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Double Dissociations in the Processing of Conceptual Relations

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SUMMARY

Background: The aim of the present paper is to analyze if taxonomic and thematic conceptual relations are processed primarily in the linguistic system, in the simulation system or in both. Because the verbal modality is the best way to access the linguistic system and the pictorial modality is the best way to access the simulation system (Barsalou, 1999), we studied these processes through verbal and pictorial tasks.

Material/ Methods: We studied a group of 60 patients with focal brain lesions to explore the presence of double dissociation, based on the assumption that such patients will reveal the existence of independent processes according to conceptual relation type and the modality in which information is presented (verbal vs. pictorial).

Results: The results reveal the presence of double dissociations in the processing of thematic relations, but not in taxonomic relations. This suggests that there may be two ways to store relations of this type: through the co-occurrence of words in language or through the joint representation of both objects in a contextual representation.

Conclusions: The thematic relations may be primordially stored within one of the two systems (linguistic and simulation) or both. Taxonomic relations, on the other hand, are principally processed in the simulation system.Keywords: Thematic Relations – Taxonomic Relations – Stroke – Conceptual Knowledge.

Key words: mental structure, naming disorders, semantic representations, taxonomic and thematic conceptual relations

The concepts stored in our cognitive system are linked to each other by different types of relations. Two of these types – thematic and taxonomic – play a fundamental role.

Taxonomic relations are those that link concepts of the same semantic category. They can be classified in: supraordinate, which link a concept with the corresponding semantic category (dog-animal); subordinate, which link a concept with a specific exemplar (dog-poodle); and coordinate, which link concepts of the same level of specificity within a semantic category (dog-cat) (Lin & Murphy, 2001). Objects in the same taxonomic category usually share a generic name (eg., animals) and have similar properties that may or may not be perceptible (eg., encyclopedic). Since the components of these types of relations share common traits, the links are principally established through mechanisms that detect similarities; in other words, the degree of similarity between two components is determined via a comparison of their properties (Estes, Golonka & Jones, 2011). This type of relation makes it possible to organize a category's concepts, as well as to anticipate, via deductive inferences, the properties that a new exemplar of the category would have.

Thematic relations, on the other hand, are defined as complementary relations between objects, persons or events that interact or co-occur in time and space (Lin & Murphy, 2001). They are topological and contextual in nature; they exist between objects that are not necessarily of the same taxonomic category, but that can be found in the same context. Thus, thematic relations imply contiguous temporal-spatial relationships between experience, stimuli, sensations and actions. This type of relation makes it possible to organize experiences contextually, and, as regularly redundant phenomena occur, they help us make predictions in the face of similar future situations through the mechanism of inductive inference through patterns completion. When a stimulus is perceived, this mechanism activates simulators and contexts in which this stimulus is usually present, making it possible to anticipate the elements that might appear together with the stimulus (see Barsalou, 2003).

The scientific literature lacks consensus as to the way both types of conceptual relations are stored and processed. Some authors consider them as independent processes. For instance, Kalénine, Peyrin, Pichat and Segebarth (2009) proposed that taxonomic relations are based on perceptual similarities, while thematic relations should activate viso-motor regions devoted to the processing of actions and space. Meanwhile, Semenza, Bisiachi and Romani (1992) proposed that there exist two different components relying conceptual relations, one devoted to training categories (taxonomic categorization), and strongly related to naming, and another related to semantic situational information (thematic categorization). However, others consider that both types of relations are interdependent and that thematic relations can influence similarity judgments underlying taxonomic relations (Gentner & Bremm, 1999; Golonka & Estes, 2009).

The language and simulation theory proposed by Barsalou, Santos, Simmons & Wilson (2008) serves as an interesting theoretical starting point to integrate the processing of conceptual relations into a larger model of cognition. This model suggests that there are two principal systems that intervene in conceptual processing: the linguistic system and the simulation system. The former contains mainly linguistic forms. When a quick response is required, responses from the linguistic system dominate. Meanwhile, the simulation system includes simulations, which are modal states captured by the brain during perception, action and introspection. When there is more time to respond, the subject's attention is focused on evaluating the simulations (Barsalou *et al*., 2008). Barsalou and colleagues obtain evidence to test this claims using property generation and word association tasks, where they observed that linguistic responses appeared in the first place, then taxonomic responses and finally object-situation responses (related to physical properties of the objet, its components and the scene in which they appear) (Santos, Chaigneau, Simmons, & Barsalou, 2011). Meanwhile, these authors propose that the verbal modality is the best way to access the linguistic system, while the pictorial modality is the best way to access the simulation system (Barsalou, 1999). Furthermore, this model assumes that when a situation is experienced repeatedly, multimodal knowledge accrues in the respective simulators for the relevant people, objects, actions, introspections and settings. Thus it constitutes a situated conceptualization. This is why Barsalou proposes that conceptualization is always situated, or contextualized.

According to this model, thematic associations originate more frequently in the simulation system (Barsalou *et al*., 2008). Objects that appear repeatedly in certain common situations tend to be represented together in the same simulator; for example, a boat and an anchor. However, thematic relations can also originate in the linguistic system. That is to say that co-occurring lexical items are stores at the word-form (Moss et al., 1995). For example, people can frequently hear the phrase "close the window´s curtains" besides actually perceiving a window and a curtain. Therefore, we can learn thematic relations in both ways: by binding together both elements in a simulator, or by hearing both words frequently together.

On the other hand, taxonomic relations between coordinate concepts can occur as situational associations in simulations (for example, a dog chasing a cat) and they are generally viewed as residing on the conceptual system (Smith 1978; Murphy 2002). Objects of the same semantic category (coordinates) that usually share the same scenarios are probably represented together in situated simulations. Besides, a taxonomic relation can result from an evaluation of common properties (eg. similarity judgments) between both concepts (both have tails, legs, hair and ears). Objects of the same taxonomic category often share common properties. These properties are represented in the simulator; therefore to establish taxonomic relations between coordinate elements, people must access the simulation system. In accordance with this claims taxonomic relations would be accessed more directly through pictorial tasks than through verbal tasks (Lin & Murphy, 2001).

It is important to note that a stimulus pair, such as dog and cat, can have both taxonomic and thematic conceptual relation types. For this reason, Golonka and Estes (2009) suggest that thematic relations affect similarity judgments by stressing similarities and decreasing differences. It is essential to consider this when assessing conceptual relations.

As can be seen, there is not enough evidence to determine if thematic and taxonomic relations are processed in the linguistic system, in the simulations system or in both of them. The aim of this study is to increase our understanding of the processing of taxonomic and thematic conceptual relations by the linguistic and simulation systems. This study examines taxonomic relations between coordinated elements exclusively. The objective is to analyze whether taxonomic as well as thematic relations are processed primarily in the linguistic system, in the simulation system or in both. We hypothesize that thematic relations are processed independently by both systems depending on the familiarity with the concepts involved. Familiar thematic relations are most probably learned through direct experience (hence coded in the simulation system), while not familiar thematic relations are probably learned through verbal exposure to the corresponding linguistic associations. Meanwhile, coordinated taxonomic relations would be primarily processed by the simulation system, because they are established according to the share correlated properties of the exemplars (Simmons & Barsalou, 2003). To determine this, we studied a group of patients with focal brain lesions for the purpose of exploring the presence of a double dissociation, based on the assumption that such a dissociation will reveal the existence of independent processes according to conceptual relation type and the modality in which information is presented (verbal vs. pictorial).

METHODOLOGY

Subjects: The sample was comprised of 90 participants in two groups: the first group consisted of 60 stroke patients and the second group served as a control group, consisting of 30 participants with ages, education and socioeconomic levels matched with those of the stroke patients in the first group. All participants were native Spanish speakers and right-handed. The complete data about the brain lesions of the patients can be seen in Appendix 1. The sample was recruited from two hospitals in the City of Mar del Plata: Hospital Privado de Comunidad and Hospital Interzonal General de Agudos Oscar Alende. Both the research protocol and the informed consent form were approved by the ethics commission of the Comité Institucional de Revisión de Estudios de Investigación (the research review committee) of Hospital Privado de Comunidad. This research was completed in accordance with the Helsinki Declaration. We assessed patients in the subacute phase of their illness, a month after their release from the hospital, as has been done in prior studies that assessed cognitive functions following a stroke (for example, Rasquin, Verhey, Lousberg, Winkens & Lodder, 2002). The one-month time period is used because symptoms are still clearly present and deficit compensatory mechanisms that might interfere with the interpretation of performance have not yet been developed. It is generally accepted that once the lesion occurs, deficit compensatory mechanisms functionally reorganize to make up for the damaged brain area (Basso & Pizzamiglio, 1999; Voytek, *et al*., 2010).

The inclusion criteria for patients were as follows: 1) must have suffered a stroke diagnosed by a neurologist (transient ischemic attack (TIA) and cerebellar stroke victims were not included); 2) must not present alterations in temporal-spatial orientation; 3) must not be on artificial respiration; 4) must not have a previous diagnosis of dementia or cognitive deficit show up in the clinical history, in the interview with a family member and in the information obtained via the Informant Interview; 5) must not have a demonstrable clinical history of another neurological or psychiatric illness; 6) must score less than 5 and less than 3 in the anxiety and depression subscales respectively of the Goldberg Anxiety and Depression Scale (Spanish-language version by Montón *et al*., 1993); 7) must not present a severe comprehension deficit; and 8) must voluntarily accept informed consent to participate in the study. The exclusion criteria were: 1) had a previous stroke; 2) have clinical manifestations consistent with prior dementia or cognitive deterioration according to clinical history or family member interview; and 3) show a general deterioration that makes a neuropsychological assessment impossible (failure to understand simple orders, etc.).

Additionally, we assessed a group of people without a neurological or cognitive impairment. Participants in this group were recruited externally through an intentional sample. Of the 35 participants assessed, 5 were excluded due to scoring less than 27 points in the mini-mental state examination. Participants in this group met the following criteria: 1) scored higher than 26 points on an Argentine version of the MMSE (Butman *et al*., 2001); 2) scored less than 5 and less than 3 in the anxiety and depression subscales respectively of the Goldberg Anxiety and Depression Scale (Spanish-language version by Montón *et al*., 1993); did not have a prior history of neurological, psychiatric and/or neuropsychological illness; 4) did not have a prior history of alcoholism or other toxic dependency; and 5) were not undergoing treatment with anti-depressants or anxiolytics at the time.

Table 1 shows the socio-demographic data for the stroke patients and the cognitively healthy control group.

Table 1. Socio-demographic data by group

	Age	Education level	Gender
Stroke patients	73.96 (SD 11.083)	61% elementary 28% high school 7% higher education/university	32%F/58%M
Control group	70.04 (SD 15.428)	65% elementary 26% high school 8,7% higher education/university	59%F/41%M

F: female; M: male; SD: standard deviation

Instruments: Following a neurological consultation, participants were assessed to ensure a minimal level of verbal comprehension, the ability to recognize the stimuli the tests consist of (absence of visual agnosia), the presence of anxiety or depression and the type of aphasia. The following tests were applied for these purposes: the Goldberg Anxiety and Depression Scale (Spanish-language version by Montón *et al*., 1993); abbreviated version of the Informant Interview (Morales, González-Montalvo, Bermejo & Del Ser, 1995); the comprehension-of-verbal-material subtest of the Barcelona Test battery (Peña-Casanova, 2005); the Brief Aphasia Assessment (Vigliecca et al., 2011); the word-picture matching subtest of the Battery for Semantic Memory Deterioration in Alzheimer´s disease (known by the Spanish acronym EMSDA) (Peraita, González, Sánchez & Galeote, 2000); and the naming subtest of the EMSDA (Peraita *et al*. 2000).

Afterwards, a series of tasks were administered to specifically assess conceptual relations. The four tasks are equivalent in terms of stimuli, instructions and difficulty (both have ceiling effect in healthy control subjects). They feature a triadic comparison format that requires a forced-choice response (meaning there is only one correct response). The following four tasks were administered to assess both types of conceptual relations – taxonomic and thematic – in two modalities – pictorial and verbal:

Pyramids and Pharaohs Test, verbal version (P&P-VERBAL). An abbreviated adaptation of the Pyramids and Palm Trees Test (Howard & Patterson, 1992) by Argentine researchers Martinez-Cuitiño and Barreiro (2010). The test assesses a subject's ability to recognize thematic relations. The test is a matching-to-sample task, where two words are presented below a third and the subject must decide which of the two words below is associated with the word above. The test consists of 19 items. It was administered using the Presentation 10.1 software package (Neurobehavioral Systems, http://www.neurobs.com/). The Argentine version of the test has a specificity of 98.8% and a sensitivity of 85% in the detection of individuals with semantic difficulties.

Pyramids and Pharaohs Test, pictorial version (P&P-PICTORIAL). The pictorial version of the above-mentioned task.

Taxonomic Relations Task, verbal version (TAXON-VERBAL). This task was designed to fulfill the need for a taxonomic relations task equivalent to Pyramids and Pharaohs. The test is a matching-to-sample task just like Pyramids and Pharaohs. Triads were composed by selecting a series of pictorial stimuli from the Cycowicz, Friedman, Rothstein and Snodgrass (1997) database, assuring a medium to high degree of familiarity. The corresponding words were selected according to the name agreement for the Argentine population, extracted from Argentine norms for experimental pictures (Manoiloff, Artstein, Canavoso, Fernández and Segui, 2010). Distractor types were selected based on the task model used by Semenza and his team to assess this same construct in patients with aphasia (Semenza *et al.,* 1992). Triads were composed of words or drawings belonging to the same semantic category, but with different degrees of association. To estimate associations, pairs of stimuli were composed and a panel of judges (20 psychology students and 10 psychologists) was asked to estimate the degree of association using a 7-point Likert scale. Following the judging, pairs with a very high or very low median of estimated association and high inter-judge consistency (low variability) were selected for use in the study. In this fashion, triads were composed by semantic category with an element of very high association and another of very low association with the target. We also avoided strong thematic relations between word pairs (for example, cow and pig have a thematic relation because both are farm animals), given that it has been demonstrated that this can reinforce the estimation of similarity (Golonka & Estes, 2009). Further, we adjusted the presentation for the items so as to assure that verbal and pictorial presentations were similar and that words were unambiguous. The task's validity was pilot tested with 15 adult subjects with medium to high education levels and without neurological disorders. We analyzed the functionality of both the items and the instructions. Additionally, we consulted a group of experts (psychologists and linguists) to evaluate the validity of the content, keeping only those items that the majority of experts agreed upon. In the end, the final version of the task consisted of 18 items, giving us the approximated number of items of the Pyramids and Pharaohs Test and the Taxonomic Relations Task. There were selected 3 items for each semantic category (animals, fruits/vegetables, clothing, furniture, transport, tools). Figure 1 shows an example of a Taxonomic Relations Task item in both its verbal and pictorial versions.

Subjects were instructed to indicate which of the two items below is most closely associated with the item above. These instructions are the same as those used for the Argentine version of the Pyramids and Pharaohs Test. The Taxonomic Relations Task was administered using the Presentation 10.1 software package (Neurobehavioral Systems, http://www.neurobs.com/). Appendix 2 lists the stimuli used.

Taxonomic Relations Task, pictorial version (TAXON-PICTORIAL). The pictorial version of the above-mentioned task using black and white line drawings from the Cycowicz database.

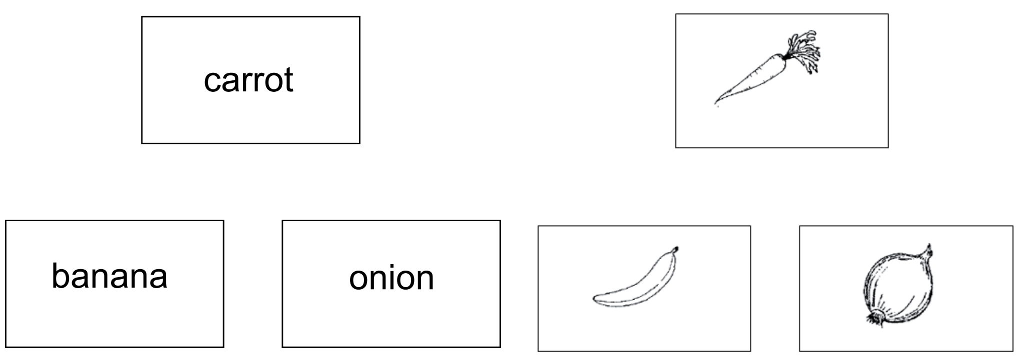

Figure 1. Verbal and pictorial versions of an example item from the Taxonomic Relations Task

Procedures: Patients were assessed the month after being released from the hospital. The interview took place following an assessment by a neurologist. After obtaining informed consent, each patient was assessed individually. The administration of the instruments required two separate sessions of approximately 30 minutes each.

The control group was selected via an intentional sample to mirror the sociodemographic characteristics of the patient group. After obtaining informed consent and verifying that the inclusion criteria were met, the instruments were administered in two separate sessions of approximately 30 minutes each.

Statistical analysis: Each subject was inspected individually for double dissociations as defined by Shallice (1988). This process is frequently used in the field of neuropsychology (Davies, 2010; Jones, 1983; Vallar, 1999) and consists of detecting subjects with opposite performance patterns, such that subject or group A fails in task 1 but not in task 2, and subject or group B fails in task 2 but not in task 1. This method makes it possible to establish the relative independence of the processes that underlie each task. First of all, z scores were calculated for all the patients based on mean and standard deviation of healthy control group's performance. After that, the difference between the pair of triadic comparison tests was calculated for each subject based on standardized scores. These values were compared with the mean differences between tasks of the control group using a Student's t test, given that the data present a normal distribution according to the Kolmogorov-Smirnov´s test (Z=1,273; p=.078). Based on the significance value obtained, we kept those subjects with *p* values less than 0.01 and who had, in one of the tasks, z scores within the 95% confidence interval around the 0 mean (which is to say, between +2 and -2) and a score of at least 2 standard deviations below the mean in the other. The 95% significance criterion was used because it is the value commonly used in neuropsychology (Damasio *et al*., 2004; Kemmerer, Rudrauf, Manzel & Tranel, 2012).

RESULTS

Observing each subject's performance, we explored the presence of double dissociations between patients in taxonomic and thematic relations tasks depending on the modality (verbal or pictorial). Based on the results of the t test, we selected those participants with significant differences of 1% between verbal and pictorial task scores. Double dissociations were not found between verbal and pictorial TAXON. Only three patients were found to present significantly greater difficulties when the task was presented in a verbal modality as opposed to a pictorial modality. Patients EN ($p<0.01$), MPR ($p<0.01$) and ASI ($p<0.001$) present a significant difference in performance in these two tests; they performed better in TAXON-PICTORIAL than in TAXON-VERBAL. The results are depicted in Figure 2.

On the other hand, when comparing the Pyramids and Pharaohs tasks, five patients were found to present significantly inferior performance in P&P-PICTO-

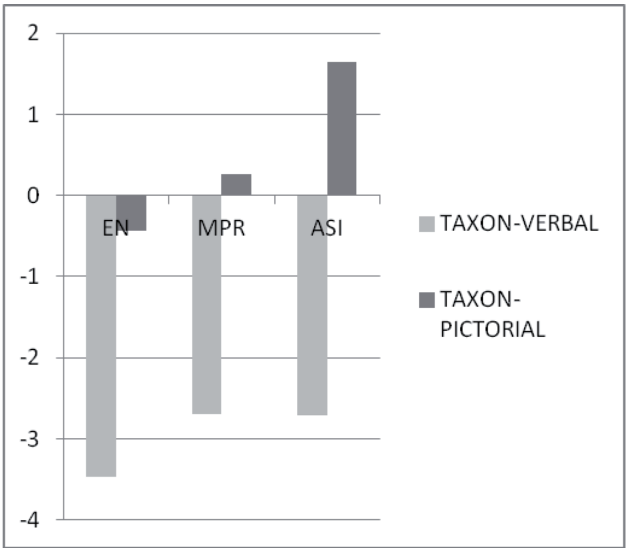

Figure 2. Patients with simple dissociation between TAXON-PICTORIAL and TAXON-VERBAL

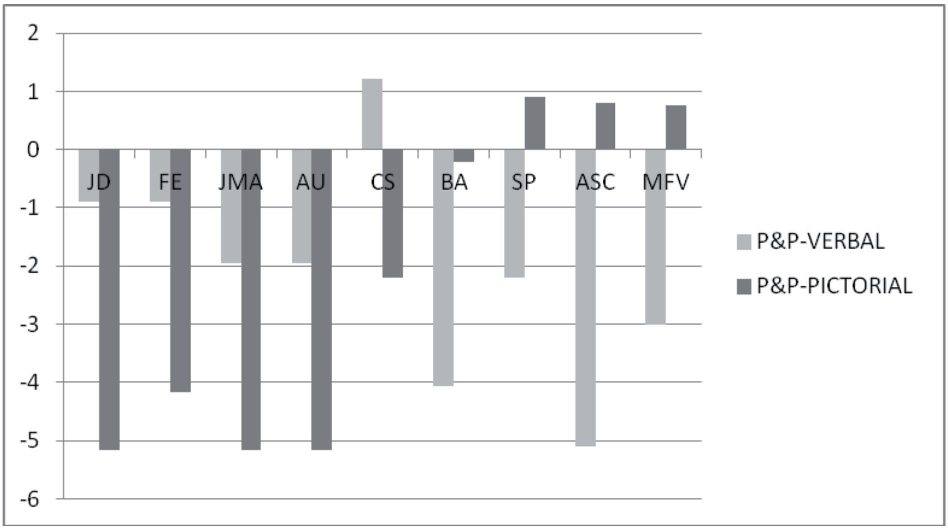

Figure 3. Patients with double dissociation between P&P-VERBAL and P&P-PICTORIAL

RIAL, but not in P&P-VERBAL; four patients presented the opposite performance pattern. Patients JD, FE, JMA, AU and CS presented significant differences in performance in these two tests ($p<0.01$); they performed better in P&P-VERBAL than in P&P-PICTORIAL. Meanwhile, patients BA, SP, ASC and MFV present significant differences in performance in these two tests ($p<0.001$), but with the opposite performance pattern. These results are depicted in Figure 3.

In Table 2 can be seen the values corresponding to the general neuropsychological assessment of the patients who showed double dissociations.

Table 2. General Neuropsychological Assesment

		MMSE	Com-preh-ension	DD	RD	VFAnimals	VFFruits	VFFurniture	VFclothing	Fonological VF	Naming	Word-piture matching
Controls	Media Deviation	28.83 1.085	14 .000	5.11 .916	3.75 .844	16.48 4.315	13.03 3.417	11.55 3.611	16.93 4.391	11.54 4.760	24 .000	12 .000
EN	24	12	4	3	8	7	5	6	5	23	12	EN
ASI	19	12	4	3	4	2	0	2	1	17	11	ASI
MPR	22	12	5	3	5	10	7	8	3	20	12	MPR
JD	23	14	6	3	12	16	10	11	12	24	12	JD
FE	23	14	5	2	8	15	9	13	3	24	12	FE
JMA	16	12	5	3	9	11	3	3	1	24	12	JMA
AU	25	14	5	4	11	10	4	7	5	24	12	AU
CS	17	14	5	5	7	7	5	7	5	24	12	CS
BA	30	14	5	3	11	8	6	9	8	24	12	BA
SP	26	12	3	2	16	4	11	9	15	24	12	SP
ASC	20	14	3	0	3	6	5	5	2	18	12	ASC
MFV	26	12	5	3	10	8	7	7	6	24	12	MFV

MMSE: Minimental State Examination. DD: Direct Digits. RD: Reverse Digits. VF: Verbal Fluency.

Table 3. Patients presenting dissociation in TAXON according to presentation format

SUBJECT	TAXON-VERBAL	TAXON-PICTORIAL	LESION LATERA-LIZATION	LESION SITE	APHASIA
Healthy Controls	0.117 (SD 0.889)	0.091 (SD 0.949)	---	---	---
EN	-3.471	-0.433	Right	Frontoparietal	Without aphasia
MPR	-2.699	0.258	Left	ND	Non-fluent aphasia
ASI	-2.708	1.642	Left	Frontal	Non-fluent aphasia

ND: no data

Tables 3 and 4 show the neuroanatomical location of the lesion and the z scores obtained by each of the participants presenting dissociations in the test pairs. As it can be seen patients who had more difficult in TAXON-VERBAL have frontal lesions (one of them has no CT data but as he has non-fluent aphasia it is possible that he has a frontal lesion). Meanwhile, patients who had more difficult in P&P-PICTORIAL only have in common the absence of aphasia, while patients who had more difficult in P&P-VERBAL have principally parietal lesions.

Further, when the performance of both groups presenting P&P dissociations were analyzed, it was found that patients with the lowest P&P-PICTORIAL scores also presented dissociations between P&P-PICTORIAL and TAXON-PICTORIAL, with lower scores in the former, as depicted in Table 5.

Additionally, analyzing the group of patients with difficulties in P&P-VERBAL but not in P&P-PICTORIAL, we found that of these four patients, only one (BA)

Table 4. Patients presenting dissociations in P&P according to presentation format

SUBJECT	P&P-VERBAL	P&P-PICTORIAL	LESION LATERA-LIZATION	LESION SITE	APHASIA
Healthy Controls	-0.015 (SD 1.032)	0.022 (SD 1.031)	---	---	
JD	-0.897	-5.154	Right	Frontoparietal	Without aphasia
FE	-0.897	-4.167	Right	Temporal-occipital	Without aphasia
JMA	-1.95	-5.154	Left	Thalamic	Without aphasia
AU	-1.95	-5.154	Left	Occipital	Without aphasia
CS	1.211	-2.192	Right	ND	Without aphasia
BA	-4.059	-0.219	Right	Basal Ganglia	Without aphasia
SP	-2.203	0.915	Right	Parietal	Without aphasia
ASC	-5.112	0.769	Left	Parietal	Non-fluent aphasia
MFV	-3.006	0.769	Left	Frontoparietal	Without aphasia

ND: no data

Table 5. Dissociations between P&P-PICTORIAL and TAXON-PICTORIAL

SUBJECT	P&P-PICTORIAL	TAXON-PICTORIAL	LESION LATERA-LIZATION	LESION SITE	APHASIA
Healthy Controls	0.022 (SD 1.031)	0.091 (SD 0.949)			
JD	-5.154	-1.819	Right	Frontoparietal	Without aphasia
FE	-4.167	0.258	Right	Temporal-occipital	Without aphasia
JMA	-5.154	-1.817	Left	Thalamic	Without aphasia
AU	-5.154	-0.375	Left	Occipital	Without aphasia
CS	-2.192	1.642	Right	ND	Without aphasia

ND: no data.

also presented a dissociation with the TAXON-VERBAL task, obtaining a lower score in P&P-VERBAL (z=-4.059 in P&P-VERBAL compared to z=-0.386 in TAXON-VERBAL). In contrast, the three other patients with significant difficulties in P&P-VERBAL performed more than one deviation below the mean in TAXON-VERBAL (SP: z=-1.986; ASC: z=-2.669; MFV: z=-3.471).

As can be seen in tables 3 and 4 the great majority of the patients who presented dissociations had no aphasia.

DISCUSSION

The aim of this study was to increase our understanding of the processing of taxonomic and thematic conceptual relations by the linguistic and simulation systems. We hypothesized that thematic relations were processed independently by both systems, while, coordinated taxonomic relations would be primarily processed by the simulation system. To determine this, we studied a group of patients with focal brain lesions for the purpose of exploring the presence of a double dissociation, based on the assumption that such a dissociation will reveal the existence of independent processes according to conceptual relation type and the modality in which information is presented (verbal vs. pictorial).

Double dissociations were found between P&P-VERBAL and P&P-PICTORIAL. This may be due to one of the access modalities to conceptual information being damaged. Thus, in the case of patients with difficulties in P&P-PICTORIAL, the impairment could be anywhere along the visual access modality, from the primary visual areas to the association areas that make it possible to establish thematic relations. In the case of patients with P&P-VERBAL difficulties, the impairment could be anywhere between the primary auditory areas and the association areas. Following this line of reasoning, we analyzed the performance of the group of patients with P&P-PICTORIAL difficulties in the other conceptual relations tasks and observed that they also present dissociations between P&P-PICTORIAL and TAXON-PICTORIAL, with lower scores in the former. This indicates that the impairment is not in the visual modality's primary stages of access, which are tested by both tasks, but rather in a specific component linked with the processing of thematic relations. If the damage had been in the visual modality's primary stages of access, there would have been difficulties in TAXON-PICTORIAL as well.

On the other hand, of the four patients with difficulties in P&P-VERBAL but not in P&P-PICTORIAL, only one (BA) also presented a dissociation with the TAXON-VERBAL task, scoring lower in P&P-VERBAL. This patient has a basal ganglia lesion, while the other three patients on this group has parietal lesions. Thus, we can assume that, in the case of this patient, the primary processing stages are not affected, since they are shared by both tasks. Nonetheless, the other three patients with significant difficulties in P&P-VERBAL performed at more than one deviation below the mean in TAXON-VERBAL, which leads us to assume that in these three cases what is impaired is some component common to both tasks and associated with the verbal processing modality, despite two of them has no aphasia. This dissociation was also found by other researchers (Plante, Van Petten & Senkfor, 2000).

To sum up, on the one hand, there are patients who present greater difficulties exclusively with pictorial thematic relations, but not with verbal thematic relations and pictorial taxonomic relations. On the other hand, there are patients who present greater difficulties with verbal thematic relations and also with verbal taxonomic relations, but not with pictorial thematic relations. This means that thematic relations can be impaired in an independent manner depending on the modality; further, they can be impaired independently of the taxonomic relations in the pictorial modality, but not in the verbal modality. This suggests that thematic relations can be processed by both systems – linguistic and simulation – as Barsalou and colleagues propose (2008). However, linguistic system processing of thematic and taxonomic relations implies the activation of common components, while simulation system processing of both relation types is independent. This may be because conceptual relations – taxonomic as well as thematic – require that the linguistic system be undamaged in order to be processed by the verbal modality. When the linguistic system is affected, greater difficulties in the establishment of both types of conceptual relations is found, as reported by Hagoort (1993) in their study of patients with and without aphasia. Simulation system processing, by contrast, would be different for both types of conceptual relations and would depend on independent components; therefore, their processing does not require that the system be completely undamaged. The independent processing of both types of conceptual relations in the simulation system has also been observed in other studies where thematic and taxonomic relations where assessed via the pictorial modality (Kalénine, Peyrin, Pichat & Segebarth, 2009). The simulation system's processing difference for these two types of relations could lie in that thematic relations represent two stimuli in one simulator (in other words, the stimuli are integrated in the same scheme as the context in which they tend to appear together), while taxonomic relations are established based on the superimposition of traits (Simmons & Barsalou, 2003) and for this reason they are processed more quickly via the pictorial modality, as observed by Kalénine and colleagues (2009).

CONCLUSIONS

Our analysis of double dissociation revealed a finding that, should it be confirmed by future studies, could have theoretical relevance. The results indicate that the establishment of thematic relations via the pictorial and verbal modalities is a relatively independent process that can be affected in different manners. This suggests that there may be two ways to store relations of this type: through the co-occurrence of words in language (the greater the frequency of co-occurrence, the stronger the link between these words), or through the joint representation of both objects in a contextual representation (conceptualization according to the Barsalou model). In this manner, thematic relations may be primordially stored within one of the two systems (linguistic and simulation) or both.

Given that double dissociations were not found in taxonomic relations, we can assume that this is not the case with this type of conceptual relation. The results suggest that taxonomic relations are principally processed in the simulation system. In this case, there isn't independent processing as in the case of thematic relations.

The study of both types of relations and the discrimination of the components implied in their processing constitutes a rich line of research since, in the field of neuropsychology, what is typically studied is semantic memory as a single construct. In light of our results, we believe it is of great interest to further study both types of conceptual relations (taxonomic and thematic) in different populations with impairment of the semantic system, as well as to conduct research on other types of conceptual relations (eg., functional, part-whole, etc.).

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Appendix 1. Detail of patient´s brain lesion

Patients	Neuroimage	Lateralization	Localization	Cortical-subcortical site of lesion	Stroke type	Aphasia
AA	MRI	Right	Occipital	Cortical	Isquemic	Without aphasia
AB	MRI	Right	Temporo-parietal	Cortico-subcortical	Isquemic	Without aphasia
AC	MRI	Left	Talamic	Subcortical	Isquemic	Without aphasia
AL	CT	Right	Fronto-temporo-occipital	Cortico-subcortical	Isquemic	Without aphasia
AM	CT	Right	Temporal	Cortico-subcortical	Hemorragic	No fluent
ASC	CT	Left	Parietal	Cortical	Hemorragic	No fluent
ASI	MRI	Left	Fronto-parietal	Cortical	Isquemic	No fluent
ASO	CT	Left	Frontal	Cortico-subcortical	Isquemic	Without aphasia
AU	MRI	Left	Parieto-temporo-occipital	Cortico-subcortical	Isquemic	Without aphasia
BA	CT	Right	Basal ganglia	Subcortical	Isquemic	Without aphasia
BS	CT	Right	Parieto-occipital	Cortical	Hemorragic	No fluent
BZ	MRI	Left	Fronto-parietal	Cortico-subcortical	Isquemic	No fluent
CB	MRI	Right	Parieto-occipital	Cortico-subcortical	Isquemic	Without aphasia
CD	MRI	Right	Frontal/ temporal	Cortico-subcortical	Isquemic	Without aphasia
CP	CT	Left	Parietal	Cortical	Isquemic	Without aphasia
CS	CT	Right	ND	ND	Isquemic	Without aphasia
DC	CT	Left	ND	ND	Isquemic	Without aphasia
DE	CT	Left	ND	ND	Isquemic	No fluent
DM	CT	Left	Temporal	Cortico-subcortical	Hemorragic	Without aphasia
EA	MRI	Left	Basal ganglia	Subcortical	Isquemic	Without aphasia
EAL	CT	Left	ND	ND	Isquemic	No fluent
EC	CT	Right	Frontal and occipital	Subcortical	Isquemic	Fluent
ELE	MRI	Left	Frontal	Cortico-subcortical	Isquemic	No fluent
ELU	CT	Right	Temporo-parieto-occipital	Cortico-subcortical	Isquemic	No fluent
EN	CT	Left	Temporo-parieto-occipital	Cortico-subcortical	Isquemic	Without aphasia
EO	CT	Right	Fronto-parietal	Cortico-subcortical	Isquemic	Without aphasia
ER	CT	Left	Fronto-parietal	Cortico-subcortical	Isquemic	Without aphasia
FE	MRI	Right	Temporo-occipital/ basal ganglia	Cortico-subcortical	Isquemic	Without aphasia

FR	CT	Left	Talamic	Subcortical	Hemorragic	Fluent
FT	CT	Right	Perisylvian		Isquemic	Fluent
GG	CT	Left	Semioval centers	Subcortical	Isquemic	No fluent
GS	CT	Left	Fronto-parietal	Cortical	Isquemic	Without aphasia
HF	CT	Right	Frontal	Cortico-subcortical	Infarto hemorragic	Without aphasia
IM	MRI	Left	Talamic	Subcortical	Isquemia con cambios hemorragics	Without aphasia
JD	MRI	Right	Fronto-parietal	Cortico-subcortical	Hemorragic	Without aphasia
JF	CT	Right	Capsular	Subcortical	Hemorragic	Without aphasia
JMA	MRI	Left	Fronto-temporo-parietal and basal ganglia	Cortico-subcortical	Isquemic	Without aphasia
JME	CT	Right	ND	ND	Isquemic	Without aphasia
JMO	CT	Right	Internal capsule	Subcortical	Isquemic	Global
JP	CT	Right	ND	ND	Isquemic	No fluent
JS	CT	Left	Internal capsule	Subcortical	Isquemic	Fluent
LS	CT	Left	Parietal	Cortical	Isquemic	No fluent
MC	MRI	Left	Parietal	Cortico-subcortical	Isquemic con trans-formación hemorrágica	Fluent
MFV	MRI	Left	Occipital	Cortico-subcortical	Isquemic	Without aphasia
MI	CT	Left	Fronto-parietal	Cortico-subcortical	Isquemic	Without aphasia
MPR	MRI	Right	Temporo-parietal	Cortico-subcortical	Isquemic	No fluent
MR	CT	Left	Fronto-parietal	Cortical	Isquemic	No fluent
NA	MRI	Right	Fronto-parietal	Cortico-subcortical	Isquemic	No fluent
NG	CT	Left	ND	ND	Isquemic	Without aphasia
RA	MRI	Left	Frontal	Cortical	Isquemic	No fluent
RE	CT	Right	Frontal	Cortical	Isquemic	Without aphasia
RG	CT	Right	ND	ND	Isquemic	Without aphasia
RL	MRI	Left y right	Frontal and fronto-parietal	Cortico-subcortical	Isquemic	Without aphasia
SP	CT	Left	Parietal	Cortical	Isquemic	Without aphasia
SR	CT	Left	ND	ND	Isquemic	Without aphasia
ST	CT	Right	Basal ganglia	Subcortical	Hemorragic	Without aphasia
TM	CT	Left	Fronto-parietal	Cortical	Isquemic	Without aphasia
VC	CT	Left	Talamic	Subcortical	Hemorragic	Without aphasia
VP	CT	Left	Basal ganglia	Subcortical	Isquemic	Without aphasia
VS	MRI	Left	Occipital	Cortical	Isquemic	Without aphasia
ND: no data.						

Appendix 2. Stimuli used in the TAXON-VERBAL and PICTORIAL tasks

Target Stimulus	Objective Stimulus	Distractor Stimulus
dress	skirt	tie
dresser	desk	couch
carrot	onion	banana
eagle	duck	rhinoceros
truck	bicycle	sailboat
comb	brush	fork
pants	jacket	cap
bench	rocking chair	bed
pear	apple	lemon
horse	zebra	lion
bus	motorcycle	helicopter
axe	saw	screwdriver
coat	blouse	skirt
corn	tomato	grapes
lion	cat	pig
airplane	helicopter	tractor
stool	chair	bed
pencil	scissors	paintbrush