TESIS DOCTORAL

DOCTORADO EUROPEO

When Time Flows from Left to Right: Psychological Reality, Experiential Basis and Cognitive Mechanisms

REALIZADA POR

Marc Ouellet

DIRECTOR

Julio Santiago de Torres

Grupo de Psicolingüística: Comprensión, Producción y Desarrollo (PSILCOM, HUM699)

Dept. de Psicología Experimental y Fisiología del Comportamiento

Universidad de Granada
Julio 2009

Editor: Editorial de la Universidad de Granada
Autor: Marc Ouellet
D.L.: GR. 3531-2009
ISBN: 978-84-692-6411-9

UNIVERSIDAD DE GRANADA

UNIVERSIDAD DE GRANADA
DEPARTAMENTO DE PSICOLOGÍA EXPERIMENTAL
Y FISIOLOGÍA DEL COMPORTAMIENTO
-
Campus Universitario de Cartuja, s/n
Telef. +34 - 958 24 37 63 - Fax: +34 - 958 24 62 39
18071 - GRANADA - ESPAÑA

When Time Flows from Left to Right: Psychological Reality, Experiential Basis and Cognitive Mechanisms

Tesis Doctoral presentada por **Marc Ouellet** en el *Departamento de Psicología Experimental y Fisiología del Comportamiento*, para aspirar al grado de Doctor en Psicología, en el programa de doctorado de *Procesos de Traducción e Interpretación*, de la Universidad de Granada.

La tesis ha sido realizada bajo la dirección del profesor **Julio Santiago de Torres**, quien avala la calidad de la misma, así como la formación del doctorando para aspirar al grado de doctor.

Firmado en Granada, a 01 de Septiembre de 2009.

El doctorando: El director de la tesis:

Fdo.: Marc Ouellet

Fdo.: Julio Santiago de Torres
Profesor Titular de Psicología

“Mira a la derecha y a la izquierda del tiempo

y que tu corazón aprenda a estar tranquilo.”

Federico García Lorca

To my son, daughter, and wife,

my Source Domain

of happiness.

Remerciements, Agradecimientos & Acknowledgments

Remerciements:

Je tiens à commencer cette thèse par un grand MERCI à mes parents pour leur aide et soutien constants. Vos visites en Espagne, tout comme nos visites à Chicoutimi, ont toujours été des moments qui nous ont permis de refaire le plein d'énergie. Sans elles, j'aurais difficilement pu compléter ce travail. J'espère que votre prochaine visite ne saura tarder, car vos petits-enfants Julio et Elena ont déjà bien hâte de vous voir.

À mes deux frères et belles-sœurs, je peux vous dire que la vie ne serait pas pareille sans vous et encore mieux si l'on pouvait se voir plus souvent. J'espère vous voir bientôt en Espagne (Julio a besoin de se faire enseigner de nouvelles grimaces et il faudra bientôt initier Elena).

À mes oncles et tantes, c'est toujours un aussi grand plaisir quand je peux vous voir et encore plus quand c'est en Espagne. J'espère que vous pourrez tous voir le petit coin de pays où nous nous sommes établi et, pour ceux qui l'ont déjà fait, sachez que votre visite a été des plus appréciées.

À grand-maman Gigi et grand-maman Yvonne, merci pour votre affection, vos soins et toutes ces petites attentions que vous nous avez toujours témoignés.

Fred, Ben et Éric, merci pour être les amis que vous êtes et désolé si je vous ai un peu abandonnés ces derniers temps. Je suis certain que vous comprendrez et que les occasions pour se reprendre ne se feront pas attendre. Je m'ennuis du temps où tu vivais près de chez-nous, Fred, mais quand je vois la vie que vous menez toi et Karine, hé bien, je dois dire que je suis content pour vous.

Un dernier petit mot pour Marcel et Claudine. Plus que des voisins, vous avez été comme une deuxième famille. Votre générosité et patience sont des modèles que j'essaie de suivre au quotidien.

Agradecimientos:

Estos agradecimientos van, en primer lugar, a mi mujer. No sé cómo has podido soportar a ese oso canadiense gruñón que he sido durante estos últimos meses. Gracias a Dios, tu cariño y tu manera de ser me daban ánimo cuando más lo necesitaba.

Gracias también a mis hijos. Siento mucho, Julio, que la primera frase que has aprendido a decir es: "Papa está trabajando." A tu hermana también (mi maquina de sonreír) le debo disculpas por no estar mucho durante sus primeros meses de vida. Vuestras risas y energía han sido mi mejor fuente de ánimo e inspiración.

Miles de gracias a mi familia política. Nunca habéis dudado en echarnos una mano cuando lo necesitábamos. Derrocháis mucha generosidad y amor y siempre es una alegría ver hasta qué punto vuestros nietos/sobrinos os quieren.

A toda la gente del grupo, sois los mejores. Me le paso muy bien con vosotros de viaje o tomando una cerveza. Por cierto Antonio, te prometo hacer todos los esfuerzos posibles para un día ir con vosotros a ver lo que esconde el universo.

A los compañeros de la sala de becarios (disculpadme si os llamo todavía así, pero el hecho de que seáis ya profesores, en otra universidad o en casa no cambia para mí el hecho que siempre seréis mis compañeros de la sala de becarios), os lo debo casi todo. Vuestros continuos consejos, ayuda, simpatía y sin olvidar vuestro gusto bien desarrollado para la fiesta me han enseñando que un buen investigador es, ante todo, una persona con la cual es agradable de convivir.

A todos los profesores que me han ayudado y animado durante este largo camino, gracias. Aquí, hago una referencia especial a Juan Lupiáñez. Tus miles de consejos, disponibilidad y gran paciencia a la hora de explicar las cosas han hecho que este camino sea menos largo.

Y a Julio Santiago, que puedo decir sino que le he puesto un 10 sobre 5 en una evaluación que tuve que hacer sobre su trabajo como mi director de tesis. Todas las páginas de esta tesis serían pocas para agradecerte. Tu devoción, cariño y amistad son unas cualidades que han hecho que hacer la tesis contigo haya sido un placer. Antes de un director, siempre te consideraré como un amigo.

Acknowledgements:

First of all, a special thank to all the members of the tribunal who did a special effort to come in Granada, read this thesis and, I don't know how, to find a way to fit the day of the defense in their agenda. I am very sorry for the problems we had with the date, but as you all know, we faced some administrative problems.

I would also want to say a great thank to Antje S. Meyer and all the members of her speech group at Birmingham. When I am thinking to all of you it is like opening a chest full of good memories. Ana, I hope to see your baby soon and Christine, I am looking forward to go back to the Rainbow.

Great thanks as well to Ziv Israeli and Shai Gabay for making the effort to run the experiment in Israel. You are very nice persons and I look forward to see you.

Financial support came from a Researcher's Training Grant, Programa de Formación de Doctores en Centros de Investigación y Universidades Andaluzas, Consejería de Innovación, Ciencia y Empresa de la Junta de Andalucía, and from grant SEJ2006-04732/PSIC, funded by DGI, Ministerio de Educación y Ciencia, Plan Nacional de Investigación Científica, Desarrollo e Innovación Tecnológica (I+D+i), 2006-2009, to Julio Santiago (PI).

INDEX

Chapter I

Introduction & aims of the thesis

Conceptual metaphors

Introduction

Personally, I did not experience the Big Bang and I assume that no reader of this text did. Nonetheless, I know it existed, I can speak of it, and I can even imagine how the explosion was. How is that possible? It is because, somehow, I found a way to conceptualize it.

But there is no need to go that far in time and space to find intangible objects being conceptualized. Just think of the concepts of justice, time or love. They are concepts that we use in our everyday life, but we never interacted with them through our perceptuo-motor system. This lack of direct experiential basis would be the reason why abstract concepts are more complicated to conceptualize than concrete concepts (Lakoff & Johnson, 1980, 1999).

Grounding of concrete concepts

Still, concrete concepts are in some ways complicated. Explaining how outer objects can be represented, categorized, referred to, is a big challenge for conceptual theorists. Just think of the concept of "house". The perceptual appearance of houses varies so widely that it is a mystery how we can tell apart every object which is a house from others which are not.

Harnad (1990) referred to it as "The symbol grounding problem". He argued that concepts need to be grounded on the outer reality. A concept without grounding on perceptuo-motor experiences would be empty of meaning. To exemplify his position, let's have a look at the now famous "Chinese Room Argument" (Searle, 1980).

Chinese Room Argument

Suppose you are seated in your office, working on your computer, when you receive an invitation to chat with a new friend. Feeling tired and in need of a break, you accept the invitation and start to chat with her. After a while, you discover that you both share many interests and decide to include her in your contacts list.

Surprise! A message pops up: "Thank you for participating in our new Turing test. If you are interested in receiving more info about the Turing test, please visit our website: http://www.machine_simulation_of_human_thought.com." After the shock, and maybe after having visited the website, you start thinking that this computer you were chatting with maybe capable of real thinking.

Is that the case?

After all, you mistook the machine for a real human thinker (Turing, 1950). However, according to Searle (1980), there is a principled reason why we should refrain from making that assertion. Under his view, AI (Artificial Intelligence) programs, even if they are good at imitating a human thinker, they are not able of conceptualization. They give the impression of being able to, but the concepts they use are empty of meaning in themselves.

Searle (1980) used the "Chinese Room Argument" to explain why machines are not able of thinking. Basically, this argument asks you to imagine an English monolingual speaker locked in a room and presented with a set of Chinese symbols (the data). English instructions (the equivalent of the program) are given to him which explain in detail how to manipulate the strings of Chinese characters. Upon receiving a written Chinese input (let's say a Chinese question made by a Chinese speaker situated outside of the room) the English participant would follow the instructions and respond by producing a correct sequence of written Chinese symbols. The Chinese speaker situated outside the room should then think that the room contained a native Chinese speaker.

The fact that the English participant passed the Chinese Turing test doesn't mean that he knows Chinese. He can manipulate Chinese symbols, but has no meaning associated with them. The same, so the argument goes, happens with computers.

Here we do not want to enter into a philosophical debate about whether machines can think or not, but just want to use this example to highlight the importance of the grounding process for concepts.

Empirical Evidence related to the Grounding Process

The involvement of basic perceptual and motor representations in the grounding of concrete concepts has received support from several research lines. One is the Action–sentence Compatibility Effect, as studied by Glenberg & Kaschak (2002). The mere fact of reading about directional actions, like closing a drawer, interferes with real actions carried out in the opposite direction. Moreover, Pulvermüller (2001) observed comparable brain activation patterns when reading action words and carrying out the same actions. Further evidence comes from gesture studies (McNeill, 1992, 2000, 2005). When a person speaks about an object, he often simulates an interaction with it in his gestures, what suggests that the use of a concept when speaking calls up a representation very close to that activated when actually perceiving and/or using its referent.

Barsalou (1999) elaborated the Perceptual Symbol Systems theory, which offers a common explanation for these effects. He proposed that we think by means of conceptual simulations and that, when calling upon a concept, a simulator of it is activated. The simulator includes a recall of the brain activation during the perceptuo-motor experiences associated to its referent. As a result, the same areas that were activated during perceptuo-motor experiences associated to a concept are also activated when thinking about this concept, even if the task does not require doing it.

Abstract Concepts

So, what about the Big Bang? If it is true that the meaning arises from the grounding process, how can we ground a concept whose referent cannot be experienced?

Conceptual Metaphor Theory

One way of doing so is by means of a metaphorical mapping from a more concrete concept, taking advantage of its more direct grounding on perceptuo-motor experiences.

Lakoff & Johnson (1980, 1999), by analyzing recurrent patterns of everyday linguistic expressions, realized that people were using concrete concepts to speak about abstract domains. The high frequency of this borrowing process and the creative ways in which those expressions could be extended without hampering their comprehension led them to hypothesize that these idiomatic patterns were revealing the genuine conceptualization of abstract thoughts. They named the underlying operation of thought Conceptual Metaphors: the process by which a Source Domain (concrete concept) is used to help the understanding of (is mapped on) a Target Domain (abstract concept).

Lakoff & Johnson (1980, 1999) also noted that people very rarely speak about concrete concepts in terms of abstract concepts. This finding is congruent with the fact that the latter are more difficult to conceptualize than the former (Clark, 1973). As a result, they depend more strongly on structural borrowings from concrete domains, which are better understood and have a richer semantic representation. According to Lakoff & Johnson (1980, 1999), mappings in the other direction are rare because a less known concept would be of little help to understand a better known concept. They concluded that the borrowing process is asymmetrical in nature: from the concrete (Source Domain) to the abstract (Target Domain).

Conceptual metaphors are widespread in language. Some of the conceptual metaphors isolated by Lakoff & Johnson (1980) include: INTIMACY IS CLOSENESS ("He is a *close* friend of mine."), CONTROL IS UP - LACK OF CONTROL IS DOWN ("She was on *top* of the situation."), POSITIVE IS UP - NEGATIVE IS DOWN ("Her way of saying hello to me cheered me *up*."), MORE IS BIG - LESS IS SMALL ("The number two is a *small* number.") and MORE IS UP - LESS IS DOWN ("A *high* number of participants took part in our experiments.").

Why a source domain is preferred to another?

A question now arises. Why mapping, let's say, the concept of intimacy to closeness and not to another perceptuo-motor experience like that of the taste of an apple? The proposed reason is that perceptuo-motor experiences and abstract concepts need to be highly correlated to be mapped together. When experiencing intimacy with someone, this person is generally close to the self.

When an abstract concept and a perceptuo-motor experience are highly correlated, the door is opened for a conceptual mapping. The greater the correlation, the stronger becomes the metaphorical mapping. As a result, expressions mirroring such mappings emerge in language (Lakoff & Johnson, 1980, 1999).

The Solid Foundations View

The complete picture then for the conceptualization process is like that of a building firmly grounded on the external world, a view which we have called elsewhere the Solid Foundations View (Santiago, Román & Ouellet, submitted). The direct experiences with the world permit us to establish the foundations of the building, providing the grounding of the lower-level, concrete concepts. Concrete representations can then support the next floor by means of metaphorical mappings.

Are Conceptual Metaphors a Psychological Reality?

In spite of the descriptive success of the notion of conceptual metaphor at identifying several dozens metaphorical patterns in language, these patterns do not suffice as evidence for the claims of Conceptual Metaphor Theory. One of the biggest problems results from the circularity of the evidence (Murphy, 1996, 1997; Casasanto, 2009b): linguistic metaphors are both the predictor and the predicted result. Lakoff & Johnson (1980, 1999) used the linguistic patterns to infer the existence of conceptual metaphors in abstract thoughts (linguistic metaphors as predictor). Why should it be the case? Because such a mental mapping surfaces in language (linguistic metaphors as predicted result). Therefore, a reason to think why these mappings should be present in language is, in fact, because patterns of metaphoric expressions are present in language.

We can see here that the argument is a kind of a loop. To be certain that conceptual metaphors are the resulting output of mental structures, it is necessary to test their psychological reality by means other than linguistic compilations.

Psycholinguistic Evidence on the Psychological Reality of Conceptual Metaphors

The most frequent way of studying the psychological reality of Conceptual Metaphors has been by means of priming tasks. However, as we will see later on, other types of task have also been used.

Many of the conceptual metaphors reported by Lakoff & Johnson (1980, 1999) have been put to test, and very often the evidence has turned out positive, supporting their reality as a building brick of the structural organization of the mind. Here we will have a look at some of them and how they have been studied.

So we turn now to a brief and selective review of the available evidence supporting several conceptual metaphors. Note that we will not mention here conceptual metaphors involving time as target domain because the next section is entirely dedicated to them.

BRIGHT IS GOOD - DARK IS BAD

This conceptual metaphor surface frequently in our everyday speaking (e.g., "*Dark* ages." or "*Brighter* days are to come.") and seems to be universal (Osgood, 1973).

One of the sensory-motor experiences responsible for this representation might be the frightening experiences as children when listening sounds in the dark.

Meier, Robinson & Clore (2004) investigated the automaticity of this mapping by presenting words with positive or negative meanings in dark or bright font. When participants had to judge the valence of the words, they performed better when responding to positive words presented in bright font and to negative words in dark font, which they took to support that good-bright and bad-dark are mentally related concepts. Moreover, as predicted by Conceptual Metaphor Theory, the effect was asymmetrical:

when asked to judge the brightness of the font, word valence did not affect performance.

However, in a following study (Meier, Robinson, Crawford & Ahlvers, 2007), they asked their participants to perform a brightness judgment task following a valence discrimination task. Under these circumstances, they observed that word valence biased subsequent perceptual judgments. It means that the link between the source domain of brightness and the target domain of valence is not as asymmetrical as previously thought and predicted by the Conceptual Metaphor Theory (Lakoff & Johnson, 1980, 1999).

CONTROL IS UP - LACK OF CONTROL IS DOWN

Another conceptual metaphor who has received empirical support is CONTROL IS UP - LACK OF CONTROL IS DOWN.

The physical basis of this metaphor would lie in the fact that taller people (UP) are normally stronger, so they will normally win a fight if they have to, being able to exercise more CONTROL than shorter people (Lakoff & Johnson, 1980, 1999).

Schubert (2005) studied this metaphor in various ways. He first demonstrated (Experiment 1) that participants tend to graphically represent powerful concepts (names of powerful social groups) over powerless ones when they are asked to choose a spatial schema representing the relation between those two concepts.

He also demonstrated that powerful and powerless concepts could prime congruent motor responses (up and down, respectively; Experiment 3) and that the screen position of word presentation (up or down) was enough to prime congruent powerful and powerless concepts (Experiment 4).

Furthermore, Moeller, Robinson & Zabelina (2008) demonstrated that the dominant versus non-dominant personality of participants was a good predictor for their performance on a spatial attentional task. Both groups performed equally well at identifying targets over a horizontal axis, but participants with a dominant compared to non-dominant personality were better at identifying the same targets over a vertical axis, even if the task did not convey any social meaning. Authors attribute these results to a possible better and more frequent use of this metaphor by dominant versus non-dominant participants in their daily life.

MORE IS UP - LESS IS DOWN

The MORE IS UP - LESS IS DOWN conceptual metaphor is suggested to find its origins in the fact that we are frequently faced with the experience of piling up objects: when the amount increments, the height of the pile goes up (Lakoff & Johnson, 1980, 1999).

Accordingly, Joseph, Giesler & Silvera (1994) showed that self-performance and self-productivity judgments on a proofreading task were biased by the pile size of documents accumulated during the task, even if the amount of work was the same over all conditions. Participants who performed the proofread of pages inside journals (higher pile) had the impression of having done more and a better work than those who performed the same task on single pages (lower pile).

Another type of paradigm used by Ito & Hatta (2004) showed a vertical representation of number size, large numbers being associated with upper space and small numbers with lower space. Participants were faster to respond to large numbers with the upper vs. lower key and it was the opposite for the small numbers.

POSITIVE IS UP - NEGATIVE IS DOWN

Body postures would give rise to this conceptual metaphor. When feeling depressed, human beings typically adopt drooping postures. On the opposite, they are more prone to adopt erect postures when feeling happy (Lakoff & Johnson, 1980, 1999).

Meier & Robinson (2004, Exp. 1) showed a congruency effect between the position on the screen (up vs. down) and the processing of valence words (positive vs. negative), positive words were processed faster in the upper position and it was the opposite for negative words. Two more experiments permitted to demonstrate that this effect was due to a bias created by word meanings on space perception, not the other way around. The directionality of the effect (from the abstract to the concrete) goes in a direction diametrically opposed to that predicted by the Conceptual Metaphor Theory (Lakoff & Johnson, 1980, 1999).

Using a memory task, Crawford, Margolies, Drake & Murphy (2006) demonstrated that participants were better at remembering valence pictures appearing at congruent positions on the screen. Positive pictures were remembered better when they appeared on the top of the screen and negative pictures when they appeared at the bottom.

In a similar vein to the Moeller et al (2008) study with dominant vs. non-dominant participants, Meier & Robinson (2006) also showed that the more depressive was a person, the better s/he was at discriminating targets appearing at the bottom of the screen compared to the top.

Psychological Reality of Conceptual Metaphors - Discussion

This selective review shows that many conceptual metaphors present in language are more than just a linguistic phenomenon or a way of talking: they are the manifestation of lively mental structures, actually used to think and reason about those abstract domains.

Psycholinguistic studies of conceptual metaphors also permit to question some claims of Conceptual Metaphor Theory. As discussed above, an assertion of Conceptual Metaphor Theory is that the effect is asymmetrical, from the Source Domain to the Target Domain. Even if some studies seem to support this position (e.g., Meier et al, 2004, plus studies from the domain of time like Borodistky, 2000, to be discussed later on) other studies show strong evidences for bidirectional effects (e.g., Meier et al, 2007) or at least of flexible directionality (see Santiago et al, submitted, for a detailed review of evidence supporting a high degree of flexibility in conceptual mappings).

Santiago et al (submitted) offer an alternative explanation to the asymmetrical directionality with conceptual metaphors. According to them, the modulation of a concrete or abstract concept by the simultaneous processing of another concept is a matter of relative activation. The degree of activation of concepts within the contents of the mental workplace is affected by intrinsic strength, practice, saliency, and attentional factors (both endogenous and exogenous). The more active concept will interfere with the processing of the less active concept, no matter if the latter is the concrete or abstract component of the conceptual metaphor. This way of conceiving the directionality in conceptual metaphors can explain the flexibility observed in the studies mentioned above and in several others (see full review in Santiago et al, submitted).

Are there Windows on the Mind other than Language?

Lakoff & Johnson (1980, 1999) identified many conceptual metaphors in language and, as we have seen in the last section, the proofs concerning their psychological reality are constantly growing.

Cognitive linguists have had a lot of success at implementing Lakoff & Johnson (1980, 1999) proposals, but their work has been restricted only to conceptual metaphors that surface in language.

As we will see, there exist correlations between perceptuo-motor experiences and abstract concepts other than those present in language. In principle, all those correlations are possible candidates to generate conceptual metaphors.

Left-Right representation of abstract concepts

The left-right representation of abstract concepts will be discussed in more detail in Chapter III. Withal, we will have a fast look at those metaphors that use a spatial left-right horizontal axis as structural donor because most of those metaphors are not present in language.

Ordered sequences

Ordered sequences like series of objects (Nachson, 1981), numbers (Dehaene, Bossini & Giraux, 1993; Zebian, 2005) letters of the alphabet, days of the week, months of the year (Gevers, Reynvoet & Fias, 2003, 2004) are normally represented over a left-right horizontal axis, even if there are no such traces in language.

It is thought that this bias is originated by the directionality of the writing system first learned by the participants and/or the graphical conventions present in their respective cultures. Readers of a left-to-right orthographic system represent the first components of the series on the left and further components to the right, whereas it is the opposite for right-to-left readers (e.g., Nachson, 1981).

Aesthetic preferences

Another metaphor which is not present in language is the left-right mapping of aesthetic preferences. As for the ordered sequences, aesthetic preferences are biased by the orthographic directionality of the participant.

Gaffron (1950) already noticed that left-to-right readers preferred rightward pictures. Subsequent studies permitted to show that this preference was linked to scanning habits (when reading) of the participants: the directional aesthetic preference was the opposite in right-to-left readers (Nachson, Argaman & Luria, 1999; Chokron & De Agostini, 2000).

Agent-patient relations

The same happens with the graphical representation of agent-patient relations. While left-to-right readers tend to represent the agent to the left of the patient (Chatterjee, Southwood & Basilico, 1997; Maass & Russo, 2003; Dobel, Diesendruck & Bölte, 2007), right-to-left readers normally do the opposite (Maass & Russo, 2003; Dobel, Diesendruck & Bölte, 2007).

Valence

We often speak about negative and positive concepts in terms of left and right spaces, respectively ("Trust him, he is my *right*-hand man." or "Our star footballer could not do worst, he played with his two *left* feet.").

However, Casasanto (2009a) found that this mapping of valence in language is not representative for a large group of its users. While right-handed participants showed a typical right-good left-bad mental representation, left-handed participants showed the opposite mapping. This finding means that the linguistics expressions mapping good on the right and bad on the left are not a good predictor, since the effect depends on the handedness of the participants.

Are there Windows on the Mind other than Language? - Discussion

As we can see, not all conceptual metaphors are present in language. It is still unclear what are the conditions for a conceptual metaphor to be manifested in linguistic expressions.

It seems that another good window on the mind to identify conceptual metaphors would be the way we graphically represent abstract concepts. Particular cultures have their graphical conventions to map abstract concepts such as numbers, days of the week, letters of the alphabet… It seems that the inhabitants of these cultures mentally structure these abstract concepts accordingly to the way they are spatially mapped by convention.

General Discussion

To sum up, it seems that concrete and abstract concepts need to be grounded on direct experiences with the world. Under Conceptual Metaphor Theory (Lakoff & Johnson, 1980, 1999), while concrete concepts execute this grounding process in a kind of direct fashion, because their referent is directly experienced by the sensory-motor system, abstract concepts need to do it metaphorically.

This process is thought to help the understanding we have about abstract concepts. It was first thought to be asymmetrical (Lakoff & Johnson, 1980, 1999), but recent findings (see Santiago et al, submitted) call the assumption of asymmetrical directionality into question.

Supporting evidence, both from the linguistic analysis of idiomatic patterns and behavioral tasks, is constantly growing, demonstrating that conceptual metaphors are a psychological reality. It is also important to note that not all conceptual metaphors are present in language. Using new methods for identifying them is essential and it will probably result in the identification of many new conceptual metaphors.

Conceptual metaphors of TIME

Introduction

Conceptual metaphors having time as structural receiver are very frequent in language and they are among the best studied metaphors by metaphor theorists. As Casasanto (2009b) puts it:

Time has become for the metaphor theorist what the fruit fly is for the geneticist: the model system of choice for linguistic and psychological tests of relationships between metaphorical source and target domains.

We will have a close look at their presence in language, their psychological reality and at those time metaphors which are not present in language.

TIME IS MONEY

Expressions like “I *spent* two hours doing that homework.”, “I am *wasting* my time with this company.” or “I *invested* so much time in this relationship.” will surely sound familiar to the reader. They all express the TIME IS MONEY conceptual metaphor (Lakoff & Johnson, 1980, 1999). It patterns together with related conceptual metaphors like TIME IS A LIMITED RESOURCE (e.g. “I am *running out* of time.), TIME IS A VALUABLE COMMODITY (e.g. “I *won* four minutes with this shortcut.”) or TIME IS A SUBSTANCE (e.g., “*How much* time do we have?”).

This metaphor would be the result of several kinds of experienced correlations (at least in some cultures), such as that between the time we spend working and the corresponding amount of money we receive for it (e.g., we will receive twice as much money if we work forty hours instead of twenty).

Psychological Reality of the TIME IS MONEY metaphor

This metaphor has not been systematically studied by linguists. Relevant evidence comes from a sociological study from Levine (1997).

In the "*Is Time Money?*" chapter, he explains how time and money can be unrelated concepts for inhabitants of cultures where the experience of money does not correlate with time, whereas it is the opposite for Americans, who practically systematically experience money as something related to time. His observations support the suggestion that people experiencing a correlation between TIME and MONEY will build a mental structure in which TIME is mapped onto MONEY, whereas people not facing such correlation will simply store these two concepts as independents from each other.

TIME IS A CONTAINER

Speaking about time in terms of a container is also very frequent (Lakoff & Johnson, 1980, 1999). Expressions like "I am *filling* time playing with my new PSP." or "I will go *in* a minute." are common.

The perceptual experience of seeing containers being filled up (e.g., glasses of water, a bath, the toilet…) while the time goes by might be the related experience for the emergence of this metaphor.

Psychological Reality of the TIME IS A CONTAINER metaphor

As far as we know, nobody has studied the psychological reality of this metaphor. The only study that used the concept of container to study time is that of Casasanto, Boroditsky, Phillips, Greene, Goswami, Bocanegra-Thiel, Santiago-Diaz, Fotokopoulu, Pita & Gil (2004), but even this study is not telling about the psychological reality of the TIME IS A CONTAINER metaphor. They asked their participants to estimate the volume of the liquid or the time duration of a schematic container (on a computer screen) being filled at different speeds and levels. Doing so, they did not study the TIME IS A CONTAINER conceptual metaphor, but the TIME IS A SUBSTANCE metaphor, which is thought to be part of the more general TIME IS MONEY conceptual metaphor (Lakoff & Johnson, 1980).

More research on this conceptual metaphor will permit to shed light on its psychological realm.

TIME IS MOTION

The conceptual metaphors that will be most interesting for us for the purpose of this thesis are the TIME IS MOTION family of conceptual metaphors. We will have a look at the motion of time over three axes: vertical (up-down), horizontal (front-back) and horizontal (left-right).

FUTURE IS UP - PAST IS DOWN

Languages vary regarding how often the vertical axis is used when talking spatially about time. In English this metaphor is not very frequent (e.g., "Summer is coming *up*."), and horizontal front-back metaphors are generally preferred, whereas in Mandarin both axes are used nearly as frequently (Chen, 2007; Radden, 2004).

Lakoff & Johnson (1980) hypothesized that the physical origin of this metaphor, which they termed FORESEEABLE FUTURE EVENTS ARE UP (AND AHEAD) lies in the fact that when something (or somebody) is getting closer to a person, this person perceives it as becoming larger. From his/her point of view, and taking the ground as a referent, the top of the approaching entity is moving upwards.

Psychological Reality of the FUTURE IS UP - PAST IS DOWN metaphor

Going back to the differences between English and Mandarin native speakers in their frequency of use of the FUTURE IS UP - PAST IS DOWN conceptual metaphor, Boroditsky (2001, 2008) tested whether English and Chinese participants think like they speak.

In her 2001 study, she observed that English participants responded faster to questions about time when primed by a horizontal compared to a vertical spatial prime, whereas Mandarin native speakers showed the opposite pattern. However, this correlational effect between the way English and Mandarin native speakers speak and think about time has been found difficult to replicate (Chen, 2007; January & Kako, 2007).

Nonetheless, in a subsequent study Boroditsky (2008) asked her participants to graphically organize time sequences, and observed that English and Mandarin native speakers make use of the vertical compared to the horizontal axis in a proportion similar to the frequency of use of horizontal versus vertical expressions of time in their native language.

FUTURE IS IN FRONT - PAST IS BEHIND

The use of the front-back horizontal axis to represent time is present in all the languages studied to date (Haspelmath, 1997; Radden, 2004) and its use in English is very frequent (e.g., "Einstein was a man *ahead* of his time." or "In order to not repeat the same mistakes, we have to look *behind*.").

Overtones of the FUTURE IS IN FRONT - PAST IS BEHIND metaphor are also present in many other expressions implying motion of TIME in which the mention of the front-back horizontal axis is not explicit. In the expressions "We are *approaching* vacations." and "Summer is *arriving*.", the front-back horizontal axis is implicit. In the former expression, the action of *approaching* refers to the action of going *forward* to attain a goal whereas in the latter expression, we can assume that it is more frequent to see someone *arriving* in *front* of you, except if this person wants to give you a fright.

An important point to note is that, even if these two last expressions refer to an act of motion when speaking about time, each of them is using a different spatial perspective to map the abstract concept of time. The first example uses the *ego-moving* perspective (Clark, 1973). It conjures an image of the ego walking forward along a path, heading towards its future.

The second example uses the so-called *time-moving* perspective (Clark, 1973). While in the *ego-moving* perspective, the ego is moving forward toward its future, in the *time-moving* perspective the ego stands still and it is the future which is coming towards it.

Note that in both cases the future is situated in front of ego, so they are subtypes of the front-back metaphor.

There are also cultures, such as the Aymara, which map time onto the front-back axis in the opposite way, past being considered as something you can see (in front) and future as something you can't see (behind) (Núñez & Sweetser, 2006).

Psychological Reality of the FUTURE IS IN FRONT - PAST IS BEHIND

Boroditsky (2000), following on McGlone (1998)'s work, studied the psychological reality of this conceptual metaphor and its two spatial perspectives. She presented participants with drawings of ego- and time-moving scenarios and observed how they modulated their responses to the ambiguous question "Next Wednesday's meeting has been moved *forward* two days. Which day the meeting has been rescheduled?".

The word *forward* in the sentence is ambiguous, because, from an ego-moving perspective, it means that the meeting has been moved farther away from the ego. However, if it is the time which is considered to move, it means that the meeting has been moved towards the ego.

If the FUTURE IS IN FRONT - PAST IS BEHIND conceptual metaphor is only a set of linguistic expressions not representing our construal of time, then no effect should be expected from the previous ego- or time-moving scenarios on the responses to the ambiguous question. Otherwise, participants should show a modulation by the primes, the ego- and time-moving primes inducing the Friday and Monday response, respectively.

In accordance with such expectations, she observed a bias induced by the drawing scenarios. When primed by an ego-moving scenario, participants tended to respond Friday, whereas they preferred the Monday response when the prime was a time-moving frame. Moreover, when she carried out the converse manipulation, she did not observe influences of the concept of time over spatial judgments, suggesting that the effect is unidirectional in nature, from the concrete domain to the abstract.

In a second set of studies, Borodistky & Ramscar (2002) demonstrated that real life experiences of motion were able to modulate the perspective adopted to respond to the ambiguous question, adding weight to the psychological reality of this metaphor. For example, in one of their studies, the question was asked to people at an airport who had just flown in or were about to fly away, as well as to a control group of participants who were waiting to pick up somebody. These authors observed that participants who had travelled or were about to travel were much more prone to say Monday than participants who were at the same place just waiting for someone.

LEFT-RIGHT mapping of TIME

TIME IS MOTION metaphors over the up-down and front-back axes are manifested in language. However, as we saw earlier, there is now evidence suggesting that not all conceptual metaphors are expressed linguistically. Studies on the spatial representation of time have demonstrated that time can also be mapped onto a left-right horizontal axis (Fuhrman & Boroditsky, 2007; Santiago, Lupiáñez, Pérez, & Funes, 2007; Santiago, Román, Ouellet, Rodríguez, & Pérez-Azor, 2008; Torralbo, Santiago, & Lupiáñez, 2006; Tversky, Kugelmass, & Winter, 1991). This metaphor seems to be absent from all languages (Haspelmath, 1997; Radden, 2004), with the only exception of signed languages (Emmorey, 2001).

Even if not attested in language, it is possible to observe its traces in everyday life. Graphical conventions often map time onto the left-right horizontal axis. In left-to-right writing cultures, advertisements often use the LEFT IS PAST - RIGHT IS FUTURE metaphor to promote the effects of their product (Figure 1), charts normally use a left-to-right order for time passing (Figure 2) and comic strips also run from left-to-right (Figure 3).

Figure 1. Use of the left-rigth axis for the representation of time in advertisement.

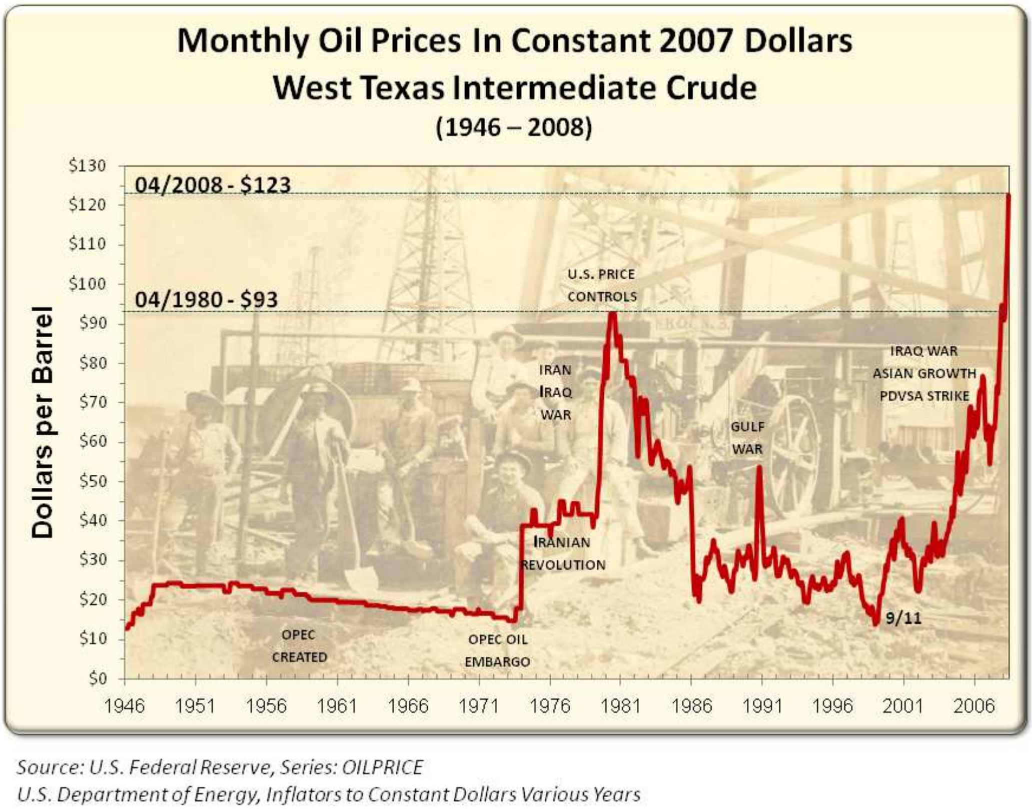

Figure 2. Use of the left-right axis for the representation of time in charts.

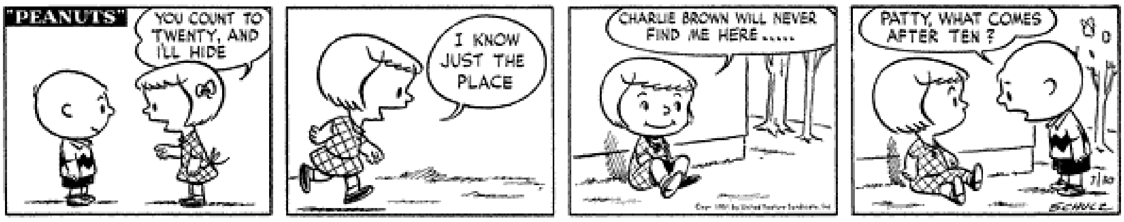

Figure 3. Use of the left-right axis for the representation of time in comic strips.

As with other conceptual metaphors which map onto the left-right horizontal axis (see above), the left-right representation of time is also linked to the direction of reading. Santiago et al (submitted) suggested that the origin of this conceptual mapping lies in the correlation between the order in which past and future events are mentioned in the text and their physical location on paper. The directionality of the action of reading a text is left-to-right for readers of a left-to-right orthography. Past eye fixation locations are situated on the left and future fixations on the right of the current fixation point. Moreover, due to pragmatic constraints (Levinson, 1983), narrated events in a story normally appear in a chronological order, which means that past events are physically on the left and future events are on the right. This spatial positioning of the events in the texts would be transposed to a coherent mental timeline representation.

Few cross-cultural studies have addressed the question whether the left-right representation of time is due to the direction of reading. Tversky et al (1991) and Chan & Bergen (2005) showed that left-to-right compared to right-to-left readers tend to graphically represented event sequences in accordance with the directionality of their orthographic system.

The graphical organization task used in these studies was highly conscious and offered to the participants the possibility to use unconventional strategies. For this reason, Santiago et al (2007) wanted to investigate whether the left-right mapping of time was automatic. In their experiment, Santiago et al (2007) asked Spanish participants, by pressing a left or right key, to judge the temporal meaning of past and future words presented either to the left or to the right on the screen. In concordance with the direction of reading/writing hypothesis, participants showed a left-past/right-future congruency effect both in perceiving and responding to the temporal words.

Santiago et al (2008) investigated whether this representation of time was qualitative in nature or due to a continuous mental timeline in which events are flowing from the leftmost part of it towards its rightmost part. They first presented silent movie clips and photograph series to the participants. Afterwards, participants were asked to judge whether a movie frame or a photo of the series appeared before or after the reference point in the movie clip or in the photo series. More than just finding a facilitation effect for LEFT-PAST/RIGHT-FUTURE responses, they also obtained a distance effect. The farther from the reference point was the photo or the movie frame, greater was the effect. It suggests that TIME is organized as a continuum, over a timeline going from left-to-right.

Finally, Fuhrman & Boroditsky (2007) confirmed that the left-right representation of time is closely linked the direction of the orthography used by the participants. Using a temporal judgment task on sets of pictures representing naturalistic events (responding earlier or later to a picture presented after another picture of the same event), they demonstrated that English and Hebrew native speakers living in their country of origin showed an opposite pattern: a left-past/right-future facilitation effect for the English and the opposite for the Hebrews.

Discussion

Probably without noticing it, in our everyday life we are using many expressions in which time is termed as closely linked to concrete concepts (money, container and motion). The available evidence points to the psychological reality of the TIME IS MONEY, TIME IS A CONTAINER and TIME IS MOTION conceptual metaphors.

Conceptual metaphors often come in closely related clusters. The TIME IS MOTION metaphor comprises several variations. While two of them are present in language (FUTURE IS IN FRONT - PAST IS BEHIND and FUTURE IS UP - PAST IS DOWN), another seems to be completely absent of all spoken languages (Haspelmath, 1997; Radden, 2004).

This third subcategory maps time onto the left-right horizontal axis, corresponding to the directionality of the orthographic system being used by the participant (e.g., Fuhrman & Boroditsky, 2007). Moreover, the left-right mapping of time seems to be gradual (Santiago et al, 2008): the more an event is in the past or future, the farther on the left or right it is.

Aims of the present research

Introduction

The three studies presented hereby will focus on the TIME IS MOTION conceptual metaphor, more precisely on its left-right mapping subcategory.

The main goals of the present studies are: 1) to strengthen the psychological reality of the left-right mapping of time; 2) to investigate the nature of this mental representation; 3) to test whether reading-writing direction is responsible for this construal; and 4) to explore how works the mapping of time when the presentation of stimuli is auditory compared to when it is visual.

Study 1: Spatial orienting of attention with temporal concepts.

The first study (Ouellet, Santiago, Funes & Lupiáñez, in press) will study whether or not past and future temporal meanings can orient visuo-spatial attention of Spanish participants towards left and right hemispace, respectively.

Previous studies on the spatialization of time[1] suggest that this metaphor is of an asymmetrical nature (e.g., Boroditsky, 2000), that is to say, that space can modulate the processing of temporal concepts, but that time cannot interfere in the processing of space. Such results are in agreement with the tenets of Conceptual Metaphor Theory (Lakoff & Johnson, 1980, 1999), since it is thought that concrete concepts are called

---

[1] Throughout this thesis, we will use the TIME IS MOTION and TIME IS SPACE conceptual metaphors as synonyms.

upon to help the understanding of abstract concepts, but that abstract concepts can hardly help the understanding of concrete concepts.

If it would be the case, past and future temporal concepts should not be able to modulate spatial attention. In concordance with Lakoff & Johnson (1980, 1999), Weger & Pratt (2008, Exp. 2a and 2b) showed a failure to find an orienting of the visuo-spatial attention with past and future temporal meanings.

However, findings from other conceptual metaphors (e.g., Meier et al, 2007; Fitousi, & Algom, 2006; see Santiago et al, submitted, for a review) suggest that the asymmetry of the phenomenon is open to question.

A revised cuing paradigm will let us test whether or not past and future temporal meanings can orient visuo-spatial attention. What is more, if they do orient attention, having a look at how they do it will permit us to peek into the nature of the effect. In particular, we will be able to know if the spatialization of time involves the same cognitive mechanism put to work by arrows and directional words like “left” and “right”.

Study 2: Does the direction of reading influence the LEFT-RIGHT conceptualization of TIME?

As we saw above, although interesting, the studies that directly address this question are scarce (Chan & Bergen, 2005; Fuhrman & Boroditsky, 2007; Tversky et al, 1991). They all point to a positive answer, but they all also suffer from some methodological limitations.

First, with the exception of Fuhrman & Boroditsky (2007), their tasks are highly conscious and give the participants enough time to use strategies not necessarily representative of the automatic processes used for the processing of temporal concepts. For this reason we decided to use a highly implicit and automatic task.

Second, in all of these cross-cultural studies, participants were asked to organize or to judge the relative order of events.

Our goal here is to investigate whether these cross-cultural findings also apply when the temporal reference is absolute. To do so we used stimuli directly referring to the past or to the future, by means of conjugated verbs and adverbs, as in Santiago et al (2007) and Torralbo et al (2006).

Third, all the paradigms being used were visual. Since the modality of vision is the sense engaged in the development of the left-right mapping of time, it is possible that the simple act of using this modality was enough to prime the left-right mapping of time.

So we decided to use another modality, audition, which is not involved in the development the left-right metaphor of time. An effect obtained in the auditory modality would be further evidence that the left and right association with the concept of time is genuine, and not an artifact induced by characteristics of the task.

Fourth, these cross-cultural studies investigated the priming of motor responses only. They did not look at whether spatial perception interacts with the semantic access of temporal meanings (as in Santiago et al, 2007).

Therefore, we decided to include also a perceptual manipulation in order to investigate the perceptual properties of this metaphor in a new modality and in a language with a different orthographic direction, Hebrew.

To sum up, Spanish and Hebrew native speakers were asked to judge (with their left or right hand) the temporal meaning of words (verbs and adverbs) presented to their left or right ears.

Study 3: Is the perception of time modality specific?

The third and last study is a follow-up of the second one. Because in the second study we were unable to find a significant interaction between PAST and FUTURE meanings and perceptual space (left or right origin of the sound target), we decided to investigate whether this perceptual effect was modality specific or it could also be found in the auditory modality under certain conditions.

We hypothesized that the reason for the failure in finding a significant perceptual effect might be due: 1- to the fact that words were presented to only one ear at a time and not interaurally; 2- to a hybrid (visual and auditory) spatial representation of the external world resulting in a mapping of time onto the visual map because vision is much stronger than audition in space perception tasks (Middlebrooks & Green, 1999).

If hypothesis 1 is right, then presenting the temporal words interaurally (via loudspeakers instead of headphones) should result in a modulation of their semantic access by the sound origin. If hypothesis 2 is right, presenting the words interaurally should not change anything, but asking the participants to perform the same task blindfolded should result in a significant left-right modulation of the processing of past and future meanings. Otherwise, if the effect is modality specific, this interaction should remain not significant in both cases.

Chapter II

Thinking about the future moves attention to the right

Pre-publication version of

Ouellet, M., Santiago, J., Funes, M. J., & Lupiáñez, J. (in press). Thinking about the future moves attention to the right. *Journal of Experimental Psychology: Human Perception and Performance.*

Abstract

Previous studies have shown that past and future temporal concepts are spatially represented (past being located to the left and future to the right in a mental time line). This study aims at further investigating the nature of this space-time conceptual metaphor, by testing whether the temporal reference of words orient spatial attention or rather prime a congruent left/right response. A modified version of the spatial cuing paradigm was used in which a word's temporal reference must be kept in working memory whilst participants carry out a spatial localization (Experiment 1) or a direction discrimination, spatial Stroop task (Experiment 2). The results showed that the mere activation of the past or future concepts both oriented attention and primed motor responses to left or right space, respectively, and these effects were independent. Moreover, in spite of the fact that such time-reference cues were non-predictive, the use of a short and a long SOA in Experiment 3 showed that these cues modulated spatial attention as typical central cues like arrows do, suggesting a common mechanism for these two types of cuing.

Introduction

How do we represent abstract concepts? Do they need a concrete grounding to sustain the abstraction they refer to? Findings from linguistic studies suggest that they do (Lakoff & Johnson, 1980, 1999; Johnson, 1987). As an example, think of the concept of time and how it would be possible to represent past and future. Everyday expressions of time in possibly all languages (Haspelmath, 1997; Radden, 2004) show how this abstract concept is naturally associated with the more concrete concept of space. In

English, Spanish, and many other languages, a back-front spatial metaphor is often used, which maps past to locations in the back, future to locations in front, and time passing to forward movement (e.g. "Serbia plunges *back* into the past", title from an article of the Inter Press Service News Agency, or "Looking *forward* to seeing you", in a common letter).

However, linguistic analysis alone is limited to the metaphors manifested in language, which may not be the only ones available (Casasanto, 2009b). Empirical data from Torralbo, Santiago, & Lupiáñez (2006, exp. 1) support, on one hand, the projection of time onto a back-front spatial frame, as previously reported in linguistic literature (Lakoff & Johnson, 1980, 1999; Johnson, 1987). Participants were asked to judge if a word appearing to the front or the back of a side-looking head silhouette referred to the past or to the future. Words were conjugated verbs and temporal adverbs, and word location was completely orthogonal to word temporal meaning. However, participants were faster to respond when *past* words were presented to the *back* of the head and *future* words were presented to the *front*.

On the other hand, Torralbo et al (2006, exp. 2) also showed in the same study that when participants are asked to give a left-right manual response, they activate a left-past right-future representation of time. This mapping, although never found in linguistic expressions of any oral language (Radden, 2004), overruled the back-front mapping when manual responses were used. In another study, Santiago, Lupiáñez, Pérez & Funes (2007) investigated directly this horizontal left-right representation of time. They found a facilitation effect when past words were presented on the left side of the screen or responded to with the left hand. The opposite was true for future words. Recently, Santiago, Román, Ouellet, Rodríguez, & Pérez-Azor (2008) extended this left-right space-time congruency effect to meaningful event sequences presented by means of movie clips or picture sequences. Again, order judgments between two events were faster when the left hand was used to respond "before" and the right hand to respond "after" than with the opposite mapping. These data are consistent with the observation that people gesture from left to right when describing events that unfold in time (Núñez & Sweetser, 2006), and also with data from an off-line task asking participants to place stickers on a paper to represent events such as breakfast, lunch and dinner (Tversky, Kugelmass, & Winter, 1991). The latter study also found evidence suggesting that this horizontal mapping of time might be related to the habitual direction of reading and writing.

The left-right space-time congruency effect could be accounted for in, at least, two different ways. It could be that temporal meanings direct spatial attention, or alternatively, that they are associated with left/right manual response codes (or both), leading to the automatic activation of congruent reactions. The main goal of the present paper is to discriminate between these two alternative underlying mechanisms.

In order to do this, we devised a variation of the widely used cuing paradigm to study attentional orienting (Posner, 1980; Posner & Cohen, 1984; Posner, Nissen & Ogden, 1978). In a cuing paradigm, a spatial cue is used to prime a region of the visual field, and its effects are measured on the processing of a target appearing at the cued location. The processing task may be a detection, localization or discrimination task. Two different types of cues have been found to modulate attentional orienting: centrally and peripherally presented cues (Posner & Cohen, 1984). Central cues are symbolic signals which need to be semantically processed. Usually, they are also highly predictive about the target location (but see Hommel, Pratt, Colzato, & Godijn, 2001; and Ho & Spence, 2006). On the other hand, peripheral cues are salient stimuli, able to produce cuing effects even if they are uninformative signals about target location.

These two kinds of spatial cues produce different effects on the magnitude and time course of cuing effects (see Funes, Lupiáñez & Milliken, 2005, and Corbetta & Shulman, 2002, for recent reviews). Centrally presented cues generate a larger facilitation effect, which arises later than the facilitation effect produced by peripherally presented cues (Jonides, 1976, 1981; Müller & Rabbitt, 1989; Hommel et al., 2001; Frischen & Tipper, 2004). In addition, peripheral non-predictive, but not central, cues also generate a negative cuing effect at long cue-target intervals (SOA), which is known as inhibition of return (IOR; Posner & Cohen, 1984; Posner et al., 1985).

Studies on the orientation of visuo-spatial attention have mostly used salient peripheral flashes and centrally presented arrows as cues. Nevertheless, other more complex types of cues have proven efficient too. Hommel et al. (2001) and Ho & Spence (2006) used non-predictive direction words (i.e., the word "LEFT" written on the center of the screen), and found facilitatory effects on congruent spatial regions. Following up on the mental number line proposal (Dehaene, Bossini & Giraux, 1993), Fischer, Castel, Dodd, & Pratt (2003) found that numbers are also able to direct attention to the sides, small numbers facilitating targets presented on the left and large numbers facilitating targets on the right. These findings are very important for the purpose of our study, as they show that spatial attention can be directed on the basis of symbolic meaning even when the signal is non-predictive and its relation to a location is mediated by a metaphorical mapping.

Furthermore, Weger & Pratt (2008, Exp. 2a and 2b) already used a cuing paradigm to discriminate between spatial attention orienting and manual response codes activation when using future and past words as cues. The same experiment was carried out with two different groups: group A performed a discrimination task to a target presented to the left or right of the temporal word by pressing a left or right key, whereas group B performed a detection task to the same target by pressing the spacebar. They obtained a significant facilitation effect only for group A, what made them conclude that the effect obtained was due to a facilitation of response-codes. If the effect was of an attentional nature, they should have obtained a facilitation effect with group B as well.

However, we think that some methodological problems in their study might have lead to a non-significant cuing effect in group B. First, the authors recognized that the use of very few words (4 past and 4 future words) repeated many times could result in semantic satiation (Smith & Klein, 1990): a failure to access word semantics due to repetition. Second, the cue remained on screen during target presentation. The presence of another stimulus on the screen during target presentation could have interfered with the processing of the target. Third, the selection of participants did not seem to be strict enough. In their first experiment they used the name of past and present actors as cues. They had to eliminate fourteen participants out of thirty-four from the analysis because they did not know who the actors were. This lack of knowledge was attributed to the multicultural origins of the participants. Recent experiments from our lab demonstrate that a careful control over the cultural origin of participants is very important because the facilitation effect obtained in a culture can take the opposite shape in another culture (Ouellet, Santiago, Israeli, & Gabay, in press). These methodological problems could be responsible of their failure to observe a significant spatial attention orienting effect by means of temporal words. Alternatively, it might be the case that participants need to have activated an ego-centered reference point and the left-right horizontal axis, which is compulsory when participants have to respond with their left and right hands, but not when they use only one hand to press the space bar (Torralbo et al., 2006).

The present study aimed at investigating whether centrally written words with a temporal reference (inflected verbs and adverbs) can orient visuo-spatial attention in line with the left-past, right-future horizontal spatial metaphor. Our second goal was to assess whether this mode of cuing is more coherent with typically central or peripheral cuing mechanisms. Our cues are centrally presented and need to be semantically processed, but they are also uninformative about target location and their meaning does not refer explicitly to target location. The three experiments reported hereby use a common paradigm in which a word's temporal meaning must be kept in working memory while cuing effects are tested on a localization task (Experiment 1) or a discrimination task (Experiments 2 and 3). According to Awh & Jonides (2001), the maintenance in working memory of a given spatial location leads to the orienting of spatial attention towards such location, facilitating the processing of those stimuli appearing at the remembered location (see Awh & Jonides, 2001; and Soto, Hodsoll, Rotshtein, & Humphreys, 2008, for reviews on the relations between spatial attention and spatial working memory). In our first two experiments, a word is centrally presented and participants are asked to keep in mind its temporal reference (either past or future), as it will be probed at the end of the trial. Then, in Experiment 1, two empty squares at the left and right of the screen center are presented and a target stimulus is flashed in one of them. The participants must press a left or right key to indicate its position. Finally, the question "past?" or "future?" appears, and keypresses are now used to give a yes/no answer. Experiment 2 is similar to Experiment 1 except from the fact that a discrimination task with an embedded spatial Stroop procedure is used instead of the localization task. In this case, arrows are used as targets, and participants must press a left or right key to indicate arrow direction while ignoring arrow location. This task, contrary to a pure detection task, allowed us to study the influence exerted by temporal meanings on the orientation of visuo-spatial attention, while keeping activated the ego-centered reference point and horizontal axis. Experiment 3 uses the same spatial Stroop procedure as Experiment 2, with the following differences: the probe question at the end of each trial is replaced by a questionnaire at the end of the experiment (intended to reduce working memory load) and two different SOAs (one short and one long) are introduced in order to investigate the nature of the attentional orienting mechanism (Funes, Lupiáñez & Milliken, 2005; Corbetta & Shulman, 2002).

Experiment 1

The goal of the first experiment was to test whether processing and keeping in working memory the temporal reference of a word (past or future) is able to modulate processing in a concurrent left-right localization task.

Procedure

Participants

Twenty-seven undergraduate students from the University of Murcia and the University of Granada (mean age 19.48 years; 10 females and 17 males) participated for course credit. All of them were native Spanish speakers and reported to have normal or corrected-to-normal vision.

Materials

We used the same list of words as in Torralbo et al (2006): 24 Spanish words referring to past (e.g., “dijo” - “he said”) and 24 referring to future (e.g., “dirá” - “he will say”). The word set comprised 18 verbs inflected in either past or future tense, and 6 past and 6 future temporal adverbs (e.g., “antes” - “before”). All words appeared in

Courier New Bold font, point size 24. The task was programmed in E-prime (Schneider, Eschman, & Zuccolotto, 2002) and ran in an Intel Pentium IV PC 1.70GHz. Stimuli were presented on a 15-in. (38.1-cm) colour monitor. The target stimulus consisted of a dot of 5 mm diameter, which could appear in one of two 1.3 x 1.3 cm boxes, presented at the center of the left and right halves of the screen (7.39º of visual angle -7.75 cm - from the center). All stimuli were presented in white on a black background.

Procedure and design

Participants sat in a quiet room at approximately 60 cm from the screen. Trial structure was as follows. First, a fixation point was presented for 500 ms, followed by a centrally presented word for 1500 ms, which could refer either to the past or to the future. Participants were instructed to memorize the temporal reference of the word. A blank screen followed during 500 ms, and two empty squared boxes were presented at left and right positions. After 250 ms, a white dot was flashed for 50 ms in one of the boxes. The two boxes remained on screen for 2300 ms or until the participant responded. The participant pressed the “z” key if the dot appeared to the left and the “m” key if it appeared to the right. After the localization task, a blank screen for 1000 ms preceded one of two questions: “¿FUTURO?” (“FUTURE?”) or “¿PASADO?” (“PAST?”). The question remained on the screen for 4000 ms or until a response was recorded. Finally, there was a blank screen for 1000 ms before the beginning of the next trial. Participants were asked to press the same “z” or “m” keys to indicate a yes or no response. They were not told about any possible relationship between the cue word and the target location or the target location and the final probe question.

The experiment had two blocks, differing in the mapping of “z” and “m” to yes or no responses. The order of blocks was counterbalanced over participants. Within each block, each experimental word was presented 4 times, paired with targets at either location and with both final probe questions. Temporal reference of words was neither predictive of the target location nor predictive of the final probe question. Participants were allowed to take a break between blocks. Each block consisted of 16 practice and 192 experimental trials. The experiment lasted about 45-50 minutes.

Results

The data obtained from four participants were discarded because they failed to execute the task properly and the data from a further participant were lost due to technical problems. The results obtained from the remaining 22 participants are summarised in Table 1. Localization errors occurred on 1.42% of the trials (120 trials), and memory errors on 7.5% (634 trials). Trials with errors in any of the two tasks (8.79%, 743 trials) were excluded from the latency analysis. Correct trials with latencies below 100 ms and above 650 ms in the localization task (114 trials, 1.48%) were considered outliers and also discarded.

Resulting latency and accuracy data were submitted to a 2 (Temporal Reference: past/future) X 2 (Target Location: left/right) ANOVA taking both participants (*F1*) and items (*F2*) as random factors. Temporal Reference was a within-subject factor in the analysis by participants and a between-items factor in the analysis by items.

Accuracy data revealed no significant results (both main effects: *F*s less than or near 1; Interaction: $F1(1,21) = 1.3$, $MSE = 0.0001$, $p > 0.1$; $F2(1,46) = 1.701$, $MSE = 0.0001$, $p > 0.1$). In the latency analysis, Temporal Reference of the cue was not significant (both Fs < 1) and the main effect of Target Location was significant only by items ($F1 < 1$; $F2(1,46) = 20.04$, $MSE = 36.06$, $p < 0.001$): participants tended to respond faster to targets on the left. More important for the purpose of our study, we found a significant facilitation effect, indexed by an interaction between Temporal Reference and Target Location ($F1(1,21) = 11.22$, $MSE = 29.53$; $F2(1,46) = 8.82$, MSE

= 36.06, both *p*s < 0.01). Responding to left targets was 5 ms faster when the prime word referred to the past than when it referred to the future, and responding to right targets was 3 ms faster for future than past primes. Although small-sized, the effect was very systematic over participants and items, as suggested by the high *F* values.

Temporal Reference	Past	Future
Target Location		
Left	260 (1.3)	265 (1.1)
Right	268 (1.3)	265 (1.7)

Table 1. Mean latency and percent errors (in brackets) per condition in Experiment 1 for the factors Temporal Reference and Target Location.

Discussion

The first experiment showed a left-past/right-future facilitation effect for targets presented at the location cued by the centrally presented temporal word. This suggests that temporal reference is able to orient attention along the left-right axis, thus biasing processing on a concurrent but completely unrelated localization task. However, given that left-right responses were correlated with left-right target locations, we cannot definitely dismiss the possibility that, instead of orienting attention, temporal meaning directly primes left or right response codes, as already shown by previous research (Santiago et al., 2007; Torralbo et al., 2006; Weger & Pratt, 2008). Disentangling these two possibilities was the aim of Experiment 2.

Experiment 2

In order to dissociate purely attentional orienting from response priming as the factor underlying the left-right space-time congruency effect observed in Experiment 1, as well as in previous studies (Torralbo et al., 2006; Santiago et al., 2007), we replaced the localization task with a spatial Stroop task. Targets were arrows pointing either to the left or right, and participants were asked to respond with the key that matched the pointing direction of the arrow, independently of where the arrow was presented. By doing so, we were able to dissociate spatial attentional orienting and response priming as the underlying mechanisms for the effect observed in Experiment 1.

Procedure

Participants

Thirty-four undergraduate students (mean age 20.94 years; 30 females and 4 males) from the University of Granada participated for course credit. All of them were native Spanish speakers and reported to have normal or corrected-to-normal vision. None of them participated in the first experiment.

Materials

The same words as in Experiment 1 were used.

Procedure and design

The main difference between Experiments 1 and 2 was that the localization task was replaced by a spatial Stroop task. The two squared boxes were removed and the target dot was replaced by an arrow (13 mm length, 12 mm height), either pointing to the left or to the right. Arrow's location and pointing direction were completely orthogonal to the prime word's temporal reference. The participant's task was to indicate in which direction the arrow pointed to, by hitting the "z" keys if it pointed to the left and the "m" key if it pointed to the right. Words were presented 4 times each, matched with each of two target locations and two arrow pointing directions. To avoid increasing the number of trials unnecessarily, the final probe questions were counterbalanced over participants.

Results

Participants failed to respond correctly on 3.75% of the trials (490 trials) in the Spatial Stroop task and on 7.83% of the trials (1022 trials) in the memory task. Trials with one error in any of the two tasks (11.17%, 1459 trials) were excluded from the latency analysis. Correct trials with latencies outside the 150-750 ms interval were considered outliers and excluded from the latency analysis, leading to a further rejection of 3.08% (357 trials) of data points.

An ANOVA was carried out to study the interaction between Temporal Reference (past-future), Target Location (left-right) and Response Side (left-right). Results are summarized in Table 2.

Accuracy data showed that participants made fewer errors when Target Location was congruent with Response Side ($F1(1,33) = 23.22$, $MSE = 0.0108$, $p < 0.001$; $F2(1,46) = 343.37$, $MSE = 0.0005$, $p < 0.001$). The Temporal Reference of the words (past/future) did not affect the distribution of errors ($F1(1,33) = 3$, $MSE = 0.0006$, $p > 0.05$; $F2(1,46) = 2.31$, $MSE = 0.0006$, $p > 0.1$) and the three-way interaction between Temporal Reference, Target Location and Response Side was not significant ($F1(1,33) = 2.91$, MSE = 0.0006, $p > 0.05$; $F2(1,46) = 2.24$, $MSE = 0.0005$, $p > 0.1$). The *F1* and *F2* values of all the other factors and interactions were smaller than 1.

The latency analysis showed that participants were faster both responding with the right versus the left hand (*F1*(1,33) = 18.54, *MSE* = 1434.04, $p < 0.001$; *F2*(1,46) = 98.03, *MSE* = 179.13, $p < 0.001$), and to arrows presented on the right versus on the left side (*F1*(1,33) = 8.47, *MSE* = 309.32, $p < 0.01$; *F2*(1,46) = 13.33, *MSE* = 122.17, $p < 0.001$). The main effect of Temporal Reference was not significant (both *Fs* < than 1). Latencies also showed a highly significant spatial Stroop effect, as indexed by a Target Location x Response Side interaction, (*F1*(1,33) = 217.25, *MSE* = 1282.79, $p < 0.001$; *F2*(1,46) = 1492.37, *MSE* = 124.15, $p < 0.001$). Participants were faster responding to arrows pointing at a direction consistent with their position. Importantly for the goals of this analysis, the interaction between Temporal Reference and Response Side was significant by participants only (*F1*(1.33) = 4.56, *MSE* = 127.11, $p < 0.05$; *F2*(1.46) = 1.64, *MSE* = 179.13, $p > 0.1$), and the interaction between Temporal Reference and Target Location was significant in both analyses (*F1*(1,33) = 4.24, *MSE* = 174.95, $p < 0.05$; *F2*(1,46) = 5.428, *MSE* = 122.17, $p < 0.05$). Participants were faster both to identify targets and to respond to the left when the cue was a past word, and the opposite was true when the cue was a future word. There was no three-way interaction between the three factors (both *F*s < 1).

Target Location	Left		Right	
Temporal Reference	Past	Future	Past	Future
Response Side				
Left	372 (0.9)	378 (0.9)	434 (7.5)	432 (6.1)
Right	421 (7)	419 (6.5)	353 (0.6)	346 (0.6)

Table 2. Mean latency and percent errors (in brackets) per condition in Experiment 2 for the factors Target Location, Temporal Reference and Response Side.

Discussion

The results of the second experiment were clear-cut. First of all, there was a clear interaction between target location and pointing direction, indicating that we were able to replicate the spatial Stroop effect. Secondly, and more importantly for present goals, the temporal reference of the prime word interacted independently with response side (by participants) and target location (both by participants and items). The latter finding is very important because it supports the notion that the left-right past-future congruency effect in the present experiments and prior studies (Santiago et al, 2007; Torralbo et al, 2006) is not only based on the priming of manual response codes. Instead, temporal concepts seem to orient spatial attention, thus enhancing processing of spatially congruent targets.

Experiment 3

The main goal of the third experiment was to investigate in more detail the nature of the attentional orienting mechanism engaged by temporal word cues. To do so, we introduced one short and one long SOA. It is known that orientation of visual attention with central cues typically arises at long SOAs, whereas peripherally presented cues usually produce a facilitatory effect at short SOAs and an inverted effect at long SOAs (Funes, Lupiáñez & Milliken, 2005; Corbetta & Shulman, 2002). Experiments 1 and 2 did not study what happens at short SOAs, but the observed pattern of results was most consistent with temporal meaning orienting attention like central cues typically do. With the long cue-target SOA (2250 ms) used, had the observed cuing effect been similar to peripheral cuing, IOR would have been a likely outcome (Posner & Cohen, 1984; Posner et al., 1985). Therefore, we predicted a larger cuing effect at long SOAs, suggesting the use of an orienting mechanism similar to that activated by central cues. In order to reduce as much as possible experimental noise, we reduced working memory load by replacing the probe question at the end of each trial by a recognition phase at the end of the experiment, in which the participants had to identify the words presented during the experiment. Using a working memory task similar to ours, Han & Kim (2008) observed that in the high working memory load condition, when their participants were asked to perform two distinct manual responses within a trial, the precision of the cuing effect decreased.

Procedure

Participants

Thirty-two undergraduate students (mean age 23.17 years; 23 females and 9 males) from the same population as in Experiment 2. None of them participated in prior experiments.

Materials

The same words as in Experiments 1 and 2 were used.

Procedure and design

Experiment 3 differed in some ways from Experiment 2. In order to be able to use a short SOA, we reduced cue presentation time to 300 ms. One short and one long SOA were introduced by using two different interstimulus intervals (ISI), 250 ms. for the short SOA and 800 ms. for the long SOA. Short and long SOAs were randomly presented and completely orthogonal to the arrow's location and pointing direction and to the prime word's temporal reference. The participant was instructed at the beginning of the experiment to pay attention to the cue words because s/he would be asked at the end of the experiment to carry out a recognition test. Nothing was mentioned about the temporal reference of the cue words.

Words were presented 8 times each, matched with each of two SOAs, two target locations, and two arrow pointing directions. Experiment 3 doubled the number of trials, as compared to Experiments 1 and 2, but, because the probed question was removed, the experiment lasted approximately the same (more or less 50 minutes).

Results

Participants did not respond correctly on 3.1% of the trials (763 trials). Correct trials with latencies outside the 200-1000 ms interval were considered outliers and excluded from the latency analysis, leading to a further rejection of 1.44% (342 trials) of data points.

Resulting latency and accuracy data were submitted to a 2 (SOA: short/long) X 2 (Temporal Reference: past/future) X 2 (Target Location: left/right) X 2 (Response Side: left/right) ANOVA taking both participants (*F1*) and items (*F2*) as random factors. Temporal Reference was a within-participants factor in the analysis by participants and a between-items factor in the analysis by items.

Accuracy data showed that participants tended to make fewer errors at short compared to long SOAs ($F1(1,31) = 2.05$, $MSE = 0.0012$, $p > 0.1$; $F2(1,46) = 4.64$, $MSE = 0.0003$, $p < 0.05$). They were also more accurate responding at targets appearing to the right vs. to the left ($F1(1,31) = 3.45$, $MSE = 0.001$, $p = 0.073$; $F2(1,46) = 9.31$, $MSE = 0.0003$, $p < 0.01$). They also tended to respond better when the response was to the right compared to the left ($F1 < 1$; $F2(1,46) = 3.27$, $MSE = 0.0005$, $p = 0.077$). More important for the purpose of our study, there was a highly significant congruency effect between Target Location and Response Side ($F1(1,31) = 24.54$, $MSE = 0.0057$, $p = 0.001$; $F2(1,46) = 214.4$, $MSE = 0.0005$, $p < 0.001$), an evidence that the spatial Stroop task worked as expected. The Temporal Reference main effect and all other interactions did not reach significance (with all *Fs* less than or near 1).

SOA	Short				Long			
Target Location	Left		Right		Left		Right	
Temporal Reference	Past	Future	Past	Future	Past	Future	Past	Future
Left Response Side	411 (1.6)	407 (2.3)	463 (3.5)	468 (4.6)	402 (2.0)	412 (1.5)	465 (5.3)	456 (5.2)
Right Response Side	459 (4.4)	463 (4.4)	395 (0.9)	391 (0.9)	454 (4.9)	455 (5.3)	391 (1.0)	389 (0.9)

Table 3. Mean latency and percent errors (in brackets) per condition in Experiment 3 for the factors SOA, Target Location, Temporal Reference and Response Side.

As in Experiment 2, latency analyses revealed a preference to the right compared to the left both at localizing targets ($F1(1,31) = 5.14$, $MSE = 759.18$, $p < 0.05$; $F2(1,46) = 25.87$, $MSE = 160.65$, $p < 0.001$), and responding to them ($F1(1,31) = 4.5$, $MSE = 3403.21$, $p < 0.05$; $F2(1,46) = 51.11$, $MSE = 169.04$, $p < 0.001$). There was a tendency for participants to respond faster at the long SOA ($F1(1,31) = 1.203$, $MSE = 1860.28$, p > 0.1; $F2(1,46) = 6.75$, $MSE = 175.44$, $p < 0.05$). The main effect of Temporal Reference was not significant (both $Fs < 1$). Latency analyses also showed a clear spatial Stroop effect ($F1(1,31) = 143.85$, $MSE = 3252.04$, $p < 0.001$; $F2(1,46) = 1507.42$, $MSE = 226.97$, $p < 0.001$). Of a central interest, Temporal Reference again interacted with Target Location ($F1(1,31) = 4.61$, $MSE = 230.86$, $p < 0.05$; $F2(1,46) = 4.01$, $MSE = 160.65$, $p = 0.051$) and this interaction was modulated by SOA ($F1(1,31) = 5.69$, $MSE = 174.54$, $p < 0.05$; $F2(1,46) = 4.3$, $MSE = 166.95$, $p < 0.05$). Planned comparisons showed that the cuing past-left/future-right at the short SOA was not significant (*F1* and *F2* < 1) whereas it was reliable at the long SOA ($F1(1,31) = 9.79$, $MSE = 210$, $p < 0.01$; $F2(1,46) = 9.59$, $MSE = 141.87$, $p < 0.01$). Surprisingly, Temporal Reference did not interact with Response Side, nor there was a significant three-way interaction among Temporal Reference, Response Side and Target Location (both *Fs* < 1). Finally, the latency analysis showed a significant four-way interaction ($F1(1,31) = 11.81$, $MSE = 189.3$, $p < 0.01$; $F2(1,46) = 9.04$, $MSE = 173.82$, $p < 0.01$). This interaction was due to the fact that the Temporal Reference by Target Location interaction was modulated by SOA only for left side responses ($F1(1,31) = 17.94$, $MSE = 173.07$, $p < 0.001$; $F2(1,46) = 11.68$, $MSE = 188.97$, $p < 0.01$), but not for right side responses (*F1* and *F2* < 1).

Discussion

Experiment 3 confirmed that past and future words can orient visual attention towards left and right sides, respectively. This occurred under conditions which do not require the maintenance in working memory of temporal reference, but only the subsequent recognition of the presented words. Contrary to Experiment 2, the processing of Temporal Reference in Experiment 3 did not affect significantly the activation of congruent motor response codes. Torralbo et al (2006) studied the flexibility of the conceptual projection of time onto space and their results demonstrated that the spatial frames of reference could be activated or not depending on their relevance for the task. It is possible that the spatial frame responsible for the Temporal Reference X Response Side interaction became less relevant for the task when participants were not asked anymore to manually respond to the cue at the end of each trial, thereby leading to a smaller influence of the temporal meaning of words on left-right response codes. In this case, as in Torralbo et al (2006), the more relevant to the tasks visuo-spatial frame of reference was the only one affected. Although this interpretation remains as a post hoc speculation, the present pattern of results highlights the strength and consistency of the cuing effect on stimulus localization produced by the semantics of temporal words while the motor response activation effect seems to be weaker and can even fade out under some circumstances.

Moreover, the modulation of the Temporal Reference X Target Location interaction by SOA tells us more about the nature of the cuing effect. The cuing effect arose only at the longer SOA, as it is typically observed with the use of central cues. It is unclear why this effect was concentrated on left responses. One possibility is that the effect was enhanced with left responses because the level of difficulty was increased on the side contrary to the handedness of participants (only one of our participants was left handed). Another possibility would be a spatial bias originated by the directionality of the orthographic system used by the participants. Spalek & Hammad (2005) already observed a modulation of a well known cuing effect (IOR) by the reading/writing direction of the participants. Left-to-right readers (English) showed a bigger IOR effect when previously cued on the left compared to the right, whereas it was the opposite with right-to-left readers (Arabic). Future research comparing left-to-right to right-to-left readers will permit to show whether or not the observed concentration on left responses is due to the direction of the orthographic system in use by the participants.

General discussion

The first important finding of this study is that the temporal meaning of word cues orients spatial attention according to the space-time left-right conceptual metaphor. In contrast to prior studies (Santiago et al. 2007; Torralbo et al, 2006), participants did not respond directly to the prime words. Data were collected from responses to a target in a task orthogonal to the temporal concepts concurrently activated by the prime words. Nevertheless, the active temporal concept biased the processing of targets presented at locations consistent with a left-past right-future mental representation of time.

Secondly, and more importantly, the spatial Stroop discrimination task used in the second and third experiments allowed us to determine the nature of the influence of the lexical cue by dissociating between two possibilities: the orienting of visual attention vs. the activation of motor responses. In principle, the effect produced by the temporal words could result from a direct binding between the concepts of past and future to left and right responses (Pollmann & Maertens, 2005). Núñez & Sweetser (2006) showed that when we speak about the past we gesture to the left, whereas gestures referring to the future are directed towards the right. Consistently, the results of Experiment 2 showed that past/future meanings primed a motor response toward their congruent side. However, there was also a clear effect on the orientation of visuo-spatial attention produced by the semantics of temporal words: past cues produced a benefit for targets appearing on the left side, and future cues facilitated processing of targets appearing on the right side. These two effects were independent of each other. Contrary to Weger & Pratt (2008), the results of Experiment 3 confirmed that the temporal meanings of past/future words could prime visual locations. It is still unclear whether or not an ego-centered reference point needs to be activated, but present results strongly suggest that a purely attentional mechanism, based on a space-time mental line, contributes to explain left-right past-future congruency effects observed in present and previous studies.

Finally, the manipulation of SOA in Experiment 3 allowed us to peek into the nature of the underlying attentional mechanism. The cuing effect was larger at the longer SOA, therefore suggesting that temporal cues direct spatial attention by means of a typically central cuing mechanism (Funes, Lupiáñez & Milliken, 2005; Corbetta & Shulman, 2002).

Having demonstrated an effect of attentional orienting after temporal cues, as we did not control for eye movements, we cannot be confident about whether temporal cues led to either covert or overt attentional orienting. Nevertheless, the type of analysis we used here offers clues to disentangle between sensory and motor activation effects. It has been demonstrated that saccade and manual responses share the same higher order spatial map (Briand, Larrison, & Sereno, 2000; Khatoon, Briand, & Sereno, 2002; Nemire, & Bridgeman, 1987). Therefore, if the present cuing effect were due to overt orienting of attention, an interaction between temporal reference, target location and response location would have been a likely outcome (i.e., a faster response facilitation effect when the cue, the response and the target location are all in one direction, compared to when target location is incongruent with the cue and response). This was not the case. Moreover, if the orientation of the spatial attention produced by the temporal word cues would be arising at a motoric level, it would be difficult to explain how in Experiment 3 the cues did facilitate target localization but failed to facilitate congruent manual responses (motoric facilitation). For these reasons, we think that the present cuing effect is due to a covert attentional mechanism, although future research addressing directly this question is necessary before arriving to a firmer conclusion.

Present results hold important implications for both the nature of spatial attention and the mental representation of abstract concepts. They extend prior observations that meaning can be used to direct spatial attention (Hommel et al, 2001; and Ho & Spence, 2006, with literal spatial words; and Fischer et al, 2003, with arabic numerals), and suggest that these conceptual cuing effects and the traditional central cues like arrows may engage a shared common attentional orienting mechanism. Moreover, the fact that Hommel et al (2001), Ho & Spence (2006) and Fischer et al (2003), as well as the experiments reported hereby, used non-predictive cues casts doubt on the necessity of predictivity as a property of central cuing. More research is needed to establish the conditions under which a symbolic central cue needs or needs not to be predictive to exert an effect on attention.

Regarding the mental representation of abstract concepts, the present investigation supports the notion that at least some abstract concepts are represented by means of metaphorical mappings from more concrete, spatial domains. Although experimental scrutiny of this hypothesis has started only recently, the available evidence is growing steadily (e.g., Casasanto & Boroditsky, 2008). Our results highlight the importance of not limiting the study of conceptual metaphors to those mappings attested in language (Casasanto, 2009b), as the left-past/right-future metaphor is not present in linguistic expressions of any oral language (Radden, 2004, see the Introduction).

The domain of space seems to have a privileged role as a structural "donor" to many other conceptual domains (Gentner, Bowdle, Wolff, & Boronat, 2001), but the available evidence only very rarely goes further than the mere test of psychological reality. With the exception of the number domain (see Fias & Fischer, 2001), the present study is one of the first efforts to assess the underlying mechanisms which support abstract conceptual processing. Our main conclusion so far is that such mechanisms are surprisingly similar to those that are activated by literal words and symbols such as arrows.

Chapter III

Is the future the right time?

Pre-publication version of

Ouellet, M., Santiago, J., Israeli, Z., & Gabay, S. (in press). Is the future the right time? *Experimental Psychology*.

Abstract

Spanish and English speakers, tend to conceptualize time as running from left to right along a mental line. Previous research suggests that this representational strategy arises from the participants' exposure to a left-to-right writing system. However, direct evidence supporting this assertion suffers from several limitations and relies only on the visual modality. The present study subjected to a direct test the reading hypothesis using an auditory task. Participants from two groups (Spanish and Hebrew) differing in the directionality of their orthographic system had to discriminate temporal reference (past or future) of verbs and adverbs (referring to either past or future) auditorily presented to either the left or right ear by pressing a left or a right key. Spanish participants were faster responding to past words with the left hand and to future words with the right hand, whereas Hebrew participants showed the opposite pattern. Our results demonstrate that the left-right mapping of time is not restricted to the visual modality and that the direction of reading accounts for the preferred directionality of the mental time line. These results are discussed in the context of a possible mechanism underlying the effects of reading direction on highly abstract conceptual representations.

Introduction

In order to facilitate our understanding of abstract concepts (e.g., justice, happiness, time…), it has been suggested that we need to ground them onto more concrete domains, such as space. This grounding is often called a Conceptual Metaphor, a term that refers to the use of a source domain (concrete) to help understanding a target domain (abstract concept). Conceptual metaphors were originally detected in the linguistic analysis of everyday expressions (i.e., “looking forward to see you”; Clark, 1973; Lakoff & Johnson, 1980) and the empirical evidence supporting their psychological reality is steadily growing (see, e.g., Meier & Robinson, 2004, for emotional concepts; or Schubert, 2005, for social power). Many abstract concepts use space as their structural donor (Gentner, Bowdle, Wolff & Boronat, 2001). Here we will focus on one of those: time. Our goal is to evaluate whether directional reading-writing habits affect the preferred form of the conceptual mapping of time onto space: left-to-right or right-to-left.

Directional reading habits have been shown to influence performance in several perceptuo-motor tasks. Native users of a left-to-right orthographic system probably never noticed that they prefer paintings, portraits and pictures with a rightwards direction (Gaffron, 1950; Nachson, Argaman & Luria, 1999; Chokron & De Agostini, 2000). In contrast, readers of right-to-left orthographies such as Arab and Hebrew show the opposite preference (Nachson et al, 1999; Chokron & De Agostini, 2000).

When bisecting lines, French participants are biased to the left whereas Israelis are biased to the right (Chokron & De Agostini, 1995). Korean participants having learned to read in a vertical top-to-bottom right-to-left direction, compared to their peers having learned to read from left to right, tended to place their drawings more to the left on the page (Barrett, Kim, Crucian & Heilman, 2002). Moreover, the left-to-right bias in inhibition of return normally found with English speakers is reversed in native Arab speakers (Spalek & Hammad, 2005).

Nachson (1981) compared Hebrew and Arabic native speakers from Israel with English native speakers from Europe and America in a task involving the reproduction from memory of a horizontal series of objects presented visually. When they reproduced the series, English participants proceeded more often from left to right, whereas Arabic participants tended to proceed from right to left. Hebrew speakers were somewhere in between, a result which has been observed in several other studies (e.g., Tversky, Kugelmass & Winter, 1991). The difference between Arabs and Hebrews is thought to be due to the fact that the Hebrew orthography is not a completely right-to-left system: words are written and read from right to left, but single letters are frequently written from left to right (Lieblich, 1975). Moreover, the numerical system as well as the musical notation runs from left to right (Braine, 1968). Importantly, the differences between left-to-right and right-to-left readers found in some of these studies are stronger in young children and start to weaken around the seventh grade, coinciding with the learning of a new language at school, English. Nachson (1983) investigated whether the introduction of this left-to-right language was the origin of the effect. He compared a group of young English-Hebrew bilinguals from Israel with young English and Hebrew monolinguals. As predicted by the reading-writing habits hypothesis, bilingual young children (from grade 1 to 6) showed a pattern more similar to seventh grade children (when English is introduced at school) than age-matched monolingual participants.

Overall, directional biases linked to reading direction in perceptuo-motor tasks have been interpreted as the result of the habitual direction of perceptual scanning (as when reading or interpreting charts) or performing actions (as in writing). The evidence about the effect of reading habits on higher-order cognitive processes is less clear, and its interpretation more complex. Chatterjee, Southwood & Basilico (1997) showed that English participants tend to represent agent-patient actions with the agent to the left of the patient. Maass & Russo (2003) and Dobel, Diesendruck & Bölte (2007) showed that Arabs (versus Italians) and Hebrews (versus Germans) tended to place agents on the right side of the patient. However, Altmann, Saleem, Kendall, Heilman & Gonzalez

Rothi (2006) did not find traces of such contrasting preferences when comparing a group of Arabic to a group of English native speakers, neither did Barrett et al (2002) when comparing their left-to-right and right-to-left reading groups of Korean participants. Contrary to Chatterjee et al (1997), both English and Arab participants in Altmann et al (2006) study tended to place agents on the right. They interpreted this right spatial bias as the result of the left hemisphere advantage for language processing. Nevertheless, because their English participants were living in Saudi Arabia, we think that their interpretation should be reconsidered. It has been discussed earlier that the exposure of right-to-left readers to a left-to-right orthography can change and even invert their pattern of response (Nachson, 1983). The opposite could also be true: an inversion of the effect for English readers being exposed to Arab language. A similar problem was also present in the Barrett et al (2002) study. Even if their Korean top-to-bottom right-to-left readers learned to read and write this way in first place at school (during the Japanese occupation), they had been exposed all the rest of their life to a left-to-right orthographic system.

A second conceptual domain in which spatialization has been shown to be affected by reading habits is the number mental line. Dehaene, Bossini & Giraux (1993) reported an association between small numbers with left space and large numbers with right space (the so-called SNARC effect). In their final experiment, they found that the SNARC is reduced and even disappears when Persian-French bilingual participants are tested (Persian is written from right to left). Using monolingual Arabic speakers, Zebian (2005) was able to find a complete reversal of the SNARC effect. Moreover, she also found a reduction of the effect in English-Arabic bilinguals, and no effect in illiterate Arabic monolinguals.

Currently, that the mental representation of the abstract concept of time also resources to a left-to-right spatial axis is a well-established notion. Centrally presented words referring to the past and to the future (verbs and adverbs) are able to orient visual attention (Ouellet, Santiago, Funes & Lupiáñez, in press) and prime motor responses (Ouellet, Santiago, Funes & Lupiáñez, in press; Santiago, Lupiáñez, Pérez & Funes, 2007; Torralbo, Santiago & Lupiáñez, 2006; Weger & Pratt, 2008) in correspondence with the habitual reading and writing direction of the participants: past words facilitate left space, and future words facilitate right space. Moreover, presenting these words on the left or right side of a fixation point also interacts with their temporal meanings (Santiago et al, 2007; Torralbo et al, 2006). Finally, Santiago, Román, Ouellet, Rodríguez & Pérez-Azor (2008) extended those results to naturalistic event sequences shown by means of silent movie clips and photograph series. These findings suggest that the concept of time is mapped onto a horizontal axis running from left to right, as expected from the reading habits hypothesis, but do not rule out the possibility that these results are due to universal perceptual, motoric or cerebral factors.

Some evidence already points to the fact that at least some aspects of the spatialization of time are not universal and do indeed vary across cultures. Looking at other spatial mappings in which time partakes, Núñez & Sweetser (2006) reported that, contrary to Spanish native speakers, Aymara speakers both speak and gesture about time as if the future is located behind them and the past in front of them. Casasanto, Boroditsky, Phillips, Greene, Goswami, Bocanegra-Thiel, Santiago-Diaz, Fotokopoulu, Pita, & Gil (2004) studied how distance and quantity information could modulate the estimation of time across four different cultural groups. Their study showed that English and Indonesian participants (who mainly use the “Time as Distance” metaphor in their native language) were only influenced by physical distance in a time estimation task, whereas Greek and Spanish participants (who use more often the metaphor "Time as Quantity" in their native language) were only influenced by physical quantity in the same task. Boroditsky (2001) found that, contrary to English speakers, Mandarin speakers responded faster to temporal questions when primed by vertical displays compared to horizontal displays, a pattern congruent with the more frequent use of vertical metaphors in Mandarin than in English (however, this study has proven difficult to replicate, see Chen, 2007, and January & Kako, 2007, what suggests that its conclusions should be taken with great care). Finally, Boroditsky (2008) showed that Mandarin and English speakers tend to spatially organize temporal sequences in ways that depend on the proportion of space-time linguistic expressions in use in their corresponding language.

Given these signs of cultural flexibility in temporal conceptual mappings, and the evidence linking the spatialization of agent-patient structure and number sequences with the directionality of reading habits, the domain of time seems to be a prime candidate to be similarly affected by those habits. If the influence of reading habits generalizes to the temporal domain, it may be a sign of the workings of a common underlying mechanism. The question of what may have in common agent-patient structure, number sequence, and time that makes them all similarly amenable to be affected by the directionality of reading habits arises as an intriguing and theoretically fruitful question (in the Discussion section we will briefly explore a possible answer).

However, those few studies that so far have directly addressed this question used temporal order judgment tasks only and never used other modality than vision. Tversky et al (1991) asked English, Hebrew and Arab participants to represent graphically a day sequence (breakfast, lunch and dinner) by placing three stickers on a board. English participants majoritarily used a left-to-right arrangement, Arab participants used a right-to-left arrangement, and Hebrew participants lied somewhere in between. Chan & Bergen (2005, exp. 3), using a similar procedure, reported that English and Chinese participants consistently preferred left-to-right arrangements of events, whereas Taiwanese participants, who habitually read Chinese from top-to-bottom and right-to-left, showed a wide variation, including a high proportion of right-to-left arrangements.

The prior studies suffer from a methodological problem: their task is likely to activate a highly conscious problem-solving mode of thought, and therefore, a wide variety of strategies. So far, the only relevant report using a more automatic and implicit task is Fuhrman & Boroditsky (2007). They used triplets of pictures, each representing different stages of an event (‘early’, ‘middle’, ‘late’). In each trial, their participants were presented with the 'middle' picture as reference point followed by either the 'early' or 'late' picture, and were asked to make a temporal judgment (‘earlier’ or ‘later’). The results showed that earlier and later in a temporal sequence facilitated left and right manual responses respectively for English speakers and right and left responses respectively for Hebrew participants.

The main goal of the present investigation is to widen the empirical base of a putative effect of reading habits on the conceptualization of time. Moreover, we do so improving on several aspects of prior studies. Firstly, the present task is highly implicit and automatic and, therefore, more likely to be free of strategic biases. Secondly, prior cross-cultural studies investigated the representation of time by means of tasks that resource to a sequence of events. In other words, participants were asked to judge relative order of events. We aim to extend these results to stimuli directly referring to the past or to the future. To do so, we used words with an intrinsic temporal reference (conjugated verbs and temporal adverbs) as in Santiago et al (2007) and Torralbo et al

(2006) studies, with two different groups of participants, Spanish and Hebrew native speakers.

Note also that all prior studies that investigated the left-right horizontal axis mapping of time used visual tasks. This is the same modality which is thought to be involved in the construal of the left-right spatial representation of time, vision (when reading, writing, looking at graphs, comics, gestures…). It is perhaps possible that the use of the visual modality in these tasks activates the left-right mapping of time. In the case of those studies using printed words (e.g., Santiago et al, 2007; Torralbo et al, 2006) the directional action of reading might itself constitute an additional source of spatial biases. In order to provide a clearer test of preferred thought strategies, we decided to present stimuli in another modality, audition. Participants were asked to judge the temporal reference of auditorily presented words, to either the left or right ear (via headphones), by pressing a left or right key.

Firstly, we expected to replicate previous findings in the Spanish group (Santiago et al, 2007): they should be faster processing past words presented on the left ear and responded to with the left hand, as well as future words presented and responded on the right. Secondly, Hebrew participants should show the opposite pattern at both levels (perceiving and responding): they should show facilitation for the association of past with right and future with left.

Experiment

Participants

Participants were divided into two groups: 20 native Spanish speakers living in Spain (16 females, one left-handed, mean age 22.3) and 28 native Hebrew speakers living in Israel (18 females, one left-handed, mean age 26.9). They all reported to have normal hearing.

Materials

We used the same list of words as in Torralbo et al (2006) for the Spanish group, and their translation for the Hebrew group (see appendix): 24 words referring to the past (e.g., “dijo” - “he said”) and 24 referring to the future (e.g., “dirá” - “he will say”). It is important to note that the formation of the future tense in Hebrew and Spanish are considerably different. In Spanish, an inflexional ending (agreeing with the elliptical subject in person and number) is added to the verb stem, whereas in Hebrew, it is via a prefix (agreeing with the subject in person, number and gender) added to the verb stem (“א” - “I will”; “י” - “he, they will”; “נ” - “we will”; “ת” - “she, you will”).

The word set comprised 18 verbs inflected in either past or future tense, and 6 past and 6 future temporal adverbs (e.g., “antes” - “before”). Eight further words were used for the practice block. Spanish words and instructions were recorded from a female native Spanish speaker, and Hebrew words and instructions were recorded from a female native Hebrew speaker. They were auditorily presented via a Sony headphone set, model MDR-023. The task was programmed in E-prime (Schneider, Eschman, & Zuccolotto, 2002) and ran in an Intel Pentium IV PC 1.70GHz.

Procedure and design

The procedure for the Spanish and Hebrew groups was identical with the only exception of location (Spain vs. Israel) and language of the target words and instructions (Spanish vs. Hebrew).

Participants sat in a quiet room in front of a computer at approximately 60 cm from the screen. The headphone set was fixed on their head before the experiment began. All instructions were given auditorily via the headphones, and participants could press a key (“p” in Spanish or “פ” in Hebrew) if they wanted the instructions to be repeated. When participants were ready, they pushed the space bar to start the experiment. First, a white fixation cross was presented over a black background for 250 ms, followed by a spoken word presented to the left or right ear. Word location was completely orthogonal to temporal reference. Participant’s task was to discriminate if the word referred to the past or to the future by pressing “z” or “m” keys in Spanish or “ז” or “צ” keys in Hebrew. Spanish and Hebrew response keys occupy similar locations in their keyboards. The fixation cross remained on screen during word presentation and for a further 4000 ms or until a response was detected. Before the beginning of the next trial, a blank screen was presented for 1000 ms. Reaction time was measured from the onset of stimulus presentation.

The experiment had two blocks, differing in the mapping of the left and right keys to “past” or “future” judgments. The order of blocks was counterbalanced over participants. Within each block, each experimental word was presented once on the left and once on the right location. Participants were allowed to take a break between blocks. Each block consisted of 16 practice and 96 experimental trials. The experiment lasted about 15-20 minutes.

Results

Errors occurred on 507 trials (5.5% of the trials). Correct trials with latencies below 850 ms and above 3000 ms (334 trials, 3.84%) were considered outliers and also discarded from the latency analysis.1 Results are summarized in Table 1. Two 2 (Group: Spanish or Hebrew) X 2 (Temporal Reference: past or future) X 2 (Target Location: left or right) X 2 (Response Location: left or right) ANOVAs taking both participants (F1) and items (F2) as random factors were used for the latency and accuracy analyses. In the analyses by participants, Temporal Reference, Target Location and Response Location were all within-subject factors. In the analyses by items, Temporal Reference was a between-items factor while Target Location and Response Location were within-item factors. In both F1 and F2 analyses, Group was a between-subjects and items factor.

Temporal Reference	Response Location	Target Location	Group	
			Spanish	Hebrew
Past	Left	Left	1328 (6.05)	1538 (3.89)
		Right	1376 (4.85)	1543 (4.04)
	Right	Left	1435 (7.1)	1550 (3.29)
		Right	1393 (7.35)	1510 (2.79)
Future	Left	Left	1433 (6.15)	1489 (6.68)
		Right	1472 (6.45)	1510 (7.25)
	Right	Left	1430 (5.05)	1553 (6.46)
		Right	1399 (5.05)	1502 (4.86)

Table 1. Mean latency (in ms) and percent errors (in brackets) per condition for the factors Group, Temporal Reference, Response Location and Target Location.

There were somewhat more errors on future than past words ($F1(1, 46) = 3.412$, $p = 0.071$; $F2 < 1$). Contrary to the Spanish group, Hebrew participants tended to respond more accurately on future than past words ($F1(1, 46) = 8.914$, $p < 0.005$; $F2(1, 92) = 2.275$, $p > 0.1$). There were no significant interactions (Group X Response Location: $F1(1, 46) = 2.063$, $p > 0.1$; $F2(1, 92) = 1.932$, $p > 0.1$; Temporal Reference X Response Location: $F1(1, 46) = 1.666$, $p > 0.1$; $F2(1, 92) = 2.863$, $p = 0.094$; Group X Temporal Reference X Response Location: $F1(1, 46) = 1.012$, $p > 0.1$; $F2(1, 92) = 1.51$, $p > 0.1$; Group X Response Location X Target Location: $F1(1, 46) = 1.192$, $p > 0.1$; $F2(1, 92) = 1.219$, $p > 0.1$; Temporal Reference X Response Location X Target Location: $F1(1, 46) = 1.507$, $p > 0.1$; $F2 < 1$; all other $Fs < 1$).

The ANOVAs on latencies showed that Spanish participants tended to respond faster than Hebrew participants ($F1(1, 46) = 3.562$, $p = 0.065$; $F2(1, 92) = 12.346$, $p < 0.001$). Main effects of Response location ($F1(1, 46) = 1.056$, $p > 0.1$; $F2(1, 92) = 2.7$, $p > 0.01$), Temporal Reference ($F1(1, 46) = 2.441$, $p > 0.1$; $F2 < 1$) and Target Location (both $Fs < 1$) were not significant. Responses were faster when the stimulus was presented on the same side of the response ($F1(1, 46) = 18.247$, $p < 0.001$; $F2(1, 92) = 18.828$, $p < 0.001$). All other interactions involving Target Location were far from significance (Target Location X Group ($F1(1, 46) = 2.085$, $p > 0.1$; $F2(1, 92) = 1.566$, $p > 0.1$), all other Fs smaller than or near to 1 and $ps > 0.1$). The Group factor did not interact significantly with Response Location ($F1$ and $F2 < 1$) but it showed a trend to interact with Temporal Reference ($F1(1, 46) = 14.86$, $p < 0.001$; $F2 < 1$). Whereas Spanish participants responded faster to past tense words, Hebrew participants gave faster responses for future words. This was probably due to the fact that future in Hebrew is marked by a prefix, allowing a faster recognition of the temporal reference for these words. Past words tended to be responded faster with the left hand and future words with the right hand ($F1 < 1$; $F2(1, 92) = 7.425$, $p < 0.01$).

Of central interest for the purpose of this study, there was a clear interaction between Group, Temporal Reference and Response Location ($F1(1, 46) = 5.156$, $p < 0.05$; $F2(1, 92) = 27.181$, $p < 0.001$). Hebrew and Spanish participants showed opposite patterns of congruency between response side and temporal reference: Spanish participants showed the left-past right-future congruency pattern, whereas Hebrew participants responded faster with their left hand to future words and with their right hand to past words (see Figure 1). Planned comparisons demonstrated that this congruency effect was significant for Spanish participants ($F1(1, 46) = 4.571$, $p < 0.05$;

$F2(1, 92) = 31.509$, $p < 0.001$) whereas it did not reach significance for Hebrew participants ($F1 < 1$; $F2(1, 92) = 3.097$, $p = 0.082$).

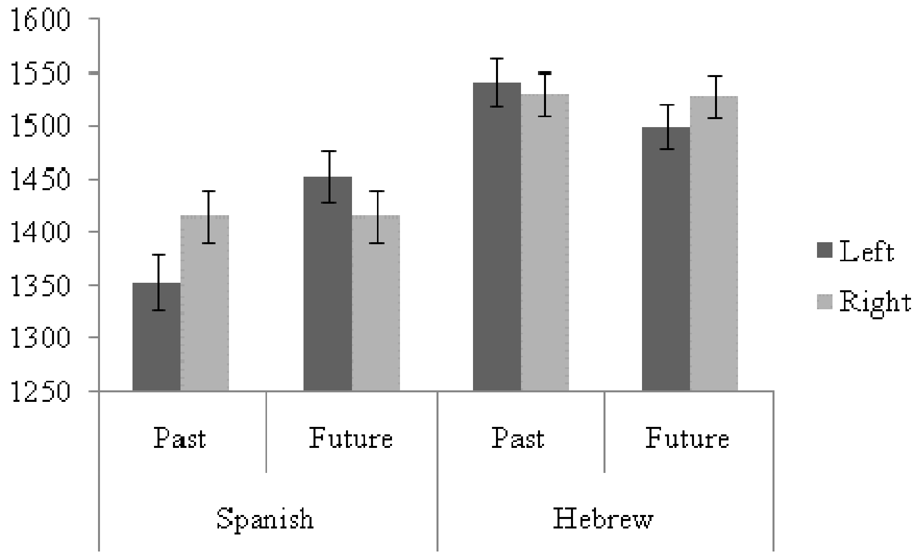

Figure 1. Mean RTs (in ms) for Spanish and Hebrew groups and their left-right responses to past and future concepts.

Discussion

Our results were clear-cut. Spanish participants showed facilitation when responding to past words with their left hand and future words with their right hand. This pattern replicates in the auditory modality prior results by Santiago et al. (2007) and Torralbo et al. (2006) using visual presentation of words.

Of greater interest, Hebrew participants showed the opposite pattern. Their responses were faster when responding past with their right hand and future with their left hand, supporting the hypothesis that the spatial grounding of time along the horizontal left-right axis is linked to the habitual direction of reading and writing. Note also that our participants did not have to read the target words and all instructions were auditorily presented, which rules out the possibility of spatial biases being induced on the spot by the directional action of reading, and suggests a deeper influence of reading habits on spatial construals of abstract meanings.

The fact that the congruency effect was weaker with Hebrew participants compared to their Spanish equivalent is congruent with previous findings comparing English to Hebrew participants (e.g., Tversky et al, 1991). This is probably due to the characteristics of the Hebrew writing system, which is not entirely right-to-left (see Introduction), and also to the fact that all our Hebrew participants have learned and frequently used an orthographic system (English) which proceeds in the opposite direction to that of their first language (Nachson, 1983). This was not the case for our Spanish participants (none of them read or wrote a right-to-left writing language).

It is still unclear why we did not obtain a facilitation effect at the perceptual level, as it was observed with visual stimuli in prior studies (Santiago et al, 2007; Torralbo et al, 2006). One explanation relates to the more complex computation needed by sound localization, often resulting in a null effect on spatial tasks (Spence & Driver, 1994). However, if this were the case, it would be difficult to explain how we obtained a congruency effect between Target Location and Response Location (Simon & Rudell, 1967). Another possibility is that the perceptual facilitation effect with temporal words is modality dependent.

However, our guess is that the auditory spatial frame of reference created by the left or right presentation of auditory stimuli was not salient enough to counteract the visual frame of reference. Studies on the selection of spatial frames of reference show competition between simultaneously active frames (e.g., Carlson, 1999). Consistent with this possibility, recent research from our laboratory demonstrates that incrementing the saliency of the auditory frame of reference by instructing participants to perform the task blind-folded results in a facilitation effect at the perceptual level as well (Ouellet, Santiago & Román, in preparation).

To conclude, present data using a paradigm which makes simultaneously salient both spatial and temporal dimensions show that the direction of habitual reading and writing is able to bias how time is mapped onto a left-right mental line: the preferred mapping runs in the same direction as the orthographic system. Why should this be the case? Santiago, Román & Ouellet (submitted) suggest a possible mechanism. Under their mental model theory of abstract reasoning, people build mental models in order to support comprehension and thought. Such models include all the elements (both structure and content) needed to solve the problem at hand, and they are constrained to be maximally internally coherent. When mental models are built from text in a left-to-right orthography, entities are mentioned literally from left to right. A strategy that helps building a maximally coherent mental model for such a situation is, therefore, to place their referents from left to right in mental space. Due to pragmatic constraints, events that occur earlier are usually mentioned earlier (Levinson, 1983), which in writing means more to the left. The proposed strategy then results in the habit of placing earlier events on left mental space followed by later events being located more to the right.

The same mechanism can readily be extended to explain the left-to-right arrangement of numbers (Dehaene et al, 1993), and even to explain the trend to draw agents on the left of patients, as reported by Chatterjee et al (1997; see the Introduction). As the languages assessed so far use a SVO word order, and agents typically surface at subject position (Bock, 1982), maximally coherent mental models will arise when agents are placed on the left and patients on the right. Of course, both for time and agent-patient structure, reversals are expected when the written input runs from right to left.

To sum up, the spatialization of event order, number sequences and agent-patient structure may be the emerging result of a common, underlying strategy of thought, one that intends to fulfill a very global constraint on all mental models: to have a maximal internal coherence.

Chapter IV

Is the spatial perception of time modality specific?

Abstract

Recent studies on the conceptualization of abstract concepts suggest that the concept of time is represented onto a left-right horizontal axis in which past and future meanings are mapped in concordance with the directionality of the orthographic system first learned by participants: left-to-right readers represent past on the left and future on the right whereas right-to-left readers show the opposite pattern. A still recent finding is that this mapping is also activated by auditorily presented words referring to the past and the future. However, contrary to what happens with visual stimuli, temporal meaning only interacted with response side, but failed to interact with stimulus location (Ouellet, Santiago, Israeli & Gabay, in press). We hypothesized that this failure could be accounted for by three possibilities: firstly, the perceptual congruency effect maybe modality dependent; secondly, auditory presentation to a single ear may not provide enough interaural mismatch information to map time onto an auditory-spatial map; finally, the availability of vision may foster the mapping of time onto a visuo-spatial instead of auditory-spatial frame. Experiment 1 provided interaural information by presenting stimuli via loudspeakers instead of headphones, without finding a significant congruency effect between sound origin and temporal meaning. Experiment 2 elliminated all visual information by asking the participants to perform the task blindfolded. A significant interaction between sound origin and temporal meaning arised under these conditions, supporting the existence of perceptual congruency effects between stimulus location and temporal meaning with auditory stimuli, as well as the modality independence of the effect.

Introduction

The conceptualization of abstract concepts, like time or justice, just to name two of them, is more complicated than that of concrete concepts because we cannot experience them through the senses (Clark, 1973). Conceptual Metaphor theory (Lakoff & Johnson, 1980, 1999) suggests that abstract concepts are conceptualized by using concrete concepts as structural donors. As a result, this mapping strategy facilitates the understanding of abstract concepts.

First evidences of this structural mapping came from linguistic studies that investigated the occurrence of everyday expressions that metaphorically map abstract concepts onto concrete ones (Lakoff & Johnson, 1980, 1999; Johnson, 1987). Among many other mappings, these studies reported a pattern of expressions in which the concept of time is grounded onto the experience of motion (TIME IS MOTION), over a horizontal axis going from back to front (e.g., “I finally left the past *behind* me and started to *advance* towards my future.”).

However, as pointed out by Murphy (1996, 1997), the analysis of linguistic expressions alone is not sufficient to demonstrate the psychological reality of these metaphors: it is not because we speak in a certain way that we necessarily think that way. Casasanto (2008) offers a good example of the importance to put to test the psychological reality of conceptual metaphors. Investigating the SIMILARITY IS PROXIMITY conceptual metaphor, he observed that under certain conditions his participants behaved in a way opposite to the way predicted by Conceptual Metaphor Theory: when they were asked to judge the visual similarity of two objects, the closer they were, the greater the perceived dissimilarity.

Other conceptual metaphors, like the TIME IS MOTION metaphor mentioned above, have shown a stronger consistency between the way we speak about their target domains and the way they are conceptualized. In her studies, Boroditsky (2000; Boroditsky & Ramscar, 2002) investigated priming effects produced by spatial primes depicting movement of an observer approaching an object or an object approaching the observer before the presentation of an ambiguous question such as: “Next Wednesday's meeting has been moved *forward* two days. Indicate to which day the meeting has been rescheduled.”

The word *forward* in this statement is ambiguous because its meaning depends on the perspective you adopt to respond the question (McGlone & Harding, 1998). In an ego-moving perspective, you are heading towards your future, whereas in a time-moving perspective you are staying still and it is the future which is coming to you. As a result, the word *forward* in the ego-moving perspective means farther from ego (expected response: Friday), whereas it means closer to ego in the time-moving perspective (expected response: Monday). Boroditsky's participants were accordingly biased toward an ego- or time-moving perspective by her spatial primes, supporting the psychological reality of the back-front mapping of time (see also Gentner, Imai & Boroditsky, 2002).

Still, it is important to note that not all conceptual metaphors are present in language (e.g., Gevers, Reynvoet & Fias, 2003, 2004, for ordered sequences; Nachson, Argaman & Luria, 1999, for aesthetic preferences) and that there is also a spatial mapping of time over the left-right horizontal axis which is not attested in any oral language (Radden, 2004). Torralbo, Santiago, & Lupiáñez (2006, exp. 2) and Santiago, Lupiáñez, Pérez & Funes (2007) asked Spanish participants to perform a temporal judgment task with their left and right hands on temporal words (conjugated verbs and temporal adverbs) visually presented either on the left or on the right of the screen.

Congruency effects were found both for response side and stimulus location: on both dimensions, past words were faster on the left and future words on the right.

Cross-cultural studies suggest that such representation may be the result of exposure to a directional orthographic system. When asked to represent graphically a day sequence, like "breakfast/lunch/dinner" (Tversky, Kugelmass & Winter, 1991), or stages of development of a natural entity, like "seed/sapling/big tree" (Chan & Bergen, 2005, exp. 3), left-to-right readers tend to organize events running from left to right, whereas right-to-left readers tend to do the opposite. A similar finding is reported by Fuhrman & Boroditsky (2007) using temporal judgments of early, intermediate and late stages of events.

Ouellet, Santiago, Israeli & Gabay (in press) aimed to extend these cross-cultural findings to words intrinsically referring to the past or future, as in Torralbo et al (2006, exp. 2) and Santiago et al (2007). In agreement with prior results, temporal words primed motor response codes in concordance with the direction of the orthographic system first learned by participants. While Spanish speakers were faster to respond to past words with their left hand and to future words with their right hand, Hebrew participants were faster to respond to past words with their right hand and to future words with their left hand.

Ouellet, Santiago, Israeli & Gabay (in press) also extended prior cross-cultural findings to a new modality, audition. Words in their study were auditorily presented via headphones. Besides avoiding an induction of the left-right representation of time by the action of reading itself, this mode of presentation permitted to observe an activation of the left-right mapping of time in a modality not involved in its grounding process. The only study using auditory stimuli reported so far, Ishihara, Keller, Rossetti, & Prinz (2008), reported consistent results by having their participants (German left-to-right readers) judging, by pressing a left or right button, the temporal onset ("early" or "late") of an auditory target presented after a periodic auditory stimuli sequence. Responses to the left were facilitated with "early" responses and to the right with "late" responses.

In Ishihara et al (2008) study, participants had to perform the task with their eyes closed. Ouellet, Santiago, Israeli & Gabay (in press) demonstrated that this preventive measure is not necessary to activate the left-right mapping of time and to find priming of congruent manual responses. However, in their study, Ouellet, Santiago, Israeli & Gabay (in press) also tested whether spatial localization of sound origin would interact with temporal word meaning. To do so, they presented the words dichotically (to the left or right ear). Contrary to Torralbo et al (2006, exp. 2) and Santiago et al (2007) with visual stimuli, there was no interaction between the left or right stimulus location and past or future reference. Interestingly, this occurred in the context of a congruency effect between word location and response side (Simon & Rudell, 1967), which rules out the possibility that participants were unable to localize sound origin. The present study aims to deepen into the causes of the observed dissociation between congruency effects between time and response side, on one hand, and between time and stimulus location, on the other, in the auditory modality.

Sound localization depends on interaural mismatch times and interaural frequency level differences (Palmer & Grothe, 2005). It is possible that dichotic presentation provided enough information to modulate the activation of manual response codes, but not enough to create a topographical map on which the time flows.

Experiment 1 was designed to test this hypothesis. Instead of using headphones, we used two loudspeakers situated to the left and right of the participant, which would support binaural perception of the words.

It is also possible, though, that just the availability of visual information is enough to override the use of auditory cues for creating the conceptual time-space frame. Experiment 2 aimed at investigating this question by asking participants to perform the task blindfolded.

A final possibility is that the modulation of time by spatial cues is modality specific. If this is true, no significant interaction should arise between sound location and the temporal meaning of the words in any of the experiments.

Experiment 1

Every detail of the procedure was identical to the Spanish group in Chapter III, with the following exception: headphones were replaced by two external loudspeakers situated on the left and right sides of the screen.

Participants

Thirty-six native Spanish speakers (31 females, three left-handed, mean age 21.9) from the University of Granada took part in Experiment 1 and received course credit as an incentive. They all reported to have normal hearing and normal vision.

Procedure and design

Materials

We used the same Spanish materials from Chapter III. The word set comprised 18 verbs inflected in either past or future tense, and six past and six future temporal adverbs (e.g., "antes" - "before"). Eight further words were used for the practice block. Words and instructions were recorded from a female native Spanish speaker. Two external NGS (Sphere 2.0) speakers were placed to the left and right of the participants, 1 m. away from the screen and oriented towards the participant. The task was programmed in E-prime (Schneider, Eschman, & Zuccolotto, 2002) and ran in an Intel Pentium IV PC 1.70GHz]

Procedure and design

All instructions were given auditorily via the external speakers, and participants could press a key ("p") if they wanted the instructions to be repeated. When participants were ready, they pushed the space bar to start the experiment. First, a white fixation cross was presented over a black background for 250 ms, followed by a spoken word presented through the left or right speaker. Word location was completely orthogonal to temporal reference. Participant's task was to discriminate if the word referred to the past or to the future by pressing the "z" or "m" keys. The fixation cross remained on screen during word presentation and for a further 4000 ms or until a response was detected. Before the beginning of the next trial, a blank screen was presented for 1000 ms. Reaction time was measured from the onset of stimulus presentation.

The experiment had two blocks, differing in the mapping of the left and right keys to "past" or "future" judgments. The order of blocks was counterbalanced over participants. Within each block, each experimental word was presented once on the left and once on the right location. Participants were allowed to take a break between blocks.

Results

There were 440 (6.37%) error trials. An additional 142 correct trials (2.19%) were discarded from the latency analysis because their latencies fell below 850 ms or above 3000 ms (see Table 1, "Sighted" section). These cutoff points were the same as in Chapter III, and were established after inspection of the RT distribution. In order to measure the binaurality effect, we compared the results of the present experiment to those of the Spanish group in Chapter III by adding the Binaurality factor. Two 2 (Binaurality: headphones or external speakers) X 2 (Temporal Reference: past or future) X 2 (Target Location: left or right) X 2 (Response Location: left or right) ANOVAs taking both participants (F1) and items (F2) as random factors were used for the latency and accuracy analyses. In the analyses by participants Binaurality was a between-subjects factor, and Temporal Reference, Target Location and Response Location were all within-subject factors. In the analyses by items, Temporal Reference was a between-items factor whereas Binaurality, Target Location and Response Location were within-item factors.

The analysis of accuracy yielded no significant main effect of Binaurality, Temporal Reference, Target Location or Response Location and no interactions (all *p*s > 0.1 and all *F*s smaller than or near to 1). The only exception was a trend towards an interaction between Temporal Reference and Response Location ($F1(1, 54) = 1.737$, $p > 0.1$; $F2(1, 46) = 3.981$, $p = 0{,}052$). Participants tended to be more precise when responding to future words with their right hand and to past words with their left hand as compared to the opposite mapping.

The latency analysis revealed that participants tended to respond faster to past vs. future words ($F1(1, 54) = 43.427$, $p < 0.001$; $F2(1, 46) = 1.203$, $p > 0.1$) and also tended to be faster in the experiment with external speakers as compared to headphones ($F1 < 1$; $F2(1, 46) = 9.425$, $p < 0.01$). Target Location and Response Location main effects were not significant.

The interactions of Binaurality by Response Location ($F1(1, 54) = 2.071$, $p > 0.1$; $F2(1, 46) = 2.885$, $p = 0.096$) and Binaurality by Target Location and Response Location ($F1 < 1$; $F2(1, 46) = 1.181$, $p > 0.1$) were also non-significant.

As in Chapter III, past and future words facilitated left and right responses, respectively ($F1(1, 54) = 14.893$, $p < 0.001$; $F2(1, 46) = 69.996$, $p < 0.001$).

The significant congruency effect between Target Location and Response Location ($F1(1, 54) = 15.451$, $p < 0.001$; $F2(1, 46) = 28.260$, $p < 0.001$) showed that participants were able to localize sound origin. However, the interaction of Temporal Reference by Target Location was not significant (both *F*s less than 1), nor it interacted with Binaurality (both Fs < 1).

Finally, there was no four way interaction involving Binaurality, Temporal Reference, Target Location and Response Location ($F1(1, 54) = 1.996$, $p > 0.1$; $F2(1, 46) = 2.226$, $p > 0.1$). None of the remaining interactions was significant (all *F*s less than 1).

Discussion

Experiment 1 replicated previous findings concerning the congruency effect between past and future meanings and left and right responses, respectively. Moreover, it also replicated the lack of interaction between sound location and temporal meaning. Even though sound origin was correctly localized by the participants, it did not modulate the semantic access for past and future meanings, in contrast to prior observations using written words (Torralbo et al, 2006, exp. 2; Santiago et al, 2007). The interaural hypothesis can therefore be rejected.

Experiment 2

The goal of Experiment 2 was to investigate whether the failure to find a modulation for the processing of past and future meanings by sound origin (left and right) was due to the fact that participants had visual information available while performing this auditory task. Thus, participants of this experiment performed the task blind-folded.

Participants

Thirty-eight (30 females, four left-handed, mean age 22.5) participants from the same population as in Experiment 1.

Procedure and design

Materials

Same as in Experiment 1, plus an eye mask to deprive participants from vision.

Procedure and design

The procedure was identical to that of Experiment 1 with the exception that participants were blindfolded during all the experiment and the experimenter helped them to get seated and to find the response keys on the keyboard. As logic dictates, blindfolded participants could not see the fixation cross.

Results

Trials on which an error was made (490 trials, 6.38 %) and correct trials with latencies below 850 ms and above 3000 ms (137 trials, 1.91%) were excluded from the latency analysis (see Table 1). In order to assess directly the effect of vision, we included the Experiment factor that compares participants of Experiment 1 (sighted) to participants of Experiment 2 (blindfolded). Two 2 (Experiment: sighted or blindfolded) X 2 (Temporal Reference: past or future) X 2 (Target Location: left or right) X 2 (Response Location: left or right) ANOVAs taking both participants (F1) and items (F2) as random factors were used for the latency and accuracy analyses. In the analyses by participants, Temporal Reference, Target Location and Response Location were all within-subject factors, whereas Experiment was a between-subjects factor. In the analyses by items, Temporal Reference was a between-items factor whereas Experiment, Target Location and Response Location were within-item factors.

Experiment	Sighted			
Target Location	Left		Right	
Temporal Reference	Past	Future	Past	Future
Response Location				
Left	1384 (5.8)	1471 (6.3)	1386 (6.3)	1509 (6)
Right	1447 (6.6)	1433 (7.2)	1427 (6.8)	1392 (4.6)
Experiment	Blindfolded			
Target Location	Left		Right	
Temporal Reference	Past	Future	Past	Future
Response Location				
Left	1460 (6.3)	1554 (5.5)	1477 (6.7)	1545 (7.9)
Right	1481 (8)	1517 (4.3)	1502 (7.3)	1490 (3.7)

Table 1: Mean latency (in ms.) and percent errors (in brackets) per condition for the factors Experiment, Target Location, Temporal Reference and Response Location.

The analysis of accuracy showed a trend to make less errors on future than past words ($F1(1, 72) = 3.234$, $p = 0.076$; $F2 < 1$). Congruent with the left-right conceptual metaphor of time, there were somewhat more errors on left responses to future words and right responses to past words compared to the opposite ($F1(1, 72) = 2.495$, $p > 0.1$; $F2(1, 46) = 13.047$, $p < 0.001$) and this effect tended to be stronger in the blindfolded (Experiment 2) compared to the sighted (Experiment 1) group of participants ($F1(1, 72) = 1.059$, $p > 0.1$; $F2(1, 46) = 6.23$, $p < 0.05$). The interaction between Experiment, Target Location, and Temporal Reference approached significance ($F1(1, 72) = 3.364$, p

= 0.071; $F2(1, 46) = 3.375$, $p = 0.073$), but planned comparisons for each experiment showed no significant influences (all *p*s > 0.1). There was a congruency effect between Target Location and Response Location ($F1(1, 72) = 4.38$, $p < 0.05$; $F2(1, 46) = 7.29$, $p < 0.01$), indicating that the sounds were localized. None of the other interactions or main effects were significant (all *p*s over 0.1).

Latency analyses showed that sighted participants were faster that blindfolded ($F1(1, 72) = 3.791$, $p = 0.055$; $F2(1, 46) = 151.78$, $p < 0.001$) and that past words were responded to faster than future words ($F1(1, 72) = 29.768$, $p < 0.001$; $F2 < 1$). There was an overall Response Location by Target Location congruency effect ($F1(1, 72) = 4.984$, $p < 0.05$; $F2(1, 46) = 7.364$, $p < 0.01$), which tended to be greater for the sighted (Experiment 1) compared to the blindfolded (Experiment 2) participants ($F1(1, 72) = 2.855$, $p = 0.095$; $F2(1, 46) = 3.753$, $p = 0.059$). There was also an overall congruency effect between Response Location and Temporal Reference: participants were faster to respond with their left hand to past words and with their right hand to future words ($F1(1, 72) = 13.026$, $p < 0.001$; $F2(1, 46) = 60.906$, $p < 0.001$). This pattern was somewhat stronger in the sighted Experiment ($F1(1, 72) = 1.185$, $p > 0.1$; $F2(1, 46) = 4.343$, $p < 0.05$; see Figure 1).

The most important result of this experiment was the interaction between Temporal Reference, Target Location and Experiment ($F1(1, 72) = 4.184$, $p < 0.05$; $F2(1, 46) = 2.847$, $p = 0.098$). Planned comparisons showed that the interaction between Temporal Reference and Target Location was significant only within the blindfolded group (blindfolded: $F1(1, 72) = 6.011$, $p < 0.05$; $F2(1, 46) = 4.566$, $p < 0.05$; sighted: both Fs < 1; see Figure 2).

All other main effects and interactions were not significant (all *p*s over 0.1 and *F*s less than or near to 1).

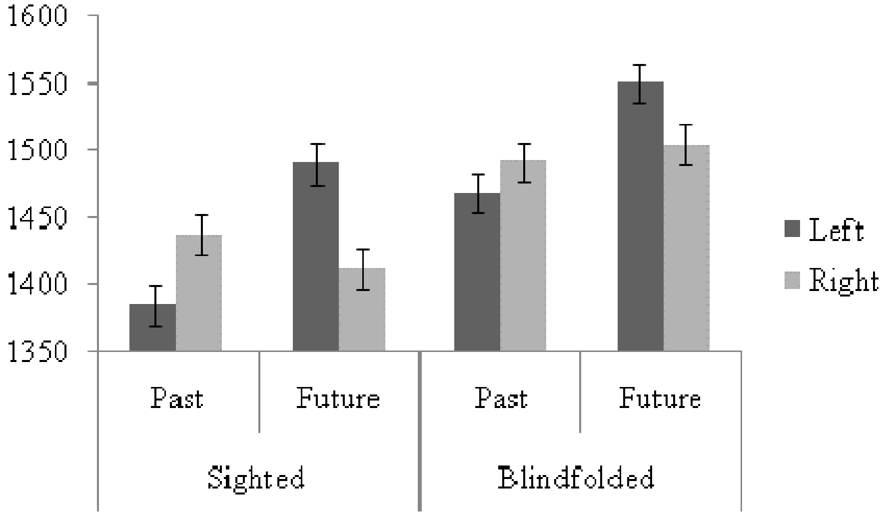

Figure 1. Mean RTs (in ms) for sighted and blindfolded participants and their left-right responses to past and future meanings.

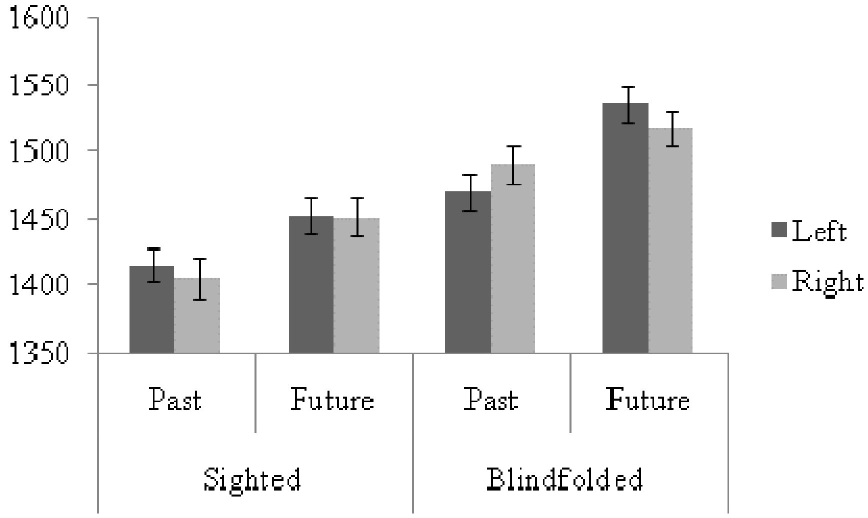

Figure 2. Mean RTs (in ms) for sighted and blindfolded participants and their responses to past and future meanings presented to the left or to the right loudspeaker.

General discussion

Results of the present study were clear-cut. First, we replicated the results observed in Chapter III with native Spanish speakers. Our participants showed a left-past/right-future facilitation of response codes.

Ouellet, Santiago, Israeli & Gabay (in press), following Santiago, Román & Ouellet (submitted) suggested that this left-right mapping of time may be due to the fact that the spatial characteristics of the activity of reading is closely correlated with the time of described events in the text. For pragmatic reasons (Levinson, 1983) events are normally referenced in chronological order. It means that, when reading a left-to-right written text, past events will be on the left and future events on the right. This spatial positioning of events in the text would then be transposed to a coherent mental model representation, an effect that can generalize to other left-to-right mappings, like the arrangement of numbers (the so-called SNARC effect, Dehaene, Bossini & Giraux, 1993; Zebian, 2005), or the positioning of agents versus patients in transitive actions (Chatterjee, Southwood & Basilico, 1997; Maass & Russo, 2003; Dobel, Diesendruck & Bölte, 2007).

Second, present data shows that the prior failure to obtain a congruency effect between temporal meanings and perceptual location of the stimuli was not due to the fact that sounds were perceived by one ear at a time: presenting the stimuli binaurally in Experiment 1 led to a pattern of results nearly identical to when the stimuli were presented dichotically (via headphones) in Chapter III.

Experiment 2 of the present study permitted to show that the congruency effect between spatial perception and temporal meanings observed with visual stimuli (Torralbo et al, 2006, exp. 2; Santiago et al, 2007) is not modality specific: the mere fact of being unable to see caused the appearance of the perceptual congruency effect with auditory temporal words.

Why is that the case? A possibility would be that we are dealing with a ventriloquism effect (Bertelson, 1998), a translocalization of sound origin onto a visual cue. In our case, it would be a translocalization of sound origin onto the fixation cross.

Even if this interpretation of the results is tempting at first sight, there are a number of studies suggesting that it might not be the case. First, the ventriloquist hypothesis suggests that sounds are translocated onto the focus of visual attention (the fixation cross), but it is known that visual attention alone is not enough to induce a sound translocalization (Bertelson, Vroomen, De Gelder & Driver 2000; Vroomen, Bertelson & De Gelder, 2001). Second, visual cues asynchronous with sound onset are bad attractors (e.g., Bertelson & Aschersleben, 1998; Choe, Welch, Gilford, & Juola, 1975; Radeau & Bertelson, 1987). In our study, the fixation cross did not appear at the same time as the auditory word, but 250 ms before. Third, the higher is the spatial separation between the auditory and the visual stimulus, the weaker is the ventriloquism effect (Bertelson & Radeau, 1981; Choe et al., 1975). In the present experiments, the loudspeakers were 1 meter apart from the computer screen, which can be considered as very far from the visual stimulus attractor. Fourth, the relative saliency between the auditory and visual signal is also important (Radeau, 1985; Alais & Burr, 2004). A less salient visual stimulus will attract less the auditory stimulus. Alais & Burr (2004) even demonstrated that a low salient visual stimulus (when the visual stimulus is difficult to localize because highly blurred) could be translocated to the sound localization (a reversed ventriloquist effect). It can be argued that a fixation cross does not constitute a highly salient visual stimulus.

Therefore, it is difficult to imagine the fixation cross being able to translocate the sound origin. Moreover, if participants were translocalizing the sound origin towards the place where they were fixating (the center of the screen), it would be difficult to explain the significant Target Location by Response Location interaction (Simon & Rudell, 1967) obtained in Experiment 1 and in Chapter III.

An alternative explanation would be that as soon as the participants have their eyes open, they map time onto visuo-spatial locations instead of audio-spatial ones. This explanation will need more research, but it can be spelled out as follows.

Lewald (2007) gave evidence that when a person is seeing, even when the vision is irrelevant for the task at hand, this person will localize sound origin by computing interaural differences, but also by executing the final calibration at a visual level. He attributed the more accurate results obtained with a light deprived group compared to a sighted group in a sound localization task to this calibration process. When vision is impaired, neurons being used for the visual calibration process become used for an auditory calibration process. The result is then a complete auditory perceptual topographic map when vision is prevented, but a hybrid (visuo- and audio-spatial) perceptual topographic map when vision is available.

Because vision is much stronger than audition in spatial tasks (Middlebrooks & Green, 1999), the spatial mapping of time would be at a visual level when the perceptual topographic map is hybrid (when the eyes are open). The mapping of time onto auditory spaces would be possible only when the perceptual topographic map is completely auditory.

This explanation could also explain other effects occurring between the modalities of vision and smell or vision and touch, where vision is the dominant modality (Welch & Warren, 1980). Morrot, Brochet & Dubourdieu (2001) asked expert wine tasters to describe the smell of white and red wines. First, they observed that experts used different terminologies to speak about red or white wines. Second, when coloring artificially the white wine into red, the expert wine tasters described their smell with the red wine terminology. Another effect is that of judging a bigger object as being heavier, even if the smaller and bigger objects weight the same (Charpentier, 1891). In these two cases, the hybrid modality mapping of the concept of "wine category" or "weight" would be represented over the dominant mapping only, the visual.

Another interesting finding in our study is the fact that sighted (Experiment 1), as compared to blindfolded participants (Experiment 2), obtained a stronger benefit from the past and future meanings for their left and right manual response programming. It means that the programming of motor responses benefited from visual information. It also suggests that previous findings concerning congruency effects between manual responses and temporal meanings (Fuhrman & Boroditsky, 2007; Santiago et al, 2007; Torralbo et al, 2006) were not completely motoric in nature.

To conclude, present results support the idea that time is conceptualized as a horizontal left-right mental line, which flows in a direction consistent with the direction of reading/writing. They also support that this mental line is of a central nature: it is not linked exclusively to either perceptual or motoric codes, and it can be accessed through both the visual and auditory modalities. Finally, they show how visual information predominates over auditory information in guiding this conceptual mapping whenever they are both simultaneously available.

Chapter V

General discussion

Summary of the results

The first set of experiments presented in Chapter II aimed at investigating whether past and future meanings could orient attention towards left and right spaces, respectively, as more traditional cues like arrows do (Posner, 1980; Posner & Cohen, 1984; Posner, Nissen & Ogden, 1978).

To ensure that participants were processing temporal words, we asked them to keep temporal meaning of words in working memory while carrying out a spatial cuing task. In the two first experiments participants had to respond to a probe question on the temporal meaning of the cue word at the end of each trial. The use of working memory in orientation of visuo-spatial attention tasks has proven to be effective (Awh & Jonides, 2001; Soto, Hodsoll, Rotshtein, & Humphreys, 2008), but no one to our knowledge ever used this kind of paradigm to study the spatialization of time.

The first experiment of the set aimed at testing whether the working memory paradigm would also work with the left-to-right conceptualization of time. To do so, we used a spatial localization task, which is less demanding than a spatial direction discrimination (spatial Stroop) task because the response and target location are always on the same side.

The results of this experiment demonstrated that the maintenance of past or future meanings in working memory modulated processing in concurrent left or right locations, respectively. However, because target and response locations were correlated in this task, it was impossible to settle whether the facilitation effect was sensory, motor or both in nature.

The second experiment aimed at disentangling these two possibilities. We replaced the localization task by a spatial discrimination task, more precisely a spatial Stroop task. Participants had to indicate, by pressing the left or right key, the pointing direction of an arrow (left or right) appearing to the left or to the right of the fixation point. The presentation location and pointing direction of the arrows were completely orthogonal.

Results of this second experiment showed congruency effects between temporal meaning and response location (motor facilitation) and between temporal meaning and presentation location of the arrow (sensory facilitation). Those congruency effects were independent from each other.

The third and last experiment of the series was similar to the second experiment, with the following changes: First, we introduced a short and a long stimulus onset asynchrony (SOA). This was intended to let us peek into the nature of the attentional mechanism activated when processing temporal word cues. While the orientation of attention with typical central and predictive cues start to modulate attention at longer SOAs, the orientation of attention with typical peripheral non-predictive cues start to orient attention at short SOAs, but the facilitatory effect reverses at longer SOAs, an effect known as "Inhibition of Return" (Corbetta & Shulman, 2002). Since our temporal word cues shared characteristics of both types of cue (centrally presented, but non-predictive), a direct test on the issue was essential to know which of the two mechanisms was involved. Secondly, there was a recognition phase for presented words at the end of the experiment instead of the probe question about their temporal meaning at the end of each trial. This manipulation intended to reduce working memory load and to investigate whether explicit processing of the temporal reference of the word cues was necessary to obtain the effect in the prior experiments.

In this experiment, the temporal meaning of words was able to orient attention at lateral locations at the long SOA only, suggesting the use of the attentional mechanism normally involved in the orientation of visuo-spatial attention with central cues. An interesting fact was that this interaction was concentrated on left responses only, a bias probably rooted in the direction of the orthographic system of the participants. Spalek & Hammad (2005) already observed stronger attentional effects (Inhibition of Return) on the left side for left-to-right and on the right side for right-to-left readers. Finally, a surprising result was that the interaction between the temporal meaning of word cues with left and right responses failed to be significant, remaining only the perceptually-based interaction of temporal meaning and cue location.

In Chapter III we investigated the cultural variability of the left-right mapping of time and its relations with the directionality of the orthographic system of the participants, introducing several methodological improvements over prior studies

The handful of previous cross-cultural studies addressing this question (Tversky, Kugelmass & Winter, 1991; Chan & Bergen, 2005, exp. 3; Fuhrman & Boroditsky, 2007) used only the modality of vision and investigated the representation of time by asking their participants to perform temporal judgments on ordered sequences (earlier or later of an event on the sequence). We intended to extend these findings to the modality of audition, under conditions that preclude the left-right effect to arise from the use of vision and reading during the experimental task. We also used stimuli that intrinsically refer to past and future (conjugated verbs and adverbs). The task was very similar to that of Santiago, Lupiáñez, Pérez & Funes (2007, with Spanish participants only), with the exception that word presentation was auditory (via headphones) instead of written.

Hebrew and Spanish participants had to perform the same task in their native language and country of origin. Words presented to their left or right ear had to be judged, with their right or left hand, as referring to the past or to the future.

As predicted by the directionality of the orthographic system hypothesis, Spanish participants showed a left-past right-future facilitation effect, whereas Hebrew participants showed the opposite pattern, although somewhat weaker.

This facilitation effect was for the manual responses only. Contrary to Santiago et al (2007), with written words, the location of the stimulus (left or right sound origin) did not modulate the processing of temporal words. This occurred in the face of a significant Simon effect (Simon & Rudell, 1967) between sound location and response hand.

Chapter IV investigated the reasons for this failure. Three possibilities were considered: 1- the perceptual modulation for the processing of temporal meanings is modality specific; 2- the participants did not create an auditory spatial map of the external world because the sounds were not presented binaurally; 3- the mere act of seeing is able to counteract the mapping of time onto an auditory map.

Presenting the words via loudspeakers (binaurally) in Experiment 1 yielded a pattern of results almost undistinguishable from that of the dichotic (headphones) presentation.

However, when we asked the participants to perform the same task, but blindfolded (Experiment 2), a significant interaction between sound origin (left or right) and temporal meaning arose, showing that option 3 was right. Interestingly, the congruency effect between manual response location and temporal meaning was stronger when the participants could see compared to when they were blindfolded.

Implications for visuo-spatial attention research

Studies on the orientation of visuo-spatial attention mostly used signals that refer explicitly to spatial locations: peripheral flashes, centrally presented arrows (Corbetta & Shulman, 2002), eye gaze (e.g., Bayliss, di Pellegrino & Tipper, 2004) or direction words like “left” and “right” (Hommel, Pratt, Colzato, & Godijn, 2001; Ho & Spence, 2006).

As far as we know, the only study that demonstrated an orientation of the attention by means of an abstract concept using space as structural donor is that of Fischer, Castel, Dodd, & Pratt (2003), with numbers. In their study, small numbers oriented attention to the left and large numbers to the right, concordant with the mental mapping of numbers onto a left-right horizontal axis, the so-called mental number line (Dehaene, Bossini & Giraux, 1993).

Our study broadens their finding to another conceptual metaphor using space as structural donor: we demonstrated that one of the consequences of the left-right mapping of time is the orientation of attention towards concurrent spatial locations (Ouellet, Santiago, Lupiáñez & Funes, in press).

The fact that both past and future temporal meanings (Chapter II) and numbers (Fisher et al, 2003) can orient visuo-spatial attention suggests the generalization that all abstract concepts having space as source domain might, in principle, orient attention congruently with their spatial mapping.

Our studies also provided information about the mechanism affecting space perception when processing abstract cues, pointing to the same mechanism used for the orientation of attention with typical central cuing paradigms. However, the size of the attentional modulation of space perception was much smaller than it is usually found with typical central cues (e.g., Funes, Lupiáñez & Milliken, 2005).

This quantitative difference could be the result of a mix mechanism between the way to orient attention with typical central and peripheral cues. However, the effect at short SOA was completely absent in our data. Another explanation could be that temporal word cues engage a mechanism of their own with a similar outcome of facilitation, although smaller than that produced by the central cueing mechanism. This possibility, though, does not look cognitively economic. This question remains, therefore, in need of further research.

Implications for Conceptual Metaphor Theory

As stated by Murphy (1996, 1997; see also Casasanto, 2009b), the use of linguistic data alone to support the psychological reality of conceptual metaphors (as Lakoff & Johnson, 1980, 1999, did) is not enough.

The most important claim of Conceptual Metaphor Theory is that abstract concepts are grounded onto more concrete domains (Lakoff & Johnson, 1980, 1999). Here we presented three studies offering experimental behavioral evidence for such claim. Present experiments demonstrated that the abstract domain of time is mapped onto the more concrete domain of space, in particular onto a left-right horizontal axis.

Furthermore, our second study (Chapter III) offered information about the perceptuo-motor activity responsible for the development of this mapping. It seems that the left-right mapping of time is closely linked to our experience with a directional orthographic system and its associated graphical conventions.

One final important point to note for Conceptual Metaphor Theory is that the left-right mapping of time is not attested in any oral language (Radden, 2004). Binding the study of conceptual metaphors to those present in language would have missed the existence of the metaphor studied in this thesis. It would also have missed other conceptual mappings, such as the spatial representation of numbers (Dehaene et al, 1993; Zebian, 2005) or agent-patient relations (Chatterjee, Southwood & Basilico, 1997; Maass & Russo, 2003; Dobel, Diesendruck & Bölte, 2007) onto a left-right horizontal axis.

Finally, the present studies further the psychological specification of Conceptual Metaphor Theory by revealing details about the nature of the attentional mechanisms involved (see discussion above) and the modal characteristics of the activated spatial frames (see below). By doing so, this research effort help pushing the theory toward its conversion into a full-fledged psychological processing model of abstract thought. In the way, Conceptual Metaphor Theory will not only be complemented with important add-ons, but will also need to be revised in some fundamental aspects. We now turn to discussing one of those in more detail: the idea of Flexible Foundations for abstract concepts.

Flexible foundations of abstract thought

Experimental research on conceptual metaphors has highlighted the high degree of cognitive flexibility which characterizes abstract thought. The flexibility is such that it goes clearly further away from what would be expected from the original tenets of Conceptual Metaphor Theory. Under this view, the grounding of an abstract concept onto a concrete domain occurs when a person is faced with recurrent perceptuo-motor experiences that correlate with a particular abstract concept. The greater the correlation, the stronger the conceptual mapping. Once the mapping is established, structure from the concrete domain is imported into the abstract domain, becoming an integral part of the understanding and thought about that domain (Lakoff & Johnson, 1980, 1999; Boroditsky, 2000).

However, these postulates face many challenges. One of them is the speed at which participants learn and start to use a new conceptual mapping when confronted to linguistic expressions reflecting such a new mapping. Boroditsky (2001) and Casasanto (2005), by comparing English native speakers to participants from other cultures who speak differently about time, observed that the latter represented time differently from the former, in concordance with the linguistic expressions being used in their native language. When their English participants were confronted to linguistic expressions that reflect the mappings used in those other cultures, they started very quickly (after a few minutes of experience) to show the use of those mappings. This occurred in the face of a life-long experience of using their own culturally-specific mappings.

Schubert, Waldzus & Giessner (2009) even demonstrated a complete reversal of the CONTROL IS BIG – LACK OF CONTROL IS SMALL conceptual metaphor in a few trials. They used words referring to powerful and powerless social groups (e.g., professor vs. student) and presented them in small or big font. When two thirds of the words were presented in incongruent font size (e.g., professor vs. student) and the participants were told about it, they started to show a facilitation effect for powerful words presented in small font and for powerless words presented in big font after just 48 trials.

Recently, Santiago, Román & Ouellet (submitted) have proposed a model aimed at accounting for the flexible deployment of conceptual metaphors in abstract thought, the Coherent Mental Simulations theory. According to them, the key is in the processing occurring in the mental workplace during task performance. A coherent mental simulation of the current situation will be formed, which will try to combine old information from long term memory with the new information made available by the situation. Moreover, the contents included in the model will have varying activation levels depending on a number of factors, including their relevance for the task and a host of attentional factors. Finally, the included contents will interact among themselves, leading to their integration into a maximally coherent mental simulation.

According to the model, very little, but necessary, practice is needed to learn (storing in long term memory) a mental simulation corresponding to a new conceptual mapping. Once stored in long term memory, this conceptual mapping will be available for future uses and it will strengthen gradually with its frequency of use.

This model can also explains why, in Chapter IV, the participants showed a modulation of temporal meanings by sound origin only when they were blindfolded. When the participants could see, the spatial location of sound was not as relevant as when they could not see due to the fact that vision is better at generating spatial maps of the external world. Being audition less relevant for space perception than vision, the sound origin was not included in the mental space.

But perhaps the more theoretically important consequence of the Santiago et al (submitted) model for Conceptual Metaphor Theory is its view on the directional relation between concrete and abstract concepts. It has been generally assumed that this directionality is asymmetrical, from the concrete to the abstract, because abstract concepts can benefit from the more elaborated structures of concrete concepts, whereas it would make little sense for concrete concepts to be understood in terms of abstract ones (Lakoff & Johnson, 1980, 1999). The predicted result then is that concrete concepts should be able to modulate the processing of abstract concepts, but that abstract concepts cannot interfere in the processing of concrete concepts. Even if some studies seem to support this positioning (e.g., Boroditsky, 2000), recent findings cast doubts on it.

Fitousi & Algom (2006) observed that the directionality of the effect between physical size and number magnitude could be predicted by the relative salience of the dimensions, not by their concreteness. The dimension which was made more salient (number or size) modulated the processing of the less salient dimension.

In the Coherent Mental Simulations theory proposed by Santiago et al (submitted), if the abstract concept is salient enough, it will be able to affect coherence interactions in mental space and, therefore, it will influence the processing of the concrete concept in the experimental task.

This saliency account would explain why we obtained an orientation of visuo-spatial attention in Chapter II. Note that in those experiments, temporal words are processed in first place, and they influence the subsequent processing of spatial cues, an effect that runs from the abstract to the concrete. The temporal word cues were made very salient in that procedure because our participants had to keep them in working memory. This would have produced a highly active representation of temporal meaning in the current mental simulation of the task, which would then interact with concurrent spatial processing in the localization and spatial Stroop tasks.

As we can see, some aspects of the present results cannot be easily explained under standard versions of Conceptual Metaphor Theory, and are better accounted by the Santiago et al (submitted) model. The studies presented in this thesis were not designed to put this model to test, and therefore they cannot be used straigtforwardly to accept or reject it, but they find a comfortable home in it. Future research is necessary to carry out direct tests of the model, which will lead us to a better understanding of how conceptual metaphors work.

Future directions

The study of the electrophysiological correlates of the Space-time conceptual metaphor

One of the main lines of research to continue this work presented in this thesis is the use of neuroimaging and electrophysiological techniques to better understand the nature of the space-time conceptual metaphor and its cerebral correlates. In a pilot ERP study, we tested whether past and future words are able to produce the same evoked potentials than explicit spatial cues such as arrows pointing left of right, or the spatial words "left" or "right". This study would allow us to further understand the similarities and differences between the brain mechanisms associated to the orientation effect produced by temporal words and explicit central spatial cues.

Based on the results obtained in Chapter II of this thesis, we expected to observe electrophysiological evidence of perceptually related facilitation of those stimuli presented at locations congruent with the space-based metaphor. Similar to results found on previous attentional ERP studies with spatial cues (e.g. Harter, Aine & Schroeder, 1982; Mangun & Hillyard, 1988, 1991; Mangun, Hillyard & Luck, 1993; Mangun, Hopfinger, Kussmaul, Fletcher & Heinze, 1997).), we expected to find a larger amplitude on P1 and N1 on contralateral sites to the attended stimulus when attention is oriented through temporal concepts.

Unfortunately, the pilot study did not produce conclusive results, as we failed to obtain a significant congruency effect produced by temporal words, neither behaviorally nor electrophysiologically.

One possible reason for this null effect might be the small number of temporal words used in this experiment. Differently to the experiments included in this thesis, this ERP study only used two words, the word “pasado” and the word “futuro”. We did so in order to improve the number of observations for the same stimulus, which is an important issue in ERP studies. However, Smith and Klein (1990) demonstrated that the repetitive presentation of a word can produce the semantic satiation effect. It is possible that the lack of congruency effect following temporal words might be due to a satiation effect.

In future research we want to run similar ERP studies, but using a larger number of words referring to past and future, in order to avoid semantic satiation effects.

Developmental Study of the space-time conceptual metaphor

A second interesting line of research to continue this thesis is to study the development of the space-time metaphor and its relation with other cognitive processes in children.

First, we would like to run an experiment with children at the age of 4-5 years, which is when most children have not yet learned or automatized reading and writing abilities, but they are old enough to use and understand temporal concepts.

As we described in Chapter III from this thesis, one of the hypothesis about the origins for the left-past/right-future representation is the direction of the reading-writing habits associated to a given culture. If such hypothesis is true, then we shouldn’t find any evidence of the space-time metaphor in this group.

However, one previous study has shown that children at that age seem to have certain spatial representation of time (Tversky, Kugelmass & Winter, 1991). This evidence suggests that the space-time metaphor might depend on other factors apart from the direction of the reading-writing habits, such as the experience with time expressions (e.g., “looking forward”), corporal gestures that we usually do when talking about time (Núñez & Sweetser, 2006), or exposition to graphical conventions such as the flow of vignettes in comic strips. However, the paradigm used by Tversky and colleagues is very different to those used in our studies, given that they used a task that induced the child to go into a reflexive process about time concepts. Consequently, it is possible that the mechanisms used to process temporal concepts under these task conditions differ from those processes (probably more automatic) measured in our studies. For this reason, one of the studies we want to run with this population uses a task adapted to the motivation and comprehension levels of children of that age, but at the same time, able to measure the automatic aspects of the space-time metaphor in order to compare their performance with those found in adults.

A second developmental research line we are interested in is to test whether the acquisition of conceptual metaphors such as the space-time metaphor can help children to better understand abstract concepts inherent to some of the basic subjects at school such as mathematics or physics. More concretely, we would like to run a study to see if there is any relationship between the presence and degree of use of this kind of conceptual metaphor and the performance of children and teenagers in those subjects. This line of research would constitute an interesting application of the basic research about the conceptual metaphor presented in this thesis.

The space-time metaphor and its applications for rehabilitation of the Action Disorganization Syndrome after brain damage

Some brain damaged patients and patients suffering dementia develop important alterations in organizing the sequence of their everyday actions, such as preparing a coffee or teeth brushing, a deficit generally known as Action Disorganization Syndrome (Buxbaum, Schwartz, & Montgomery, 1998; Giovannetti, Libon, Buxbaum, & Schwartz, 2002; Schwartz, Montgomery, Buxbaum, Lee, Carew, Coslett, Ferraro, Fitzpatrick-DeSalme, Hart & Mayer, 1998; Schwartz, Buxbaum, Montgomery, Lee, & Coslett, 1999).

These studies have shown that depending on the lesion size and localization, the error pattern varies. Whereas in some cases patients forget ("jump") some of the steps of the action sequence (omission errors), others present a larger proportion of commission errors, that is, errors in doing the steps in the correct order.

On the other side, as we have discussed in other parts of this thesis, Santiago et al (2008), have demonstrated that the space-time metaphor is present in tasks using everyday event sequences.

Based on that, we think that it would be very interesting to investigate if these patients still have preserved the space-time metaphor. If that were the case, then we could use it as a tool to ameliorate their action disorganization syndrome affecting their everyday activities. More concretely, we will select everyday action sequences and see if the number of omission and commission errors present in these patients can be reduced when the tools involved in them are spatially presented in congruent or incongruent manner in relation with the space-time metaphor. For example, if patients are told to make an orange juice, we can compare their performance on a congruent situation where we present the knife on the left hand side of the table, followed by the oranges, followed by the squeezer machine and finally the glass, which will be on the rightmost location in the table, and compare it with an incongruent situation where we present these objects arranged in the opposite order. If the space-time metaphor can be used by these participants, we could expect a reduction in the number of errors on the congruent arrangement compared with the incongruent one.

If we confirm such hypothesis, this line of research could have important applications for rehabilitation, as people taking care of these patients could be instructed to present the tools implied in problematic everyday activities in the locations congruent with the space-time metaphor.

Chapter VI

Resumen amplio en español

Introducción

Para facilitar la comprensión de los conceptos abstractos, se ha propuesto que las personas nos basamos en dominios más concretos, lo que se conoce como Metáfora Conceptual (Lakoff & Johnson, 1980, 1999). Existe en la literatura numerosa evidencia a favor de que el concepto de tiempo está representado en un eje horizontal de izquierda a derecha, de modo que los conceptos temporales que hacen referencia al pasado estarían representados a la izquierda y los conceptos de futuro a la derecha (Santiago, Lupiáñez, Pérez & Funes, 2007; Santiago, Román, Ouellet, Rodríguez & Pérez-Azor , 2008; Torralbo, Santiago & Lupiáñez, 2006; Weger & Pratt, 2008).

Orientación de la atención espacial inducida por conceptos temporales

No obstante, el efecto de congruencia espacio-temporal obtenido en los estudios de Torralbo et al (2006) y Santiago et al (2007), descritos en la introducción, podría explicarse en base a dos mecanismos diferentes. Por un lado podría ser que el significado temporal de los conceptos de pasado y futuro son capaces de orientar la atención hacia las posiciones izquierda o derecha respectivamente, con las que están conectadas. Alternativamente, es posible que dichos conceptos temporales estén asociados con códigos de respuestas manuales lateralizadas a la izquierda o derecha.

El objetivo principal de los estudios presentados en este capítulo era discriminar entre ambas posibilidades. Para ello, decidimos utilizar un paradigma de uso frecuente en los estudios sobre orientación de la atención espacial: el paradigma de “cueing” o señalización espacial propuesto por Posner y colaboradores (Posner, 1980; Posner & Cohen, 1984; Posner, Nissen & Ogden, 1978). Con este paradigma se ha comprobado que señales espaciales, tales como un flash periférico o una flecha central, facilitan el procesamiento perceptual de los estímulos presentados en el lugar previamente ocupado o indicado por dicha señal. Para ver si las palabras de futuro son capaces de orientar la atención hacia la izquierda y las palabras de pasado hacia la derecha, hemos utilizado un paradigma general que consiste en la sustitución de la señal espacial del paradigma de Posner por la presentación de una palabra de tiempo pasado o futuro. Con este paradigma se puede observar si las palabras de pasado son capaces de facilitar el procesamiento perceptual de un estímulo a la izquierda frente a un estímulo a la derecha, mientras que las palabras de futuro facilitan el procesamiento perceptual de los estímulos presentados a la derecha vs. a la izquierda.

Un estudio reciente (Weger & Pratt, 2008) ha utilizado un paradigma de este tipo para estudiar la representación espacial del tiempo, de modo que en lugar de utilizar una señal espacial, se presentó una palabra de tiempo en el centro de la pantalla. Dos grupos efectuaron un experimento con el mismo diseño, pero con la siguiente diferencia: a un grupo se le pedía localizar el estímulo objetivo tras la señal (que podía aparecer tanto a la izquierda como a la derecha, Experimento 2a); el otro grupo debía detectar este mismo estímulo (Experimento 2b). En la tarea de localización, los participantes tenían que pulsar la tecla izquierda si el estímulo aparecía a la izquierda y la tecla derecha si aparecía a la derecha. Los participantes que ejecutaron esta tarea mostraron un efecto de facilitación (menor tiempo de reacción) en los ensayos pasado-izquierda/futuro-derecha. El problema con esta tarea es que no diferencia entre facilitación motora (activación de los códigos de respuesta) y facilitación a nivel perceptual, y por tanto, no prueba si realmente hubo una orientación atencional. Por esta razón, en el segundo grupo se introdujo una tarea de detección. En la tarea de detección se les pedía a los participantes pulsar siempre la misma tecla con el índice derecho cuando aparecía el estímulo objetivo. Esta tarea permite estudiar los efectos perceptuales de forma independiente, dado que no hay diferencias entre condiciones en el patrón de respuesta. Con este grupo no encontraron efecto de facilitación, lo que les llevó a concluir que el efecto encontrado con las palabras de tiempo se debe sobre todo a un efecto de activación de los códigos de respuesta y no a la orientación de la atención propiamente dicha.

No obstante, nosotros pensamos que el procedimiento experimental que usaron estos autores podría tener varios problemas metodológicos que podrían ser responsables de la falta de facilitación perceptual descrita en dicho estudio. El primer aspecto, que los mismos autores reconocieron, fue el uso de pocas palabras (4 de futuro y 4 de pasado) que se repitieron varias veces. Al repetir varias veces un grupo pequeño de palabras es posible obtener un efecto de saciedad semántica (Smith & Klein, 1990): una pérdida del nivel semántico de las palabras cuando se repiten demasiadas veces. Sin el nivel semántico, no hay señalización posible. El segundo aspecto consiste en el hecho de que las palabras escritas estaban todavía presentes en la pantalla en el momento de aparición del estímulo objetivo. Esto pudo producir una interferencia a nivel perceptual en el procesamiento del estímulo objetivo. El tercer y último punto flojo que consideramos hace referencia al control sobre la elección de los participantes. En el primer experimento, que se hizo con nombres de actores pasados y actuales, tuvieron que eliminar 14 participantes sobre 34 porque los participantes no conocían a estos actores. La explicación que dieron a esta falta de conocimiento era la variabilidad cultural entre participantes. Numerosos estudios, entre ellos el presentado Capítulo 3 de esta tesis demuestran que es muy importante en el estudio de la metáfora conceptual espacio-tiempo el control cuidadoso del origen cultural de los participantes, ya que el efecto de facilitación izquierda-pasado/derecha-futuro se invierte con participantes provenientes de culturas en las cuales se escribe de derecha a izquierda. La ausencia de efecto perceptual obtenida por estos autores podría deberse a cualquiera de estas razones.

En el **Experimento 1** que se describe en este capítulo hemos utilizado el paradigma de señalización espacial (Posner, 1980; Posner & Cohen, 1984; Posner, Niser & Ogden, 1978) con palabras de tiempo como señales, pero incluyendo varias modificaciones con respecto al estudio de Weger & Pratt (2008). Un aspecto importante en nuestro estudio era asegurar que los participantes procesasen las señales temporales. La mera presentación de las palabras no asegura que los participantes las procesen con el nivel de profundidad suficiente. Si los participantes no prestan suficiente atención a las palabras de tiempo, pudiera darse el caso de que no se active su referencia temporal y, por tanto, no se encuentre el efecto de señalización. Para asegurarnos de que esto no sucediera, combinamos la tarea de procesamiento perceptual del estímulo con una tarea de memoria de trabajo, en la que los participantes tenían que memorizar el tiempo pasado vs. futuro indicado por la señal. Más concretamente, los participantes debían memorizar si la palabra que se les presentaba al comienzo de cada ensayo era de pasado o futuro, porque al final del ensayo se les preguntaba. El mantenimiento en memoria de trabajo de una localización espacial ha demostrado ser capaz de orientar la atención, al mejorar el procesamiento visual de los estímulos que aparecen en el lugar congruente con la posición recordada (Awh & Jonides, 2001; véase también Soto, Hodsoll, Rotshtein, & Humphreys, 2008, para un estudio reciente usando un paradigma parecido).

En este experimento se usó una tarea de localización. El principal objetivo era comprobar que con el procesamiento y mantenimiento en la memoria de trabajo de la referencia temporal (pasado o futuro) era posible encontrar el efecto de facilitación hacia la izquierda con las palabras de pasado y hacia la derecha con las palabras de futuro (Weger & Pratt, 2008). Para ello, a continuación de la palabra señal, se presentaba un estímulo en una de dos posiciones, a la izquierda y derecha del punto de fijación, y el participante debía responder indicando el lugar de aparición mediante una presión de tecla con la mano izquierda o derecha. Al final del ensayo, una de las dos preguntas ("¿PASADO?" o "¿FUTURO?") aparecía en el centro de la pantalla y la tarea del participante era responder SÍ o NO según si la referencia temporal de la pregunta era congruente con la referencia temporal de la palabra presentada al principio del ensayo.

A diferencia del estudio de Weger & Pratt (2008), hicimos un control exhaustivo de los participantes, asegurándonos de que eran todos hablantes nativos del mismo idioma, en este caso del castellano.

Para evitar un posible efecto de saciedad semántica (Smith & Klein, 1990), en lugar de utilizar un grupo pequeño de palabras, decidimos utilizar la misma lista de palabra de Torralbo et al. (2006), con 24 palabras referidas al futuro y otras 24 referidas al pasado. De estas palabras, 18 eran verbos conjugados en pasado (pretérito perfecto de indicativo) y en futuro (futuro simple de indicativo) y 12 eran adverbios de tiempo, 6 de futuro y 6 de pasado (p.ej., "antes").

Los resultados obtenidos en el experimento 1 muestran un efecto de facilitación izquierda-pasado/derecha-futuro con esta tarea de localización. Esto sugiere que la referencia temporal es capaz de orientar la atención a lo largo del eje izquierda-derecha, y sesgar el procesamiento en una tarea perceptiva concurrente de localización totalmente no relacionada. No obstante, como el lugar de respuesta coincidía siempre con el lugar del estímulo objetivo, este experimento no permite descartar la posibilidad de que el efecto de facilitación obtenido se debiese únicamente a una activación de los códigos de respuesta izquierda/derecha correspondientes a la referencia temporal de la señal.

Para discriminar claramente entre una facilitación atencional vs. sesgo de respuesta producida por las palabras temporales, realizamos el **Experimento 2,** donde sustituimos la tarea de localización por una tarea de discriminación tipo Stroop espacial, donde los participantes tenían que discriminar la dirección derecha/izquierda hacia la que apuntaba una flecha, presionando la tecla derecha si apuntaba hacia la derecha, y la tecla izquierda si apuntaba hacia la izquierda. La flecha se presentaba en ambas posiciones apuntando en ambas direcciones, lo que permitió cruzar factorialmente el lugar de presentación con el de respuesta. Con esta tarea, la observación de un efecto de facilitación ligado al lugar de presentación de la flecha sería considerado como prueba a favor de que lo que se facilita es el procesamiento perceptual del estímulo objetivo, ya que el lugar de la respuesta correcta podía corresponder o no con el lugar indicado por la señal temporal con igual probabilidad. En cambio, un efecto de facilitación ligado solamente al lugar de respuesta indicaría que el único origen del efecto se encuentra en la activación de códigos de respuesta.

Así, analizamos las interacciones entre la referencia temporal de la señal (pasado/futuro), el lugar del objetivo (izquierda/derecha) y el lugar de respuesta (izquierda/derecha). Los resultados encontrados indicaban que la referencia temporal de la señal facilitó tanto la activación de los códigos de respuesta como la percepción del estímulo objetivo, pero de manera independiente. El hecho de que estos dos efectos de facilitación fuesen independientes es muy importante porque implica que los efectos de facilitación obtenidos en este estudio y probablemente en estudios anteriores (Santiago et al., 2007; Torralbo et al., 2006) no se debían únicamente a una activación de los códigos de respuesta. Los conceptos temporales parecen poder orientar la atención espacial, facilitando el procesamiento perceptual de los objetivos previamente señalados por su referente semántico (pasado-izquierda/futuro-derecha), así como facilitar la activación de respuestas espacialmente congruentes.

¿Qué tipo de atención orientan los conceptos temporales?

Si los conceptos de tiempo producen realmente una orientación de la atención hacia la localización espacial con la que están relacionados metafóricamente, dicha orientación debería de ser de uno de los dos tipos posibles: endógena o exógena. En la literatura sobre atención espacial existe una clara distinción entre dos tipos de señales espaciales, que pueden orientar la atención de manera voluntaria o endógena versus de manera automática o exógena. El primer tipo de señales es de carácter simbólico, es decir que las señales necesitan ser procesadas a nivel semántico. Habitualmente se presentan fovealmente y son predictivas del lugar de aparición del estímulo objetivo, es decir, que el porcentaje de ensayos válidos es mucho más elevado que el porcentaje de ensayos inválidos (pero véase Hommel, Pratt, Colzato, & Godijn 2001, para un estudio de orientación de la atención espacial con señales centrales no predictivas). Suele tratarse de flechas u otras señales simbólicas tales como palabras de dirección (“izquierda”, “derecha”) que hacen referencia a determinadas localizaciones espaciales.

Por otro lado, las señales exógenas son de carácter explícito y aparecen periféricamente en el mismo lugar (ensayo válido) o en el lugar opuesto (ensayo inválido) al lugar de aparición del estímulo objetivo. Suelen ser no predictivas y normalmente consisten en la presentación de un flash en una de las posiciones posibles previamente a la aparición del estímulo objetivo.

Se ha demostrado que ambos tipos de señales son capaces de producir un efecto de facilitación perceptual de aquellos estímulos que aparecen en el lugar previamente señalado. Sin embargo, el efecto producido por cada una de ellas no es exactamente igual (ver Funes, Lupiáñez & Milliken, 2005, para una revisión reciente). Por un lado, tienen un curso temporal diferente, de modo que los efectos con señales endógenas son más tardíos que con señales exógenas (Jonides & Gleitman, 1976; Jonides, 1981; Müller & Rabbit, 1989; Hommel et al., 2001; Frischen & Tipper, 2004). Además, el efecto de facilitación obtenido con las señales exógenas, pero no endógenas, se invierte cuando el intervalo entre la señal y el objetivo se hace más largo. Dicho efecto es conocido como "Inhibición de Retorno" (Posner & Cohen, 1984; Posner, Rafal, Choate, & Vaughan, , 1985).

Es difícil predecir cuál de estos dos mecanismos de orientación atencional endógeno o exógeno, es activado a través de conceptos temporales, porque las palabras, aunque son símbolos que hay que procesar semánticamente (similar a las señales que producen la orientación endógena), no refieren de manera explícita a las direcciones izquierda/derecha. La referencia a dichas direcciones es implícita y se hace mediante procesos automáticos como en el caso de las señales exógenas.

Además, las señales temporales usadas en nuestros experimentos pueden considerarse como señales *híbridas* debido a su presentación central (característica de las señales endógenas) pero no predictiva (como las señales exógenas). Elegimos este tipo de presentación porque no sabíamos exactamente a qué tipo de señal nos enfrentábamos, y no queríamos favorecer un tipo u otro de estrategia para el procesamiento del estímulo objetivo. Por otro lado, se ha comprobado que el efecto de orientación de la atención con señales endógenas, aunque reducido, sigue presente cuando éstas no son predictivas (Hommel et al., 2001).

Los resultados obtenidos en los experimentos 1 y 2 de este capítulo ya ofrecen pistas sobre el tipo de mecanismo atencional utilizado para orientar la atención. En ellos no detectamos Inhibición de Retorno (que suele aparecer con señales exógenas cuando el intervalo temporal entre la señal y el estímulo objetivo, o SOA, es mayor de 300-400ms) aún cuando nuestro SOA fue de 2250 ms, lo que sugiere que el mecanismo de orientación es más parecido al endógeno.

Sin embargo, el paradigma usado en el **Experimento 3** del presente capítulo nos ha permitido poner a prueba más directamente esta cuestión, es decir conocer la naturaleza del mecanismo atencional orientado espacialmente por los conceptos de tiempo. Para estudiar si el curso temporal de los efectos de señalización producidos por los conceptos temporales se asemeja más al producido por señales exógenas o endógenas, introdujimos una manipulación de SOA con dos niveles, un SOA corto de 250 ms. y un SOA largo de 800ms. Una segunda variación de este experimento con respecto a los experimentos 1 y 2 es que reemplazamos la pregunta sobre el tiempo que denotaba la señal al final del ensayo, por una fase de reconocimiento al final del experimento, en la cual los participantes tenían que identificar las palabras presentadas durante el experimento. Esta variación permitiría reducir ruido experimental en nuestro paradigma y reducir la carga de memoria, ya que autores como Han & Kim (2008) han observado que cuando dentro de una tarea se requieren dos respuestas manuales distintas (condición de alta carga de memoria) la precisión de los efectos de señalización disminuye. En tercer lugar en este experimento no se hacía ninguna referencia explícita sobre el aspecto temporal de las palabras.

Los resultados encontrados en este experimento fueron los siguientes. En primer lugar volvimos a encontrar un efecto de facilitación en la discriminación de estímulos a la izquierda precedidos de palabras de pasado y para estímulos a la derecha precedidos de palabras de futuro, lo que indica que las palabras de tiempo pasado y futuro son capaces de orientar la atención hacia la derecha e izquierda respectivamente. Esto ocurre en condiciones en las que el significado temporal de dichas palabras no debe de recordarse ensayo a ensayo, sino que basta codificarlas para su reconocimiento posterior al final del experimento. Sin embargo, y contrario a lo encontrado en el experimento 2 no se encontró facilitación a nivel de respuesta. Basándonos en el trabajo de Torralbo y colaboradores (2006) pensamos que esta falta de modulación a nivel de respuesta puede deberse al hecho de que el marco de referencia espacial ligado a la respuesta fuese menos relevante en esta tarea, ya que los participantes no tenían que responder espacialmente a la señal. Otro resultado importante fue que el efecto de facilitación producido por los conceptos temporales estaba modulado por la variable SOA, de modo que dicho efecto no aparecía en el nivel de SOA corto y sólo se encontró en el nivel de SOA largo. Esto parece indicar aún más claramente, que el tipo de orientación atencional que tiene lugar con este tipo de señales se parece más al tipo de orientación producida por señales centrales normalmente usadas en los estudios de orientación espacial (Funes, Lupiáñez & Milliken, 2005; Corbetta & Shulman, 2002).

Una conclusión adicional que puede derivarse del presente estudio es que pedir a los participantes que procesen la señal en función de su significado temporal tal y como se hace en los Experimentos 1 y 2 no parece ser una condición necesaria para producir el efecto atencional espacial por este tipo de señales, ya que en este experimento no se hizo referencia explícita a este aspecto de las palabras.

Una conclusión que podría derivarse de los resultados del experimento 3 es que las palabras temporales podrían producir efectos de orientación espacial parecidos a los producidos por señales espaciales híbridas, tales como palabras que hacen referencia directa al espacio o flechas, presentadas centralmente pero que no predicen el lugar de aparición del estímulo objetivo (Hommel et al, 2001; and Ho & Spence, 2006). Sin embargo, antes de concluir esto, hay que tener en cuenta que en dichos estudios, las señales espaciales eran totalmente irrelevantes para la tarea, ya que además de no ser predictivas del lugar de aparición de la señal, no se les pedía a los participantes ninguna tarea adicional con ellas. Aun así la mera presentación estas palabras de manera previa al estímulo objetivo, produjo efectos de facilitación significativos. Sin embargo, en el experimento 3 aquí expuesto, las palabras no eran totalmente irrelevantes, ya que los participantes tenían que procesarlas de algún modo, para ser capaces de reconocerlas al final del experimento.

De esta serie experimental podemos concluir que los conceptos temporales son capaces de orientar la atención hacia el lugar al que están metafóricamente ligados (el pasado a la izquierda y el futuro a la derecha), de un modo similar a como lo hacen las señales espaciales. Es importante destacar que tanto en los experimentos realizados en nuestro laboratorio como en los de Weger & Pratt (2008), los participantes no respondieron directamente a las palabras de tiempo (en contraste con estudios como Santiago et al., 2007, y Torralbo et al., 2006), sino a estímulos señalados por ellas. Aún así, la señalización generó un efecto de facilitación en armonía con los resultados encontrados en estudios anteriores donde sí se tenía que responder directamente a las palabras, es decir, unos menores tiempos de reacción cuando el estímulo objetivo aparecía a la izquierda y estaba señalado por una palabra de pasado o cuando aparecía a la derecha y estaba señalado por una palabra de futuro. En su conjunto los resultados obtenidos indican que efectivamente se trata de un efecto de facilitación tanto a nivel de respuesta (Weger & Pratt, 2008; presente capítulo, experimentos 1 y 2) como a nivel perceptual (experimentos 2 y 3), lo que afianza aún más que se trata de un proceso de orientación atencional. Por último los resultados de del experimento 3 nos ha ayudado a conocer qué tipo de atención (automática vs. endógena) orientan este tipo de conceptos. En el Experimento 3 hemos encontrado evidencia de un curso temporal de los efectos de facilitación más congruente con el producido por señales de tipo endógeno, ya que el efecto de facilitación sólo se encontró a un nivel de SOA largo pero no corto.

Estos resultados tienen implicaciones importantes tanto para las teorías sobre orientación de la atención como para las teorías sobre las metáforas conceptuales. Extienden observaciones previas sobre la capacidad de señales no directamente vinculadas al espacio de orientar la atención espacial (véase Fischer, Castel, Dodd, & Pratt, 2003, para un caso de orientación de la atención espacial mediante el uso de números como señales). Además, ponen en duda la necesidad de que las señales sean predictivas para poder orientar la atención de forma endógena. Se necesitará más investigación para saber bajo qué condiciones las señales necesitan ser o no predictivas, pero esta característica no parece ser necesaria al menos en el caso de las señales que tienen un fuerte vínculo con su lugar de referencia (Hommel et al., 2001). Las palabras temporales podrían ser otro caso.

Con respecto a la teoría de la Metáfora Conceptual, esta investigación apoya la noción de que, por los menos para el concepto del tiempo, los conceptos pertenecientes a dominios abstractos están constituidos, al menos en parte, mediante estructura y contenidos importados de dominios concretos (Lakoff & Johnson, 1980, 1999; Johnson 1987; Mandler, 1992). Las evidencias que apoyan la validez de la teoría de la Metáfora Conceptual están en constante aumento (p.ej., Casasanto & Boroditsky, 2008) y parece ser que el dominio del espacio tiene una disposición privilegiada para ser utilizado como dominio fuente (Gentner, Bowdle, Wolff, & Boronat, 2001). No obstante, aún queda mucho camino por andar para comenzar a desentrañar la naturaleza metafórica de los conceptos abstractos y los mecanismos que subyacen a su procesamiento.

Modulación cultural de la metáfora espacio-tiempo

El principal objetivo de este capítulo es analizar los factores que han dado lugar a dicha conceptualización. Más concretamente, pretendemos evaluar si la direccionalidad de los hábitos de lecto-escritura asociados a una cultura (de izquierda a derecha vs. de derecha a izquierda) son responsables del mapping conceptual del concepto del tiempo a través del eje espacial izquierda-derecha, o si por el contrario este mapping se debe a factores universales de tipo perceptual, motórico o cerebral.

Existe evidencia empírica a favor de que los hábitos en la dirección de la lecto-escritura de una determinada cultura pueden influir en la ejecución de diferentes tareas perceptuo-motoras. Por ejemplo, se ha demostrado que los participantes nativos de un sistema ortográfico que va de izquierda a derecha tienen una preferencia mayor por pinturas, retratos y fotografías que están orientadas de izquierda a derecha (Gaffron, 1950; Nachson, Argaman & Luria, 1999; Chokron & De Agostini, 2000), tienen un sesgo hacia la izquierda a la hora de biseccionar líneas (Chokron & De Agostini, 1995), tienden a colocar mayor contenido de sus dibujos en el lado izquierdo del papel (Barrett, Kim, Crucian & Heilman, 2002), suelen colocar el agente de una acción a la izquierda y el paciente a la derecha (Chatterjee, Southwood & Basilico, 1997), o asociar números pequeños a la izquierda y números grandes a la derecha (el llamado efecto SNARC, Dehaene, Bossini & Giraux, 1993). Por el contrario, los participantes nativos de sistemas ortográficos de derecha a izquierda, como el árabe, el persa o el hebreo, presentaban una tendencia hacia el patrón contrario en este tipo de tareas (Dobel, Diesendruck & Bölte, 2007; Maass & Russo, 2003; Zebian, 2005).

Esta clase de sesgos ligados al sentido de la lecto-escritura han sido interpretados como resultado de la dirección habitual o automatizada de escaneo perceptual (lectura) y de las acciones (escritura). Sin embargo existen discrepancias en la literatura, de modo que algunos estudios no han encontrado evidencia de dicho sesgo hacia el sentido de lecto-escritura en algunas de las tareas antes mencionadas (Altmann, Saleem, Kendall, Heilman & González, Rothi, 2006; Barrett et al, 2002). Una posible razón de esta falta de modulación puede ser que algunos grupos incluidos en los estudios, habían estado expuestos a experiencias con tipos de culturas con direccionalidad de la lecto-escritura opuesta. Por ejemplo, los efectos más débiles normalmente encontrados con participantes hebreos pueden ser debidos al hecho de que aunque el sentido de la lecto-escritura es de derecha a izquierda, la escritura de letras aisladas es de izquierda-derecha, así como el sistema numérico y la notación musical. Por último, los hebreos comienzan a tener una alta experiencia con la lengua inglesa desde la infancia (grado siete).

Más directamente relacionado con la metáfora espacio-tiempo, existe cierta evidencia a favor de que el sentido de dicha metáfora no sea universal, sino que se pueda ver modulado con la direccionalidad de los hábitos de lecto-escritura asociados a una cultura (Fuhrman y Boroditsky (2007); Chan & Bergen (2005); Tversky et al, 1991). Por ejemplo, en el estudio de Tversky y colaboradores (1991) se les pedía a participantes ingleses, hebreos y árabes que representasen gráficamente una secuencia diaria (por ejemplo el desayuno, el almuerzo y la cena) colocando tres señales en una pizarra. Los participantes ingleses las colocaron de izquierda a derecha, los árabes de derecha a izquierda y los hebreos en posiciones intermedias.

Un aspecto común de todos estos estudios transculturales es que siempre han usado la misma modalidad, la visión. Este hecho podría suponer un problema, ya que se trata de la misma modalidad implicada en la lecto-escritura. Por otro lado, otro punto problemático de los estudios previos es el uso de tareas que requieren un modo de procesamiento y resolución de problemas altamente consciente, y por tanto muy susceptible de ser controlado por estrategias. Dado que la metáfora conceptual que conecta el concepto tiempo y espacio podría ser altamente automática, estos estudios podrían no ser una medida directa de dicha conexión. Hasta la fecha, el único estudio que ha utilizado una tarea de carácter automático o implícito ha sido el de Fuhrman y Boroditsky (2007). Estos autores presentaban conjuntos de tres fotografías, cada una representando diferentes eventos de una secuencia (temprano, intermedio y tardío). En cada ensayo, a los participantes se les presentaba en primer lugar la fotografía del evento intermedio como punto de referencia, y luego la fotografía referente al evento temprano o futuro. Los autores encontraron que las fotografías de eventos tempranos y tardíos de una secuencia temporal facilitaban respuestas manuales izquierdas y derechas respectivamente en los participantes ingleses, mientras que para los participantes hebreos se encontraba el patrón contrario.

El objetivo del presente estudio es completar la base empírica sobre si los hábitos de lectoescritura de una cultura pueden modular el sentido de la conceptualización del tiempo a través del espacio comparando participantes españoles y hebreos. Para ello hemos diseñado una tarea que intenta mejorar algunos de los aspectos problemáticos de los estudios previos.

Los participantes tenían que decidir (presionando una tecla a la derecha vs. izquierda) si las palabras con referencia de tiempo presentadas auditivamente, al oído izquierdo vs. derecho (con el uso de auriculares), hacían referencia al pasado o al futuro. Se utilizó la misma lista de palabra de Torralbo et al. (2006), con 24 palabras referidas al futuro y otras 24 referidas al pasado. De estas palabras, 18 eran verbos conjugados en pasado (pretérito perfecto de indicativo) y en futuro (futuro simple de indicativo) y 12 eran adverbios de tiempo, 6 de futuro y 6 de pasado (p.ej., “antes”). El procedimiento usado para los grupos de participantes españoles y hebreos era idéntico, con la excepción del lugar de realización del experimento (España vs. Israel) y la lengua en la que se pronunciaron las palabras (castellano vs. hebreo). El experimento tenía dos bloques, que diferían en el mapeo de respuesta derecha vs. izquierda para los juicios de pasado vs. futuro.

En primer lugar nuestra tarea implica procesos altamente automáticos e implícitos, y por tanto libres de sesgos estratégicos. En segundo lugar, hemos introducido un test que mida la metáfora espacio tiempo en otra modalidad distinta a la visión, y por ello presentamos los estímulos de forma auditiva. Esto evitará problemas de interpretación de los resultados en términos de sesgos inducidos por el mismo acto de leer. Una tercera característica que distingue el presente estudio de los estudios previos es que la decisión que los participantes tenían que hacer sobre conceptos temporales era en términos absolutos. Tal y como hicieron Santiago y colaboradores (2007) y Torralbo et al (2006) en estudios con participantes españoles, en este estudio transcultural utilizamos tiempos verbales y adverbios temporales de pasado vs. futuro. Los estudios transculturales previos siempre habían utilizado tareas que implicaban decisiones de carácter relativo entre unos estímulos y otros. En cuarto y último lugar nuestra tarea permite diferenciar entre un efecto de la metáfora espacio-tiempo sobre los procesos perceptivos vs. de respuesta, ya que además de medir el efecto de los conceptos de tiempo sobre las respuestas derecha e izquierda, esta tarea nos permitía medir el efecto de dichas palabras en función de que se presentasen por el oído izquierdo vs. derecho. Todos los estudios transculturales previos sólo han medido la metáfora a nivel de respuesta. Nuestro diseño permite disociar entre estos dos niveles de procesamiento.

Los resultados encontrados eran claros. Los participantes españoles mostraron un efecto de facilitación para responder a palabras de pasado con su mano izquierda y a palabras de futuro con su mano derecha. Este resultado generaliza, en la modalidad auditiva, los estudios previos realizados por Santiago et al. (2007) y Torralbo et al. (2006). De gran interés es el hecho de que los hebreos presentaron el patrón contrario, es decir, eran más rápidos respondiendo a las palabras de pasado con su mano derecha y a las palabras de futuro con su mano izquierda. Este resultado apoya la hipótesis de que la representación espacial del tiempo a lo largo de un eje horizontal izquierda-derecha está ligado a la dirección habitual de lectura y escritura. Es importante resaltar que con esta tarea los participantes no tenían que leer las palabras ya que todos los estímulos, incluso las instrucciones, se presentaban auditivamente, lo cual descarta la posibilidad de que el sesgo espacial haya sido inducido por la acción en la dirección de la lectura, que podría estar sesgando los resultados de estudios anteriores.

Sin embargo y en sintonía con estudios anteriores, el efecto de congruencia derecha-futuro, izquierda-pasado encontrado con los hebreos era mucho más débil que el patrón opuesto encontrado con los españoles (ej., Tversky et al, 1991). Tal y como hemos descrito previamente, esto puede deberse al hecho de que el sistema de escritura hebreo no es enteramente de derecha a izquierda, además de que todos los hebreos incluidos en el estudio habían aprendido en la escuela el sistema ortográfico inglés que va en la dirección contraria. Sin embargo este no era el caso de los participantes españoles, que ninguno tenía experiencia previa con un lenguaje con dirección de lecto-escritura de derecha a izquierda.

El segundo resultado importante encontrado en este estudio es que con esta tarea auditiva no hemos obtenido un efecto de facilitación a nivel perceptual, sólo a nivel de respuesta, lo cual contrasta con estudios previos dentro de la modalidad visual donde se encontró facilitación en ambos niveles (Santiago et al., 2007; Torralbo et al, 2006). Una posible explicación a este hecho sería que para localizar un sonido se requiere una computación más compleja, lo cual suele llevar a efectos nulos en tareas espaciales (Spence & Driver, 1994). Sin embargo, esta explicación no parece aplicarse en este estudio, dado que hemos encontrado un efecto de compatibilidad espacial entre la localización del target y la localización de la respuesta (el conocido efecto Simon, Simon & Rudell, 1967). Otra posibilidad es que la facilitación perceptual producida por palabras temporales es dependiente de la modalidad visual. Sin embargo nuestra hipótesis es que la presentación derecha o izquierda de los estímulos auditivos no puede contrarrestar el mapping del tiempo en un marco de referencia espacial visual cuando el participante puede ver. Consistente con esta hipótesis, el estudio que presentamos en el Capítulo IV demuestra que cuando los participantes realizan la tarea con los ojos tapados se encuentra facilitación espacial de los conceptos temporales también a nivel perceptual.

Para concluir, nos podemos preguntar ¿cual es la razón por la que la dirección habitual de lecto-escritura es capaz de sesgar cómo el tiempo está organizado en la línea mental izquierda-derecha? Santiago, Román y Ouellet (en revisión) sugieren un posible mecanismo. A partir de la teoría de modelos mentales para razonamiento abstracto, la gente construiría modelos mentales para comprender y pensar sobre el mundo que les rodea. Estos modelos buscan la máxima coherencia interna. Cuando los modelos mentales se construyen a partir de la lectura de textos dentro de una ortografía de izquierda a derecha, las entidades son mencionadas literalmente de izquierda a derecha. Una estrategia que puede ayudar a construir un modelo mental con máxima coherencia para esa situación es colocar sus referentes de izquierda a derecha en el espacio mental. Debido a constricciones pragmáticas, los eventos que ocurren antes en el tiempo son mencionados antes en los textos (Levinson, 1983), lo que significa que se escriben más a la izquierda. Como resultado de esta estrategia, las personas desarrollarían el hábito de colocar los eventos que ocurren antes en el espacio mental izquierdo seguido de los eventos que ocurren después, que se colocarían en el espacio mental derecho.

Este mecanismo podría ser responsable a su vez de otros efectos descritos antes, como el efecto SNARC (Dehaene et al, 1993), o la tendencia a dibujar los agentes de las acciones a la izquierda y los pacientes a la derecha como describen Chatterjee y colaboradores (1997). Por supuesto tanto la estructura mental del tiempo como la de los agentes-pacientes de las acciones, se invierte cuando la escritura va de derecha a izquierda.

¿Es la percepción espacial del tiempo específica de la modalidad visual?

En el capítulo anterior hemos encontrado que tanto el mapping izquierda-pasado y derecha futuro para los lectores de sistemas ortográficos de izquierda a derecha, como el mapping contrario para lectores de sistemas ortográficos de derecha a izquierda, se puede observar también cuando las palabras son presentadas a través de una nueva modalidad, la audición. Sin embargo y al contrario de lo que se ha encontrado en estudios con las palabras presentadas por la modalidad visual (Torralbo et al, 2006, exp. 2; Santiago et al., 2007), el significado de las palabras presentadas auditivamente solo interactuaba con el lugar de la respuesta, pero no con el lugar del estímulo (Capítulo III).

El objetivo del presente capítulo es profundizar en las causas de esta diferencia entre ambas modalidades.

Una posible razón de esta discrepancia es que la presentación dicótica (a través de un solo oído con auriculares) haya producido información suficiente para modular la activación de la respuesta manual congruente, pero no suficiente para crear un mapa topográfico del tiempo a nivel perceptual. Para probar esto en el experimento 1 utilizaremos altavoces en comparación a auriculares, que sí permiten la audición biaural. Por otro lado es posible que dicha falta de modulación a nivel perceptual se deba a que los participantes seguían teniendo información visual disponible mientras escuchaban el sonido. La capacidad de visión ha podido inducir un mapping del tiempo con un marco de referencia visuo-espacial en lugar de audio-espacial. Para comprobar esto en el experimento 2 los participantes realizan la tarea con los ojos cerrados. Por último es posible que la falta de dicho efecto se deba a que la modulación del tiempo a través del espacio es específica de la modalidad visual y nunca se pueda obtener a través de la audición. Si esto es así, esperaríamos encontrar una ausencia de interacción entre el lugar del sonido y los conceptos de tiempo en ambos experimentos.

El Experimento 1 fue diseñado para probar la primera hipótesis citada arriba. El procedimiento y diseño de este experimento era idéntico al usado en el experimento del Capítulo III, pero con una importante diferencia: En lugar de usar auriculares, usamos altavoces situados a izquierda vs. derecha del participante, para asegurarnos la percepción biaural de las palabras.

En este experimento hemos replicado los hallazgos anteriores, de modo que los participantes eran más rápidos respondiendo con su mano izquierda a palabras de pasado y su mano derecha a palabras de futuro. Además, volvimos a encontrar una interacción nula entre el lugar del sonido y significado de las palabras de tiempo. Es decir, aunque el sonido fue correctamente localizado por los participantes, esto no fue suficiente para modular el acceso semántico de las palabras de pasado y futuro, al contrario de lo observado en la modalidad visual. Por tanto la hipótesis interaural puede ser rechazada.

En el experimento 2 hemos investigado si la falta de modulación de las palabras de tiempo a nivel perceptual a través de la audición se debe al hecho de que los participantes seguían teniendo información visual disponible mientras escuchaban el sonido. La capacidad de visión ha podido inducir un mapping del tiempo con un marco de referencia visuo-espacial en lugar de audio-espacial.

Para probar esta hipótesis en este experimento los participantes realizaron la misma tarea que los participantes del experimento anterior pero en esta ocasión los participantes tenían los ojos cerrados a lo largo de todo el experimento. Con esta manipulación se pretendía evitar la creación de un mapa de referencia visuo-espacial, y por tanto inducir un único mapa de referencia audio-espacial.

Los resultados de este experimento fueron claros. En primer lugar volvimos a replicar los resultados del Capítulo III con participantes con el castellano de primera lengua, es decir los participantes mostraron el patrón de facilitación izquierda-pasado/derecha-futuro a nivel de código de respuesta. En segundo lugar también encontramos la misma facilitación pero esta vez también a nivel perceptual. Es decir, una facilitación para las palabras de pasado presentadas por el altavoz izquierdo y para las palabras de futuro presentadas por el altavoz derecho,

Los hallazgos de estos dos experimentos demuestran por un lado, que la incapacidad de obtener un efecto de congruencia entre el significado de las palabras temporales y el lugar de los estímulos cuando se presentan auditivamente no se debe a que los sonidos se perciben por un oído cada vez. La presentación auditiva biauralmente a través de altavoces llevó a los mismos resultados que cuando se presentaban monoauralmente.

Por otro lado los resultados del Experimento 2 demuestran que los efectos de congruencia entre el lugar de presentación de los estímulos y el significado temporal de las palabras normalmente observado con estímulos presentados visualmente (Torralbo et al, 2006, exp. 2; Santiago et al, 2007) no es específico de la modalidad visual. El simple hecho de no poder ver es capaz de causar la aparición de dicho efecto con palabras presentadas en la modalidad auditiva.

¿A qué se debe este hecho? Una posibilidad es que la presencia de efecto de congruencia tanto a nivel de respuesta como a nivel perceptual en el experimento 2 cuando los participantes tenían los ojos cerrados y la ausencia del segundo efecto cuando tenían los ojos abiertos se deba a lo que se conoce como efecto de Ventrilocuismo (Bertelson, 1998). Este efecto consiste en una trasladación del origen del sonido hacia un punto de referencia visual. En nuestro caso, dado que en la pantalla se presentaba visualmente un punto de fijación en el centro de la pantalla que se podía procesar en la condición de ojos abiertos (Experimento 1), dicho efecto de trasladación podría haber limitado el procesamiento lateralizado del origen del sonido.

Sin embargo existe evidencia proveniente de otros estudios que van en contra de dicha explicación. Bertelson y colaboradores han demostrado que la atención visual hacia un punto no es suficiente para que se produzca este fenómeno de trasladación del sonido (Bertelson, Vroomen, De Gelder & Driver 2000; Vroomen, Bertelson & De Gelder, 2001); hace falta que se den otras condiciones tales como la sincronía entre onset del sonido y la señal visual (Bertelson & Aschersleben, 1998; Choe, Welch, Gilford, & Juola, 1975; Radeau & Bertelson, 1987), o la cercanía entre las dos señales, la visual y la auditiva (Bertelson & Radeau, 1981; Choe et al., 1975). Sin embargo en nuestro estudio no se daban estas circunstancias. Por un lado había una asincronía temporal de 250 ms entre la aparición del punto de fijación y la palabra presentada auditivamente. Por otro lado los altavoces estaban a un metro de distancia de la pantalla de ordenador. Por último, es difícil afirmar que el punto de fijación visual está produciendo un efecto de traslocación del sonido cuando hemos encontrado una interacción significativa entre el lugar de la respuesta y el lugar del sonido (efecto Simon, Simon & Rudell, 1967) tanto en el experimento 1 como en Capítulo III.

Una explicación alternativa es que cuando los participantes tienen los ojos abiertos realizan el mapping espacial de los conceptos temporales en coordenadas visuo-espaciales en lugar de coordenadas auditivo-espaciales.

Esta interpretación está basada en otros estudios que demuestran que a la hora de localizar el origen de un sonido, utilizamos la visión para hacer la calibración final de dicha localización (Lewald, 2007). Es decir, se crea un mapa completamente auditivo cuando la visión está limitada pero se crea un mapa híbrido (visual y auditivo) cuando la visión está presente. Por otro lado se ha demostrado que la visión es mucho más potente que la audición en tareas de localización en humanos (Middlebrooks & Green, 1999).

Basándonos en estas conclusiones proponemos que el mapeo espacial del tiempo se hace a nivel visual cuando el mapa perceptual es híbrido (cuando los ojos están abiertos), mientras que se hace exclusivamente a nivel auditivo cuando el mapa perceptual espacial es completamente auditivo (cuando los ojos están cerrados).

Esta explicación es congruente con otros efectos que ocurren entre la modalidad de la visión y el olfato, o entre la visión y el tacto, donde la visión ha demostrado ser la modalidad dominante capaz de modular la información proveniente de otras modalidades (Charpentier, 1891; Morrot, Brochet & Dubourdieu, 2001).

Finalmente, otro efecto importante encontrado en nuestro estudio es el hecho de que hay un mayor efecto de congruencia entre las palabras de pasado y futuro para las respuestas izquierda y derecha respectivamente cuando las personas tenían los ojos abiertos (Experimento 1) que cuando los tenían cerrados (Experimento 2). Esto sugiere que la programación motora de las respuestas se beneficia de la información visual. También sugiere que los efectos de congruencia entre respuestas manuales y conceptos temporales (Fuhrman & Boroditsky, 2007; Santiago et al, 2007; Torralbo et al, 2006) no es completamente de naturaleza motora.

Direcciones futuras

Estudio de los correlatos electrofisiológicos de la metáfora conceptual Espacio-Tiempo

Una de las líneas principales de continuación de esta tesis, es la de estudiar los correlatos cerebrales de la metáfora conceptual del tiempo. Utilizando la técnica de registro electrofisiológico en la corteza cerebral, queremos comprobar si las palabras de pasado y futuro son capaces de producir los mismos potenciales evocados que las señales espaciales que indican izquierda vs. derecha de manera explícita cuando orientan la atención hacia dichos lugares. Basándonos en los resultados encontrados en el Capítulo II de esta tesis, queremos encontrar evidencia electrofisiológica de facilitación perceptual de los estímulos presentados a la izquierda señalados por conceptos que hacen referencia al pasado y facilitación perceptual de los estímulos presentados a la derecha cuando están precedidos por palabras que denotan futuro. Al igual que los resultados obtenidos en estudios realizados con señales espaciales (ej. Harter et al, 1982; Mangun & Hillyard, 1988, 1991; Mangun et al., 1997, 1993), esperamos encontrar una mayor amplitud en P1 y N1 en localizaciones contralaterales a la localización de los estímulos atendidos cuando se usan señales temporales.

Para realizar este proyecto ya contamos con un primer estudio, pero desgraciadamente los resultados no han sido concluyentes, ya que a diferencia de los estudios comportamentales anteriores, no hemos encontrado efecto atencional ni a nivel comportamental ni electrofisiológico. Una posible razón de esta falta de efecto puede deberse a que en dicho experimento, en vez de utilizar un set de múltiples palabras, utilizamos solo dos palabras, una con referencia al pasado y otra al futuro (ayer y mañana, respectivamente) para incrementar el número de respuestas a un mismo estimulo y así facilitar los análisis posteriores. Sin embargo, tal y como hemos descrito en otras secciones de esta tesis, Smith & Klein (1990) demostraron que una palabra repetida demasiadas veces produce el fenómeno de saciación semántica: una debilitación del acceso a la semántica de la palabra por haber sido repetidas demasiadas veces.

Por ello, nuestro objetivo es realizar un segundo experimento de potenciales evocados, volviendo al paradigma original donde se presentan diferentes palabras (48 adverbios de tiempo y verbos: 24 de pasado y 24 de futuro), tal y como hicimos en nuestros estudios comportamentales. Esperamos que con esta modificación experimental encontremos resultados concluyentes.

Estudio evolutivo de la metáfora conceptual

Un segundo proyecto interesante que surge a raíz de los resultados obtenidos en esta tesis es realizar un estudio con niños de 4-5 años que todavía no han automatizado los procesos de lecto-escritura, pero que ya comienzan a comprender los conceptos de pasado y futuro. Tal y como se concluye de los estudios citados y realizados en el Capítulo III de esta tesis, uno de los orígenes de la representación izquierda-pasado/derecha-futuro viene de los hábitos de lectoescritura asociados a una determinada cultura. Si está hipótesis es cierta, no se debería de encontrar ningún efecto de espacialización del tiempo con esta población. Sin embargo, un estudio previo apunta a que los niños de edad preescolar sí parecen tener ya una cierta representación espacial del tiempo (Tversky, Kugelmass & Winter, 1991), lo que apunta a que el origen de dicha metáfora no depende sólo de la dirección del hábito de lecto-escritura, sino de otros aspectos también asociados a la cultura como las expresiones de tiempo con conexiones a aspectos espaciales (ej. "Tenemos que mirar hacia adelante, hacia nuestro futuro.") o los gestos corporales que realizamos cuando hablamos sobre el tiempo (Núñez & Sweetser, 2006). Sin embargo, el paradigma utilizado en el estudio de Tversky y colaboradores es muy diferente a los usados para estudiar este tema en nuestra tesis, ya que se trataba de una tarea que incitaba a un proceso reflexivo por parte del niño y es posible que en dichas condiciones, los mecanismos utilizados para organizar los conceptos temporales no sean los mismos que los usados en los estudios con adultos. Por esta razón, creemos que es muy importante realizar estudios con esta población pero con el uso de tareas que aunque adecuadas al nivel de comprensión y motivación de los niños de esta edad, midan mejor el carácter automático de la metáfora espacio-tiempo, y permitan una comparación directa entre los resultados obtenidos con niños y con los adultos de nuestro estudio.

Aplicación de la metáfora espacio-tiempo en el estudio del Síndrome de Disejecución de la Acción tras daño cerebral

Diferentes poblaciones de pacientes que han sufrido una lesión cerebral presentan graves alteraciones en la secuencia de acciones de sus actividades de la vida diaria tales como prepararse un café o lavarse los dientes. Dependiendo del lugar de la lesión, el patrón de errores varía (Buxbaum, Schwartz, & Montgomery, 1998; Giovannetti, Libon, Buxbaum, & Schwartz, 2002; Schwartz 2006; Schwartz et al., 1998, 1999). En algunos casos los pacientes olvidan ("se saltan") algunos pasos de la secuencia, mientras que en otros casos cometen errores en el orden de secuenciación, lo que también se conoce como apraxia ideacional.

Por otro lado un estudio reciente realizado en nuestro laboratorio con personas sanas (Santiago et al, 2009), demuestra que la metáfora espacio-tiempo está presente en tareas más ecológicas. En este estudio, Santiago y colaboradores presentaron fotografías de secuencias de acciones ordenadas, por ejemplo un hombre preparando el coche para un viaje o preparando una comida. Una vez vistas todas las fotografías los participantes deben responder bien con su mano izquierda o bien con la derecha si una fotografía concreta ha ocurrido antes o después de un punto temporal de referencia. Los resultados demuestran que los participantes son más rápidos en responder con su mano izquierda a aquellas fotografías de pasos anteriores al punto de referencia y con su mano derecha a fotografías posteriores al punto de referencia que cuando el "mapping" de respuesta era el contrario. Además este efecto seguía un patrón gradual, de modo que los efectos eran mayores para fotografías más alejadas temporalmente del punto de referencia

Basándonos en este estudio, creemos que sería interesante investigar si pacientes con alteraciones cerebrales que afectan a la secuenciación de sus acciones tienen preservada la metáfora espacio-tiempo. En el caso de que así sea, haremos un estudio con actividades de la vida diaria reales, para ver si los errores de omisión y comisión que presentan estos pacientes pueden reducirse cuando los útiles necesarios para realizarlas están dispuestos de modo espacialmente congruente con la metáfora conceptual espacio-tiempo en comparación a cuando son presentados en posición incongruente. Por ejemplo, ante la acción de hacer un zumo de naranja podemos manipular el lugar de presentación de los distintos útiles en el eje horizontal. En el orden de presentación congruente colocaríamos el cuchillo en el extremo izquierdo, seguido de las naranjas, seguido del exprimidor y finalmente seguido del vaso que quedaría en el extremo derecho. En la condición incongruente este orden estaría invertido. Si la metáfora conceptual espacio-tiempo puede ser usada por estos pacientes esperaríamos encontrar una reducción de los errores de omisión y secuencia cuando el "mapping" es congruente en comparación a cuando es incongruente. Si esta hipótesis se cumple, esto pudiera tener importantes repercusiones de cara a la rehabilitación, ya que se podría entrenar a los cuidadores a presentar los útiles implicados en una actividad de la vida diaria determinada en el sentido congruente con la metáfora conceptual espacio-tiempo de manera sistemática.

References

Alais, D., & Burr, D. (2004). The ventriloquist effect results from near-optimal bimodal integration. *Current Biology, 14*, 257-262.

Altmann, L.J.P., Saleem, A., Kendall D., Heilman K. M., Gonzalez Rothi, L.J. (2006). Orthographic directionality and thematic role illustration in English and Arabic. *Brain and Language, 97*, 306–316.

Awh, E., & Jonides, J. (2001). Overlapping mechanisms of attention and spatial working memory. *Trends in Cognitive Sciences, 5*, 119–126.

Barrett, A., Kim, M., Crucian, G.P., & Heilman, K.M. (2002). Spatial bias: effects of early reading direction on Korean subjects. *Neuropsychologia, 40*, 1003–1012.

Barsalou, L.W. (1999). Perceptual symbol systems. *Behavioral and Brain Sciences, 22*, 577-609.

Bayliss, A. P., di Pellegrino, G., & Tipper, S. P. (2004). Orienting of attention via observed eye-gaze is head-centred. *Cognition 94*, B1-B10.

Bertelson, P. (1998). Starting from the ventriloquist: The perception of multimodal events. In M. Sabourin, F. I. M. Craik, & M. Robert (Eds.), *Advances in psychological science: Vol. 1. Biological and cognitive aspects* (pp. 419-439). Hove, U.K.: Psychology Press.

Bertelson, P., & Aschersleben, G. (1998). Automatic visual bias of perceived auditory location. *Psychonomic Bulletin & Review, 5*, 482-489.

Bertelson, P., & Radeau, M. (1981). Cross-modal bias and perceptual fusion with auditory-visual spatial discordance. *Perception & Psychophysics, 29*, 578-584.

Bertelson, P., Vroomen, J., De Gelder, B., & Driver, J. (2000).The ventriloquist effect does not depend on the direction of deliberate visual attention. *Perception & Psychophys, 62*, 321-332.

Bock, J. K. (1982). Toward a cognitive psychology of syntax: Information processing contributions to sentence formulation. *Psychological Review, 89*, 1-47.

Boroditsky, L. (2000). Metaphoric structuring: Understanding time through spatial metaphors. *Cognition, 75*, 1-28.

Boroditsky, L. (2001). Does language shape thought? English and Mandarin speakers' conceptions of time. *Cognitive Psychology, 43*, 1-22.

Boroditsky, L. (2008). Do English and Mandarin speakers think differently about time? In B. C. Love, K. McRae, & V. M. Sloutsky (Eds.), *Proceedings of the 30th Annual Conference of the Cognitive Science Society* (pp. 427-431). Austin, TX: Cognitive Science Society.

Boroditsky, L. & Ramscar, M. (2002). The roles of body and mind in abstract thought. *Psychological Science, 13*, 185-189.

Braine, L. G. (1968). Asymmetries of pattern perception observed in Israelis. *Neuropsychologia, 6*, 73–88.

Briand, K. A., Larrison, A. L., & Sereno A. B. (2000). Inhibition of return in manual and saccadic response systems. *Perception & Psychophysics, 62*, 1512-1524.

Buxbaum, L. J., Schwartz, M. F., & Montgomery, M. W. (1998). Ideational apraxia and naturalistic action. *Cognitive Neuropsychology, 15*, 617– 643.

Carlson, L.A. (1999). Selecting a reference frame. *Spatial Cognition and Computation, 1*, 365-379.

Casasanto, D. (2005). *Perceptual foundations of abstract thought*. Doctoral dissertation, MIT, Cambridge.

Casasanto, D. (2008). Similarity and Proximity: When does close in space mean close in mind? *Memory & Cognition, 36,* 1047-1056.

Casasanto, D. (2009a). Embodiment of Abstract Concepts: Good and bad in right- and left-handers. *Journal of Experimental Psychology: General.* DOI:10.1037/a0015854.

Casasanto, D. (2009b). When is a Linguistic Metaphor a Conceptual Metaphor? In V. Evans & S. Pourcel (Eds.), 127-145, *New Directions in Cognitive Linguistics*. Amsterdam: John Benjamins.

Casasanto, D., & Boroditsky, L. (2008). Time in the Mind: Using space to think about time. *Cognition, 106,* 579-593.

Casasanto, D., Boroditsky, L., Phillips, W., Greene, J., Goswami, S., Bocanegra-Thiel, S., Santiago-Diaz, I., Fotokopoulu, O., Pita, R., & Gil, D. (2004). How deep are effects of language on thought? Time estimation in speakers of English, Indonesian, Greek, and Spanish. In K. D. Forbus, D. Gentner, T. Regier (Eds.), *Proceedings of the 26th Annual Conference Cognitive Science Society* (pp. 186-191). Mahwah, NJ: Lawrence Erlbaum.

Chan, T.-T., & Bergen, B. (2005). Writing direction influences spatial cognition. In B. Bara, L. Barsalou & M. Bucciarelli (Eds.), *Proceedings of the 27th Annual Conference of the Cognitive Science Society* (pp. 412-417). Mahwah, NJ: Lawrence Erlbaum.

Charpentier, A. (1891). Analyse expérimentale: De quelques éléments de la sensation de poids. [Experimental analysis: On some of the elements of sensations of weight]. *Archives de Physiologie Normale et Pathologique, 3*, 122-135.

Chatterjee, A., Southwood, M. H. & Basilico, D. (1997). Verbs, events and spatial representations. *Neuropsychologia, 26*, 284-391.

Chen, J. Y. (2007). Do Chinese and English speakers think about time differently? Failure of replicating Boroditsky (2001). *Cognition, 104*, 427-436.

Choe, C. S., Welch, R. B., Gilford, R. M., & Juola, J. F. (1975). The “ventriloquist effect”: Visual dominance or response bias? *Perception & Psychophysics, 18*, 55-60.

Chokron, S., & De Agostini, M. (1995). Reading habits and line bisection: a developmental approach. *Cognitive Brain Research, 3*, 51–58.

Chokron, S., & De Agostini, M. (2000). Reading habits influence aesthetic preference. *Cognitive Brain Research, 10*, 45–49.

Clark, H.H. (1973). Space, time, semantics and the child. In: T. E. Moore (Ed.), *Cognitive development and the acquisition of language* (pp. 27–63). New York: Academic Press.

Corbetta, M., & Shulman, G. L. (2002) Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience, 3*, 201–215.

Crawford, L. E., Margolies, S. M., Drake, J. T., & Murphy, M. E. (2006). Affect biases memory of location: Evidence for the spatial representation of affect. *Cognition and Emotion, 20*, 1153-1163.

Dehaene, S., Bossini, S., & Giraux, P. (1993). The mental representation of parity and number magnitude. *Journal of Experimental Psychology: General, 122*, 371-396.

Dobel, C., Diesendruck, G. & Bölte, J. (2007). How writing system and age influence spatial representations of actions. *Psychological Science, 18*, 487-491.

Emmorey, K. (2001). Space on hand: The exploitation of signing space to illustrate abstract thought. In: M. Gattis (Ed.), *Spatial Schemas and Abstract Thought*. Cambridge, MA: MIT Press.

Fias, W., & Fischer, M. H. (2005). Spatial Representation of Numbers. In J.I.D. Campbell (ed.), *Handbook of Mathematical Cognition* (pp. 43-54). Hove: Psychology Press.

Fischer, M. H., Castel, A. D., Dodd, M. D., & Pratt, J. (2003). Perceiving numbers causes spatial shifts of attention. *Nature Neuroscience, 6*, 555-556.

Fitousi, D., & Algom, D. (2006). Size congruity effects with two-digit numbers: Expanding the number line? *Memory & Cognition, 34*, 445-457.

Frischen, A., & Tipper, S. P. (2004). Orienting attention via observed gaze shifts evokes longer-term inhibitory effects: Implications for social interactions, attention and memory. *Journal of Experimental Psychology: General, 133*, 516-533.

Fuhrman, O., & Boroditsky, L. (2007). Mental time-lines follow writing direction: comparing English and Hebrew speakers. In D. S. McNamara & J. G. Trafton (Eds.), *Proceedings of the 29th Annual Conference of the Cognitive Science Society* (pp. 1007-1001). Austin, TX: Cognitive Science Society.

Funes, M. J., Lupiáñez, J., & Milliken, B, (2005). The role of spatial attention and other processes on the magnitude and time course of cueing effects. *Cognitive Processing, 6*, 98-116.

Gaffron, M. (1950). Right and left in pictures. *Art Quarterly, 13*, 312-331.

Gentner, D., Bowdle, B., Wolff, P., & Boronat, C. (2001). Metaphor is like analogy. In D. Gentner, K. Holyoak and B.N. Kokinov (Eds.), *The analogical mind: Perspectives from cognitive science* (pp. 199-253). Cambridge, MA: MIT Press.

Gentner, D., Imai, M., & Boroditsky, L. (2002). As time goes by: Evidence for two systems in processing space-time metaphors. *Language and Cognitive Processes, 17*, 537-565.

Gevers, W., Reynvoet, B., & Fias, W. (2003). The mental representation of ordinal sequences is spatially organized. *Cognition, 87*, B87-B95.

Gevers, W., Reynvoet, B., & Fias, W. (2004). The mental representation of ordinal sequences is spatially organized: Evidence from days of the week. *Cortex, 40*, 171-172.

Giovannetti, T., Libon, D. J., Buxbaum, L. J., & Schwartz, M. F. (2002). Naturalistic action impairments in dementia. *Neuropsychologia, 40*, 1220–1232.

Glenberg, A. M., & Kaschak, M. P. (2002). Grounding language in action. *Psychonomic Bulletin & Review, 9*, 558-565.

Han, S. W., & Kim, M. S. (2008). Spatial working memory load impairs signal enhancement, but not attentional orienting. *Attention, Perception & Psychophysics, 70*, 916-923.

Harnad, S. (1990). The symbol grounding problem. *Physica D, 42*, 335-346.

Harter, R. M., Aine, C., & Schroeder, C. (1982). Hemispheric differences in the neural processing of stimulus location and type: Effects of selective attention on visual evoked potentials. Neuropsychologia, 20,

421–438.

Haspelmath, M. (1997). *From space to time: Temporal adverbials in the world's languages.* Newcastly, UK: Lincom Europa.

Ho, C., & Spence, C. (2006). Verbal interface design: Do verbal directional cues automatically orient visual spatial attention? Computers in Human Behavior, 22, 733-748.

Hommel, B., Pratt, J., Colzato, L., & Godijn, R. (2001). Symbolic control of visual attention. *Psychological Science, 12*, 360-365.

Ishihara, M., Keller, P. E., Rossetti, Y., & Prinz, W. (2008). Horizontal spatial representations of time: evidence for the STEARC effect. *Cortex, 44*, 454-461.

Ito, Y. & Hatta, T. (2004). Spatial structure of quantitative representation of numbers: Evidence from the SNARC effect. *Memory & Cognition, 32*, 662-673.

January, D. & Kako, E. (2007). Re-evaluating evidence for the linguistic relativity hypothesis: response to Boroditsky (2001). *Cognition, 104*, 417-426.

Johnson, M. (1987). *The Body in the Mind.* Chicago: University of Chicago Press.

Jonides, J. (1981). Voluntary versus automatic control over the mind's eye's movement. In J. Long & A. Baddeley (Eds.), *Attention and performance IX* (pp. 187–203). Hillsdale, NJ: Erlbaum.

Jonides, J., & Gleitman, H. (1976). The benefit of categorization in visual search: Target location without identification. *Perception and Psychophysics, 20,* 289-298.

Joseph, R. A., Giesler, R. B., & Silvera, D. H. (1994). Judgment by Quantity. *Journal of Experimental Psychology: General, 123*, 21-32.

Khatoon, S., Briand, K. A., & Sereno A. B. (2002). The role of response in spatial attention: direct versus indirect stimulus–response mappings. *Vision Research, 42,* 2693-2708.

Lakoff, G., & Johnson, M. (1980). *Metaphors we live by.* Chicago: University of Chicago Press.

Lakoff, G., & Johnson, M. (1999). *Philosophy in the flesh: The embodied mind and its challenge to Western thought.* New York: Basic Books.

Levine, R. (1997). *A geography of time*. New York, NY: Basic Books.

Levinson, S. (1983) *Pragmatics.* Cambridge, UK: Cambridge University Press.

Lewald, J. (2007). More accurate sound localization induced by short-term light deprivation. *Neuropsychologia, 45*, 1215-1222.

Lieblich, A., Ninio A., & Kugelmass (1975). Developmental trends in directionality in drawing in Jewish and Arab Israeli children. *Journal of Cross Cultural Psychology, 6*, 504-511.

Mangun, G. R., & Hillyard, S.A. (1988). Spatial gradients of visual attention: Behavioral and electrophysiological evidence. *Electroencephalography and Clinical Neurophysiology, 70*, 417-428.

Mangun, G. R., Hillyard, S. A., & Luck, S. J. (1993). Electrocortical substrates of visual selective attention. In D. Meyer and S. Kornblum (Eds.), *Attention and Performance XIV*. (pp. 219-243). Cambridge, MA: MIT Press.

Mangun, G. R., Hopfinger, J., Kussmaul, C., Fletcher, E., & Heinze H. J. (1997). Covariations in PET and ERP measures of spatial selective attention in human extrastriate visual cortex. *Human Brain Mapping, 5*, 273-279.

Mass A., & Russo, A. (2003). Directional bias in the mental representation of spatial events: Nature or culture? *Psychological Science, 14*, 296-301.

McGlone, M. S., & Harding, J. L. (1998). Back (or forward?) to the future: The role of perspective in temporal language comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 24*, 1211-1223.

McNeill, D. (1992). *Hand and mind: What gestures reveal about thought*. Chicago: University of Chicago Press.

McNeill, D. (2000) Introduction. In D. McNeill (ed.), *Language and gesture*, pp. 1-10. Cambridge: Cambridge University Press.

McNeill, D. (2005). *Gesture and thought*. Chicago: University of Chicago Press.

Meier, B. P., & Robinson, M. D. (2004). Why the sunny side is up: Associations between affect and vertical position. *Psychological Science, 15*, 243-247.

Meier, B. P., & Robinson, M. D. (2006). Does “feeling down” mean seeing down?: Depressive symptoms and vertical selective attention. *Journal of Research in Personality, 40*, 451-461.

Meier, B., Robinson, M., & Clore, G. (2004). Why good guys wear white: Automatic inferences about stimulus valence based on color. *Psychological Science, 15*, 84-87.

Meier, B. P., Robinson, M. D., Crawford, L. E., & Ahlvers, W. J. (2007). When 'light' and 'dark' thoughts become light and dark responses: Affect biases brightness judgments. *Emotion, 7*, 366-376.

Middlebrooks, J. C., & Green, D. M. (1991). Sound localization by human listeners. *Annual Review of Psychology, 42*, 135-159.

Moeller, S. K., Robinson, M. D., & Zabelina, D. L. (2008). Personality dominance and preferential use of the vertical dimension of space: Evidence from spatial attention paradigms. *Psychological Science, 19*, 355-361.

Morrot, G., Brochet, F. y Dubourdieu, D. (2001). The color of odors. *Brain and Language*, 79, 309-320.

Müller, H. J., & Rabbitt, P. M. A. (1989). Reflexive and voluntary orienting of visual attention: Time course of activation and resistance to interruption. *Journal of Experimental Psychology: Human Perception and Performance, 15*, 315-330.

Murphy, G. (1996). On metaphoric representation. *Cognition, 60*, 173-204.

Murphy, G. (1997). Reasons to doubt the present evidence for metaphoric representation. *Cognition, 62*, 99-108.

Nachson, I. (1981). Cross-cultural differences in directionality. *International Journal of Psychology, 16*, 199-211.

Nachson, I. (1983). Directional preferences in bilingual children. *Perceptual and Motor Skills, 56*, 747-750.

Nachson, I., Argaman, E. & Luria, A. (1999). Effects of directional habits and handedness on aesthetic preference for left and right profiles. *Journal of Cross-Cultural Psychology, 30*, 106-114.

Nemire, K. & Bridgeman, B. (1987). Oculomotor and skeletal motor systems share one map of visual space. *Vision Research 27,* 393-400.

Nuerk, H. C., Wood, G., & Willmes, K. (2005). The universal SNARC effect: the association between number magnitude and space is amodal. *Experimental psychology, 52*, 187-194.

Núñez, R., & Sweetser, E. (2006). With the Future Behind Them: Convergent Evidence From Aymara Language and Gesture in the Crosslinguistic Comparison of Spatial Construals of Time. *Cognitive Science, 30*, 1–49.

Ouellet, M., Santiago, J., Funes, M.J. & Lupiáñez, J. (in press). Thinking about the future moves attention to the right.

Ouellet, M., Santiago, J., Israeli, Z., & Gabay, S. (in press). Is the future the right time? Experimental psychology.

Ouellet, M., Santiago, J. & Román, A. (in preparation). Is the perception of time modality specific?

Pollmann, S., & Maertens, M. (2005). Shift of activity from attention to motor-related brain areas during visual learning. *Nature Neuroscience, 8*, 1494-1496.

Palmer, A. R., & Grothe, B. (2005). Interaural Time Difference Processing. In Syka, J., & Merzenich, M. M. (eds). *Plasticity and Signal Representation in the Auditory System.* New York, NY: Springer Science + Business Media, Inc.

Posner, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology, 32*, 3-25.

Posner, M. I., & Cohen, Y. (1984). Components of visual orienting. In H. Bouma & D. Bowhuis (Eds.), *Attention and performance X* (pp. 531– 556). Hillsdale, NJ: Erlbaum.

Posner, M. I., Nissen, M., & Ogden, W. (1978). Attended and unattended processing modes: The role of set for spatial location. In H. L. Pick & E. Saltzman (Eds.), *Modes of perceiving and processing information* (pp. 128–181). Hillsdale, NJ: Erlbaum.

Posner, M. I., Rafal, R. D., Choate, L. S., & Vaughan, J. (1985). Inhibition of return: Neural basis and function. *Cognitive Neuropsychology, 2*, 211–228.

Pulvermüller, F. (2001). Brain reflections of words and their meaning. *Trends in Cognitive Sciences, 5*, 517-524.

Radden, G. (2004). *The metaphor TIME AS SPACE across languages.* In: Baumgarten, N. et al. (eds). *Uebersetzen, interkulturelle Kommunikation, Spracherwerb und Sprachvermittlung - das Leben mit mehreren sprachen: Festschrift fuer Juliane House zum 60. Geburtstag.* Bochum: Aks-verlag.

Radeau, M. (1985). Signal intensity, task context, and auditory-visual interaction. *Perception, 14*, 571-577.

Radeau, M., & Bertelson, P. (1987). Auditory-visual interaction and the timing of inputs: Thomas (1941) revisited. *Psychological Research, 49*, 17-22.

Rhodes, G. (1987). Auditory attention and the representation of spatial information. *Perception and Psychophysics, 42*, 1-14.

Santiago, J., Lupiáñez, J., Pérez, E., & Funes, M. J. (2007). Time (also) flies from left to right. *Psychonomic Bulletin & Review, 14*, 512-516.

Santiago, J., Román, A., & Ouellet, M. (submitted) Flexible foundations of abstract thought: A review and a theory.

Santiago, J., Román, A., Ouellet, M., Rodríguez, N., & Pérez-Azor, P. (2008). In hindsight, life flows from left to right. *Psychological Research.* DOI 10.1007/s00426-008-0220-0

Schneider, W., Eschman, A., & Zuccolotto, A. (2002). *E-Prime User's Guide.* Pittsburg: Psychology Software Tools Inc.

Schubert, T. W. (2005). Your highness: Vertical positions as perceptual symbols of power. *Journal of Personality and Social Psychology, 89*, 1-21.

Schubert, T. W., Waldzus, S. & Giessner, S. R. (2009). Control over the association of power and size. *Social Cognition, 27*, 1-19.

Schwartz, M. F., Buxbaum, L. J., Montgomery, M. W., Lee, S. S., & Coslett, H. B. (1999). Naturalistic action production following right hemisphere stroke. *Neuropsychologia, 37*, 51–56.

Schwartz, M. F., Montgomery, M. W., Buxbaum, L. J., Lee, S. S., Carew, T. G., Coslett, H. B., Ferraro, M., Fitzpatrick-DeSalme, E. J., Hart, T., & Mayer, N. (1998). Naturalistic action impairment in closed head injury. *Neuropsychology, 12*, 13–28.

Searle, J. (1980). Minds, Brains, and Programs. *Behavioral and Brain Sciences, 3*, 417-424.

Simon, J. R. & Rudell, A. P. (1967). Auditory S-R compatibility: The effect of an irrelevant cue on information processing. *Journal of Applied Psychology, 51*, 300-304.

Smith, L., & Klein, R. (1990). Evidence of semantic satiation: Repeating a category slows subsequent semantic processing. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 16*, 852-861.

Soto, D., Hodsoll, J., Rotshtein, P., & Humphreys, G. W. (2008). Automatic guidance of attention from working memory. *Trends in Cognitive Sciences, 12*, 342-348.

Spalek, T. M., & Hammad, S. (2005). The left-to-right bias in inhibition of return is due to the direction of reading. *Psychological Science, 16*, 15-18.

Spence, C. J. & Driver, J. (1994). Covert spatial orienting in audition: exogenous and endogenous mechanisms. *Journal of Experimental Psychology: Human, Perception and Performance, 20*, 555-574.

Torralbo, A., Santiago, J., & Lupiáñez, J. (2006). Flexible conceptual projection of time onto spatial frames of reference. *Cognitive Science, 30*, 745-757.

Turing, A. (1950). Computing Machinery and Intelligence. *Mind*, 59, 433-460.

Tversky, B., Kugelmass, S., & Winter, A. (1991) Cross-cultural and developmental trends in graphic productions. *Cognitive Psychology, 23,* 515-557.

Vroomen, J., Bertelson, P. & De Gelder, B. (2001). The ventriloquist effect does not depend on the direction of automatic visual attention. *Perception & Psychophysics, 63*, 651-659.

Weger, U., & Pratt, J. (2008). Time flies like an arrow: Space-time compatibility effects suggest the use of a mental time-line. *Psychonomic Bulletin & Review.15,* 426-430.

Welch, R. B., & Warren, D. H. (1980). Immediate perceptual response to intersensory discrepancy. *Psychological Bulletin, 3*, 638-667.

Zebian, S. (2005). Linkages between Number Concepts, Spatial Thinking, and Directionality of Writing: The SNARC Effect and the REVERSE SNARC Effect in English and Arabic Monoliterates, Biliterates, and Illiterate Arabic Speakers. *Journal of Cognition and Culture*, 5, 165-190.

Appendix

Experimental materials

Past

ayer (yesterday) אתמול

anteriormente (previously) מקודם

antes (before) לפני

antiguamente (formerly) בעבר

recientemente (recently) לאחרונה

anteayer (before yesterday) שלשום

apareció (he showed up) הופיע

buscasteis (you-plural looked for) חיפשתם

condujeron (they drove) נהגו

creyó (he believed) האמין

decidisteis (you-plural decided) החלטתם

dijo (he said) אמר

fue (he went) הלך

habló (he spoke) צעק (he shouted)

hizo (he made) עשה

miró (he looked at) ראה

pensaron (they thought) חשבו

preguntó (he asked) שאל

probasteis (you-plural tried) ניסיתם

pudimos (we were able to) יכולנו

quisimos (we wanted) רצינו

trabajó (he worked) עבד

tuvimos (we had) רכשנו (we bought)

vio (he saw) התבונן

Future

mañana (tomorrow) מחר

posteriormente (subsequently) מאוחר (late)

después (after) אחרי

inmediatamente (immediately) מיד

próximamente (soon) בקרוב

enseguida (next) בהמשך

apareceremos (we will show up) נופיע

buscaremos (we will look for) נחפש

conduciremos (we will drive) ננהג

creerá (he will believe) יאמין

decidiréis (you-plural will decide) תחליטו

dirá (he will say) יגיד

irá (he will go) ילך

hablarán (they will speak) יאמרו

hará (he will make) יעשה

miraremos (we will look at) נסתכל

pensarán (they will think) יחשבו

preguntará (he will ask) ישאל

probaréis (you-plural will try) תנסו

podremos (we will be able to) נוכל

querremos (we will want) נירצה

trabajará (he will work) יעבוד

tendremos (we will have) נרכוש (we will buy)

verá (he will see) יראה