40	63.35	1579.48	934.41	362.88	162.59
	SEM	.44	.21	248.61	82.73	1642.25	872.26	368.90	188.07
	SEM+SYN	.42	.21	260.21	137.41	1546.14	655.39	362.42	182.10

Note--Reading times are in milliseconds. **CON**, congruent; **SEM**, semantic violation; **SEM+SYN**, semantic + syntactic violation.

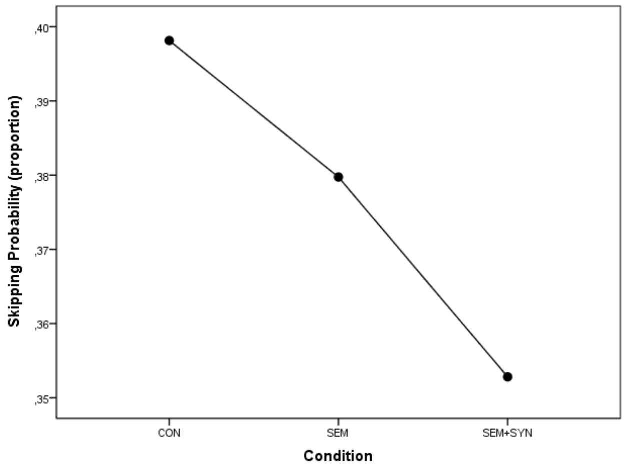
First-Pass Processing

Skipping probability. The interaction between the regions and the conditions was not statistically significant [F (6,172) =.568, p=754, MSE=.011, η2=.019]. Instead of this, there was a significant effect of the regions [F (3, 83) =10.256, p<.001, MSE=.411, η2=.261], but no significant effect of the conditions was found [F (2, 58) =4.677, p<.05, MSE=.078, η2=.139]. This result can be observed in the following graphs:



Graph 10: *Proportion of skipping probability for the region variable.*

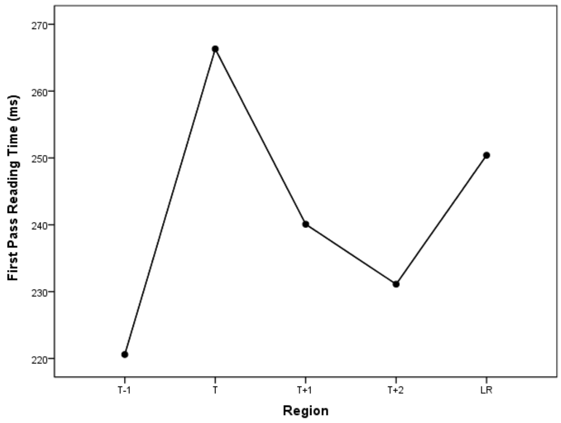
The tendency of skipping probability presented the following distribution: T-1 region and LR region obtain the higher value, while the T region and T+2 region the lower value and the T+1 region was marked in middle. The head and the tail of the reading region were more easily neglected, perhaps because they do not contain important information, while the T to T+1 region that are set in middle are judged as more informative and leave a deeper impression on readers, according to their language customs.



The probability of skipping a character in the sentence gradually decreases across conditions, that is, the readers skipped in a lowest proportion in the SEM+SYN condition than in the CON and SEM conditions.

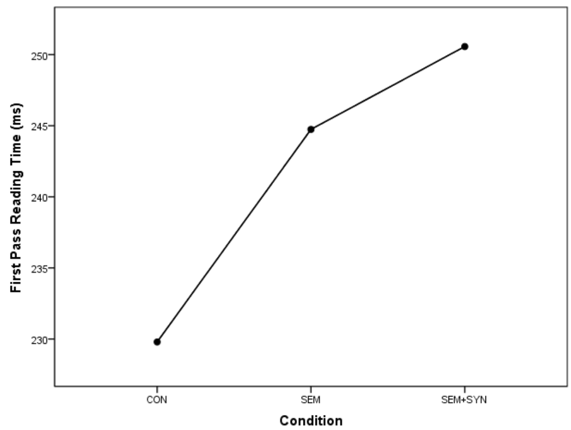
Graph 11: *Proportion of skipping probability for the condition variable*

Fixation time. In the first-pass reading time there was no statistically significant effect [F (3,99) = 2.351, p=.069, MSE=18288.070, η2 =.075]. Instead of this, there was a significant effect of the region [F (3, 83) =20.002, p<.01, MSE=38870.793, η2=.144] and also of the condition [F (2, 58) =4.550, p<05, MSE=17224.874, η2=.136]. This result can be seen in the following graphs:



Graph 12: *First-pass reading time for the region variable.*

The lowest first pass reading time was found on the T-1 region, and the highest value on the T region. The trend is judged as normal for the T set region. However, it is noteworthy that the LR region shows the second lagest value in first fixation time. LR seems to be the segmentation place for information supplement.



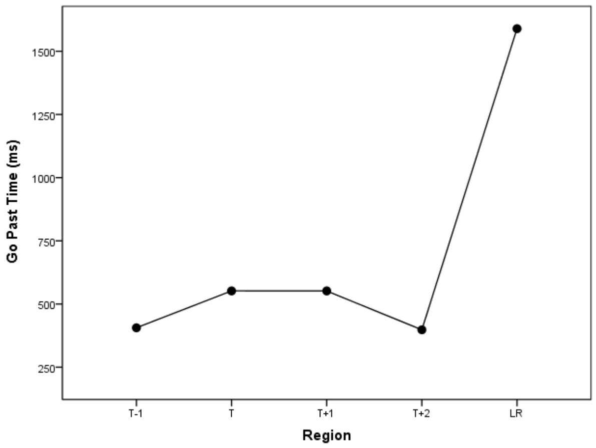
Graph 13: *First pass reading time for the condition variable.*

The first pass reading time gradually increases across conditions, that is, readers spend more time in the SEM and SEM+SYN conditions than in the CON condition.

Later Processing

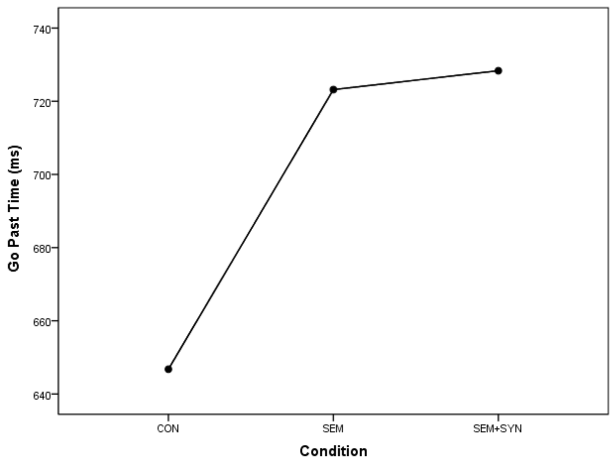
Go-past time was computed for the words and regions. **Go-past time** includes the amount of time that the reader looked at the CW/target region and any time spent rereading earlier parts of the sentence before moving ahead to inspect new parts of the sentence. Thus, it most likely reflects both lexical processing and integration processes, because the reader likely realized that there was some problem with the CW/target region and, thus, made a regression back to some earlier part of the sentence (Rayner et al., 2004). **Second-pass reading time** (which also reflects integration processes) includes the sum of all fixations on the word/region, except those made in first-pass reading. For completeness, we also computed **total reading time**, which includes all fixations on the word/region. Since the pattern of second-pass reading time was identical to that of go-past time, we will discuss only the go-past time and the total reading time measures.

Go past time. The interaction between the region and condition was not statistically significant [F (3, 86) = 1.097, p=.355, MSE=52900.315, η2 =.036]. Instead of this, there was a significant effect of the region [F (1, 37) =79.136, p<.001, MSE=71949724.112, η2=.732], but not of the conditions [F (2, 58) =3.757, p<.05, MSE=313042.339, η2=.115]. This result can be observed in the following graphs:



The LR region obtained the longest go past time, which is far larger than the value of T set region.

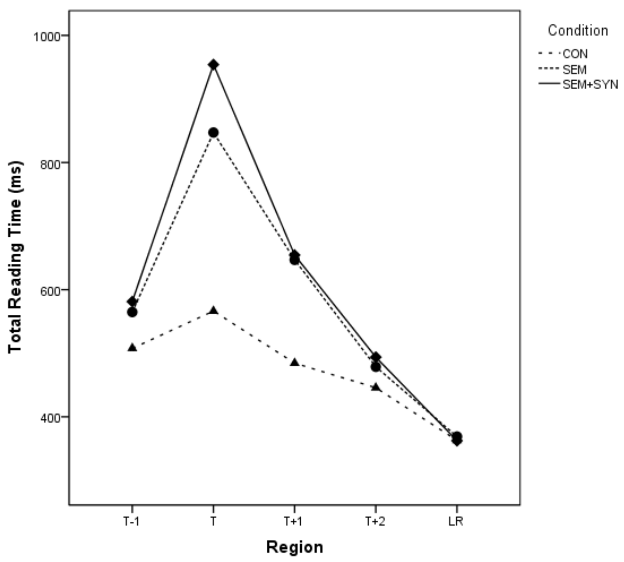
Graph 14: *Go past time for the region variable*



The go past time gradually increases across conditions, although the difference between the SEM and SEM+SYN conditions was very small, and both show larger go-past times than the CON condition.

Graph 15: *Go past time for the condition variable.*

Total reading time. (See Table 4) In the total reading time measure there was a significant interaction between regions and condition [F(5,155)=14.843, p<.001, MSE=192885.101, η2=.339]. In addition, total reading times were significantly longer in the SEM condition than in the CON condition in the T [MD=-280.709, p<.001], and T+1 [MD=-162.536, p<.01] regions, and also longer in the SEM+SYN condition than in the CON condition in the T-1 [MD=-73.504, p<.05], T [MD=-387.664, p<.001] and T+1 [MD=-169.976, p<.001] regions, and still longer in the SEM+SYN condition than in the SYN condition in the T [MD= -73.504, p<.05] region. Moreover, the readers also presented longer total reading time between the three different conditions (CON, SEM violation, and SEM+SYN violation) [F (2, 58) =43.778, p<.001, MSE=771090.932, η2=.602] and the five different regions (T-1, T, T+1, T+2 and LR) [F (2, 63) =53.001, p<.001, MSE=2237523.041, η2=.646]. This result can be observed in the following graph:



***Graph 16**: Total reading time for the variable region and condition.*

A similar pattern of total reading times can be observed in the three conditions, but the differences between the CON condition and the other two conditions are considerable. Large differences can be observed between the different conditions in T region, in which the differences between SEM+SYN and SEM conditions are also accentuated. In other words, the differences between SEM+SYN and SEM conditions are minimal, the observed effects being almost exclusively related to their comparison with the CON condition.

After revieweing all the results of the region-based analysis, a more detailed analysis of each measure will be reported now. The initial skipping probability **in the region-based analysis** revealed a significant effect of character and condition. The probability was cut down to about .35 for most of the regions, since readers generally skipped less in the SEM+SYN violation than in the CON and the SEM conditions.

The first-pass reading time of the analyzed regions only revealed a significant effect of character and condition, but no significant interaction effects. The time in the SEM+SYN condition is longer than in the SEM and the CON conditions. Moreover, the region T got the longest reading time, and the LR region also seemed like the important part of the sentence in Chinese reading.

To sum up, eye movement measures reflecting initial processing (i.e., gaze duration in the character-based analysis and first pass reading time in the region-based analysis) indicated that the SEM and the SEM+SYN violations can be detected right at the CW/target region. Moreover, first pass reading times were longer in the SEM+SYN condition than in the SEM condition in the T region, which suggests that the introduction of a syntactic and semantic violation yielded more disruption than did the pure semantic violation. (This is in line with the results of Rayner, 2009).

For **go past time** (see Table 4), it only revealed a significant main effects for characters and conditions, but no significant effect of the interaction. The readers fixated longest time in the LR region, and the two violations still attracted longer fixations than the CON condition, suggesting that they had more difficulty integrating the information in the former conditions than in the latter condition. In addition, there were longer go-past times in the SEM-SYN condition than in the SYN condition, which shows that the introduction of a syntactic and semantic violation yielded more disruption than did the syntactic violation alone.

Total reading times (see Table 4) were significantly longer in the SEM condition than in the CON condition in the T and T+1 regions, and also longer in the SEM+SYN condition than in the CON condition in the T-1 to T+1 regions; moreover, there was also a significant difference between the SEM+SYN condition and the SEM condition at the T region.

In short, the eye movement measures reflecting later processing indicate that readers encountered more difficulties in integrating the CWs/regions in the violation conditions, since they had longer go past times and total reading times in the SEM and SEM+SYN conditions than in the CON condition from CW-1 to CW/T-1 to T+1 regions, and they were more likely to regress out from CW-2, CW and CW+1 to look back to an earlier portion of the sentence. Furthermore, there were significantly longer go past times in the LR in the SEM and the SEM+SYN conditions than in the CON condition, indicating that some integration processing was conducted at the end of sentence. More important, a joint effect of the semantic and syntactic violation was larger than the pure semantic violation, since total reading times in the T and T+1 region were longer in the SEM+SYN condition than in the SEM condition. Also, the readers made more regressions out from CW and CW+1 to an earlier portion of the sentence and were more likely to look back into CW-1 when they encountered anomalies in the SEM+SYN condition than in the SEM condition, suggesting that syntactic and semantic processing could be dissociated from pure semantic processing in the reading Chinese.

Conclusion

In the analysis of eye-tracking measures with Chinese readers reported in this chapter, most reading measures showed no significant interactions between the factors character/region and condition: Skipping Probability (CW); First Fixation Duration; Gaze Duration; Regressions Out; Skipping Probability (R); First Pass Reading Time and Go Past Time. Interactions only showed up in Regressions in and Total reading time. We will now focus on these two measures, since they provide valuable information about the joint effect of the two independent variables manipulated in our study.

In Regressions in, the Chinese readers tend to read back to the CW and the CW-1 (the verb) in the conditions of semantic violation (SEM) and semantic and syntactic violation (SEM+SYN), but between these two conditions (SEM and SEM+SYN) there was not a very obvious difference.

As for Total Reading Time, it is plain to see that people need more time to read a sentence with a semantic violation (SEM) and with a semantic and syntactic violation (SEM+SYN) than a congruent sentence (CON). Moreover, in the region T (CW and CW-1), we also found a difference a difference between SEM+ SYN and SEM, showing that people spent more time in the SEM+ SYN condition than in the SEM condition. Those significant values only appeared in the region of T-1, T and T+1, but there were no differences at the end of the sentence.

Comparing our results with those reported by Yang et al. (2009), we find that both studies share similar results in some respects. First, both the character-based analysis and the region-based analysis of Chinese reading showed that semantic + syntactic violations and pure semantic violations were detected relatively soon and yielded disruption effects right on the CW/ target region in these three studies. These effects were also evident for CW-1, which may reflect a parafoveal-on-foveal effect, although as previously stated, this could be due to mis-located fixations. Moreover, the effect of the violation spilled over to the subsequent characters/region. Thus, in the study of Yang et al. (2009), the first-pass reading time in the post target T+1 and T+2 regions, in the SEM, and the SEM+SYN conditions were significantly longer than that in the CON condition; however, in our current study of Chinese reading, we only got a similar effect in total reading times in the post target T+1 region in the SEM and the SEM+SYN conditions, which were longer than that in the CON condition. Note that these results are not consistent with a delayed processing hypothesis, according to which Chinese readers wait for more information after the CW to build up a coherent representation. Instead, they are in line with the idea that the higher-level integration processes are initiated quite rapidly. Furthermore, these results imply that Chinese readers are trying to use contextual information to resolve the inconsistent information, since the violation effects were significant in the study of Yang et al. (2009) in go-past time, second-pass reading time, regressions out and regressions in, whereas in the present study we only found significant effects in regressions in and total reading time, as previously mentioned. In sum, with respect to the first question addressed by the present study, the results suggest that higher-level integration starts immediately when reading Chinese, although its completion spills over to subsequent parts of the text.

A second issue that is worth pointing out is the relative time course of syntactic and semantic processing in reading. In this regard, the effects of the SEM+SYN violations did not appear earlier than those of the SEM violation, since both violation effects were first evident on the same character CW-1 in our study, much the same as in the three studies reported by Yang et al. (2009). Since the difference between the SEM and SEM+SYN conditions was not significant at CW-1 (the verb) in Chinese reading, it is possible that this effect at CW-1 was due to the detection of an inappropriate meaning in the CW (a semantic parafoveal-on-foveal effect). In other words, semantic processing may start earlier than syntactic processing in Chinese reading. However, as was mentioned above, further studies are needed to test this possibility. What can be concluded from the present experiment is that syntactic processing is not initiated earlier than semantic processing in the reading of Chinese. This conclusion differs from studies involving the reading of alphabetic languages, wherein syntactic processing is claimed to start earlier than semantic processing (Boland, 1997; Braze et al., 2002; McElree & Griffith, 1995). A possible reason for the difference between Chinese and alphabetic languages like Spanish may lie in the fact that most alphabetic languages have some explicit markers (which we have mentioned before) to specify the word categories and the syntactic role played by words, and this may trigger syntactic processes in advance of the semantic processing of the words in the sentence. However, in Chinese, a language with virtually no markers for identifying grammatical functions, syntactic information might be inferred from the semantic information of words and from the sentence context.

In addition, differences between the SEM+SYN and SEM conditions appeared in first-pass reading time in the target region T in the study of Yang et al. (2009), whereas in the current study they only appeared in total reading time at the target region T. This might suggest that syntactic violations resulted in greater comprehension difficulties than semantic violations. It is probably the case that the readers were trying to reanalyze the sentence structure to solve the contradiction in the SEM and the SEM+SYN conditions in later processing, such as taking the incongruent CW as a modifier for a following congruent noun. This is compatible with the results of Yang et al.'s (2009) study, but we didn't find this early effect in our data. However, it may have been harder for readers to reanalyze the sentence structure when the target noun in the congruent condition was replaced by a verb, as in the SEM+SYN condition, than when the target noun in the congruent condition was replaced by a noun, as was the case in the SEM condition. Although it is hard to tell what causes the difference between the semantic and the semantic + syntactic conditions, our results clearly show that these two kinds of processing can be discriminated by eye movement measures. These results are consistent with those from a functional neuroimaging study that demonstrated a dissociation between semantic and syntactic processes in the reading of Chinese sentences, using the same violation paradigm (Wang, Zhu, et al., 2008; Yang et al., 2009).

Chapter III

Experiment II

The time course of syntactic and semantic processing in Spanish sentence comprehension: an eye-tracking study of the integration process during language comprehension

Abstract

In this experiment we analyze the time course of semantic and syntactic processing when Spanish is read. Readers' eye movements were monitored following the paradigm used by Yang et al., (2009), where they examined the relation between a single-character critical word and the sentence context in Chinese. We used the same pattern applied to Spanish sentences. Three kinds of conditions were developed: congruent, semantic violation, and semantic and syntactic violation. Thirty-three native Spanish-speaking university students of the Universidad Autónoma de Madrid took part in this study. The eye movement data showed that the first-pass reading times were significantly longer for the target region in the two violation conditions than in the congruent condition. Moreover, the semantic + syntactic violation caused more severe disruption than did the pure semantic violation, as reflected by longer first-pass reading times for the target region and by longer go-past times for the target region and post target region in the former than in the latter condition. These results suggest that the effects of a semantic violation can be quickly detected by Spanish readers and that the processing of syntactic and semantic information is distinct in both first-pass and second-pass reading.

Keywords: Spanish readers; time course; semantic and syntactic processing; sentence comprehension; eye-tracking; integration process; language comprehension.

Introduction

As is well known, Indo-European languages like English and Spanish have explicit morphological markers or inflectional indicators, such as certain lexical categories and bound morphemes for number, tense, or other grammatical features, to specify different types of syntactic information. See the following Spanish sentences with inflected verbs for tense, person and number:

1a. He is going to play basketball after the class.

[él *irá* a jugar al baloncesto después de la clase]

1b. He played basketball after the class yesterday.

[él jug*ó* al baloncesto después de la clase de ayer]

In a similar fashion to Experiment I (Chapter II), I will begin with a brief description of certain features of the Spanish grammar that are relevant for the experiment reported in this chapter.

1. Word Order and Information Structure of Spanish: Free word order in Spanish

Spanish allows for a fairly unrestricted ordering of constituents in simple and embedded declaratives. Thus, a transitive verb like "*comprar*" (to buy), realizing all its arguments, an optionally overt subject pronoun "él" (he), and a direct object "*el periódico*" (the newspaper), and with a temporal adjunct "*todos los días*" (every day), can appear in a sentence in, at least, the following constituent orders:

(1) a. (Él) compraba el periódico todos los días
(He) used-to-buy the newspaper every day
b. (Él) compraba todos los días el periódico
c. El periódico, (él) lo compraba todos los días
The newspaper, (he) it used-to-buy everyday
d. Él, el periódico lo compraba todos los días
e. El periódico lo compraba todos los días
f. El periódico es lo que (él) compraba todos los días
The newspaper is what (he) used-to-buy everyday
g. El periódico es lo que compraba todos los días (él)
h. Compraba (él) el periódico todos los días
i. Todos los días compraba (él) el periódico.

All the sentences in (1) have the same propositional content: it would be difficult to imagine a situation in which any one of them is true but the rest are not. The example (1a) has been considered in the grammatical tradition the basic, unmarked S(ubject) V(erb) O(bject) order in Spanish. Examples (1b-i), on the other hand, show derived word orders. These syntactic varieties of the same sentence differ from each other not only in the order of their constituents, but also in their discourse informational content and in their prosodic properties: in (1) specific constituents are interpreted as either background or new information, or as belonging to a restricted set of options. They are emphasized with respect to other sentential constituents or may show different intonation patterns to express syntactic and informational prominence. Even though all of them are well-formed sentences that satisfy all the syntactic, morphological, semantic and phonological principles of Spanish grammar, not all of them can be used interchangeably in a given discourse context. (Olarrea, 2012).

2. The SVO order and information structure: *Focus and topic in SVO*

The traditional way to posit a neutral or unmarked word order in a language is to establish the compatibility of a sentence with an informational or out-of-the-blue question, such as what happens/happened? In Spanish, the unmarked SVO order in "*Juan compró el periódico*" (Juan bought the newspaper) is a felicitous response to such a question, a sentence in which the entire utterance is new or asserted. This neutral order also presents a characteristic neutral prosodic pattern in Spanish in which the Nuclear Stress or intonation peak of the sentence falls in the rightmost stressed syllable, in this case the stressed syllable in "*periódico*" (see Zubizarreta 1994).

Juan compró el periódico, with the same neutral intonation described above, can also be a felicitous answer to questions that establish a different discourse context (e.g. *What did Juan buy?*). Now only the DP object *el periódico* in the answer provides new information, while *Juan compró* is given or previously known information. In this new discourse context, the SVO order also exemplifies the well-known tendency for languages to order given, old, presupposed, or background information before new or asserted information. The part of an utterance that is new, asserted, or not-presupposed information is referred to as the **focus** of the sentence (Jackendoff, 1972), whereas the rest of the utterance, which represents what is already known by the speakers, is the background or **presupposition**. In a question like *What happened?* the presupposition is that there is an *x, x is an unspecified event, such that x happened.* In *What did Juan buy?* on the other hand, the presupposition *is* that there is an *x, x is an unspecified object, such that Juan bought x.* In both cases, the wh-element in the question stands for a variable and the corresponding answer, the entire sentence *Juan compraba el periódico* in the first case, and the DO *el periódico* in the second, provide a value for that variable. Focus is thus understood as the constituent that provides a resolution for a variable established previously in a presupposition structure.

Different types of focus and many different definitions for the concept have been proposed in the literature, based on semantic, pragmatic, and syntactic distinctions (see Jackendoff 1972; Rochemont & Michael, 1986; Vallduví, 1992; Lambrecht, 1994; Kiss, 1998, among others, cited in Olarrea (2012), *Handbook of Hispanic Linguistics*).

3. Sentence Processing in Spanish

An assumption of psycholinguistics is that the processes which constitute language production and comprehension are based both on mental processes and on the restrictions imposed by the language being processed. An important paper by Cuetos and Mitchell (1988) demonstrated that English-speaking subjects tend to employ a late closure strategy in processing sentences, while Spanish-speaking subjects do not. Thus, Cuetos and Mitchell concluded that it cannot be the case that late closure is a generally (across languages) efficient strategy for processing sentences, and they suggest that the processing strategies which comprehends employ might be based on the inflections or marking that the language demands.

English is a word-order-dependent language; that is, the position of the words in the sentence determine their grammatical roles. Spanish, on the other hand, has relatively free word order and signals the grammatical relationships among the words in the sentence by means of prepositions (e.g. the preposition *a* to mark a human direct object), and especially through the verbal inflectional system. Cuetos and Mitchell's (1988) results make perfect sense if we assume that English speakers are relying on word order, which means that they must hear all of the words before knowing the complete order and, therefore, wait before they close off a phrase (i.e., employ a late closure strategy). Spanish speakers, on the other hand, can process more on-line, since the verb and its critics (or lack thereof) and the prepositional system will generally carry the information about the grammatical relationship among the noun phrases in the sentence.

The reasonable strategy for the English speaker is to wait until the end of the clause in order to ensure that s/he has all of the relevant word-order information. There is considerable evidence in the literature that English speakers do a great deal of processing at the end of the clause [the so-called end-of-clause effect (EOC)], as shown by "click" studies, in which Fodor and Bever (1965) found that subjects responded less quickly to a distracter task at the end of a clause, and eye-movement studies (Just and Carpenter, 1980), which found that English speakers spend a longer time reading words at the end of a clause.

Spanish and English differ strikingly in how the information needed to understand a sentence is marked. One important distinction between the two languages is the relative lack of marking on English verbs vis-à-vis Spanish. For example, the Spanish speaker can generally rely on verbal inflection to disambiguate sentences like (1) and (2):

(1) Los disquetes la computadora estropeó.

(1a) The computer ruined the diskettes.

(2) Los disquetes la computadora estropearon.

(2a) the diskettes ruined the computer.

Any bottom-up, as well as any processing strategies model, would predict that the Spanish speaker would pay attention to the inflection in the above examples. However, consider the ambiguous case (3):

(3) El disquete la computadora estropeó.

Here the verb inflection provides no information about which word is the subject and which is the object, so that a strict bottom-up model would predict that the uninformative inflection would not be central to processing, whereas a processing strategies model would still predict that it would be, because the understander is used to dealing with sentences where the inflection is informative.

The verbal marking also has important consequences for semantic case role (e.g., agent vs. patient) assignment. Consider the following contrast between (4) and (5):

(4) John sank the boat.

(4a) Juan hundió el barco.

(5) The boat sank.

(5a) El barco se hundió.

In English, the form of the verb *sink* is identical in both versions (whether the subject or the object of the verb is going beneath the water), whereas in Spanish, when the subject of the sentence is doing the sinking the verb must be marked with *se*. This relative paucity of morphology requires that the English speaker wait until the end of the clause to determine which noun phrase is undergoing the action of the verb, whereas the Spanish speaker may assign this semantic role immediately upon recognizing that it is the subject of the appropriately marked verb. On hearing "John sank... ," the English speaker cannot yet determine whether John went under the water, or whether John caused something else to go under the water. In the parallel situation, the Spanish speaker who hears "Juan hundió..." knows that it was Juan who caused something else to go beneath the water, and has no need to wait for further information in order to process that part of the sentence.

If Spanish speakers are employing a processing strategy which relies on verbal inflection, two predictions can be made: (a) that when word-by-word reading times are measured, the Spanish speaker will spend relatively more time in the middle of the sentence than the English speaker, and (b) that the English speaker will spend relatively more time at the end of the clause or phrase than the Spanish speaker, even when reading sentences which are word-for-word translations of each other, and even when no disambiguating marking is presented to the Spanish speakers.

Furthermore, this difference in verb-centered vs. whole-clause processing strategies in Spanish and English, respectively, should have clear effects on the kinds of sentences which the speakers of the two languages are able to process and understand. Specifically, a sentence in which the usual word order is disturbed should be relatively more difficult for the English speaker than for the Spanish speaker.

Spanish speakers do not need to process the whole clause at once, but can use relatively local cues to process the sentence, and then they will be less affected by this interruption. So, a relative clause sentence should be relatively easier for the Spanish speaker to comprehend since the primary information used in processing sentences is less disturbed.

The marking on all verbs is identically third person singular, so it is not the case that the Spanish speaker had access to some extra information that the English speaker has not. In fact, no evidence for facilitation was found for sentences with a plural noun in Spanish--where such a distinction is also marked on the corresponding verb--as a strictly bottom-up model would predict, suggesting that the facilitation for the Spanish speaker is not just a function of ease of knowing which verb goes with which subject. Rather the difference must lie in the different kinds of strategies that English and Spanish speakers generally employ. The English speaker's processing strategy of waiting until the end of the clause to assign semantic roles is disrupted by the embedding, whereas the Spanish speaker's strategy of assigning these roles more on-line is less disturbed and only fails with three embedded clauses (Hoover, 1992).

If the reasonable assumption is made that processing strategies reflect the grammar of the language involved, then these results make sense. English speakers must rely on word-order information to assign the semantic roles to the nouns in the sentence, while Spanish speakers generally rely on the richer s inflection a prepositional system as well as some word-order cues to assign these roles. However, when the Spanish speaker is presented with a complex nonpreferred-order sentence (such as the self-embedded sentences with inverted word order in the most embedded clause), performance plummets. The Spanish speaker is clearly using some word-order information, but also tends to rely on other information while processing the sentence. The English speaker, on the other hand always relies on this word-order information, so that disruption of the order reduces comprehension (see Rochemont & Michael, 1986).

Objectives

In the current study, we followed the pattern used by Yang et al. (2009) and our previous study in Chinese. We analyzed the time course of semantic and syntactic processing when Spanish is read. Reader’s eye movements were monitored following the paradigm used in the previous Chinese study, with the materials in Spanish translated from Chinese; we only changed some names and other background information to make sentences more familiar to Spanish participants. Again we examined the relation between a single critical word and the sentence context. Three kinds of conditions were developed: congruent, semantic violation, and semantic + syntactic violation. Thirty-three native Spanish speaking university students at the Universidad Autónoma of Madrid took part in this study. As in the previous study, two sets of analyses were carried out: word-based analysis and region-based analysis.

Method

1. Participants

Thirty-three university students of the faculty of Psychology of the Universidad Autónoma de Madrid participated in this experiment. All participants were native Spanish speakers. They all had normal or corrected-to-normal vision. The average age of the subjects is 26 years old, the eldest was 31 and the youngest was 20.

2. Design

The design of this experiment was a within subject design. The independent variables were "condition", with three levels (CON, SEM and SEM+SYN), and "CW/region", with six/five levels (actually they are the same variable; we will explain them in detail in the following section). The dependent variable was Reading Comprehension. This variable was operative by several eye-tracking measures that will be explained in subsequent sections.

3. Materials

There were 39 experimental sentence frames; each sentence frame contained a single CW. By manipulating the relation between the CW and the sentence context, three kinds of sentences were developed: CON, SEM, and SEM + SYN. Two sets of analyses were carried out to analyze the eye movement data for the experimental sentences. The first set was based on individual words and included the CW, the two words before it (CW-2 and CW-1) and up to three wordws after it (CW+1, CW+2, and CW+3). The second set was based on regions based on the meaning of each word or a whole phrase. Specifically, the sentences were divided into several regions (this will be explained with details in the Data Analysis section.) Examples are shown in Table 5 (CW and regions), and the full set of sentences is provided in Appendix I. In the example shown on Table 5, the CW *vino* (a noun that means *wine*) in the CON Sentence A was both, semantically and syntactically appropriate to the sentence context. In the SEM Sentence B, the CW *pistola* (a noun that means *gun*) maintained the syntactic property of the CON CW, being a noun, but was semantically inappropriate for the context. And in the SEM + SYN Sentence C, the CW *colgar* (a verb that means *hang*) yielded both a syntactic and a semantic violation in the sentence context. Note that all the CWs in this condition can be used as verbs only when they are presented in isolation. Given that context plays an important role in determining word category, two norming studies (presented below) were used to ensure that this condition really introduced a syntactic violation. For each sentence frame, the three kinds of CWs were located at the same position in the sentence: some of them were in the middle of the sentence, at least 3 words away from the beginning and 5 words away from the end of the sentence, so that we could examine how many words the effect of violation would spill over to; and little ones are at the end of the sentence, so that we could examine how many words the effect of violation would spill over to.

Three sets of materials were created for this experiment, each of them containing 39 experimental sentences and 57 filler sentences. The experimental stimuli in each set included 13 sentences in the

CON version, 13 in the SEM version, and 13 in the SEM + SYN version. Each version of the experimental sentences appeared once across each of the three sets.

Table 5: Examples of a Stimulus Sentence in Spanish Used in the Experiment

Congruent (CON):

A. Pablo bebe mucho **vino** por lo que fácilmente podría conseguir enfermedad estomacal.

Pablo / (1) bebe/ (2) mucho vino/ (3) por lo que/ (4) fácilmente/ (5) podría conseguir/ (6) enfermedad estomacal.

Peter drinks a lot of **wine** so he could easily get stomach illness.

Semantic violation (SEM):

B. Pablo bebe mucha **pistola** por lo que fácilmente podría conseguir enfermedad estomacal.

Pablo/ (1) bebe/ (2) mucha pistola/ (3) por lo que/ (4) fácilmente/ (5) podría conseguir/ (6) enfermedad estomacal.

Peter drinks a lot of **gun** so he could easily get stomach illness.

Semantic + syntactic violation (SEM + SYN):

C. Pablo bebe mucho **colgar** por lo que fácilmente podría conseguir enfermedad estomacal.

Pablo / (1) bebe/ (2) mucho colgar/ (3) por lo que/ (4) fácilmente/ (5) podría conseguir/ (6) enfermedad estomacal.

Peter drinks a lot of **hang** so he could easily get stomach illness.

Note—The word in boldface is the critical word; in the sentence: (1) the region T - 1; (2) the target region T; (3) the first post-target region T + 1; (4) the second post-target region T + 2; (5) the third post-target region T + 3; (6) the last region of the sentence.

4. Apparatus

An SR Eyelink 1000 Plus eye-tracking system was used to track eye movements at the rate of 1000 Hz. The eye tracker monitored movements of the right eye, although viewing was binocular. A NEC 21-in. MultiSync EA221WM monitor was used to display the stimuli. All the stimuli were presented in white on a black background on the computer monitor. All the characters were printed in Times New Roman font. The size of each character was 20 points (0.71×0.71 cm2, with 0.2 cm between individual words). Each character subtended approximately 0.8° of visual angle with the participant’s eyes being 71 cm away from the monitor. For each experimental trial, the sentence always appeared in the center of the screen, and the CW also appeared in the middle of the sentence.

5. Procedure

A similar procedure to that of Yang et al.'s (2009) experiment was used. Prior to beginning the experiment, the participants received the experimental instructions. They were randomly assigned to one of the three stimuli sets and were tested individually. The experiment consisted on a calibration phase and an experimental phase. In the calibration phase, each participant performed a 6-point calibration procedure to make sure that the eye-tracker recordings were accurate. Then, the experimental phase followed. At the beginning of the experimental phase, participants were told to read each sentence carefully for comprehension. Before reading each sentence, they were asked to fixate on a dot at the middle left end of the computer screen that indicated the position of the first word of the sentence. Once they fixated on the dot, the sentence was displayed. The participants read each sentence at their own pace and then pressed a button to terminate the end of the trial. One third of the sentences was immediately followed by a true/false comprehension question to ensure that the participants were not merely skimming the sentences. The participants answered the question on the basis of the information from the previous sentence by pressing an appropriate button. The answer to a question of an experimental sentence was identical in the CON, SEM, and SEM + SYN conditions. Each participant read the 39 experimental and 57 filler sentences in a random order; the whole experiment lasted about 30 min. Six practice sentences were presented at the beginning of the experiment to familiarize the participants with the procedure. The participants were informed that they could take a break whenever they needed one.

6. Data analysis

Two sets of analyses were carried out to analyze the eye movement data for the experimental sentences. The first set was based on individual Spanish words and included the CW, two words before it (CW-2 and CW-1) and three words after it (CW+1, CW+2, and CW+3). The second set was based on regions that were based on the meaning of each word or a phrase. Specifically, the sentences were divided into different regions, because we used the same experimental sentences of our previous Chinese study and translated them into Spanish. In the translation, we changed some Chinese words into similar Spanish concepts to make participants understand the sentences easily, e.g.:

Los oficiales antiguos iban en **caballos / desastres / cultivar** en vez de caminar para mostrar su poder.
Ancient officers all ride in **sedan-chairs / disaster / cultivate** instead of walking to show off their power.

Many people do not know what a "sedan-chair" is; if we translated it as "sillas de manos", it would confuse most of the participants, and so according to the history of the ancient time, in Spain they used horses (caballos) as a way to move. In addition, we changed the Chinese names into Spanish names, see Table 1 and Appendix I. Later, we divided the region for the semantic meaning of the context. An illustration of the combination of words is shown in Table 1. We included the regions prior to and following the CW in order to examine so-called parafoveal-on-foveal effects (Starr & Rayner, 2001) and spillover effects of the violations, respectively. We will return to these two kinds of effects when reporting the results.

In each set of analyses, a number of eye movement measures reflecting first-pass processing (i.e., initial skipping probability, first-fixation duration, gaze duration for the word-based analysis/first-pass reading time for the region-based analysis) and later processing (i.e., second-pass reading time, go-past time, regressions in, regressions out, and total reading time) were computed as a function of the violation (Rayner, 1998). Analyses were performed using Repeated-Measures ANOVAs (R-M ANOVAs) in IBM SPSS Statistics 19.

Results

All the participants scored 83% or better in response to the questions, averaging 95%. Fixations whose duration was less than 250 msec were eliminated from the analyses. Thus, 4.3% of the data were lost, including track losses. This percentage does not represent a problem for the data analysis. This experiment followed the same pattern of Yang et al. (2009), so the analysis was also the same; the only difference was that we changed the character-based analysis to the word-based analysis (necessary for the Spanish reading). The region-based analysis was the same.

The major issues are the following: (1) Can Spanish readers detect semantic and/or syntactic violations immediately?; and (2) can syntactic and semantic processing be separated from each other? To address these issues, three comparisons were considered: (1) CON versus SEM, (2) CON versus SEM+SYN and (3) SEM versus SEM+SYN. The eye movement measures reflecting the word-based analysis and the region-based analysis in the first-pass and later processing are reported separately below. Means and standard deviations are also reported in Tables 2 and 3, as follows:

i. Word-Based Analysis

Skipping probability means the probability of skipping the word when you are reading; **first-fixation duration** references the time that the eyes initially fixate on the word, regardless of the number of total fixations on it; and **gaze duration** is the sum of the time of all fixations on a word before the eyes move to another word. The three of them are sensitive online measures of processing (Birch & Rayner, 1997; Ehrlich & Rayner, 1983; Rayner, 1998).

Although the pattern in the word-based analysis was similar to that in the region-based analysis, and the effects were generally more robust in the latter analysis, we will report all the results in detail. The word-based reading time analysis is informative even though there was considerable missing data due to the high skipping probability for individual Spanish words (about .40; for a similar finding; see Chen, Song, Lau, Wong, & Tang, 2003; Wong & Chen, 1999; or Wang, Chen, Yang, & Mo, 2008).

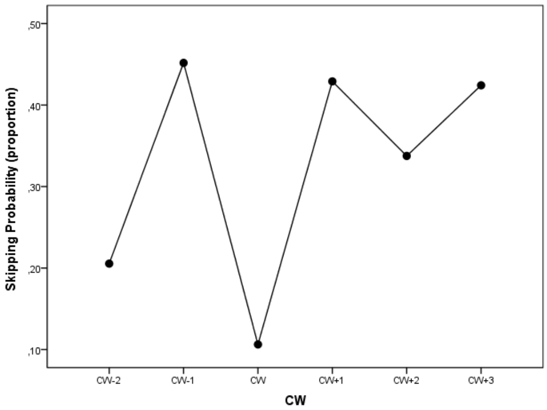
Table 6: Participant Means (With Standard Deviations) of Initial Skipping Probability (SP), First- Fixation Duration (FFD), Gaze Duration (GD), and Percentages of Regressions-Out (Reg. Out) and Regressions-In (Reg. In), As a Function of Congruency at Different Characters of the Experimental Sentence**s**

		SP		FFD (msec)		GD (msec)		Reg. Out		Reg. In	
Position	Violation	M	SD	M	SD	M	SD	M	SD	M	SD
CW-2	CON	.17	.15	211.85	29.87	269.42	70.28	14.50	12.06	39.85	16.14
	SEM	.23	.10	214.07	32.46	281.11	71.36	19.44	16.35	54.26	19.36
	SEM+SYN	.21	.09	218.87	29.94	275.10	49.93	17.56	13.47	57.46	22.65
CW-1	CON	.45	.18	217.01	47.83	254.51	65.50	15.70	12.93	38.47	22.76
	SEM	.48	.15	224.97	40.80	260.92	64.45	14.72	13.95	55.48	22.81
	SEM+SYN	.42	.16	222.99	50.69	263.76	65.28	17.95	16.60	64.18	21.71
CW	CON	.16	.12	223.31	36.59	275.58	63.95	21.32	16.15	28.92	18.33
	SEM	.11	.11	233.64	32.35	299.45	74.01	32.96	19.24	49.63	18.69
	SEM+SYN	.05	.07	234.29	40.07	317.57	86.85	36.94	19.25	54.33	19.91
CW+1	CON	.46	.19	215.41	39.40	240.09	56.05	7.63	10.79	35.54	19.66
	SEM	.43	.20	225.98	48.72	261.68	56.77	17.96	16.79	33.91	18.39
	SEM+SYN	.40	.22	244.54	54.55	267.31	55.39	24.13	17.88	43.82	20.99
CW+2	CON	.33	.14	218.17	36.30	258.43	55.85	18.05	15.73	29.89	14.85
	SEM	.35	.13	219.30	30.02	271.36	56.39	17.06	13.48	35.01	15.56
	SEM+SYN	.33	.12	230.36	34.10	273.56	54.13	29.69	18.82	30.32	15.65
CW+3	CON	.42	.15	209.27	31.53	251.24	55.79	15.00	11.61	29.51	14.83
	SEM	.42	.17	216.22	35.36	254.59	54.32	14.36	15.88	26.84	16.86
	SEM+SYN	.43	.17	217.96	38.28	262.69	56.13	23.01	14.47	27.10	17.99

Note--CON, congruent; **SEM**, semantic violation; **SEM+SYN**, semantic + syntactic violation.

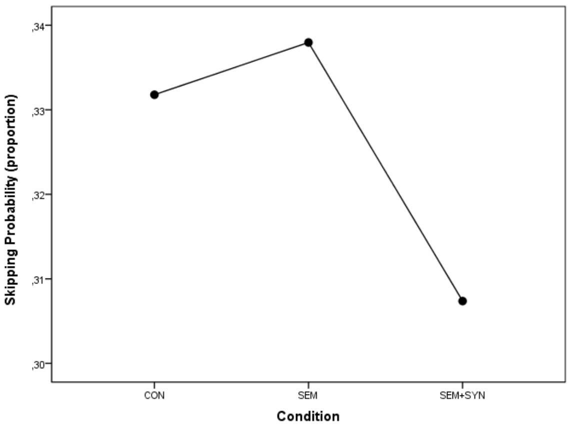
First-Pass Processing

Skipping probability. The interaction between the CWs and the conditions was not statistically significant [F (10,320) = 1.446, p=.159, MSE=.028, η2 =.043]. Instead of this, there was a significant effect of the CWs [F(5,160)=80.922, p<.001, MSE=1.961, η2=.717] and also of condition [F(2,64)=4.113, p<.05, MSE=.052, η2=.114]. This result can be observed in the following graph:



Graph 17: Proportion of skipping probability for the CW variable.

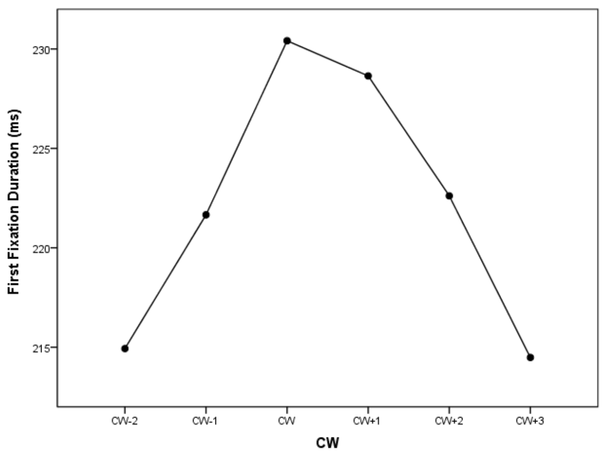
The CW obtained the lowest skipping rates, followed by the CW-2. On the contrary, CW-1 and CW+1, both flanking the CW, obtained the highest skipping probabilities.



Graph 18: Proportion of skipping probability for the condition variable.

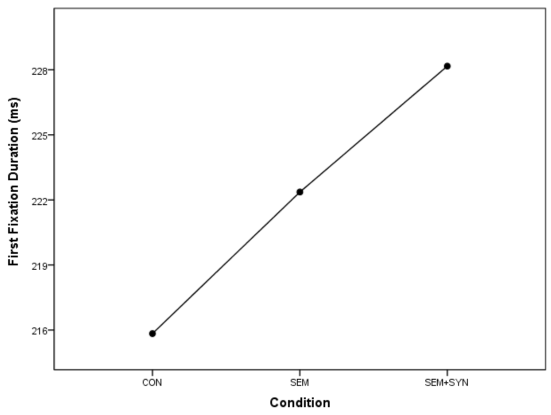
The SEM violation condition showed the highest skipping rates, but the readers skipped fewer words with the SEM+SYN violation.

First fixation duration. The interaction between the CWs and the conditions was not statistically significant [F (6, 206) =.896, p=.504, MSE=1268.948, η2=.027]. Instead of this, there was a significant effect of the CWs [F (5,160) =4.034, p<.01, MSE=4391.494, η2=.112] and also of condition [F (2,64) = 7.241, p<.01, MSE=7538.366, η2=.185]. This result can be seen in the following graph:



Graph 19: First fixation duration for the CW variable.

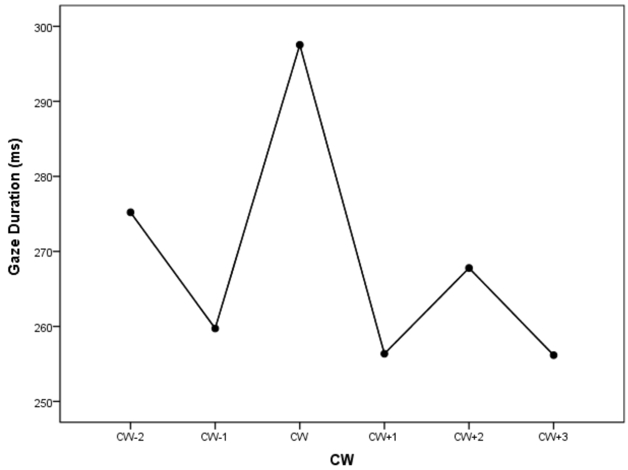
The CW presented the highest value of first fixation duration. No matter the position shifting to the positive towards the CW+3 direction or the negative towards the CW-2 direction, the first fixation duration gradually decreased in both.



Graph 20: First fixation duration for the condition variable.

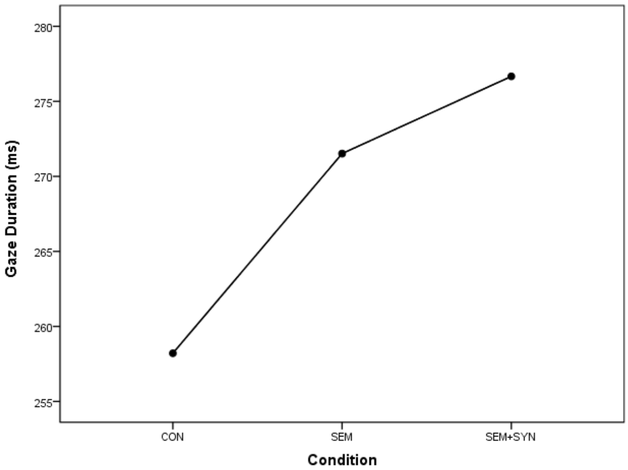
The time of the first fixation duration gradually increased by across conditions, the SEM+SYN condition showing the highest duration.

Gaze Duration. The interaction between the CWs and the conditions was not statistically significant [F (10,320) =.739, p=.687, MSE=1741.806, η2=.023]. Instead of this, there was a significant effect of the CWs [F (4,122) =8.370, p<.001, MSE=32863.089, η2=.207] and of condition [F (2,64) =7.676, p<.01, MSE=17955.100, η2=.193]. This result can be observed in the following graphs:



Graph 21: Gaze duration for the CW variable

The CW words presented the top highest gaze duration, while the shortest gaze durations were found on the words at CW+3, CW+1 and CW-1 (which are next to the CW word). Other words were marked in the middle range of the gaze duration. There was the broken line instead of a linear trend, as shown in the figure.



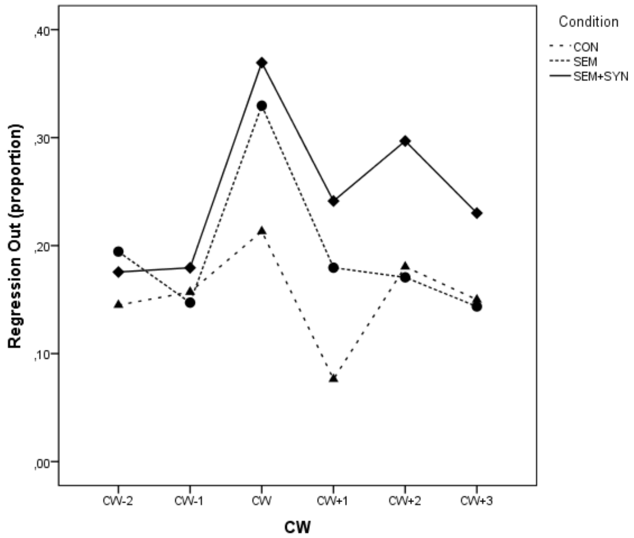
Graph 22: Gaze duration for the condition variable

The time of gaze duration increased across conditions, that is, the readers fixated longer in the SEM and SEM+SYN conditions than in the CON condition.

Later Processing

The probability of regressions in and regressions out of individual words will also be reported. These measures indicate where the readers encountered anomalies and looked back to try to integrate the anomalies into the sentence or repair them. We will report these two measures only for the character-based analysis, because some regressions from one word to another word within a region would not be counted in the region-based analysis. For example, in the T region with CW-1 and CW, when readers regressed back from CW to CW-1, it would be considered a refixation of the same region, rather than a regression.

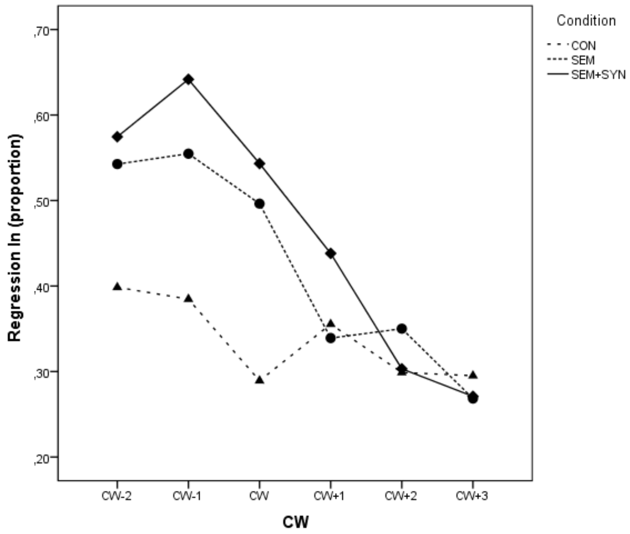
Regressions out. The interaction between the CWs and the conditions was statistically significant [F (10,320) =3.552, p<.001, MSE=.053, η2=.100]. Readers were more likely to regress to CW [MD=-.116, p<.01], CW+1 [MD=-.103, p<.001] in the SEM condition, as compared to the CON condition (see Table 2), and also they were more likely to regress to CW [MD=-.156, p<.001], CW+1 [MD=-.165, p<.001], CW+2 [MD=-.116, p<.01] in the SEM+SYN condition than in the CON condition; furthermore, readers were more likely to regress to CW+2 [MD=-.126, p<.01], CW+3 [MD=-.087, p<.05] in the SEM+SYN condition than in the SEM condition. Finally, readers also presented differences in the regressions between the three different conditions [F(2,64)=43.723, p<.001, MSE=.451, η2=.577] and the six different words [F (5,160) = 12.509, p<.001, MSE=.301, η2=.281]. This result can be observed in the following graph:



Graph 23: Proportion of regressions out for variables CW and condition.

The CON condition presented less regressions out than the other two conditions, in general. The SEM+SYN condition presented the highest rate. For the three conditions there was an increment of regressions out in the CW; this punctuations nosedive for the CON condition in the CW+1 and seem to stabilize in the following words, as well as the SEM condition in the last three words. In SEM+SYN condition, however, it remains high after the CW, though it decreases later.

Regressions In. The interaction between the CWs and the conditions was statistically significant [F(10,320)=7.897, p<.001, MSE=.153, η2=.198]. Readers were more likely to regress to CW-2 [MD=-.144, p<.01], CW-1 [MD=-.170, p<.01] and CW [MD=-.207, p<.001] in the SEM condition than in the CON condition (see Table 6), and also to CW-2 [MD=-.176, p<.001], CW-1 [MD=-.257, p<.001] and CW [MD=-.254, p<.001] in the SEM+SYN condition than in the CON condition, and to CW-1[MD=-.087, p<.05] in the SEM condition than in the SEM+SYN condition. Moreover, the readers also presented some differences in regressions in between the three different conditions [F (2,64) =33.454, p<.001, MSE=.817, η2=.511] and the six different words [F(5,160)=27.112, p<.001,MSE=1.007, η2=.459]. This result can be observed in the following graph:



The CON condition presented less regressions in than the other two conditions, especially between CW-2 and CW. There was an increment of regressions in for SEM+SYN and SEM conditions in front of CON condition in the first words. These differences were accentuated in the CW. The differences were minimal between CW+1 and CW+3.

Graph 24: Proportion of regressions in for variables CW and condition.

Next, I will offer a summary of the main results of the word-based analysis.

In the word-based analysis, it is worth noting the effect of gaze duration for CW [i.e., the SEM+SYN condition yielded longer fixation times than did the CON condition (MSE=-41.985, $p<.05$), whereas there was no significant difference between the SEM and SEM+SYN conditions ($p > .6$)]. This may suggest that the characteristics of the word to the right of fixation exerted an influence on the processing of the currently fixated word (a parafoveal-on-foveal effect). Although there is controversy concerning the validity of lexical parafoveal-on-foveal effects in the reading of English (see Rayner & Juhasz, 2004; Rayner, White, Kambe, Miller, & Liversedge, 2003; Starr & Rayner, 2001), there is some evidence for this effect in Chinese (see Yang, Wang, Xu, & Rayner, 2009). The effect of violation on CW in the present study seems to suggest that there are lexical parafoveal-on-foveal effects in reading Spanish. However, it is difficult to determine whether this effect was due to semantic processing or occurred because of mis localized fixations. In alphabetic writing systems, it was demonstrated (Drieghe, Rayner, & Pollatsek, 2008; Nuthmann, Engbert, & Kliegl, 2005) that mislocalized fixations occurred wherever the reader intended to fixate on word n but the saccade fell short of the target and the eyes landed on word n-1 instead. In such situations, the reader's eyes would be fixating word n-1, but the word n would be processed. Further research specifically aimed at examining parafoveal-on-foveal effects (which the present study was not) is needed before we can conclude that the effects observed in the present experiment were due to semantic processing.

First fixation duration and **gaze duration** revealed a significant effect for words and conditions. Attention is kept on the CW words, while the non-critical words, especially the words next to the CW word seem to be easily forgotten, which entails that words next to the critical word don't provide enough useful information (e.g. prepositions). Moreover, readers fixated longer in the SEM and SEM+SYN conditions than in the CON condition.

Skipping probability, CW and CW-2 are the words that the readers did not skip much; on the contrary, CW-1, CW+1 and CW+3 were the most skipped words. Moreover, readers skipped less in the SEM+SYN condition than in the CON condition, but the SEM condition got the highest skipping rates.

Regressions out. Readers were more likely to regress to an earlier portion of the sentence from CW+3 to CW. The proportions were always higher in the SEM condition and SEM+SYN condition than in the CON condition. Furthermore, differences between the two kinds of violations were significant in regressions out for CW+2 and CW+3.

Regressions in. Readers were more likely to regress from an earlier portion of the sentence from CW-2 to CW. The proportions were always higher in the SEM and SEM+SYN conditions than in the CON condition. Furthermore, differences between the two kinds of violations were significant in regression in only for CW-1.

Together, the regressions out and regressions in results suggest that the violations caused at the CW were immediately evident and spilled over to the next three words, and that readers were trying to use contextual information prior to the CW (CW-2 and CW-1) to resolve the anomalies. This means that when readers were reading, they were more likely to reread the word (always a verb) before the critical word. Moreover, these effects were larger at CW-1 in the SEM+SYN condition than in the SEM condition, suggesting that the readers encountered more difficulties in integrating the anomalies with the context.

ii. Region based Analysis

We computed two standard measures typically used in region-based eye movement analyses (Rayner, 1998): the probability of initially skipping the region and first pass reading time (i.e., the sum of all fixations on a region prior to moving to another region, similar to the gaze duration in the word-based analysis). The means of the different regions of the sentence are shown in Table 7.

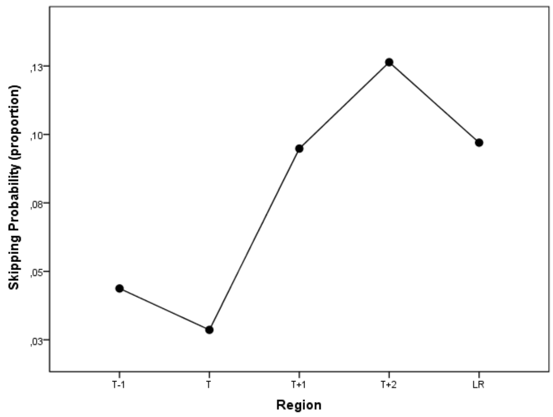
Table 7: Participant Means of Initial Skipping probability (SP), First-Pass Reading Time (FPRT), Go-Past Time (GP), and Total Reading Times (TRT) as a function of congruency at different regions of the experimental sentences (with standard deviations).

		SP		FPRT		GP		TRT	
Region	Violation	M	SD	M	SD	M	SD	M	SD
T-1	CON	.04	.07	428.59	125.58	559.78	147.33	913.96	359.63
	SEM	.05	.07	414.92	88.34	562.84	114.03	1023.64	356.90
	SEM+SYN	.04	.05	426.90	101.67	580.64	135.13	1100.05	400.89
T	CON	.03	.05	407.49	115.33	557.92	183.54	826.50	353.50
	SEM	.04	.06	464.33	133.38	669.29	183.84	1154.19	382.93
	SEM+SYN	.01	.03	536.13	154.94	774.26	221.04	1419.47	488.70
T+1	CON	.10	.09	357.68	65.98	443.47	128.94	671.50	222.44
	SEM	.10	.09	356.60	82.71	558.92	178.16	786.98	252.97
	SEM+SYN	.09	.09	380.60	91.24	790.96	294.78	936.74	315.22
T+2	CON	.12	.12	359.69	117.10	696.86	374.75	646.75	233.53
	SEM	.13	.12	344.14	89.22	915.52	487.92	720.36	241.56
	SEM+SYN	.13	.14	351.44	89.14	921.65	461.53	726.60	238.60
LR	CON	.10	.15	477.46	210.75	2046.55	1117.92	679.75	305.45
	SEM	.09	.13	453.53	152.22	2394.22	1097.65	735.50	262.34
	SEM+SYN	.10	.13	439.27	128.84	2574.70	1209.84	704.29	232.84

Note--Reading times are in milliseconds. **CON**, congruent; **SEM**, semantic violation; **SEM+SYN**, semantic + syntactic violation.

First-Pass Processing

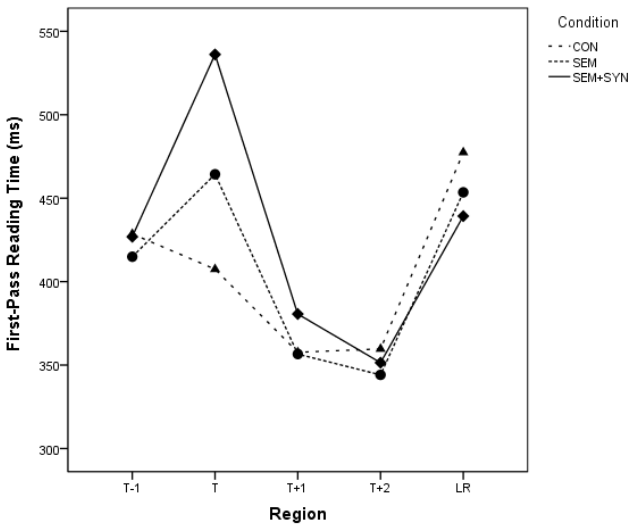
Skipping probability. The interaction between the regions and the conditions was not statistically significant [F (5,160) =.418, p=.835, MSE=.003, η2=.013]. Instead of this, there was a significant effect of region [F (2,80) =13.086, p<.001, MSE=.261, η2=.290], but not of condition [F (2,64) =.070, p=.932, MSE=.001, η2=.002]. This result can be observed in the following graph:



Graph 25: Proportion of skipping probability for the region variable.

The T region presented the lowest value, while the T+2 in region presented the highest value in skipping probability. The increment trend of skipping probability started in the T region, which indicates that the region beyond the T region seems to be unworthy of attention. Maybe, a possible reason is that the region cannot provide enough information for readers or that they were preparing for the completion of the sentence.

Fixation time. In the first-pass reading time there was a significant interaction effect between the regions and the conditions [F (5,165) = 7.065, p<.001, MSE=52900.315, η2 =.181]. When the readers were reading, they usually had longer fixation to region T [MD= -56.840, p<.01] in the SEM condition than in the CON condition (see Table 7), and the first pass reading time is also longer in region T [MD= -128.638, p<.001] in the SEM+SYN condition than in the CON condition, still the time is longer in the region T [MD=-71.798, p<.01] in the SEM+SYN condition than in the SEM condition. Moreover, the readers presented differences in fixation time between the five different regions [F (3,85) =20.002, p<.001, MSE=420504.840, η2 =.385]. This result can be observed in the following graph:



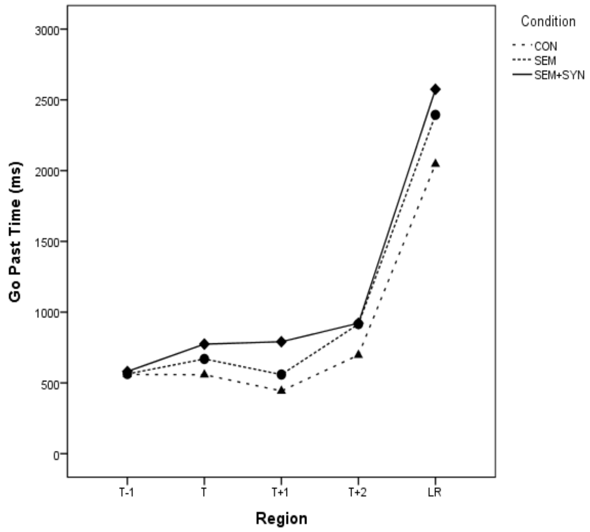
Graph 26: First-pass reading time for the variable region and condition.

On-relevant differences can be found in the three conditions when comparing first pass reading times, except for the T region in which the differences are considerable. SEM+SYN condition obtained the higher first pass reading time in front of the other two conditions, although SEM condition were significantly higher than the CON condition.

Later Processing

Go-past time was computed for the words and regions. Go-past time includes the amount of time that the reader looked at the CW/target region and any time spent rereading earlier parts of the sentence before moving ahead to inspect new parts of the sentence. Thus, it most likely reflects both lexical processing and integration processes, because the reader likely realized that there was some problem with the CW/target region and, thus, made a regression back to some earlier part of the sentence (Rayner et al., 2004). Second-pass reading time (which also reflects integration processes) includes the sum of all fixations on the word/region, except those made in first-pass reading. For completeness, we also computed total reading time, which includes all fixations on the word/region. Since the pattern of second-pass reading time was identical to that of go-past time, we will discuss only the go-past time and total reading time.

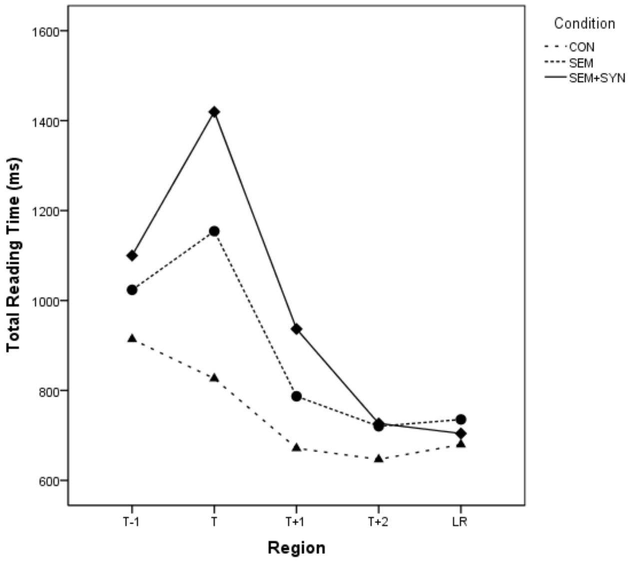
Go past time. The interaction between the regions and conditions was noT statistically significant [F (3,128) =1.284, p=.283, MSE=1017402.883, η2=.026]. When the readers were reading, they usually took longer to go back to earlier regions from T [MD=-111.370, p<.01], T+1[MD=-115.449, p<.001] and LR [MD=-347.668, p<.001] in the SEM condition than in the CON condition (see Table 7). Go past time was also longer in regions T [MD=-216.340, p<.001], T+1[MD=-347.488, p<.001] and LR [MD=-528.147, p<.001] in the SEM+SYN condition than in the CON condition, and the time is also longer in the regions T [MD=-71.798, p<.01] and T+1[MD=-232.039, p<.001] in the SEM+SYN condition than in the SEM condition. Moreover, the readers presented differences in go past time between the three conditions [F (2,64) =29.373, p<.001, MSE=2987977.880, η2=.479] and in the five different regions [F (1,34) =88.411, p<.001, MSE=211016595.400, η2=.734]. This result can be observed in the following graph:



Graph 27: Go past time for the variable region and condition.

A similar pattern of go past times can be observed for the different regions. Here, the main differences between the conditions were found in regions T and T+1. In these two regions, the SEM+SYN condition obtained higher go past times than the SEM condition and also than the CON condition. The differences between SEM+SYN and SEM conditions were reduced between T+2 and LR, increasing the differences between these conditions with respect to the CON condition.

Total reading time. (see Table 7) The total reading time presented statistically significant differences for regions and conditions [F (4,139) =17.397, p<.001, MSE=769917.974, η2=.352]. The total reading time was significantly longer in the SEM condition than in the CON condition at T [MD=-327.682, p<.001] and T+1 [MD=-592.968, p<.001] regions, and also longer in the SEM+SYN condition than in the CON condition at T -1[MD=-186.086, p<.01], T [MD=-592.968, p<.001], and T+1 [MD=-265.245, p<.001] regions, as well as in the SEM+SYN condition than in the SEM condition at T [MD=-265.286, p<.001] and T+1 [MD=-149.764, p<.01] regions. Moreover, readers presented differences across the three different conditions [F (2,64) =43.116, p<.001, MSE=2202745.137, η2=.574] and in the five different regions [F (2,72) =63.104, p<.001, MSE=6696596.894, η2=.664]. This result can be observed in the following graph:



***Graph 28**: Total reading time for the variable region and condition.*

Considerable differences were observed between the conditions in total reading times for T-1, T and T+1 regions. Total reading time in the SEM+SYN condition was considerable larger than in the SEM condition, and total reading time in the SEM condition was higher than in the CON condition. In T+2 and LR, the differences between SEM+SYN and SEM conditions were reduced. Instead of this, the differences between both and the CON condition were more stable.

By way of summary, these are the most outstanding results of the region-based analysis:

The initial skipping probability **in the region-based analysis** reduced to about .12 for most of the regions, since the readers generally skipped less in the SEM+SYN violation than in the CON condition and the SEM condition. However, no contrasts were significant in any condition (ps>.05).

The first pass reading time of the analyzed regions showed that the SEM condition yielded longer fixation time than did the CON condition, the SEM+SYN condition also had longer fixation time than the CON condition in region T, moreover, the difference between the SEM and SEM+SYN conditions was also significant in region T.

To sum up, eye movement measures reflecting initial processing (i.e., gaze duration in the word-based analysis and first pass reading time in the region-based analysis) indicated that the SEM and the SEM+SYN violations can be detected right at the CW/target region. Moreover, first pass reading times were longer in the SEM+SYN condition than in the SEM condition in the T region, which suggests that the introduction of a syntactic and semantic violation yielded more disruption than did the pure semantic violation.

For **go past time** (see Table 7), the readers fixated longer in the SEM condition than in the CON condition, and the go past time was longer in the SEM+SYN condition than in the SEM condition, suggesting that they had more difficulty integrating the information in the former condition than in the latter condition, or the introduction of a syntactic and semantic violation yielded more disruption than did the pure semantic violation.

Total reading times (see Table 7) were significantly longer in the SEM condition than in the CON condition in the T and T+1 regions, and also longer in the SEM+SYN condition than in the CON condition in the T-1, T and T+1 regions; moreover, between the SEM+SYN condition and the SEM condition, the T and T+1 regions also had a significant effect.

In short, the eye movement measures reflecting later processing indicate that the readers encountered more difficulties in integrating the CWs/regions in the violation conditions, since they had longer go past times and total reading times in the SEM and SEM+SYN conditions than in the CON condition from CW to CW+2/T and T+1 regions, and they were more likely to regress out from CW to CW+3 to look back to an earlier portion of the sentence. Furthermore, there were significantly longer go past times in the LR in the SEM and the SEM+SYN conditions than in the CON condition, indicating that some integration processing was conducted at the end of sentence. More importantly, a joint effect of the semantic and syntactic violation was larger than the pure semantic violation, since go past times and total reading times in the T and T+1 region were longer in the SEM+SYN condition than in the SEM condition. Also, the readers made more regressions out from CW+2 and CW+3 to an earlier portion of the sentence and were more likely to look back into CW-1 when they encountered anomalies in the SEM+SYN condition than in the SEM condition, suggesting that a syntactic and semantic processing could be dissociated from a pure semantic processing in the reading of Spanish.

Conclusion

In this study carried out in Spanish, the following measures showed no significant interactions: Skipping Probability (CW); First Fixation Duration; Gaze Duration and Skipping Probability (R). Therefore, in this conclusion to Experiment II, we will focus on the following measures:

Spanish readers showed an interesting pattern of regressions in and out. Our results showed that the Spanish readers did most regressions into the beginning of the sentence, concentrating on CW-2, CW-1 and CW, and also after CW, they did the regressions out from the end of the sentence, including CW, CW+1, CW+2 and CW+3. From this, we may infer that after detecting the anomaly at CW, Spanish readers went back to recover the meaning of the sentence in order to understand it. That might occur because in Spanish, nouns and verbs always change their morphology when the subject changes, which induces changes in gender (e.g. male or female), tense (e.g. present, past or future) and number (e.g. singular or plural), among other features. Once the readers spotted the error on CW, or when they noticed that sentences are not concordant, they needed to confirm where the problem was, hence the numerous regressions in and out.

In the region analysis, the first-pass reading time only showed a significant effect in region T (CW-1 and CW), with a larger magnitude in the SEM+SYN condityion than in the SEM condition. Moreover, the go past time showed significant effect in regions T and T+1, a very important result. Lastly, in total reading time, people need more time to read a sentence with a semantic anomaly (SEM) and semantic and syntactic anomalies together (SEM+SYN) than a congruent sentence (CON). Moreover, at regions T (CW and CW-1) and T+1, we also found a difference between SEM+ SYN and SEM conjditions, with readers spending more time in the SEM+ SYN than in the SEM condition. These significant effects only appeared at regions T-1, T and T+1, with no special effects at the end of the sentence.

Comparing the pattern of results in Spanish with the results of the study in Chinese, we find similar effects in most of the measures. First, both the character-based analysis and the region-based analysis of the Chinese and the Spanish studies showed that semantic + syntactic violations and pure semantic violations were detected immediately and yielded disruption effects right on the CW/ target region. These effects were also evident at CW-1, which may either reflect a parafoveal-on-foveal effect or mislocated fixations. Moreover, the effect of the violation spilled over to subsequent characters/regions: in the Chinese study, only the total reading time in the post target T+1 region in the SEM and the SEM+SYN conditions was significantly longer than that in the CON condition; however, the first-pass reading times in the post target T+1 and T+2 regions, in the SEM and the SEM+SYN conditions were significantly longer than those in the CON condition, with the same pattern in the Spanish study in go-past time and total reading time. Note that these results are not consistent with the delayed hypothesis, according to which (Chinese) readers wait for more information after the CW to build up a coherent representation. Instead, they are in line with the idea that higher-level integration processes are initiated quite rapidly. Furthermore, these results imply that Chinese readers were trying to use contextual information to resolve the inconsistent information, as shown by the significant effects in regressions in and total reading time. In the case of Spanish, this search for contextual cues is reflected in regressions out, first-pass reading times and go-past times. In sum, with respect to the first question addressed in the present study, the results suggest that higher-level integration starts immediately in the reading of Chinese, although its completion spills over to subsequent parts of the text. As for Spanish readers, they sem to keep their comprehension efforts until the end of the sentence, unlike Chinese readers, which may be attributed to syntactic differences between Chinese and Spanish.

Another interesting point of comparison between Chinese and Spanish readers concerns the relative time course of semantic and semantic + semantic processing In both cases the violation effect in the SEM+SYN condition did not show up earlier than in the SEM condition, since violation effects in these two conditions were first evident on the same character/word CW-1 both in Chinese and Spanish. Since the difference between the SEM and SEM+SYN conditions was not significant at CW-1 (the verb) in Chinese reading, but it was in Spanish reading, it is possible that the effect at CW-1 was due to the processing of inappropriate semantic meaning from the CW (a semantic parafoveal-on-foveal effect) for the reading of Chinese. In other words, syntactic processing may start earlier than semantic processing in Spanish. However, as was mentioned above, further studies are needed to test this possibility. This tentative conclusion is congruent with other studies involving the reading of alphabetic languages, where syntactic processing was initiated earlier than semantic processing (Boland, 1997; Braze et al., 2002; McElree & Griffith, 1995). A possible reason for the difference between Chinese and Spanish may lie in the fact that most alphabetic languages have explicit markers (that we have mentioned before) to specify the word categories and the syntactic role played by words, and thesde markers may enable readers to immediately understand the syntactic structure of a sentence even without retrieving the meanings of the words in the sentence.

In addition, in the Chinese study, differences between the SEM+SYN and SEM conditions appeared in first-pass reading time and total reading time in the target region T, indicating that the syntactic violation resulted in greater comprehension difficulties than did the semantic violation. Furthermore, in the study of Spanish, differences between these two kinds of violations were evident in the first-pass reading time in the target region T and also go-past time and total reading time in the post target region T+1. It is probably the case that the readers were trying to reanalyze the sentence structure to solve the contradiction in the SEM and the SEM+SYN conditions in later processing, such as taking the incongruent CW as a modifier for a following congruent noun. In this regard, Chinese and Spanish differ. However, it may have been harder for the readers to reanalyze the sentence structure when the target noun in the congruent condition was replaced by a verb in the SEM+SYN condition than when the target noun in the congruent condition was replaced by a noun in the SEM condition. Although it is not known for sure what causes the difference between the semantic and the semantic + syntactic conditions, the results of our studies clearly show that these two kinds of processing can be discriminated by means of eye movement measures.

Chapter IV

Experiment III

Eye movements during the perception of scenes: Are there culturally-based differences between Spanish and Chinese?

Abstract

Recent studies have suggested that eye movement patterns while viewing scenes differ for people from different cultural background, and that these differences in how scenes are viewed are due to differences in the prioritization of information (background or foreground). The current study examined whether there are cultural differences in how quickly eye movements are drawn to highly unusual aspects of a scene. Spanish and Chinese viewers examined photograph scenes while performing a preference rating task. For each scene, participants were presented with a normal and an unusual/weird version. Not only were there differences between the normal and weird versions of the scenes, according to the time of initial examination of the ROI (region of interest) and the subsequent examination of the ROI, but also there was evidence of cultural differences between Chinese and Spanish while viewing either scene type.

Keywords: Scene perception; Chinese; Spanish; cultural differences; eye tracking.

Introduction

Some recent research has suggested that Asian participants look at scenes differently from the way American participants do. Specifically, Chua, Boland & Nisbett (2005) reported that Chinese viewers spent less time looking at the focal objects in a scene and more time looking at the background of the scene than did their American counterparts. These results were discussed in the wider context of a general theory of cultural differences in cognition (Nisbett, 2003), whereby Asian cultures lead people to not place as much value on the individual as on the group, while American culture places more emphasis on the individual. According to Chua et al.'s reasoning, this underlying cultural difference in thinking led the Chinese viewers to look more at the background and spend relatively less time (in comparison to the Americans) looking at the focal objects. However, two recent reports have at least raised some questions about the validity of Chua et al.'s (2005) findings. Rayner, Li, Williams, Cave & Well (2007) reported no differences in the viewing patterns for Chinese and American participants, with both groups looking more at focal objects than at the background information. Boland, Chua & Nisbett (2008) noted that the Rayner et al. study was not a direct replication of Chua et al. (2005), given that the same materials were not used (i.e., the focal objects were more apparent in the Chua et al. study) and the task varied between the two studies (i.e., the expectation of a memory test in Rayner et al. vs. a rating task for scene likeability in Chua et al.). However, Evans, Rotello, Li & Rayner (2009) used the original scenes used by Chua et al. (as well as additional scenes for increased power) and the same task, and also found no differences between the two groups (both with the entire set of stimuli and with the subset that had been previously used by Chua et al.).

In the present study, we used the original scenes used by Yang et al. (2009) for Chinese and American viewers. We used the same procedure of testing for Chinese and Spanish viewers, but rather than dividing scenes in focal and background regions and examining eye movements, we used a different type of manipulation. Specifically, we asked Chinese and Spanish participants to look at scenes that had a rather unusual or weird component to them. In the study of Yang et al. (2009), they reasoned that if cultural differences can influence where viewers look in a scene and how quickly they look there, then there could be differences in how quickly Chinese viewers look at the unusual/weird parts of the scene. That is, if they truly are intent on looking more at the background information, it is likely that the unusual/weird object would not be as apparent to them as quickly as it would be for the American viewers. On the other hand, Masuda & Nisbett (2006) found that in a change blindness flicker paradigm, configurable changes (e.g. the spacing between two objects) were noticed sooner by Japanese viewers than by Americans. Thus, it could also be argued that because many of the weird regions in the present study were configurably odd, the Chinese viewers might look to the unusual/weird part of the scene sooner due to a better ability to detect these configural differences. Either of these two positions would lead to differences between the Chinese and American viewers in terms of how quickly they looked at the weird part of the scene. Alternatively, and consistent with Rayner et al. (2007) and Evans et al. (2009), there might not be differences between the two cultural groups (suggesting that culture does not strongly influence oculomotor control in scene perception).

Although we used a manipulation in which we examined how quickly viewers from two different cultures looked at highly unusual aspects of a scene, it is also the case that how quickly viewers (apart from any cultural differences) do this is actually somewhat contentious. That is, some experiments indicate that the eyes are quickly drawn to unusual or emotional aspects of a scene, while others suggest that they are not. Loftus & Mackworth (1978) embedded a tractor in an underwater scene and an octopus in a farm scene. They found that viewers moved their eyes much more quickly to the octopus in the farm scene than to the same octopus in an underwater scene. However, Pollatsek & Rayner (1992) pointed out that the eyes may be drawn to objects that are out of place because they are physically distinctive in the scene. Indeed, De Graef, Christiaens & d'Ydewalle (1990) and Henderson, Weeks & Hollingworth (1999) controlled for visual distinctiveness, and none of them replicated the finding that semantically inconsistent objects were fixated earlier than were consistent objects (see also Brockmole & Henderson, 2008).

Becker, Pashler & Lubin (2007) and Harris, Kaplan & Pashler (2008) also recently examined the extent to which odd (or semantically out-of-place) objects in scenes draw attention and eye movements. Unlike many earlier experiments, which used line drawings of scenes, both studies used color photographs as stimuli. In Becker et al.'s (2007) study, scenes were presented either normally or with a change that yielded anomalous objects. For example, a person's hand was changed from flesh color to green, and a stop sign was green instead of its normal red color. The primary finding was that viewers fixated the anomalous objects earlier (both in time and in order of eye fixations) than the normal objects. Becker et al. argued that the results indicate that violations of canonical form can be detected from extrafoveal vision and can affect the likelihood of fixating them. In Harris et al.'s (2008) study, viewers saw either normal scenes or scenes in which a normal object in the scene was replaced by an odd/emotional object. Both Becker et al.'s and Harris et al.'s studies found that viewers looked much earlier at the emotional aspect of the scene; that is, in a beach scene they looked earlier at a baby flying through the air than at a beach ball flying through the air. Other recent studies (Calvo & Lang, 2005; Calvo & Nummenmaa, 2007; Nummenmaa, Hyönä & Calvo, 2006) have likewise reported that the eyes move more quickly to emotional objects/scenes (though in these studies, the object/scene was usually presented in parafoveal vision and the latency of a saccade from a central fixation point was measured for an emotional object/scene vs. a neutral object/scene).

In the research by both Becker et al. (2007) and Harris et al. (2008), a research strategy was used wherein a small number of scenes were presented to a large number of viewers. The rationale was that if viewers continually viewed odd scenes, then they might adopt an unusual viewing strategy. While this concern obviously has some validity, it is important (given prior results) to replicate these findings with a larger stimulus set. We obtained the scenes used by Yang et al. (2009) and presented them to viewers, who were asked to rate how much they liked each scene. Thus, in addition to the main goal of examining cultural differences in the extent to which the eyes are drawn to unusual or weird aspects of a scene, our secondary goal was to replicate Harris et al.'s (2008) results (as well as in principle Becker et al.'s results) with a wider range of stimuli.

Objectives

In the present study, we intended to find cultural differences between Chinese and Spanish when they are viewing pictures in normal scenes and unusual/weird scenes by means of an eye-movement experiment. Unlike the two previous studies, in the third study we wanted to compare both groups (Chinese and Spanish) in the same study and with the same stimuli. In this case, we did not use any sentences, but only images that could be understood regardless of language. If there are differences between Spanish and Chinese readers also in the present study, then these differences might be attributable to cultural differences.

Method

1. Participants

Sixty-three members of Universidad Autónoma de Madrid participated in the experiment. They were compensated with either credit for an introductory psychology course or a language course in the language center of the university. Thirty-three participants were native Spanish speakers born in Hispanic countries (we refer to these participants as the Spanish group below), and thirty were native Chinese speakers who grew up in China (the Chinese group).

2. Design

The design of this experiment was a mixed between-within subject design, 2x2. The independent variables were "group" (between-subject factor), with two groups of viewers (Chinese and Spanish), and "region" (within-subject factor), with two different regions of interest (ROI: normal scene and weird scene). We will explain all of them in the following section. The dependent variable was Cultural Difference. This variable was operative by several eye tracking measures that will be explained in the subsequent sections. We will report the whole scene analysis and the ROI analysis. We divided the ROI according to the different areas of each set of pictures, just marked the different areas in the normal scene (left side) and the same areas in the weird scene (right side), e.g.: in the first example of Figure 2, we marked the baby and the ball in the normal scene as the region of interest; in the weird scene, we also marked the same regions (the baby and the ball) but they are in the opposite position.

3. Stimuli

Forty full-color photographs--20 sets of scenes, each set with two versions: a normal scene and an anomalous scene in which one object (e.g., a baby) replaced another object (e.g., a beach ball) --were used as stimuli. All these scenes were from the Yang et al. (2009) study; besides, three were from the Harris et al. (2008) study. In addition, Yang et al. collected 17 other weird pictures from the Internet and then, using Adobe Photoshop, they prepared a control version of each scene in which the unusual object was replaced with the background elements or with another suitable object. The photographs were viewed by three independent observers to confirm that the modifications were not easily detectable. The scenes typically had a focal object or a central group of objects. For the weird version, the weird aspect of the scene was a part of a single object or a group that was incompatible with the rest of the scene. Figure 1 shows three examples of scenes from our collection that were edited from weird to normal. In the first example, the weird condition arises from a beach ball which is replaced by a baby beside the sea, which makes it look at first glance as though the baby is in the air (the scenes taken from Harris et al., 2008). In the second example, the legs of the football players are at first interpreted as unnaturally showing that one player has only one leg (in the experiment, many participants did not find the difference between the normal scene and the weird). In the third example, a cat seems to be pondering to watch TV with a beer and a TV remote control like a human being. There are two things to note from these examples: The weird objects were not weird in the sense that they were contrary to the scene context, but rather the configuration of the objects allowed for a strange interpretation. Of the 20 weird scenes used, 9 yielded strange misinterpretations (like Examples 1 and 2 in Figure 1), and 11 were funny configurations that are somewhat unexpected (like Example 3 in Figure 1). The focus of this study was not on focal versus background elements of the scenes but rather on the fixation of its components, depending on whether they were out of place or strangely configured.

4. Apparatus

The eye movements of each participant were tracked with an Eyelink 1000 plus eye tracker (SR Research, Osgoode Ontario, Canada). The scene (which subtended a visual angle of 35° horizontally and 28° vertically) were displayed at a resolution of on a 21-in. monitor with a refresh rate of 100Hz.

5. Procedure

Participants were seated 60cm from the monitor, and a chinrest restricted head movement. They were instructed to view each scene and then rate how much they liked it (as in the Chua et al., 2005, study) on a scale from 1 (don't like it at all) to 7 (like it very much). After the instructions were given to the participant, the eye tracker was calibrated. Calibration was assessed before each trial, and the participant was recalibrated if the tracking error was greater than 0.4°. At the beginning of each trial, a fixation marker appeared on either the far left or the far right of the screen. When a fixation on the marker for at least 250ms was detected, the marker disappeared and the scene then appeared. The location of the fixation marker was counterbalanced across the preference scale was displayed (digits 1-7). Participants gave their preference rating by fixating on their preference rating for the scene viewed immediately prior to pressing a response button. There were 20 trials composed of either the normal or the weird picture conditions, counterbalanced across participants. The entire experiment lasted about 25 min.

Figure 2: Three sample stimuli are depicted, with the normal version on the left and the weird version on the right.

Results

First, eye movement measures as a function of cultural differences will be discussed. Then different analyses of eye movement measures related to the entire scene (see Table 8) and the normal and weird interest areas (see Table 9) are presented. For each unusual/weird scene, a rectangular region encompassing the weird interest area-- (i.e., the modified area, when comparing the two versions of the scene--) was defined. These same areas were also used to define a region of interest (ROI) in the normal scenes for comparison purposes. For the statistical analyses, different mixed-effects models were conducted with groups (Spanish and Chinese), areas (normal and weird) and their interaction as fixed effects and subjects as random effects using REML (Baayen, Davidson, & Bates, 2008).

Table 8: Eye Movements Measures for the Entire Scene for Each Experimental Condition and Participant Group

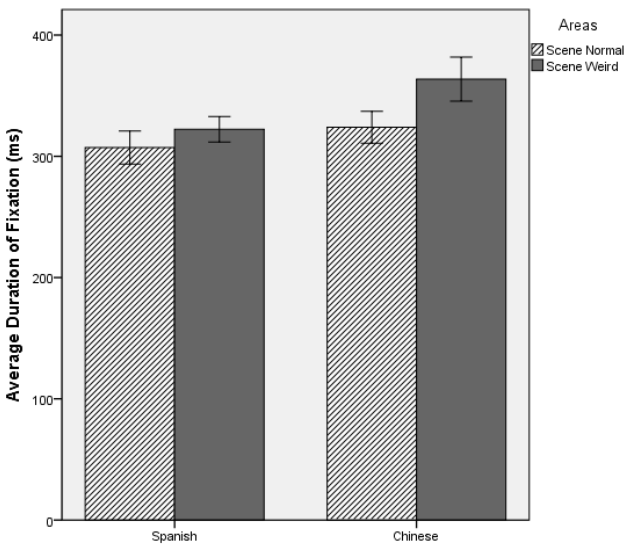
Time (ms)	Chinese		Spanish	
	Normal	Weird	Normal	Weird
Average duration of fixation on scene	307.78	341.14	299.99	315.18
Total viewing time	2023.82	2621.71	1605.35	2311.94

i. Whole Scene Analysis

Given that some parts of the scene (others than the predefined ROI) could be fixated differently due to the addition or subtraction of weird regions, it is difficult to objectively decide *a priori* which regions were likely to be most affected by these configurable changes. Therefore, we also analyzed eye movement measures on the overall scene (see Table 1).

Average fixation duration

On average, participants' fixation durations on the scene were 303.89ms, which is in the range of expected for fixations on natural scenes, whose modal values range from 200 to 350 ms (Rayner, 1998; Unema, Pannasch, Joos, & Velichkovsky, 2005; Henderson, 2003). Average fixation durations were significantly longer for the weird scenes than for the normal scenes [F (1,800.818) = 11.064, p<.01], but there were no significant differences between Chinese and Spanish viewers[F(1,72.255) = 1.351, p=.249]. The interaction between the two variables (group and areas) was not statistically significant [F(1,800.818) = 1.559, p=.214]. This result can be seen in the following graph:

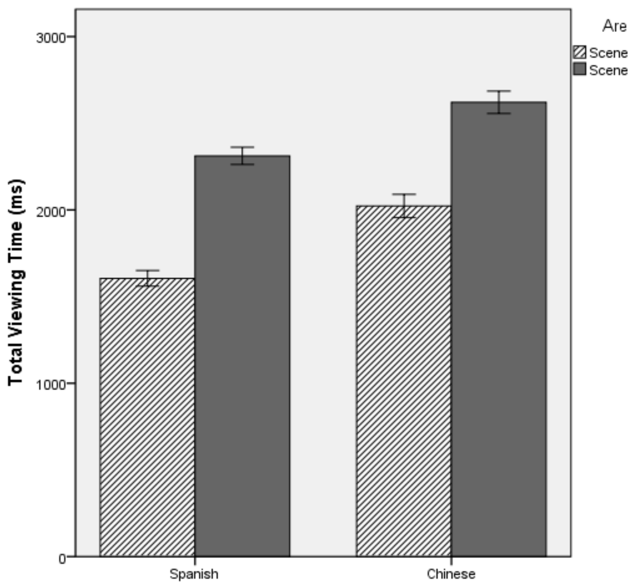


The average duration of fixation for the weird scene is always longer than viewing the normal scene in each group (Spanish and Chinese).

Graph 29: Average duration of fixation for the whole scene for Spanish and Chinese viewers.

Total viewing time

The average total viewing times for the weird scenes were (590-710ms) longer than those for the normal scenes. The total viewing time was significantly different in the areas [F (1,2523.779) = 512.499, p<.001)] and the groups (Chinese and Spanish) [F (1,63.947) = 55.551, p<.001]. Also, there was a marginally significant interaction effect between areas and groups [F(1,2523.779) = 3.558, p=.059]. This result can be seen in the following graph 30. Participants spent more time in the weird scenes than in the normal scenes, but there is an interaction effect because of these differences were more important for the Spanish than for the Chinese.



Graph 30: Total viewing time for the whole scene

ii. Region of Interest Analysis

The analyses of the Region of Interest (ROI) include three types of eye movement measures: (1) measures reflecting the time until the ROI was fixated; (2) measures reflecting initial examination of the region; and (3) aggregate measures reflecting the time spent examining the region. We address each in turn below. A summary of all the means for these measures is presented in Table 9.

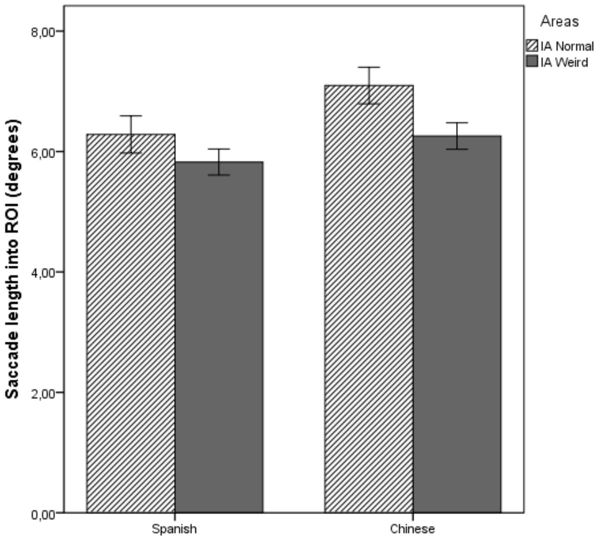
Table 9: Eye Movements Measures for the Region of Interest (ROI) by Experimental Condition and Participant Group

Measure	Chinese		Spanish	
	Normal	Weird	Normal	Weird
Time until ROI is fixated				
Saccade length into ROI (degrees)	7.06	6.36	6.34	5.90
Initial examination of ROI				
First fixation duration (ms)	345.42	357.35	341.30	357.39
First gaze duration (ms)	444.33	627.97	494.26	576.58
No. of gaze fixations	2.03	3.70	2.17	3.24
Subsequent examination for ROI				
Average no. of times examined	1.45	2.04	1.35	1.78
Second gaze duration (ms)	577.24	786.00	604.17	630.48
Average fixation duration (ms)	343.80	367.87	325.88	339.86
Total time (ms)	847.23	1368.71	897.20	1101.39

Note: ROI= region of interest

Time until the ROI was fixated

As a measure of how well the weird ROIs attracted fixations compared with the rest of the regions, the average length of the saccade to the region was analyzed. Overall, viewers' saccades to the region tended to be between 5 and 7.10 of visual angle. Moreover, there were significant differences between areas [$F(1,8803.440) = 18.025$, $p<.001$] and groups [$F(1,66.760) = 4.818$, $p<.05$], but no significant interaction effect was found [$F(1,8803.440) = .990$, $p=.320$]. This result can be seen in the following graph:



Chinese viewers' saccades were bigger than Spanish viewers. Also, they were always bigger for the normal region than for the weird region.

Graph 31: Saccade length into ROI

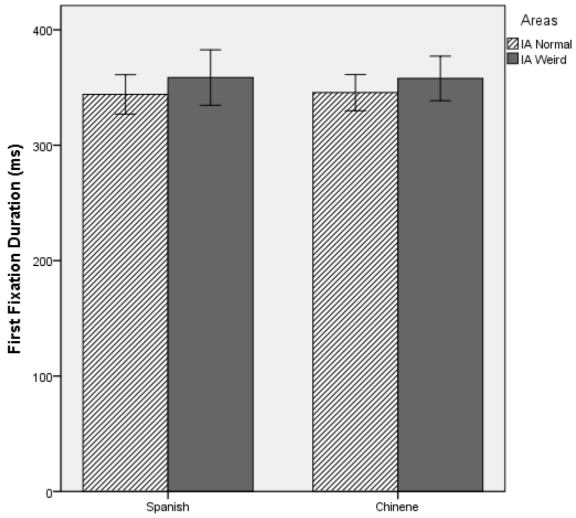
Initial examination of the ROI

For the initial examination of the region, we examined the *duration of the first fixation* made on the region as well as the duration and number of fixations for the *first gaze* (defined as the time spent examining a region before the eyes moved to a location outside the region).

Table 10: Difference Scores (Between Chinese and Spanish Participants) and 95% Confidence Intervals (CIs) for Eye Movement

Measures	Normal			Weird		
	Difference	95% CI		Difference	95% CI	
		Min	Max		Min	Max
Time until ROI is fixated						
Saccade length into ROI (degrees)	.72	.75	.69	.45	.46	.44
Initial examination of ROI						
First fixation duration (ms)	4.11	4.46	3.77	-.04	1.12	-1.20
First gaze duration (ms)	-49.93	-49.11	-50.75	51.39	53.27	49.50
No. of gaze fixations	-.15	-.14	-.16	.46	.47	-.45
Subsequent examination for ROI						
Average no. of times examined	.09	.10	.09	.27	.27	.26
Second gaze duration (ms)	-26.94	-19.04	-34.84	155.52	166.01	145.02
Average fixation duration (ms)	17.92	17.88	17.96	28.01	29.07	26.95
Total time (ms)	-49.97	-47.03	-52.92	267.32	270.73	263.92

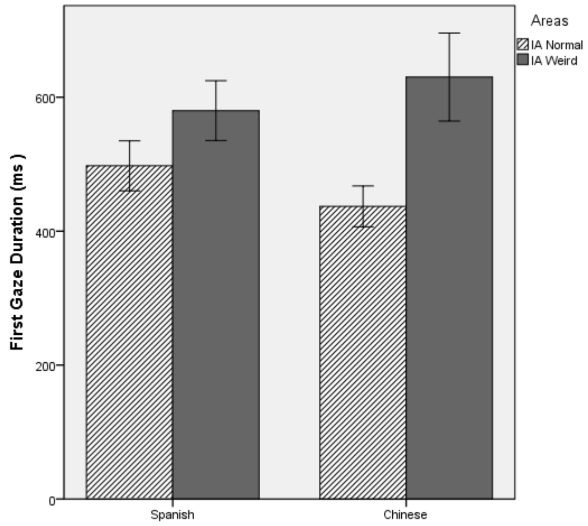
Although *the first fixation duration* on the normal ROI was shorter for the weird region than for the normal region, no statistical differences were found [F (1,715.093) = 1.956, p=.162]. Moreover, there were no significant differences between Chinese and Spanish viewers [F (1,62.671) = .027, p=.871] and no interaction effect was found [F (1,715.093) = .043, p=.836]. This result can be seen in the following graph:



Chinese and Spanish viewers almost have a same first fixation duration to view normal region and weird regions.

Graph 32: First fixation duration in ROI

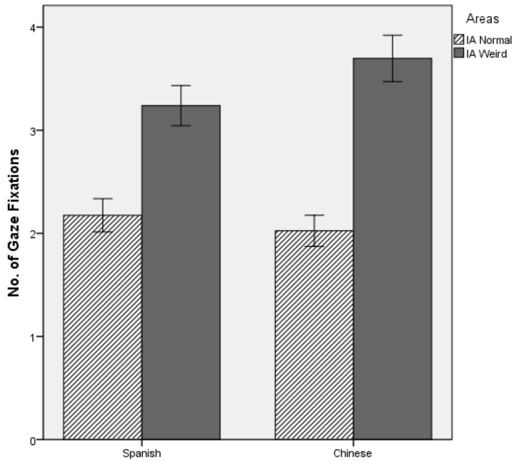
However, there was a significant difference in the first gaze duration between the weird region and the normal region [F (1,1359.412) = 26.944, p<.001], which resulted in a significant interaction effect with groups [F (1,1359.412) = 3.910, p<.05]. No main effect, however, was found for the two groups [F (1,63.840) = .000, p=.988]. This data result can be seen in the following graph:



Viewers always spent longer time in the weird region than in the normal region. However, there is an interaction effect because the difference between the weird and the normal regions were larger for Chinese than for Spanish viewers.

Graph 33: First gaze duration in ROI

As was expected, there were also significant effects in *the number of fixations* made during the first gaze between the different areas [F (1,3164.125) = 208.941, p<.001], showing an interaction effect with groups [F (1,3164.125) = 10.296, p<.01]. Again, no significant effect between Chinese and Spanish viewers was found [F(1,64.067) = 1.505, p=.224]. This result can be seen in the following graph:



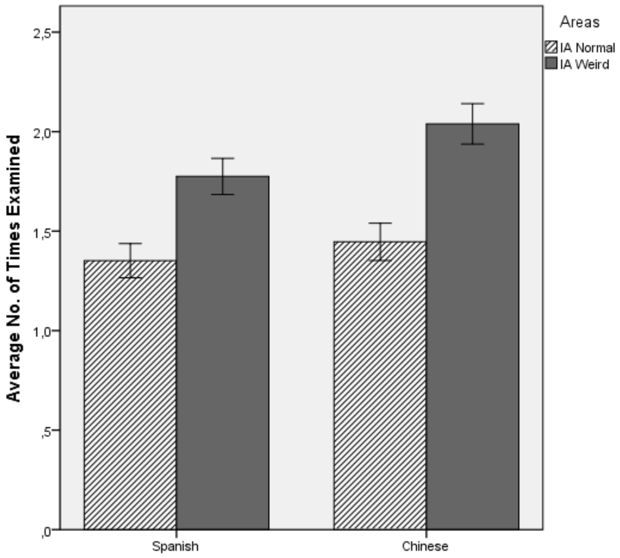
Weird regions received (on average) one more fixation than normal regions. Again, the significant interaction effect with groups showed that the difference in the number of gaze fixations between normal and weird scenes is different for Chinese and Spanish.

Graph 34: No. of gaze fixations in ROI

Subsequent examination of the ROI

We also examined, beyond the initial examination, how often the region was returned to for continued examination, as well as the total amount of time spent on the region.

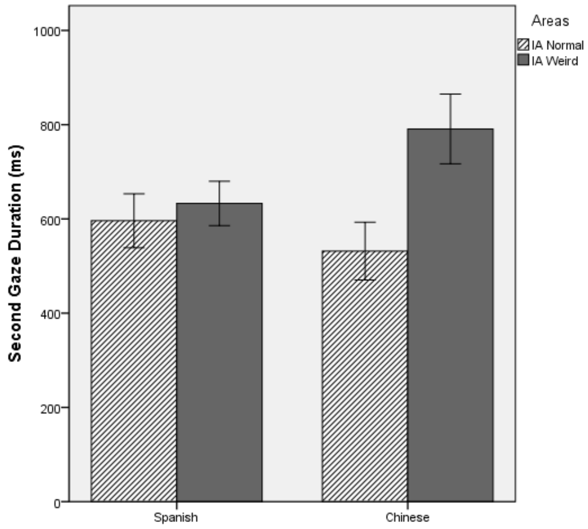
First, after the eyes moved to another area of the scene, computed as *the average no. of times examined*, the weird region was more likely to be fixated again than was the normal region [F (1,3164.070) = 117.810, p<.001]; moreover, there were differences between the Chinese and the Spanish viewers returning to view the scene [F (1,64.033) = 5.210, p<.05]. In addition, however, there was a marginally significant interaction effect between areas and groups [F (1,3164.070) = 3.326, p=.068]. This result can be seen in the following graph:



The weird areas tend to be fixated more frequently than the normal areas. Also, the Chinese tend to present more examinations than the Spanish. The marginally significant interaction effect shows that the differences between the normal and the weird areas were less important for Spanish compared to the Chinese.

Graph 35: Average no. of time examined

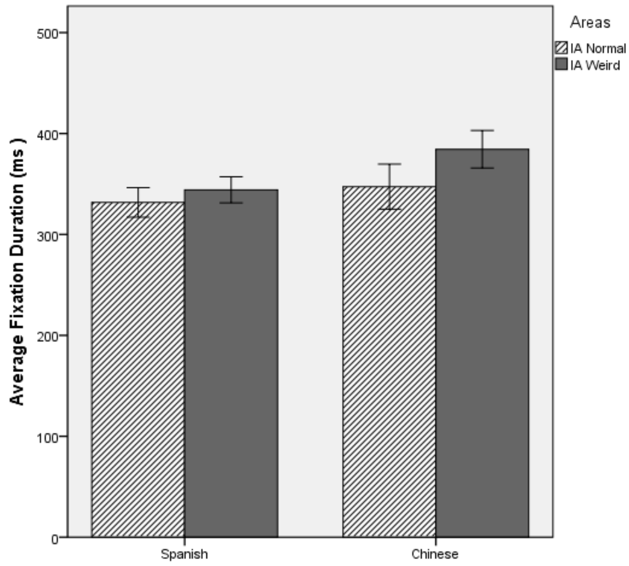
For those instances in which the region was returned to for further examination, *the second gaze duration* was longer for the weird region than that for the normal region [F (1,1039.413) = 13.439, p<.001], but no differences between Chinese and Spanish were observed in this measure [F (1,59.967) = .684, p=.411]. Instead of this, a significant interaction effect between areas and group was observed [F (1,1039.413) = 8.096, p<.01]. This result can be seen in the following graph:



A considerable interaction effect shows that the differences between the normal and the weird areas were much larger for the Chinese but not as relevant for the Spanish.

Graph 36: Second gaze duration in ROI

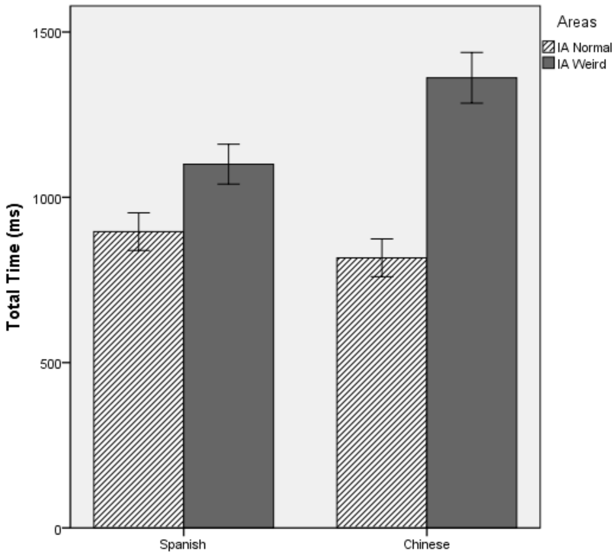
Second, *average fixation duration* (for all fixations on the region) was significantly longer for the weird region than for the normal region [F (1,980.813) = 5.046, p<.05]. Despite this, there were no significant effects of groups [F (1,70.715) = 1.863, p=.177] or of the interaction [F (1,980.813) = .355, p=.551]. This result can be seen in the following graph:



The differences were related to the normal and the weird areas.

Graph 37: Average fixation duration in ROI

Third, the *total amount of time* spent examining the region (sum of all fixations on the region) was longer for the weird region than for the normal region [F (1,2064.833) = 122.984, p<.001] but no differences were observed between Chinese and Spanish participants [F(1,62.349) = 2.324, p=.132]. A statistically significant interaction effect between both variables was observed [F (1,2064.833) = 23.513, p<.001]. This result can be seen in the following graph:



The mean difference in total time spent in normal and weird areas was considerably longer for the Chinese than for the Spanish.

Graph 38: Total time in ROI

Conclusion

In this section, we will concentrate on the differences between the normal and the unusual/weird conditions. We first discuss analyses concerning the entire scene. In this regard, only the total viewing time measure showed significant differences between Spanish and Chinese in the whole scene analysis.

We should recall that the primary goal of the present study was to examine possible cultural differences in scene viewing between Spanish and Chinese university students. Specifically, in previous studies between Americans and Chinese, Chua et al. (2005) reported that Chinese viewers spend less time than American viewers looking at focal objects in a scene and more time looking at the background of the scene. As we mentioned in the initial part of this study, some recent studies examining this issue have not found support for this difference (Evans et al., 2009; Rayner et al., 2007). In the current study, rather than examining eye movement patterns for focal and background objects, we examined how quickly Chinese and Spanish viewers looked at a weird/unusual object in a scene, following by the same strategy of Yang et al. (2009). For the scenes in the weird condition, a portion of a central object (or group of objects) was configured differently, resulting in an odd interpretation of the picture. The question addressed in the present study was whether Chinese viewers would be slower or faster to fixate the odd objects than would the Spanish viewers. To address either of these possibilities, we examined the viewing of regions of interest. Across all eye movement measures, there were some differences between Chinese and Spanish viewers. We found that Chinese viewers always spend more time to fixate on the scene than Spanish viewers. In contrast, the study of Yang et al. (2009) found no evidence that the unusual/weird regions were fixated later (or earlier) or for differing amounts of time as a function of cultural differences (see also Evans et al., 2009; Rayner et al., 2007). In the present study, we found that Chinese viewers always spend more time to fixate on the scene than Spanish viewers.

Rayner et al. (2007) did report some differences in the overall patterns of eye movements, with Chinese viewers making more fixations with shorter durations than did American viewers (see also Chua et al., 2005). To investigate the possibility of an overall difference in eye movement patterns (unrelated to the unusual/weird condition), we examined the average fixation duration made across the entire scene. An examination of this measure found no significant effects of viewer group and no significant interactions between the viewer groups and conditions as Yang et al. (2009) did. Indeed, the fixation time measures on the ROI showed just the opposite results to the study of Yang et al. (2009), where the Chinese viewers' average fixation duration on subsequent examination of the region were longer than Americans' (though not significantly so), and they made slightly fewer fixations. However, in the present study, both groups, Chinese and Spanish, yielded a significant difference between conditions (weird and normal ROI) in the length of Saccade, showed that the weird region was fixated sooner than the normal region. Furthermore, Chinese viewers' first gaze duration on the initial examination of ROI was longer and the average number of times examined on subsequent examination for ROI were more frequent than those of Spanish's viewers (and significantly different). It is obvious that these results replicate the earlier finding reported by Yang et al. (2009) that Chinese viewers trade off fixation duration for number of fixations, though it is instructive to note that Evans et al. (2009) did not find evidence of this trade off.

It is important to note that Yang (2009) do not view the results as compromising Nisbett's (2003) theory of cultural differences in thinking. In the present study, we have no doubts that there are cultural differences between Chinese and Spanish, and that these cultural differences show up in different ways of thinking about various issues (Nisbett, 2003). Indeed, the result of Yang et al. (2009), along with those of Rayner et al. (2007) and Evans et al. (2009), showed that cultural differences can influence processing at the basic level of oculomotor control.

A secondary goal of the present study was to examine whether the eyes are drawn more quickly to unusual aspects of a scene. The analysis comparing the normal and weird versions showed that, when people are viewing the weird images, the saccade length into ROI is shorter than for normal images. However, other measures, including average fixation duration and total viewing time for the whole scene analysis, as well as first gaze duration, number of gaze fixation, average number of time examined, second gaze duration, average fixation duration and total time in ROI, show that people devote more time (or numbers) to view the weird/unusual parts of the images than the normal parts. We found that the weird regions attracted fixation slightly sooner than did normal regions, although the regions were not fixated from farther away. The weird regions were also examined for a longer period and returned to for further examination more often over the course of viewing the scene. These findings are consistence with previous studies showing that anomalies in scenes are fixated in total for a longer period of time (Friedman, 1979; Henderson et al., 1999). The important difference with the current study is that the weird regions were not odd in the same sense as those used in previous studies. Rather than using objects that did not fit with the scene's gist or schema, in Yang et al. (2009), they used objects that suggested strange or impossible configurations in the weird regions, and we followed the same strategy. These differences rely not on an understanding of the whole scene compared with one of its parts, but on an understanding (or lack thereof) of the parts' relationships with each other.

In summary, our results are consistent with those of Becker et al. (2007) and Harris et al. (2008) in that they show that (a) weird regions attract fixations slightly sooner than do normal regions, and (b) viewers look longer at weird regions than at normal regions. More importantly, our results are consistent with those reported by Rayner et al. (2007), Evans et al. (2009) and Yang et al. (2009) in showing that cultural differences have some influence, but not too much, on oculomotor control during scene perception.

Chapter V

General conclusions

Using the violation paradigm, the present study explored the time course of semantic and syntactic processing in Chinese and Spanish. Participants 'eye movements were monitored as they read sentences with a critical single word/Chinese character that was congruent in a sentence context or yielded a semantic violation or both a semantic and syntactic violation. The results showed that (1) both joint syntactic and semantic violations and pure semantic violations were detected immediately, and (2) they can be separated from each other by eye movement measures that reflect initial and a later processing. We will discuss these two points in detail below.

Comparing our results with those of Yang et al. (2009), we find that most of the effects were similar in both studies. First, both the character/word-based analysis and the region-based analysis of Chinese reading and Spanish reading showed that semantic + syntactic violations and pure semantic violations were detected immediately and yielded disruption effects right at the CW/ target region. These effects were also evident at CW-1, which may reflect a parafoveal-on-foveal effect, but could also be due to mislocated fixations. Moreover, in the study of Yang et al. (2009), the effect of the violation spilled over to subsequent characters (words)/regions, as observed in first-pass reading times at the post target regions T+1 and T+2, with both the SEM and the SEM+SYN conditions yielding significantly longer times than that the CON condition. This effect also showed up in our study in Spanish in go-past time and total reading time measures. However, in the case of Chinese (Experiment II), we only found significantly longer total reading times in the SEM and the SEM+SYN conditions than in the CON condition in the post target T+1 region. Note that these results are not consistent with delayed hypothesis, which claims that Chinese readers wait for more information after the CW to build up a coherent representation. Instead, they are in line with the idea that the higher-level integration processes are initiated quite rapidly. Furthermore, these results imply that Chinese readers are trying to use contextual information to resolve the inconsistent information. In the study of Yang et al. (2009) violation effects were significant in go-past time, second-pass reading time, regressions out and regressions in, whereas in our Chinese study, these effects only appeared in regressions in and total reading time, and in the Spanish study also in regressions out, first-pass reading time and go-past time.

In sum, as regards the first question addressed in the current study, the results suggest that higher-level integration starts immediately in the reading of Chinese, although its completion spills over to subsequent parts of the text. The Spanish readers, in turn, concentrated on regressions in and regressions out, and directed most regressions in to the beginning of the sentence, at CW-2, CW-1 and CW sites; as for regressions out after the CW site, most came from the end of the sentence, including CW, CW+1, CW+2 and CW+3. From these results, we may conclude that after spotting the anomaly at CW, Spanish readers went back to find the central meaning of the sentence and tried to understand it. This might happen because in Spanish, nouns and verbs always change their forms when the subject changes, which leads to gender change (e.g. male or female), time change (e.g. present, past or future) and number change (e.g. singular or plural), among others. Once the readers have found the error at the CW, and the sentence is not concordant, they needed to locate the source of the error, which led them to make regressions in and out.

A second question worth emphasizing regarding the relative time course of semantic and semantic + syntactic processing is that the violation effect in the SEM+SYN condition did not appear earlier than that in the SEM condition, since violation effects in both conditions were first evident on the same character/word CW-1 in our studies with Chinese and Spanish, as well as in the Yang et al. (2009) study. Since the difference between the SEM and SEM+SYN conditions was not significant at CW-1 (the verb) in Chinese reading, but it was in Spanish reading, it is possible that the effect at CW-1 was due to the processing of inappropriate semantic meaning from the CW (a semantic parafoveal-on-foveal effect) for the reading of Chinese. In other words, semantic processing may start earlier than syntactic processing in Chinese reading. However, as was mentioned above, further studies are needed to test this possibility. What can be concluded from the present experiment is that syntactic processing is no initiated earlier than semantic processing in the reading of Chinese. This conclusion differs from those studies involving the reading of alphabetic languages, wherein syntactic processing was initiated earlier than semantic processing (Boland, 1997; Braze et al., 2002; McElree & Griffith, 1995). A possible reason for the difference between Chinese and alphabetic languages like Spanish may lie in the fact that most alphabetic languages have some explicit markers (that we have mentioned before) to specify the word categories and the syntactic role played by words, through which readers can immediately understand the syntactic structure of a sentence even without knowing the meanings of the words in the sentence. However, in Chinese, a language virtually no such markers for identifying grammatical functions, syntactic information can be inferred only from the semantic information and the sentence context.

In addition, differences between the SEM+SYN and SEM conditions appeared in first-pass reading time in the target region T in the study of Yang et al. (2009), and in the present study they also appeared in total reading time in the target region T, indicating that the syntactic violation resulted in greater comprehension difficulties than did the semantic violation. Furthermore, in the study of Spanish, differences between these two kinds of violations were evident in the first-pass reading time in the target region T and also go-past time and total reading time in the post target region T+1. It is probably the case that the readers were trying to reanalyze the sentence structure to solve the contradiction in the SEM and the SEM+SYN conditions in later processing, such as taking the incongruent CW as a modifier for a following congruent noun. This matches the results of Yang et al. (2009), but in the present study of Chinese did not appear this effect. However, it may have been harder for the readers to reanalyze the sentence structure when the target noun in the congruent condition was replaced by a verb in the SEM+SYN condition than when the target noun in the congruent condition was replaced by a noun in the SEM condition. Although it is not known for sure what causes the difference between the semantic and the semantic + syntactic conditions, the results clearly showed by our study that these two kinds of processing can be discriminated by eye movement measures. These results are consistent with those of a functional neuroimaging study that demonstrated a dissociation between semantic and syntactic processes in the reading of Chinese sentences, using the same violation paradigm (Wang, Zhu, et al., 2008; Yang et al., 2009).

As compared with Chen's (1999) study, in which pure semantic violations and semantic + syntactic violations were found to be evident in the region following the CW, the study of Yang (2009) demonstrated that the effect of these violations occurred right on the CW site. Moreover, the present study of Chinese and Spanish occurred right on the T region (CW-1 and CW). In addition, the differences between the effects of semantic and semantic + syntactic violations were observed in subsequent regions after the CW in Yang's (2009) study and in our study of Chinese (CW+3), but not in Chen's (1999) study. The reason why the results differed from Chen's (1999) may have to do with the paradigms employed; whereas Chen (1999) used a character-by-character self-paced reading procedure, Yang and us used the eye-tracking procedure, a more natural and elaborate technique. Furthermore, these differences support the view that eye movement recording is sensitive to subtle differences at various levels of sentence processing and, thus, allow researchers to better understand the integration process during language comprehension.

Overall, the present research indicates that despite deep differences between Chinese and alphabetic languages, there are still many similarities in sentence processing between them. First, both semantic and syntactic violations can be detected immediately, although Chinese is considered a highly context-dependent language. Second, although a syntactic violation is always accompanied by a semantic violation, evidence from eye tracking data confirms that syntactic violations yield more severe disruption than do pure semantic violations. However, we have to point out that these results may be dependent on the experimental manipulation in the present study, in which the context prior to the CW may have encouraged readers to develop an expectation of the word category of the CW (a noun). If the prior context had been insufficient for readers to guess the word category of the CW, the violation effect may have been delayed. However, in that case, it would not be certain that the manipulation of semantic and/or syntactic violations was effective. Further studies will be needed to elucidate the finer processing of semantic and syntactic information in the reading of Chinese. The present study at least indicates that these two types of processing can be initiated immediately and dissociated from each other under certain conditions in both reading of Chinese and Spanish.

Let us now turn to the experiment on the perception of scenes with Chinese and Spanish participants, in which we focused on possible cultural differences when viewing normal and unusual/weird scenes.

The primary goal of that study (Experiment III of this thesis) was to examine possible cultural differences in scene viewing between Spanish and Chinese university students. Specifically, in a previous study between Americans and Chinese, Chua et al. (2005) reported that Chinese viewers spend less time than American viewers looking at focal objects in a scene and more time looking at the background of the scene. As we mentioned in the introduction to Experiment III, some recent studies examining this issue have not found support for this difference (Evans et al., 2009; Rayner et al., 2007). In the present study, rather than examining eye movement patterns for focal and background objects, we examined how quickly Chinese and Spanish viewers looked at a weird/unusual object in a scene, following the same pattern of Yang et al. (2009). For the scenes in the weird condition, a portion of a central object (or group of objects) was configured differently, resulting in an odd interpretation of the picture. The question addressed in the present study was whether Chinese viewers would be slower or faster to fixate the odd objects than Spanish viewers. To address either of these possibilities, we examined the viewing of regions of interest. Across all eye movement measures, there were some differences between the Chinese and Spanish viewers. Our study showed that the Chinese viewers always spent more time to fixate on the scene than the Spanish viewers did. In turn, the study of Yang et al. (2009) found no evidence that the unusual/weird regions were fixated later (or earlier) or for differing amounts of time as a function of cultural difference (see also Evans et al., 2009; Rayner et al., 2007).

Rayner et al. (2007) did report some differences in the overall patterns of eye movements, with Chinese viewers making more fixations for shorter durations than did

American viewers (see also Chua et al., 2005). To investigate the possibility of an overall difference in eye movement patterns (unrelated to the unusual/weird condition), we examined the average fixation duration made across the entire scene. However, examination of this measure found no significant effects of viewer group and no significant interactions between the viewer groups and condition (normal vs weird) as the Yang et al. (2009) study did. Indeed, the fixation time measures on the ROI showed different results to those of the study of Yang et al. (2009), where the Chinese viewers' average fixation duration on subsequent examination of the region were longer than Americans' (though not significantly so), and they made slightly fewer fixations. However, in the present study, both groups, the Chinese and Spanish, obtained a significant difference between conditions (weird and normal ROI) in the length of saccade, showing that the weird region was fixated sooner than the normal region. Furthermore, Chinese viewers' first gaze duration on the initial examination of ROI and the average number of times examined on subsequent examination for ROI were more than Spanish's, and significantly so. It is obvious that these results replicate the earlier finding reported by Yang et al. (2009) that Chinese viewers trade off fixation duration for number of fixations, but it is instructive that Evans et al. (2009) did not find evidence of this trade off.

It is important to note that Yang (2009) do not view the results as compromising Nisbett's (2003) theory of cultural differences in thinking. In the present study, we have no doubts that there are cultural differences between Chinese and Spanish that manifest themselves in different ways of thinking about various issues (Nisbett, 2003). Indeed, the result of Yang et al. (2009), along with those of Rayner et al. (2007) and Evans et al. (2009), showed that cultural differences can influence processing at the basic level of oculomotor control.

A secondary goal of the present study was to examine the finding that the eyes are drawn quickly to unusual aspects of a scene. In the analysis between the normal version and weird version showed that, when people are viewing the weird images, the saccade length into ROI is less than the normal images, however, other measures, including average fixation duration and total viewing time for the whole scene analysis; first gaze duration, number of gaze fixation, average number of time examined, second gaze duration, average fixation duration and total time in ROI, all the data showed that people used more time/numbers to view the weird/unusual parts of the images than the normal parts. We found that the weird regions attracted fixation slightly sooner than did normal regions, although the regions were not fixated from farther away. The regions were also examined for a longer period of time and returned to for further examination more often over the course of viewing the scene. The finding is consistence with previous studies showing that anomalies in scenes are fixated in total for a longer period of time (Friedman, 1979; Henderson et al., 1999). The important difference with the current study is that the weird regions were not odd in the same sense as those used in previous studies. Rather than using objects that did not fit with the scene's gist or schema, in Yang et al. (2009), they used objects that suggested strange or impossible configurations in the weird regions, and we followed the same pattern. These differences rely not on an understanding of the whole scene compared with one of its parts but on an understanding (or lack thereof) of the parts' relationships with each other.

In summary, our results are consistent with those of Becker et al. (2007) and Harris et al. (2008) in showing that (a) weird regions attract fixations slightly sooner than do normal regions and (b) viewers look longer at weird regions than at normal regions. More importantly, our results are consistent with those reported by Rayner et al. (2007), Evan et al. (2009) and Yang et al. (2009) in showing that cultural differences have little influence on oculomotor control during scene perception.

Conclusiones Generales

El presente estudio exploró el curso temporal del procesamiento semántico y sintáctico en chino y en español. Los movimientos oculares de los participantes fueron registrados mientras leían oraciones con una sola palabra crítica / un carácter chino que era congruente en el contexto de la oración o producían una alteración semántica o una alteración tanto semántica como sintáctica. Los resultados mostraron que (1) se detectaron inmediatamente las alteraciones sintácticas y semánticas conjuntas y la alteración semántica pura, y (2) estas dos clases de alteraciones se pueden discriminar mediante medidas de movimientos oculares que reflejan estadios de procesamiento iniciales y tardíos. Vamos a discutir estos dos puntos en detalle a continuación.

Comparando nuestros resultados con los de Yang et al. (2009), observamos que la mayoría de los efectos se dan en ambos estudios. Primero, tanto el análisis basado en caracteres / palabras como el análisis de las regiones de interés de los movimientos oculares durante la lectura en chino y español mostraron que las alteraciones semánticas + sintácticas y las semánticas puras se detectaron de inmediato y produjeron efectos de interrupción directamente en la región objetivo / CW en ambos estudios. Estos efectos también fueron evidentes para la región CW-1, lo que podría interpretarse como un efecto parafoveal sobre el foveal, aunque también podría deberse a fijaciones mal localizadas. Además, en el estudio de Yang y Rayner (2009), el efecto de la alteración se extendió a los caracteres (palabras) / regiones subsiguientes, el tiempo de lectura del primer barrido (*first-pass reading time*) se observó en las regiones poseriores como la T + 1 y la T + 2, cuyos tiempos de lectura en las condiciones SEM y SEM + SYN fueron significativamente más largos que en la condición CON. Estos efectos también se registraron en el presente estudio de la lectura en español en las medidas *go-past time* y tiempo total de lectura (*total reading time*). Sin embargo, en el presente estudio de lectura en chino, solo encontramos efectos en la medida de tiempo total de lectura (*total reading time*) en la región T + 1 que fue significativamente más largo en las condiciones SEM y SEM + SYN que en la condición CON. Téngase en cuenta que estos resultados no son consistentes con la hipótesis de una demora del procesamiento, según la cual los lectores chinos esperan a obtener más información después de la CW para construir una representación coherente. En cambio, estos resultados apoyan la idea de que los procesos de integración de nivel superior se inician con bastante rapidez. Además, estos resultados implican que los lectores chinos estaban tratando de usar la información contextual para resolver la información inconsistente, ya que los efectos de la alteración fueron significativos en el estudio de Yang y Rayner (2009) en *go-past time*, tiempo de lectura del segundo barrido (*second-pass reading time*), regresiones hacia fuera (*regressions out*) y regresiones hacia adentro (*regressions in*). Sin embargo, en el presente estudio de chino solo se dio este efecto en regresiones hacia adentro (*regressions in*) y en tiempo total de lectura (*total reading time*). Además, en el estudio en español también se produeron efectos en las medidas de regresiones hacia fuera (*regressions out*), tirmpo de lectura del primer barrido (*first-pass reading time*) y *go-past time*.

En resumen, con respecto a la primera pregunta que plantea el presente estudio, los resultados sugieren que la integración de nivel superior comienza de inmediato en la lectura del chino, aunque la finalización de este proceso se extiende a partes posteriores de la frase. Por su parte, los lectores españoles se concentraron en las regresiones hacia adentro (*regressions in*) y las regresiones hacia fuera (*regressions out*), lo que indica que hicieron la mayoría de las regresiones hacia el comienzo de la oración, concentrádose en las regiones CW-2, CW-1 y CW, y también después de CW, hicieron regresiones desde el final de la oración, incluyendo las regiones CW, CW + 1, CW + 2 y CW + 3. Podemos concluir, pues, que después de aparecer la anomalía en CW, los lectores españoles vuelven hacia la parte central de la oración para tratar de darle un sentido. Esto se debe a que en el idioma español, los sustantivos y los verbos siempre cambian de forma cuando el sujeto cambia, lo que puede llevar aparejado un cambio de género (por ejemplo, masculino o femenino), de tiempo (por ejemplo, presente, pasado o futuro) o de número (por ejemplo, singular o plural), entre otros. Una vez que los lectores detectan el error de la CW, o cuando encuentran que las oraciones no son concordantes, necesitan localizar el origen del problema, por lo que hacen muchas regresiones desde y hacia otras regiones.

En segundo lugar, con respecto al curso temporal relativo del procesamiento semántico y semántico + sintáctico, el efecto de la alteración en la condición SEM + SYN no parece detectarse antes que en la condición SEM, ya que los efectos de alteración en estas dos condiciones se hacen evidentes por primera vez en el mismo carácter/palabra CW -1 tanto en nuestro estudio como en el estudio de Yang et al. (2009). Dado que la diferencia entre las condiciones SEM y SEM + SYN no resultó significativa en CW-1 (región del verbo) en la lectura en chino, pero sí en la en español, es posible que el efecto en CW-1 se deba al procesamiento de un significado inapropiado de la CW (un efecto semántico parafoveal sobre el foveal) para la lectura del chino. En otras palabras, el procesamiento semántico puede comenzar antes que el procesamiento sintáctico en el caso de la lectura en chino. Sin embargo, como se mencionó anteriormente, se necesitan más estudios para poner a prueba esta posibilidad. Lo que se puede concluir del Experimentos I de esta tesis es que el procesamiento sintáctico no se inicia antes que el procesamiento semántico en la lectura del chino. Esta conclusión difiere de aquellos estudios que examinan la lectura en lenguas alfabéticas, en las que el procesamiento sintáctico se inicia antes que el procesamiento semántico (Boland, 1997; Braze et al., 2002; McElree & Griffith, 1995). Una posible razón de la diferencia entre el chino y los idiomas alfabéticos como el español puede residir en el hecho de que la mayoría de los idiomas alfabéticos tienen marcadores explícitos (mencionado anteriormente) para especificar las categorías de las palabras y el papel sintáctico que desempeñan, con lo cual los lectores pueden analizar de inmediato la estructura sintáctica de una oración, incluso sin conocer el significado de las palabras que la integran. En cambio, en chino, una lengua que prácticamente carece de dichos marcadores para identificar funciones gramaticales, la información sintáctica solo se puede inferir de la información semántica y del contexto de la oración.

Además, las diferencias entre las condiciones SEM + SYN y SEM aparecieron en el tiempo de lectura del primer barrido (*first-pass reading time*) en la región T en el estudio de

Yang y Rayner (2009), y en el presente estudio también apareció en el tiempo total de lectura (*total reading time*) en la región T, lo que indica que la alteración semántica + sintáctica dio lugar a mayores dificultades de comprensión que la alteración semántica sola. Además, en el estudio de español, las diferencias entre estos dos tipos de alteraciones fueron evidentes en el tiempo de lectura del primer barrido (*first-pass reading time*) en la región T y también en *go-past time* y en el tiempo total de lectura (*total reading time*) en la región T + 1. Es probable que los lectores tratan de volver a analizar la estructura de la oración para resolver la contradicción en las condiciones SEM y SEM + SYN en el procesamiento posterior, por tomar el incongruente CW como modificador para un sustantivo congruente siguiente. Esto coincide con resultado de Yang et al. (2009), aunque en el presente estudio no apareció este efecto con los lectores chinos. Sin embargo, puede haber sido más difícil para los lectores volver a analizar la estructura de la oración cuando el CW en la condición congruente fue reemplazado por un verbo en la condición SEM + SYN, que cuando el CW en la condición congruente fue reemplazado por otro sustantivo en la condición de SEM. Aunque no se sabe con certeza qué es lo que causa la diferencia entre las condiciones SEM y SEM + SYN, nuestro estudio muestra claramente que estos dos tipos de procesamiento pueden ser discriminados con medidas de movimientos oculares. Estos resultados son consistentes con los de un estudio de neuroimagen funcional que mostró una disociación entre los procesos semánticos y sintácticos en la lectura de oraciones en chino, utilizando el mismo paradigma de alteración (Wang et al., 2008; Yang y Rayner, 2009).

En comparación con el estudio de Chen (1999), en el cual se observaron evidencias de alteraciones semánticas puras y semánticas + sintácticas en la región posterior a la CW, el estudio de Yang (2009) mostró que el efecto de estas alteraciones se produjo directamente en la CW y en el presente estudio en chino y en español tuvieron lugar en la región T (CW-1 y CW). Además, las diferencias entre los efectos de las alteraciones SEM y SEM + SYN se observaron en las regiones posteriores a CW en el estudio de Yang (2009) y solo en nuestro estudio del chino (CW + 3), pero no en el de Chen (1999). La razón por la cual que los resultados difieren de los de Chen (1999) puede tener que ver con los paradigmas empleados;

mientras que Chen (1999) utilizó un procedimiento de lectura autoadministrada carácter por carácter, Yang y nosotros utilizamos el procedimiento de eye tracking, una técnica más natural y elaborada. Además, estas diferencias apoyan la idea de que el registro de movimientos oculares es sensible a las diferencias en los niveles de procesamiento de oraciones y, por lo tanto, permite a los investigadores comprender mejor el proceso de integración durante la comprensión del lenguaje.

En general, la presente investigación indica que a pesar de las grandes diferencias entre los sistemas de escritura alfabéticos y los caracteres chinos, todavía hay muchas similitudes en el procesamiento de oraciones entre ellos. Primero, las infracciones semánticas y sintácticas pueden detectarse de inmediato, aunque el chino se considera una lengua altamente dependiente del contexto. En segundo lugar, aunque una alteración sintáctica siempre va acompañada de una alteración semántica, la evidencia de los datos de movimientos oculares confirma que las alteraciones sintácticas producen una interrupción más grave que las alteraciones semánticas puras. Sin embargo, debemos señalar que estos resultados pueden depender de la manipulación experimental en el presente estudio, en el que el contexto anterior de la CW puede haber alentado a los lectores a desarrollar una expectativa de la categoría de palabra de la CW (un sustantivo). Si el contexto anterior no fue suficiente para que los lectores adivinaran la categoría de palabra de la CW, el efecto de la alteración puede haberse retrasado. Sin embargo, en ese caso, no sería seguro que la manipulación de las alteraciones semánticas y / o sintácticas fuera efectiva. Se necesitarán más estudios para dilucidar el procesamiento más fino de la información semántica y sintáctica en la lectura del chino. El presente estudio al menos indica que estos dos tipos de procesamiento pueden iniciarse inmediatamente y disociarse entre sí en ciertas condiciones, tanto en la lectura del chino como en la del español.

A continuación examinaremos los resultados del experimento de movimientos oculares en escenas fotográficas con participantes chinos y españoles, centrándonos en las diferencias entre las condiciones normales y anómalas / extrañas.

El objetivo principal del Experimento III del presente estudio fue examinar las posibles diferencias culturales en la visualización de escenas entre estudiantes universitarios españoles y chinos. Específicamente, en estudios previos con estadounidenses y chinos, Chua et al. (2005) informaron que los espectadores chinos pasan menos tiempo que los estadounidenses que miran los objetos focales en una escena y más tiempo mirando el fondo de la escena. Como mencionamos en la parte introductoria de este estudio, algunos estudios recientes que examinan este problema no han corroborado estas diferencias (Evans et al., 2009; Rayner et al., 2007). En el presente estudio, en lugar de examinar los patrones de movimiento ocular para los objetos focales y de fondo, examinamos la rapidez con la que los espectadores chinos y españoles observaron un objeto extraño / inusual en una escena, siguiendo el mismo procedimiento de Yang et al. (2009). Para las escenas en la condición extraña, una parte de un objeto central (o grupo de los objetos) se configuró de manera diferente, lo que producía una interpretación anómala de la imagen. La pregunta que planteábamos en el presente estudio fue si los espectadores chinos serían más lentos o más rápidos para detectar los objetos extraños que los espectadores españoles. Para dilucidar esta cuestión, examinamos la visualización de regiones de interés (ROI). En todas las medidas de movimientos oculares, hubo algunas diferencias entre los espectadores chinos y los españoles. Así, los espectadores chinos siempre pasaban más tiempo mirando la escena que los espectadores españoles. El estudio de Yang et al. (2009) no encontró pruebas de que las regiones inusuales / extrañas se fijaran más tarde (o antes) o por períodos de tiempo diferentes en función de las diferencias culturales (véase también Evans et al., 2009; Rayner et al., 2007).

Rayner et al. (2007) informan de algunas diferencias en los patrones generales de los movimientos oculares entre chinos y estadounidenses, de tal modo que los espectadores chinos hacían más fijaciones y por períodos más cortos que los estadounidenses (ver también Chua et al., 2005). Para investigar la posibilidad de una diferencia general en los patrones de movimientos oculares (no relacionados con la condición inusual / extraña), nosotros examinamos la *average fixation duration* realizada en toda la escena. Sin embargo, el resultado de esta medida no encontró efectos significativos entre los dos grupos de espectadores y no hubo interacciones significativas entre los grupos de espectadores y las condiciones normal y extraña, a diferencia de los resultados del estudio de Yang et al. (2009). De hecho, las mediciones del tiempo de fijación en el ROI mostraron resultados diferentes a los del estudio de Yang y Rayner (2009), donde la *average fixation duration* de los espectadores chinos en la parte posterior de la región fue más larga que la de los estadounidenses (aunque no resultó significativa la diferencia) y los chinos hicieron relativamente menos fijaciones. Sin embargo, en nuestro estudio, ambos grupos, chinos y españoles, se obtuvo una diferencia significativa entre las condiciones (ROI extraño y normal) en *saccade length*, y se observó que la mirada hacia la región anómala se producía con mayor rapidez que en la región normal. Además, la *first gaze duration* de los espectadores chinos en la ROI y el promedio de fijaciones registradas con posterioridad en la ROI fueron significativamente mayores que los de los españoles. Es obvio que estos resultados replican hallazgos previos de Yang y Rayner (2009) según los cuales los espectadores chinos establecen un compromiso entre la duración de las fijaciones y el número de fijaciones, aunque hay que señalar que Evans et al. (2009) no encontró evidencia de este compromiso entre duración y número de fijaciones.

Es importante señalar que Yang et al. (2009) no consideran que los resultados comprometan la teoría de las diferencias culturales defendida por Nisbett (2003). Para nosotros, no cabe duda de que existen diferencias culturales entre el chino y el español que se manifiestan en diferentes formas de pensar sobre diversos temas (Nisbett, 2003). De hecho, el resultado de Yang et al. (2009), así como los de Rayner et al. (2007) y Evans et al. (2009), ponen de manifiesto que las diferencias culturales pueden influir en el procesamiento incluso en el nivel básico del control oculomotor.

Un objetivo secundario del presente estudio fue examinar el hallazgo de que la mirada es atraída rápidamente hacia aspectos inusuales de una escena. En la comparación entre las versiones normal y extraña de imágenes, quedó demostrado que cuando las personas ven las imágenes extrañas, la longitud de la sacada (*saccade length*) en el ROI es menor que en las imágenes normales. Sin embargo, otras medidas, tales como la duración media de la fijación (*average fixation duration*), el tiempo total de visualización (*total viewing time*) para el análisis de toda la escena, la duración de la primera mirada (*first gaze duration*), el número de fijaciones de la mirada (*number of gaze duration*), la cantidad promedio de tiempo examinado (*average number of time examined*), la duración de la segunda mirada (*second gaze duration*), la duración media de la fijación (*average fixation duration*) y el tiempo total (*total viewing time*) en el ROI, mostraron que las personas dedican más tiempo y mayor cantidad de miradas a las partes extrañas / inusuales de las imágenes que a las partes normales. En nuestro estudio se puso de manifiesto que las regiones extrañas atraían la fijación un poco antes que las regiones normales, aunque las regiones no estaban fijadas desde más lejos. Las regiones extrañas también se examinaron durante un período de tiempo más largo y se volvían a fijar más a menudo durante el curso de la visualización de la escena. Estos hallazgos son coherentes con los de estudios previos que muestran que las anomalías en las escenas se fijan en total durante un período de tiempo más largo (Friedman, 1979; Henderson et al., 1999). Una diferencia importante de nuestro estudio con otros estudios previos es que las regiones extrañas no diferían de las normales de la misma manera que en estos otros estudios. En lugar de usar objetos que no encajaban con la esencia o en el esquema de la escena, en el estudio de Yang et al. (2009) utilizaban objetos que formaban configuraciones anómalas o imposibles en las regiones extrañas, y nosotros seguimos el mismo patrón. Estas diferencias no se basan en una comprensión de toda la escena en comparación con una de sus partes, sino en una comprensión (o falta de ella) de las relaciones entre las partes.

En resumen, nuestros resultados son consistentes con los de Becker et al. (2007) y Harris et al. (2008) al mostrar que (i) las regiones extrañas atraen fijaciones un poco más rápido que las regiones normales; y (ii) los espectadores se detienen más a observar las regiones extrañas que en las regiones normales. Más importante aún, nuestros resultados son consistentes con los reportados por Rayner et al. (2007), Evans et al. (2009) y Yang et al. (2009), al mostrar que las diferencias culturales tienen poca influencia en el control oculomotor durante la percepción de la escena.

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Appendix

Appendix 1

Experimental Sentences, with the Critical Words in boldface, in the CON, SEM, and SEM + SYN Conditions (English and Spanish translations are provided below the sentences)

1. 划木舟渡**江/钢/伸**大概需要一天一夜的时间。

Remar en un barco de madera a través del **río/ acero/ estirar** probablemente requiere un día y una noche.

Rowing a wooden boat across the **river/ steel / stretch** probably requires a day and night.

2. 小李经常饮**酒/枪/挂**因此容易患上胃炎等疾病。

Pablo bebe mucho **vino/ pistola / colgar** por lo que fácilmente podría conseguir enfermedad estomacal.

Xiao Li drinks a lot of **wine / gun/ hang** so he could easily get stomach illness.

3. 陆星常遇见扫**街/湖/推**的女人到那个菜场买东西。

Ricardo a menudo vio a la mujer que barre **las calles / el lago / pulsar** hacer compras en ese mercado.

Lu Xing often saw the woman who sweeps the **streets / lake / push** do shopping in that market.

4. 刘灿回家都要脱**鞋/墙/碰**才进房间确保地板干净。

Luis siempre se quita **los zapatos / la pared / tocar** antes de entrar en la habitación para mantener el suelo limpio.

Liu Can always takes off his **shoes / wall / touch** before entering the room to keep the floor clean.

5. 爷爷喜欢边喝**茶/货/养**边和朋友一起下棋聊天。

Al abuelo le gusta beber **té / bienes / alimentar** mientras juega al ajedrez y charla con sus amigos.

Grandpa likes drinking **tea / goods / feed** while he is playing chess and chatting with his friends.

6. 妈妈习惯一边穿**衣/血/求**一边琢磨怎么搭配才有新意。

Mi mamá piensa a menudo en ir a la moda cuando se pone **ropa / sangre / mendigar**.

My mom often thinks how to dress in a fashion style when she puts on **clothes / blood / beg**.

7. 刘庸天天爬**楼/球/躲**是因为他将此当做一种运动。

Julio sube **las escaleras / la bola / ocultar** todos los días porque lo considera un buen ejercicio.

Liu Yong climbs **the stairs / the ball / hide** every day because he thinks it's a good exercise.

8. 有时用农药杀**虫/牙/夹**容易影响作物的生长周期。

A veces, el uso de pesticidas para matar **las plagas / los dientes / recortar** puede afectar el ciclo de crecimiento.

Sometimes using pesticide to kill **pests / teeth / clip** can affect crops' growing cycle.

9. 骑自行车爬**坡/诗/扔**一会儿就使人感到很疲惫。

Es fácil cansarse cuando se sube en bicicleta hasta **una colina / un poema / tirar**.

It is easy to get tired when you are biking up **a hillside / a poem / throw**.

10. 阿姨买**盐/客/染**和肉准备腌制腊肠过春节。

Mi tía compró **sal / un invitado / teñir** para hacer salchichas para el Festival de Primavera.

Aunt bought **salt / a guest/ dye** to make sausage for Spring Festival.

11. 冬天给孩子戴**帽/狼/割**可以保护头部不易受凉。

En invierno, llevar **sombreros / lobo / cortar** puede proteger a los niños de contraer un resfriado.

In winter, wearing **hats / wolf / cut** can protect children from catching a cold.

12. 老王每天都要挤**奶/竹/扫**送到农场里的便利店卖。

El Sr. Mejía tiene que ordeñar **la leche / de bambú / barrer** y llevarla a la tienda de la granja cada día.

Mr. Wang needs to take **milk / bamboo / sweep** and send it to the farm's store every day.

13. 赵伟认为捕**虎/庙/逗**是件极端危险而刺激的事情。

Alfonso considera que cazar **tigres / templo / embromar** es extremadamente peligroso y emocionante.

Zhao Wei considers hunting **tigers / temple / tease** extremely dangerous and exciting.

14. 农村人喜欢捉**禅/裤/催**那是因为他们可以入药。

A los granjeros les gusta coger **las cigarras / los pantalones / apresurarse**, porque pueden ser utilizadas como medicina.

Countrymen like catching **cicadas / trousers / hurry** because they can be used as medicine.

15. 老人一直以宰**猫/绳/抖**赚取生活费来供养小孙子。

El anciano mata **gatos/ cuerda/ temblar** para ganar dinero y criar a su nieto.

The old man butchers **cats/ rope/ tremble** for people to make money for raising his grandson.

16. 王强平常以写**稿/稻/燃**作为爱好而非糊口的手段。

Jesús generalmente escribe **artículos / arroz / quemar** por diversión, pero no por dinero.

Wang Qiang usually writes **articles / rice / burn** for fun but not for money.

17. 工人们正在铺**砖/铃/毁**准备扩建小区里的花坛。

Los trabajadores están pavimentando **ladrillos / campana / destruir** para extender el macizo de flores en la comunidad.

Workers are paving **bricks / bell / destroy** to extend the flowerbed in the community.

18. 王武常常一边煮**汤/炉/拆**一边看精彩的连环小说。

Carlos normalmente lee novelas durante el tiempo en que **la sopa / la estufa / desmantelar** se está calentando.

Wang Wu usually reads novels during the time **the soup / stove / disconnect** is boiling.

19. 小明下午洗**缸/峰/跃**准备将新买的金鱼放进去。

Hugo lavó **la pecera / el pico / saltar** para el pez que había comprado esa tarde.

Xiaoming washed **the vat / the beak / jump** for the newly bought fish in the afternoon.

20. 王芳觉得吃**桃/铅/挣**之后胃就有些不太舒服。

A Lucía le duele el estómago después de comer **unos melocotonesv/ el indiov/ ganar**.

Wang Fang has a stomach upset after she ate some **peaches / lead / earn**.

21. 农民准备割**麦/巷/吞**后种一些青菜到集市去卖。

Los agricultores planean cultivar hortalizas después de la cosecha de **trigo / carril / tragarse**.

The farmers plan to grow vegetables after they harvest **the wheat / the lane / swallow**.

22. 水灾使筑**坝/椅/捡**成为迫切需要解决的问题。

Las inundaciones convierten en un problema urgente construir **una presa / una silla / recoger**.

Floods make it an urgent problem to construct **a dams / a chair / pick**.

23. 小妹生气就会摔**碗/殿/瞒**或者扔枕头来发泄情绪。

La hermana pequeña rompió **los platos / el palacio / ocultar** y las almohadas para liberar su ira.

Little sister broke (dropped) **the bowls / the palace / conceal** and the pillows to release her anger.

24. 吴铭和同学赶**驴/柱/卧**从山上运货物到城里卖。

Javier y sus compañeros utilizan **burros / pilares / mentir** para transportar mercancías desde las montañas a las ciudades.

Wu Ming and his classmates ride **donkeys / pillars / lie** to transport goods from mountains to cities.

25. 叉烧肉淋**蜜/墓/攀**之后就有一种独特的风味。

Si echas a la barbacoa de cerdo **miel / tumba / subir** le da un sabor especial.

Serving barbecued pork with **honey / tomb / climb** makes a special flavor.

26. 肖明喜欢攀**岩/妻/轰**这种极少人敢挑战的运动。

Rogelio es aficionado a los deportes desafiantes como escalar **el acantilado / la esposa / explotar** que pocas personas se atreven a practicar.

Xiao Ming is fond of challenging sports like climbing **cliff / wife / boom** that few people dare to practice.

27. 很多农村家庭举**债/绸/烘**以供孩子去城里读大学。

Muchas familias rurales contraen **deudas / seda / cocer** para apoyar la educación de sus hijos en la universidad.

Many rural families get into **debt / silk / bake** to support their children's education in college.

28. 老板给大家提**薪/桑/瞥**庆祝公司成立五十周年。

El jefe aumentó **el salario / la morera / mirar** a sus empleados para celebrar el 50 aniversario de la fundación de la empresa.

The boss raised his employees' **salary / mulberry / glance** to celebrate the 50th anniversary of the company's foundation.

29. 小明周末采**枣/亭/牵**卖给小贩以赚点小钱。

Emilio hizo algo de dinero recogiendo **dátiles / el pabellón / dedicar** y vendiéndolos a los vendedores ambulantes.

Amy made some money by picking **dates / pavilion / devote** and selling them to peddlers.

30. 吴旭喜欢下**棋/蹄/授**因为这有助于修身养性。

A Juan le gusta jugar **al ajedrez / al casco / ayudar** porque ayuda a cultivar la personalidad de las personas.

Wu Xu likes playing **chess / hoof / help** because it helps to cultivate people's personality.

31. 古代官员都以乘**轿/祸/耕**代替步行从而显示排场。

Los oficiales antiguos iban en **caballos / los desastres / cultivar** en vez de caminar para mostrar su poder.

Ancient officers all ride in **sedans-chairs/ disasters / cultivate** instead of walking to show off their power.

32. 那艘大船扬**帆/柜/创**离开了这一个热闹的港口。

Ese gran barco desplegó **las velas / los gabinetes / crear** y salió del puerto muy animado.

That big ship put up **the sails / the cabinets / create** and left the busy harbor.

33. 小吴周末喜欢买**碟/湾/舔**回家看而不太喜欢去电影院。

Manuel suele comprar **películas / bahía / lamer** y las ve en casa durante el fin de semana.

Xiaowu usually buys **movies / bay / lick** and watches them at home during the weekend.

34. 老李家用饲料喂**猪/针/歇**之后生产效益大大提高了。

El Sr. Díaz obtuvo resultados positivos tras cambiar la alimentación de sus **cerdos / agujas / descansar** con forrajes.

Mr. Li received beneficial results after he starts feeding **pigs / needles / rest** with fodders.

35. 老人很早就上**炕/浪/拣**等着儿子给他打电话。

El viejo se fue **a una Kang (un tipo de cama) / una ola / recoger** temprano y esperó la llamada de su hijo.

The old man went to **Kang (bed) / wave / pick** early and waited for his son's call.

36. 小芳是个容易流**泪/碑/钓**但是胆子却很大的孩子。

Martita derramó **lágrimas / un monumento / pescar** con facilidad, pero, en realidad, era una chica valiente.

Xiaofang shed **tears / a monument / fishing** easily but she is actually a courageous girl.

37. 他们每年都要修**渠/柴/跪**和做好相关的防洪工作。

Tienen que revisar y reparar **las zanjas / la leña / arrodillarse** cada año en caso de inundaciones.

They need to check and repair **ditches / firewood / kneel** every year in case of floods.

38. 小红正在给吃**梨/帘/袭**的爸爸解释这水果的药性。

Cuando su padre estaba comiendo **una pera / unas cortinas / atacar**, Sofía le explicó acerca de sus propiedades medicinales.

When her father was eating **a pear/ curtains / attack**, Xiaohong explained to him about its medical properties.

39. 老张每天熬**药/窗/忘**给他身体虚弱的母亲喝。

El Sr. Montero hierve **hierbas / una ventana / olvidar** cada día para su madre enferma.

Mr. Zhang boils **herbs / a window / forget** for his sick mom every day.

Appendix 2 Images

1. Baby ledge

2. Baby toss

3.Crazy cat

4. Basketball

5. Bus

6. Child

7. Dangerous knife

8. Deer hunter

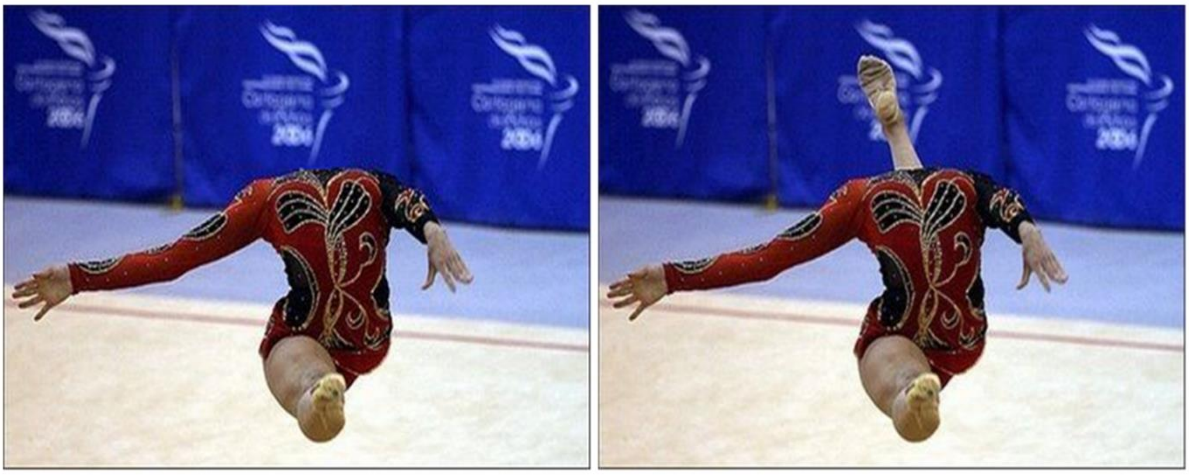
9. Dog game

10. Laughing

11. Dog glasses

12. Dog in fridge

13. Gymnastics



14. Mirror

15. Poodle

16. Raccoons

17. Soldier

18. Soccer

19. Soccer 2

20. Squirrel