

## Training structures of equivalence classes and their influence on the priming effect.

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### Original Article

#### Abstract

Semantic priming studies conducted with stimuli related through equivalence class training with different training structure has not been investigated yet. The aim of this work was to find out whether inter-group differences would be found during a semantic-priming task with stimuli related through equivalence depending on the training structure employed. 42 subjects were divided into three groups. All of them received training in three three-member equivalences classes, each with a different training structure: LS, OTM and MTO. Afterwards, all of them performed a semantic-priming task where trained and derived relations were tested. Inter-group differences were observed in the percentage of correct responses and in reaction times during the priming task, being the former lower and the latter higher for unrelated stimuli in the linear-series structure. Training structure is postulated as a possible factor which modulates the performance of subjects during lexical tasks.

#### Keywords:

Equivalence Relations, Training Structures, Semantic Priming, Matching to Sample, Directionality

#### Resumen

**Estructuras de entrenamiento de clases de equivalencia y su influencia en el efecto de priming semántico.** A la fecha no hay estudios que evalúen a través de priming semántico los efectos de la estructura de entrenamiento entre estímulos relacionados por clases de equivalencia. El objetivo de este trabajo fue corroborar si hay diferencias intergrupos durante una tarea de priming semántico con estímulos relacionados por equivalencia dependiendo de la estructura de entrenamiento. Cuarenta y dos sujetos fueron divididos en tres grupos. Todos recibieron entrenamiento en tres clases de equivalencia de tres, cada uno con una estructura de entrenamiento diferente: serie lineal, muestra como nodo y comparación como nodo. Posteriormente, todos realizaron una tarea de priming semántico evaluando las relaciones entrenadas y derivadas. Se encontraron diferencias inter-grupos en el porcentaje de respuestas correctas y en los tiempos de reacción durante la tarea de priming, siendo menor el porcentaje de aciertos y mayor el tiempo de reacción entre estímulos y no relacionados para la estructura serie lineal. Se postula que la estructura de entrenamiento es un posible factor que incide en el desempeño de tareas lexicales.

#### Palabras clave:

Relaciones de Equivalencia, Estructura de Entrenamiento, Priming Semántico, Emparejamiento con la muestra, Direccionalidad

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### 1. Introduction

A set of stimuli are said to belong to a stimulus equivalence class when, after certain conditional relations are trained between them (e.g., in presence of one of these stimuli, usually designated A1, the choice of stimulus B1 is reinforced, and in presence of stimulus A2, the choice of B2 is reinforced) it can be demonstrated that other relations, not directly

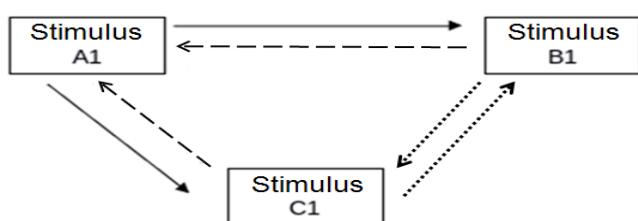
trained, have emerged (Sidman, 1994). Traditionally, this training is conducted through the procedure called arbitrary *matching to sample* (Sidman & Tailby, 1982), in which subjects are exposed to a sample stimulus (e.g., A1) and they must choose one of two or more comparison stimuli (e.g., B1 and B2). In this way, subjects learn the conditional relation A1-B1, and

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through the same process others can be taught (e.g., A2-B2, B1-C1 and B2-C2). These stimuli share no physical relation among them, and consequently which comparison stimulus must be chosen in the presence of a particular sample stimulus is completely arbitrary and decided beforehand by the experimenter. The participants must learn the conditional relations through exposition to repeated trials of this procedure. During the training their choices are followed by feedback messages indicating whether their choice was correct or not. After training resulting in at least two sets of three stimuli each (e.g., A1-B1-C1 and A2-B2-C2), a variation of this procedure without feedback is utilized to find out whether the emergence of untrained relations has taken place, namely, *reflexivity* (in the presence of a sample stimulus, choosing an identical comparison stimulus, e.g., in presence of sample A1, choosing comparison A1), *symmetry* (in presence of a sample stimulus which previously functioned as comparison, choosing the comparison stimulus which previously functioned as its sample, e.g., choosing comparison A1 in presence of sample B1), *transitivity* (in presence of a sample stimulus, choosing the comparison stimulus which belongs to the same class but that was not directly related to it, but indirectly via a third common stimulus, e.g., choosing comparison C1 in presence of sample A1) and a combination of symmetry and transitivity, also called *equivalence* relation (e.g., in presence of sample C1, choosing comparison A1). The typical finding is that humans show the emergence of these relations, which are called derived or emergent (see Figure 1).



**Figure 1.** Arrows indicate relations among the stimuli belonging to an equivalence class. Solid lines indicate trained conditional relations, while dashed lines and dotted lines indicate derived relations (symmetry and equivalence, respectively).

Many authors have proposed that this paradigm is relevant for research on semantic processes of referent-meaning learning (Catania, 1984; Penn, Holyoak, & Povinelli, 2008; Wulfert & Hayes, 1988). It has also been postulated that the associative

structure of stimuli in the *stimulus equivalence classes* (SEC) is functionally similar to that of semantic-system network models in which stimuli are represented as nodes in a network, interconnected according to their belonging to different conceptual domains (Fields, Adams, Verhave, & Newman, 1990; Fields & Nevin, 1993; Fields & Verhave, 1987; Fields, Verhave, & Fath, 1984).

Besides the growing body of empirical evidence supporting a connection between derived relations and human language, a group of behavior researchers have also argued that traditional theories of verbal or semantic networks share similarities with the concepts of equivalence classes (Barnes & Hampson, 1993; Cullinan, Barnes, Hampson, & Lyddy, 1994; Fields & Verhave, 1987; Hayes & Hayes, 1992; Reese, 1991).

The experimental paradigm of semantic priming is the most used for studies on semantic networks in natural language, which allow to investigate the processes of formation and retrieval of semantic memory (Dehaene et al., 1998; González, 2001; Hill, Strube, Roesch-Ely, & Weisbrod, 2001; Vivas, 2007). This is defined as the facilitation of a response to certain stimuli resulting from the previous exposition to them. It can be observed at the perceptual or semantic level (Soprano & Narbona, 2007).

One effect observed in the *priming* paradigm is the nodal distance between stimuli in indirect or mediated priming. In semantic priming paradigm (Meyer & Schvaneveldt, 1971) a prime word is presented followed by a target stimulus. Participants are instructed to perform the task of classifying the target (e.g., as a word or non-word). When there exists a direct semantic relation between prime and target stimuli (e.g., *tiger* - *stripes* pair) the reaction time decreases in comparison to an indirect relation (e.g., *lion* - *stripes*, connected by the word *tiger*), and even more compared to unrelated words (e.g., *table* - *stripes*). This facilitation effect has been interpreted as evidence of the previous processing of a directly related prime pre-activates the representation of the target, facilitating its subsequent recognition and processing. This facilitation should progressively decrease as the distance between prime and target increases (Neely, 1991).

Previous works have found the priming effect in SEC. Barnes-Holmes and collaborators (2005), for example, showed that the presentation of stimulus pairs belonging to different equivalence classes generated a brain potential with latency and topographical distribution similar to that of the N400 component, that is, a posterior negativity typically

observed in semantic priming studies (Bentin, McCarthy, & Wood, 1985; Rugg, 1985).

The way in which directionality is established allows the design of different forms of training, which have showed different levels of effectiveness. For example, unidirectional training may be carried out via *linear-series* (LS), *one-to-many* (OTM) or *many-to-one* (MTO) structures. In many studies the latter two have proven to be more effective than the former to develop trained and emergent relations (Fiorentini et al., 2013; Saunders & Green, 1999; Saunders & Spradlin, 1993; Sidman, 1994; Spradlin & Saunders, 1986).

According to Fields and Verhave (1987), the differences in the training structures produce differences in the relations (distance, amount of singles, class size, etc.) which are learned during training, while other authors (Saunders & Green, 1999) have suggested that this is the result of the amount of conditional discriminations learning during training. For example, in training for three three-member classes, as is the case in this experiment, a difference will be found in the amount of discriminations presented during training depending on the structure employed: in the linear-series structure the participants will be exposed to a total of 36 discriminations, leaving nine out of the training. The same applies to the OTM structure, while the MTO structure includes all the discriminations during training (that is, 45).

Starting off the investigations aforementioned, it was proposed to test the hypothesis of different training structures producing differential effects not just in the equivalence class formation, but in the performance during the semantic-priming task. The hypothesis sustained was that the group that received training following a LS structure would show a lower performance in the semantic-priming task and/or an increase in the response times in comparison to groups receiving the same training with OTM and MTO structures.

## 2. Materials and Methods

### 2.1 Ethical and legal considerations

The protocol was authorized by the Ethics Committee from the Institute of Biology and Experimental Medicine. Participant signed a note of informed consent for their participation in the experiment. The national and international recommendations for human experimentation were strictly followed (APA, 2002).

### 2.2 Participants

The sample was composed of 42 subjects, between 19 and 31 years of age ( $M = 23.47$ ,  $SD = 3.17$ ), 28 of which were women. All of them were undergraduate psychology students of the University of Buenos Aires. All participants signed a statement of informed consent and participated voluntarily. They were all properly informed about the goals and characteristics of the investigation. The following exclusion criteria were utilized: 1) Antecedents of sensory-motor or neuropsychiatric disorders. 2) Consumption of abuse substances, 3) Knowledge about the experimental paradigms employed. To assess the presence of any of these exclusion criteria, we relied on a self-administered questionnaire.

### 2.3 Installations and equipment

The study was carried out in a room with sound and light attenuation. Each participant sat in front of a table in which a PC with an Intel® Core™ 2 Duo CPU E4700 2,6 GHz processor was found. Computerized tasks, programmed in Python language, were utilized. Instructions were provided to the subjects via successive messages presented in the PC screen, and verbally before starting each task, three trained examiners administered the experiment randomly to the subject.

### 2.4 Procedure

Subjects were divided randomly into three groups. All of them performed three types of tasks. They were cited in two consecutive days. During the first day subjects were trained in a SEC task; the first group performed this task utilizing a LS structure, the second utilizing an OTM structure and the third utilizing a MTO structure. During the following day the participants were re-trained in the SEC task, and after reaching the learning criteria they performed the semantic-priming task. After this the emergence of derived relations were tested.

#### 2.4.1 SEC training

The stimuli employed were disyllabic pronounceable non-words, which possess neither perceptual similarity nor previous semantic relation (Aguado Alonso, 2005). The stimuli utilized are shown in Table 1.

Each participant was instructed to select, utilizing the PC mouse, the comparison stimulus which corresponds to the sample stimulus (matching-to-sample task). The stimuli were presented in the PC screen. In each trial a sample stimulus (in the center of the screen) and three comparison stimuli (in the inferior left, center and right areas) were successively presented.

**Table 1.**  
Stimuli and classes

	Class 1	Class 2	Class 3
Stimuli A	LAFU	TULE	DOLA
Stimuli B	SUNA	MIDU	COTE
Stimuli C	FAPE	NEPO	ESMO

Note. Stimuli employed in each of the three three-member trained classes.

During the training phase, three series of arbitrary relations between non-words were trained. During this phase only, the subjects responses were followed by feedback messages written on the screen (Spanish versions of "CORRECT" and "ERROR"), depending on whether their choice was in accordance with the relation arbitrarily established relation or not. During training, trials were grouped in two simple blocks (BA and AC in the case of LS, AB and AC in the case of OTM, and BA and CA in the case of comparison as nod) and a third combined block (BA+AC, AB+AC and BA+CA, respectively). In order to avoid effects of trial order presentation, these were counterbalanced. If percentage of correct responses happened to be inferior to 90% in the combined block, it would be restarted automatically up to three consecutive times. The learning criterion to proceed was 87% in the final combined block. In case the subject had not reached this criterion the experiment would be concluded and the data would not be utilized.

#### 2.4.2 Priming task.

The task consisted on a total of four blocks of 72 trials each, during which different of stimuli (prime-target) were presented in visual modality. These are defined according to their degree of association in the SEC: six pairs related by training, six by symmetry and six by equivalence (these were presented twice per block), besides twelve pairs unrelated by training, twelve unrelated by symmetry and twelve unrelated by equivalence, which were presented once per block<sup>2</sup>. The different types of trial for each group are presented in Table 2. The order of presentation of the stimulus pairs was pseudo-randomized for each block. Note that the pairs related by transitivity and

2 In the cases of one to many and many to one, having no transitivity relations, six pairs related indirectly by equivalence were tested (i.e., both A1-C1 and C1-A1 and so for the three classes). In the case of linear series, both transitivity (e.g., A1-C1) and equivalence (C1-A1) relations were considered as equivalence. The same criterion applies for their unrelated counterparts.

equivalence are the same for the three groups.

The succession of events in each trial begins with a fixation point presented in the center of the screen (500 ms), followed by a screen without stimuli (500 ms), prime stimulus (350 ms), screen without stimuli (50 ms), target stimulus (350 ms), screen without stimuli (3000 ms, during which the subject should answer). During each trial the participant was required to press the right-ctrl key if the stimuli were related or left-ctrl otherwise.

#### 2.4.3 Emergent relations testing.

During the testing phase three three-member stimulus classes (A1-B1-C1, A2-B2-C2, A3-B3-C3) were evaluated through a task similar to training but without feedback messages and sounds. Sample and comparison stimuli related by combined symmetry and transitivity (equivalence: B-C and C-B). The test criterion in each case was 87% or above of correct responses.

#### 2.5 Statistical analysis.

Analyses were performed with the SPSS 15 statistical package. The alpha level of significance was 0.5 for every test. The data of the priming task and the derived-relations emergence test were analyzed separately. For the priming task, three ANOVAS were performed:

##### 2.5.1 Relation x Relatedness x Training structure ANOVA.

A mixed three-factor ANOVA was employed: relation (trained, symmetry or equivalence) and relatedness (related or unrelated) as intra-subject factors with training structure as inter-subject factor (LS, OTM and MTO). Percentage of correct responses was the dependent variable.

##### 2.5.2 Relation x training structure ANOVA.

A mixed two-factor ANOVA was utilized: relation (transitivity or equivalence) as within-subject factor and training structure as inter-subject factor<sup>3</sup>. Percentage of correct responses was the dependent variable. This analysis was realized in order to test the possibility of differences existing between transitivity and equivalence relations within the LS group which would possibly be absent in the OTM and MTO groups (since they have no transitivity relations).

##### 2.5.3 Relation x Relatedness x training structure ANOVA.

3 Since the linear-series structure is the only one which allows for transitivity relations, in the other two cases the B-C relations was considered as transitivity in order to carry out this analysis, while the C-B considered as equivalence in the three cases.

A mixed three-factor ANOVA was employed: relation (trained symmetry or equivalence) and relatedness (related or unrelated) as intra-subject factors with training structure (LS, OTM or MTO) as inter-subjects factor. The dependent variable was the mean of the reaction times during the priming task (the data were normalized with natural logarithms in order to carry out this analysis)

**Table 2**  
Pairs of stimuli for each group

	LS	OTM	MTO
Trained	B1-A1, B2-A2, B3-A3, A1-C1, A2-C2, A3-C3	A1-B1, A2-B2, A3-B3, A1-C1, A2-C2, A3-C3	B1-A1, B2-A2, B3-A3, C1-A1, C2-A2, C3-A3
Symmetry	A1-B1, A2-B2, A3-B3, C1-A1, C2-A2, C3-A3	B1-A1, B2-A2, B3-A3, C1-A1, C2-A2, C3- A3	A1-B1, A2-B2, A3-B3, A1-C1, A2-C2, A3-C3
Transitivity	B1-C1, B2-C2, B3-C3	-	-
Equivalence	C1-B1, C2-B2, C3-B3	B1-C1, B2-C2, B3-C3, C1-B1, C2-B2, C3-B3	B1-C1, B2-C2, B3-C3, C1-B1, C2-B2, C3-B3
Non trained	B1-A2, B1-A3, B2-A1, B2-A3, B3-A1, B3-A2	A1-B2, A1-B3, A2-B1, A2-B3, A3-B1, A3-B2	B1-A2, B1-A3, B2-A1, B2-A3, B3-A1, B3-A2
	A1-C2, A1-C3, A2-C1, A2-C3, A3-C1, A3-C2	A1-C2, A1-C3, A2-C1, A2-C3, A3-C1, A3- C2	C1-A2, C1-A3, C2-A1, C2-A3, C3-A1, C3-A2
Non symmetry	A1-B2, A1-B3, A2-B1, A2-B3, A3-B1, A3-B2	B1-A2, B1-A3, B2-A1, B2-A3, B3-A1, B3-A2	A1-B2, A1-B3, A2-B1, A2-B3, A3-B1, A3-B2
	C1-A2, C1-A3, C2-A1, C2-A3, C3-A1, C3-A2	C1-A2, C1-A3, C2-A1, C2-A3, C3-A1, C3-A2	A1-C2, A1-C3, A2-C1, A2-C3, A3-C1, A3-C2
Non transitivity	B1-C2, B1-C3, B2-C1, B2-C3, B3-C1, C3-C2	-	-
Non equivalence	C1-B2, C1-B3, C2-B1, C2-B3, C3-B1, C3-B2	B1-C2, B1-C3, B2-C1, B2-C3, B3-C1, C3-C2  C1-B2, C1-B3, C2-B1, C2-B3, C3-B1, C3-B2	B1-C2, B1-C3, B2-C1, B2-C3, B3-C1, C3-C2  C1-B2, C1-B3, C2-B1, C2-B3, C3-B1, C3-B2

For the Derived-relations emergence test a mixed two-factor ANOVA was carried out: relation (transitivity or equivalence) as intra-subject factor and training structure as inter-subject factor. Percentage of correct responses was the dependent variable.

Effect sizes were estimated via the partial eta-squared coefficient  $\eta^2$  (Cohen, 1973; Haase, 1983). The Greenhouse-Geisser correction was applied in cases of sphericity violations and the Bonferroni correction was utilized for paired post-hoc comparisons.

### 3. Results

The data of 24 subjects who reached the criterion during the training and testing phases was analyzed ( $M = 23.47$ ,  $SD = 3.17$ ). There were eight subjects per group and did not differ in age between them ( $F(2, 42) = 2.584$ ,  $p = .099$ ). The minimum number of trials required for moving to the priming phase was 216. The total numbers of trials are shown in Table 3.

#### 3.1 Results of the priming task.

##### 3.1.1 Percentage of correct responses.

###### 3.1.1.1 Relation x Relatedness x Training structure ANOVA (see Figure 2).

A main effect of relation was found ( $F(2, 42) = 30.193$ ,  $p < .001$ ,  $\eta^2_p = .590$ ) being percentage of correct responses higher for the trained relation than for the symmetry ( $p = .018$ ) and equivalence relations ( $p < .001$ ), and higher for the symmetry relation than for the equivalence relation ( $p < .001$ ). A main effect of relatedness was also found ( $F(1, 21) = 14.885$ ,  $p < .002$ ,  $\eta^2_p = .415$ ), being the percentage of correct responses higher for pairs of related stimuli than for pairs of unrelated stimuli ( $p < .001$ ). A marginal significance in the main effect of training structure was also found ( $F(2, 21) = 3.235$ ,  $p = .06$ ,  $\eta^2_p = .236$ ), being the percentage of correct responses lower for LS than for OTM and MTO. An interaction effect was found between the variables relation and relatedness ( $F(2, 42) = 17.255$ ,  $p < .001$ ,  $\eta^2_p = .451$ ), being significative the difference

between the relations only for the relatedness factor ( $F(2, 20) = 13,169, p < .001, \eta^2p = .568$ ) but not for the unrelated ( $F(2, 20) = 0,157, p = .855, \eta^2p = .568$ ). Within the relatedness factor, the trained relation had a significantly higher percentage of correct responses than the symmetry ( $p < .01$ ) and the equivalence relations ( $p < .001$ ). Furthermore, stimuli related by symmetry resulted in a higher percentage of correct responses than those related by equivalence ( $p < .001$ ). The relatedness x training

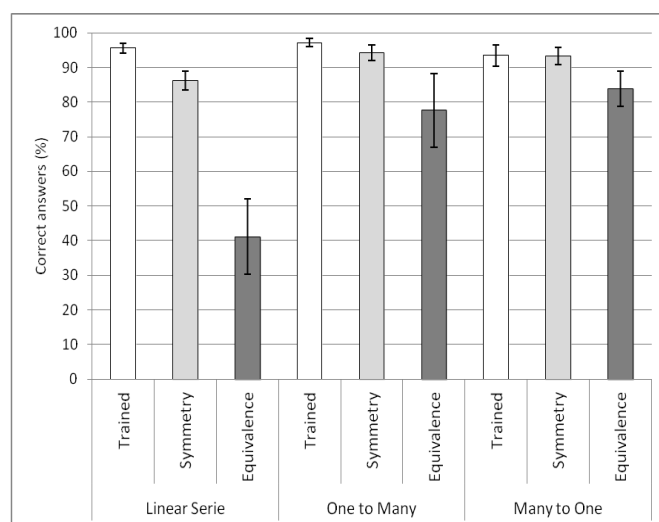
structure interaction was not significant ( $F(4, 42) = 2.587, p > .099, \eta^2p = .198$ ). Post hoc analyses show significant differences within the LS structure ( $F(1, 21) = 16.662, p < .002, \eta^2p = .442$ ), being the percentage of correct responses higher for pairs of unrelated stimuli ( $p = .001$ ). With the OTM ( $F(2, 21) = 1.463, p > .240, \eta^2p = .065$ ) and MTO ( $F(2, 21) = 1.935, p > .179, \eta^2p = .084$ ) structures no significant differences were found.

**Table 3.**  
Training Structure Scores for each group

Subject	Linear Serie			OTM			MTO		
	Adquisition		Equivalence Evaluation	Adquisition		Equivalence Evaluation	Adquisition		Equivalence Evaluation
	Total	Errors	Total	Errors	Total	Errors	Total	Errors	
1	216	6	36	216	5	36	288	53	36
2	324	38	36	324	23	35	216	14	36
3	288	77	36	288	18	34	252	35	33
4	216	15	34	216	16	36	252	18	36
5	360	87	35	360	32	35	216	13	36
6	288	64	35	288	20	36	288	38	36
7	252	35	36	252	14	36	252	14	36
8	252	25	36	252	13	36	252	22	36
Total	347			141			207		

The relation x training structure interaction was significant ( $F(2, 21) = 3.816, p < .04, \eta^2p = .267$ ). With the LS structure, significant differences were found ( $F(2, 20) = 14.478, p < .001, \eta^2p = .591$ ), being the percentage of correct responses higher for pairs of stimuli related by training than for pairs related by symmetry ( $p = .018$ ) and by equivalence ( $p < .001$ ), and higher for pairs related by symmetry than for pairs related by equivalence ( $p < .001$ ). Within the OTM ( $F(2, 20) = 2.770, p > .087, \eta^2p = .217$ ) and MTO ( $F(2, 20) = 2.625, p > .097, \eta^2p = .208$ ) structures no significant differences were found.

Finally, a marginal significance ( $F(4, 42) = 3,039, p < .063, \eta^2p = .224$ ) was found for the relation x relatedness x training structure interaction, in which significant differences were found in the percentage of correct responses for the related conditions ( $F(2, 20) = 15,856, p < .001, \eta^2p = .613$ ), but not for the unrelated ones ( $F(2, 20) = 0,988, p > .390, \eta^2p = .09$ ) in the LS structure not in the other structures, in which no significant differences were found.



**Figure 2.** Percentage of correct answers during the priming task for different conditions (Trained, Symmetry and Equivalence) in the different training structure. The graph shows the mean and standard error for each condition (N = 8).

**3.1.1.2 Relation x training structure ANOVA.**  
No significant differences were found in the

relation factor ( $F(1, 21) = 0.591, p = .45, \eta^2 p = .027$ ). A main effect of training structure was found ( $F(2, 21) = 3.748, p = .041, \eta^2 p = .263$ ). Post hoc analyses show a marginal tendency, having LS a lower percentage of correct responses than OTM ( $p = .086$ ) and MTO ( $p = .078$ ). Finally, a marginal tendency was observed in the relation by training structure interaction ( $F(2, 21) = 3.059, p = .068, \eta^2 p = .226$ ), where differences can be observed only for the equivalence relation ( $F(2, 21) = 6.147, p = .008, \eta^2 p = .369$ ), being the percentage of correct responses lower for LS than for OTM ( $p < .034$ ) and MTO ( $p < .012$ ).

### 3.1.2 Reaction times.

#### 3.1.2.1 Relation x Relatedness x training structure ANOVA (see Figure 3).

A main effect of relation was found ( $F(2, 42) = 42.234, p < .001, \eta^2 p = .668$ ), being the reaction times lower for pairs of stimuli related by training than for pairs related by symmetry ( $p < .001$ ) and equivalence ( $p < .001$ ), and lower for pairs related by symmetry than for pairs related by equivalence ( $p < .001$ ). A main effect of relatedness was also found ( $F(1, 21) = 6.992, p = .015, \eta^2 p = .250$ ), being the reaction times lower for pairs of related stimuli than for pairs of unrelated stimuli ( $p = .015$ ). No main effect of training structure was found ( $F(2, 21) = 0.311, p = .736, \eta^2 p = .029$ ). An interaction effect was found between the relation and relatedness variables ( $F(2, 42) = 18.619, p < .001, \eta^2 p = .470$ ). Post hoc analyses show that the differences among relations can only be observed between related stimuli ( $F(2, 20) = 42.6, p < .001, \eta^2 p = .810$ ), being the reaction times lower for pairs of stimuli related by training than for pairs related by symmetry ( $p < .001$ ) and by equivalence ( $p < .001$ ), and lower for pairs related by symmetry than for pairs related by equivalence ( $p < .002$ ). No interaction effect was found between the relation and training structure variables ( $F(4, 42) = 0.461, p = .714, \eta^2 p = .042$ ). A post hoc analysis was employed to find whether there were differences in the reaction times for each relation in the different structures. Within the LS structure, reaction times were significantly lower for pairs of stimuli related by training than for pairs related by symmetry ( $p < .001$ ) and by equivalence ( $p < .001$ ), and lower for pairs related by symmetry than for pairs related by equivalence, although this difference was not significant ( $p = .388$ ). Within the OTM structure, reaction times were lower for pairs related by training than for pairs related by symmetry ( $p = .034$ ) and by equivalence ( $p < .001$ ), and lower for pairs related by symmetry than for pairs related by equivalence ( $p < .001$ ). Within the MTO structure,

reaction times were lower for pairs related by training than for pairs related by symmetry ( $p < .001$ ) and by equivalence ( $p < .001$ ), and lower for pairs related by symmetry than for pairs related by equivalence ( $p < .032$ ). No interaction effect was found between the relatedness and training structures variables ( $F(2, 21) = 0.492, p = .618, \eta^2 p = .045$ ). Post hoc tests were carried out for this interaction to observe the differences between related and unrelated stimuli in each structure. A significant effect can be observed for the MTO structure ( $F(1, 21) = 5.313, p = .031, \eta^2 p = .202$ ), being the reaction times significantly lower for related stimuli than for unrelated stimuli.

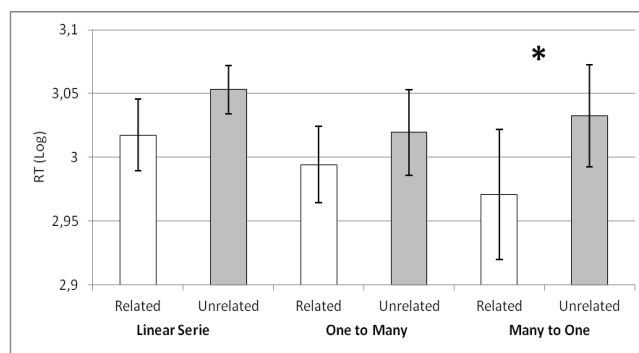


Figure 3.

Reaction time between stimuli related and unrelated to each training structure. The graph shows the mean and standard error ( $N = 8$ ). The asterisks indicate a  $p < .05$

### 3.2 Derived-relations emergence test.

#### 3.2.1 Percentage of correct responses.

No significant differences were found between the transitivity and the equivalence relations ( $F(1, 19) = 0.674, p = .422, \eta^2 p = .034$ ) nor was an interaction effect found ( $F(2, 19) = 0.712, p = .503, \eta^2 p = .105$ ). No main effect of training structure was found either ( $F(2, 21) = 0.055, p = .947, \eta^2 p = .07$ ).

A chi-squared test was also carried out to look for differences in the amount of subjects from each training structure who reached a criterion of 87% of correct responses in the testing phase. No significant differences were found among the training structures ( $\chi^2(2, N = 24) = 3.229, p > .134$ ).

## 4. Discussion

### 4.1 Training.

As aforementioned, differences were observed between the different training structures during the training phase of the baseline relations, being the amount of errors and trials needed higher for the LS structure, even among the subjects who reached the

learning criterion. These results are coherent with other investigations in which the LS structure required a higher amount of trials during training to reach the criterion of baseline-relations acquisition compared to OTM and MTO (Arntzen, Grondahl, & Eilifsen, 2011). In this very work it is mentioned that a lower amount of trials is necessary for OTM compared to MTO, but that this difference is not significant for training with three three-member classes. Nonetheless, this difference disappeared during training with three four-member classes. Faced with this non-significant discrepancy, the authors hold that the difference may be due to MTO structure requiring the subject to learn to discriminate every stimulus from each other, and this would hinder learning. Nevertheless, this assumption cannot explain the lower performance in the LS group, and would only partially explain why the difference disappears when increasing the amount of stimuli.

One possible explanation is that the main difficulty during the baseline-relations learning task is the inconstancy of the stimuli in the sample-role. Studies carried out within a zero-delay DMTS paradigm have postulated that intertrial correspondence of the sample can modulate the participants' performance (Adamson, Foster, & McEwan, 2000; Moise, 1976). In other words, if the sample stimuli are dissimilar from one trial to the next, response accuracy diminishes, unlike the case of the sample being the same in both trials. Worsham (1975) and Roberts (1980) pointed out that proactive interference would happen as well when the incorrect comparison in the present trial had appeared as a sample in the previous trial. Adamson et al., (2000) showed that an increase in the amount of sample stimuli produces a decrease in the performance during the DMTS task. This could explain why the performances are inferior when employing a LS structure in comparison to the other two. In both OTM and MTO the sample would not interact with the comparison from previous trials, which does happen in the LS structure. We consider that the same principle applies to the comparison stimuli, namely, that the lower the possibility of the sample being associated to many comparison, the lower the interference of the previous-trial comparison with the present-trial one. Exemplifying, if, with a sample related with many comparisons, in trial n-1 the relation of this sample with a comparison is reinforced, and during the following trial the same sample is presented but the correct comparison is different, reinforcement of the previous choice would interfere with the correct choice in the present trial.

The higher the number of comparisons associated with the sample, the higher the probability of interference during a randomized training. That is, in an OTM structure, if the amount of stimuli is increased, the probability of interference increases as well. This hypothesis would allow us to explain why the difference between OTM and MTO disappears as the amount of stimuli per class increases. This hypothesis may also explain why some investigations have shown better performances with a respondent-type training procedure compared with the traditional MTS procedure (e.g., Leader & Barnes-Holmes, 2001).

Another possibility is that the training structures promote the emergence of verbal strategies which facilitate the learning. Even though no precise instructions for developing these strategies of naming the stimuli were given to the subjects, McIlvane & Dube (1996) hold that these differential responses can occur indifferently of the instructions provided by the researchers. The hypotheses enunciated are not mutually exclusive; it is possible that the maintenance of the sample stimuli facilitates the emergence of verbal strategies. Future research should take this into account and employ control procedures that allow the regulation of these strategies to verify this assumption.

#### 4.2 Priming task.

##### 4.2.1. Percentage of correct responses.

Taking into account only the subjects that reached the learning criteria in both baseline and derived relations, differential effects in the priming task can be observed. In the percentage of correct responses, differences could be observed between the different relations, being the percentage of correct responses significantly higher for trained relations than for symmetry and equivalence relations, and higher for symmetry than for equivalence relations (these differences were only observed in the LS structure and not in OTM and MTO [Figure 2]). This is congruent with previous research and could be explained, in part, because trained relations had direct reinforcement while symmetry and equivalence relations did not. On the other hand, a correspondence may be drawn between the differences between symmetry and equivalence and the nodal distance effect, since in symmetry relations there are no nodes functioning as intermediaries between the stimuli. Nonetheless, this difference was only observed in one structure (LS) and not the other two. This cannot be explained by the discrimination hypothesis either, given that both LS and OTM



training share the same amount of conditionals discriminations during training.

The discrepancies between the groups can be explained by the directionality of stimuli established in LS, given that in this structure there are transitivity relations in addition to the equivalence relations, and in terms of directionality these equivalence relations are not comparable to those in OTM y MTO, given that these two always imply some directly-trained relation. That is, in the OTM structure, where there is a learning of the kind:  $C \leftarrow A \rightarrow B$ , stimulus A has been trained in two relations (maintaining its sample function), as happens in MTO ( $C \rightarrow A \leftarrow B$ ), where stimulus A is trained in two relations (maintaining its function as comparison). In contrast, in LS ( $A \rightarrow B \rightarrow C$ ) the stimulus A is trained only in one relation. In other words, in LS the equivalence relation implies two derived relations (B-A and C-B symmetries), while in the other two structures one trained a one derived relation are involved (e.g., B-A y A-B in the case of OTM).

With respect to the difference between related and unrelated stimuli, it can be observed that the percentage of correct responses was higher for unrelated stimuli only in the LS structure. It is only possible to recognize that two stimuli are related when the relation among them was learned, and not when it was not. In the latter case, the probability of an incorrect response (namely, responding as "unrelated") increases. On the contrary, when the subject does not learned a relation as "unrelated", at the moment of deciding whether the two stimuli are related, the probability of responding correctly increases (that is, responding as "unrelated"). Based on this premise and on the results observed, it can be assumed that the LS structure resulted in an inferior performance in the test for derived relations. Subsequent analyses showed that the differences between transitivity and equivalence are only observed in the LS structure, being the percentage of correct responses higher for transitivity, while there are no differences among these relations in the OTM and MTO structures. This is congruent with the hypothesis of directionality directly affecting the relations among the stimuli, in which directionality congruent with the training facilitates the response, whereas, that a non-congruent directionality has the inverse effect.

#### 4.2.2. Reaction times.

The analyses of reaction times are congruent with the results of the percentage of correct responses, being lower in trained relations when compared to

symmetry and equivalence, and lower in symmetry than in equivalence. These differences can be observed only when stimuli were related. The main difference between the results of reaction times and percentage of correct responses is that the former were lower for related stimulus pairs. It should be noted that these differences are obtained in subjects' correct responses. These results are congruent with those reported in previous experiments (Barnes-Holmes et al., 2005; Tabullo, Yorio, Zanutto, & Wainseboim, 2015). This constitutes evidence of a semantic-priming effect independently of the training structure employed.

The related stimuli in the structure MTO presented faster response times than those unrelated. This is congruent with a better learning of the relations and with that reported by Saunders and Green (1999). Even though there is no difference in reaction times within the OTM structure, the possibility exists that the higher number of conditional discriminations presented during MTO training facilitates recognition, thus resulting in a decrease in the reaction time of the discrimination of the relations, but no so in the percentage of correct responses. Future researches shall employ control procedures for both variables in order to determine their influence.

#### 4.3 Test of emergent relations.

The analyses of the test of derived-relations emergence show no difference between the structures for subjects who passed the test. This can be due to two reasons: first, the priming task may be functioning as a facilitator of the emergence of derived relations, since during this tasks all pairs of related stimuli necessary to derived the SEC are seen, and, on the other hand, because only subjects with a high performance were used for the analysis. The first hypothesis would be consistent with the theory sustained by Sidman (1986), who proposes that the testing of the derived relations is essential for their emergence, that is, that training of baseline relations alone is not enough, but exposition to testing is necessary as well. These prerequisites were also reported by Haimson, Wilkinson, Rosenquist, Ouimet & McIlvane (2009), who found significant differences of the evoked potentials of two groups in a lexical decision task with derived relations. The group which was exposed to the test first showed much more negative amplitudes during the lexical-decision task than the group which was exposed first to the testing of the derived relations and afterwards to the lexical-decision task. This difference among groups

continuously decreased during the task, as subjects not exposed to the test advanced through the task.

These results show a priming effect and a differential effect of training directionality. In contraposition to what Saunders and Green (1999) propose, OTM and MTO structures resulted in no significant difference during learning, even though differences were found between them and LS. This is congruent with other studies that show differences between LS and the other training structures but not among the latter (e.g., Fiorentini et al, 2013).

The use of verbal strategies wasn't controlled therefore this may have influenced the results obtained. (The naming behavior could still be produced in the absence of a verbal instruction to perform it) (McIlvane & Dube, 1996). However, verbal behavior seems not to be an essential requirement for the formation of stimuli Equivalence classes (Delgado, Medina, & Soto, 2011; Tonneau & González, 2004).

On the other side, no derivative relations were tested prior to the task of semantic priming. Instead, it was tested only at the end. The explanation of why it was tested in this way is the evidence supporting that the testing derived relations can influence in the formation of them (Haimson et al., 2009). For that reason, a prior evaluation would have minimized the differences caused by the structure.

#### 4.4 Brief comments.

Summarizing, differences were found in the percentage of correct responses during the priming task depending on the training structure employed, being lower for the LS structure when compared to OTM and MTO. Differences were also found in reaction times depending on the training structure, although this was only the case within the MTO structure.

Directionality is postulated as a possible factor which modulates the performance of subjects during the semantic-priming task, even though there seems to be no influence of it in reaction times. The amount of stimuli which function as samples in each structure was postulated as a tentative explanation for the difference in the baseline-relations learning depending on the training structure. It would be convenient for future researchers to employ control procedures for the influence of the amount of stimuli which function as samples and for the directionality of training.

The aim of the study is to increase the knowledge about the method of EEC concerning the procedures used. Furthermore, it is helpful to develop more effective learning methods. This paradigm proved to

be useful in several areas like: cognitive rehabilitation, education and psychotherapy (Fiorentini, Arismendi, & Yorio, 2012)

The EEC paradigm applications are useful either in the framework of evaluation and cognitive rehabilitation, education and psychotherapy. These results suggest that a lexical decision task, such as a task of semantic priming, could be a variant to evaluate de formation of derivative relationships. Showing a difference with the matching to sample task.

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### References

- Aguado Alonso, G. (2005). Contribuciones al diagnóstico del trastorno específico del lenguaje por medio de la repetición de pseudo-palabras. *Revista Extremeña de Atención Temprana*, 3, 17-28.
- Adamson, C., Foster, T. M., & McEwan, J. S. (2000). Delayed matching to sample: the effects of sample-set size on human performance. *Behavioural Processes*, 49(3), 149-161.
- American Psychological Association. (2002). Ethical principles of psychologists and code of conduct. *American psychologist*, 57(12), 1060-1073.
- Arntzen, E., Grondahl, T., & Eilifsen, C. (2011). The effects of different training structures in the establishment of conditional discriminations and subsequent performance on tests for stimulus equivalence. *The Psychological Record*, 60(3), 437-462.
- Barnes, D., & Hampson, P.J. (1993). Stimulus equivalence and connectionism: Implications for behavior analysis in cognitive science. *The Psychological Record*, 43(4), 617-638.
- Barnes-Holmes, D., Staunton, C., Whelan, R., Barnes-Holmes, Y., Commins, S., Walsh, D., Stewart, I., Smeets, P. M., & Dymond, S. (2005). Derived stimulus relations, semantic priming, and event-related potentials: testing a behavioral theory of semantic networks. *Journal of The Experimental Analysis of Behavior*, 84(3), 417-433.
- Bentin, S., McCarthy, G., & Wood, C. C. (1985). Event-related potentials, lexical decision and semantic priming. *Electroencephalography and Clinical Neurophysiology*, 60(4), 343-355.
- Catania, A.C. (1984). *Learning* (2nd ed). Englewood Cliffs, NJ: Prentice-Hall.
- Cohen, J. (1973). Eta-squared and partial eta-squared in fixed factor ANOVA designs. *Educational and Psychological Measurement*, 33, 107-112

- Cullinan, V.A., Barnes, D., Hampson, P.J., & Lyddy, F. (1994). A transfer of explicitly and non-explicitly trained sequence responses through equivalence relations. An experimental demonstration and connectionist model. *The Psychological Record*, 44(4), 559-585.
- Dehaene, S., Naccache, L., Le Clec'H, G., Koechlin, E., Mueller, M., Dehaene-Lambertz, G., ... & Le Bihan, D. (1998). Imaging unconscious semantic priming. *Nature*, 395(6702), 597-600.
- Delgado, D., Medina, I. F., & Soto, J. S. (2011). El lenguaje como mediador de la transferencia de funciones: ¿es necesario nominar para relacionar? *Revista mexicana de análisis de la conducta*, 37(2), 31-52
- Fields, L., Adams, B., Verhave, T., & Newman, S. (1990). The effects of nodality on the formation of equivalence classes. *Journal of the Experimental Analysis of Behavior*, 53(3), 345-358.
- Fields, L., & Nevin, J. A. (1993). Stimulus equivalence: A special issue of *The Psychological Record*, 43(4), 541-844.
- Fields, L., Verhave, T., & Fath, S. (1984). Stimulus equivalence and transitive associations: A methodological analysis. *Journal of the Experimental Analysis of behavior*, 42(1), 143-157.
- Fields, L., & Verhave, T., (1987). The structure of equivalence classes. *Journal of the Experimental Analysis of Behavior*, 48(2), 317-332.
- Fiorentini, L., Arismendi, M., & Yorío, A. A. (2012). Una revisión de las aplicaciones del paradigma de equivalencia de estímulos. *International journal of psychology and psychological therapy*, 12(2), 261-275.
- Fiorentini, L., Vernis, S., Arismendi, M., Primero, G., Argibay, J. C., Sánchez, F., & Yorío, A. (2013). Relaciones de equivalencia de estímulos y relaciones de equivalencia-equivalencia: efectos de la estructura del entrenamiento. *International Journal of Psychology and Psychological Therapy*, 13(2), 233-247.
- González, A. M. (2001). El rendimiento del hemisferio derecho condicionado por el grado de imaginabilidad de las palabras en una tarea de decisión léxica con priming semántico. *Anales de psicología*, 17(2), 235-246.
- Haimson, B., Wilkinson, K. M., Rosenquist, C., Ouimet, C., & McIlvane, W. J. (2009). Electrophysiological correlates of stimulus equivalence processes. *Journal of the Experimental Analysis of Behavior*, 92(2), 245-256.
- Haase, R. F. (1983). Classical and partial eta square in multifactor ANOVA designs. *Educational and Psychological Measurement*, 43(1), 35-39.
- Hayes, S. C., & Hayes, L. J. (1992). Verbal relations and the evaluation of behavioral analysis. *American Psychologist*, 47(11), 1383-1395.
- Hill, H., Strube, M., Roesch-Ely, D., & Weisbrod, M. (2001). Automatic vs. controlled processes in semantic priming – differentiation by event-related potentials. *International Journal of Psychophysiology*, 44(3), 197-218.
- Leader, G., & Barnes-Holmes, D. (2001). Matching-to-sample and respondent-type training as methods for producing equivalence relations: Isolating the critical variable. *The Psychological Record*, 51(3), 429-444.
- McIlvane, W. J., & Dube, W. V. (1996). Naming as a facilitator of discrimination. *Journal of the Experimental Analysis of Behavior*, 65(1), 267-272.
- Meyer, D. & Schvaneveldt, R. W. (1971). Facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operations. *Journal of Experimental Psychology*, 90(2), 227-234.
- Moise, S. L. (1976). Proactive effects of stimuli, delays, and response position during delayed matching from sample. *Animal Learning & Behavior*, 4(1), 37-40.
- Neely, J. H. (1991). Semantic priming effects in visual word recognition: A selective review of current findings and theories. *Basic processes in reading, visual word recognition*, 11, 264-336.
- Penn, D. C., Holyoak, K. J., & Povinelli, D. J. (2008). Darwin's mistake: Explaining the discontinuity between human and nonhuman minds. *Behavioral and Brain Sciences*, 31(2), 109-130.
- Reese, H. W. (1991). Mentalistic approaches to verbal behavior. In L. J. Hayes & P. N. Chase (Eds.), *Dialogues on verbal behavior* (pp. 151-177). Reno, NV: Context Press.
- Roberts, W. A. (1980). Distribution of trials and intertrial retention in delayed matching to sample with pigeons. *Journal of Experimental Psychology, Animal Behavior Processes*, 6(3), 217.
- Rugg, M.D. (1985). The effects of semantic priming and word repetition on event-related potentials. *Psychophysiology*, 22(6), 642-647.
- Saunders, K. J., & Spradlin, J. E. (1993). Conditional discrimination in mentally retarded subjects: Programming acquisition and learning set. *Journal of the Experimental Analysis of Behavior*, 60(3), 571-585.
- Saunders, R. R., & Green, G. (1999). A discrimination analysis of training-structure effects on stimulus equivalence outcomes. *Journal of the Experimental Analysis of Behavior*, 72(1), 117-137.
- Sidman, M. (1986). Functional analysis of emergent verbal classes. In T. Thompson & M. D. Zeiler (Eds), *Analysis and integration of behavioral units* (pp. 213-245). Hillsdale, NJ: Lawrence Erlbaum
- Sidman, M. (1994). *Equivalence relations and behavior: A research story*. Boston: Author's Cooperative Inc. Publishers.
- Sidman, M., & Tailby, W. (1982). Conditional discrimination vs. matching to sample: An expansion of the testing paradigm. *Journal of the Experimental Analysis of Behavior*, 37(1), 5-22.
- Soprano, A. M., & Narbona, J. (2007). *La Memoria Del Niño: Desarrollo normal y trastornos*. Barcelona, España: Elsevier Masson.
- Spradlin, J. E., & Saunders, R. R. (1986). The development of stimulus classes using match-to-sample procedures: Sample classification versus comparison classification. *Analysis and Intervention in Developmental*

- Disabilities*, 6(1), 41-58.
- Tabullo, A., Yorio, A., Zanutto, S., & Wainselboim, A. (2015). Transferencia de funciones sintácticas artificiales entre estímulos relacionados por equivalencia: Un estudio de potenciales cerebrales relacionados con eventos. *Interdisciplinaria*, 32(1), 127-150.
- Tonneau, F., & González, C. (2004). Function transfer in human operant experiments: The role of stimulus pairings. *Journal of the Experimental Analysis of Behavior*, 81, 239-255.
- Vivas, J. (2007). Análisis de redes semánticas aplicado a contenidos académicos. Métodos e instrumentos. En E. Kronmüller & C. Cornejo (Comps.), *Ciencias de la mente: Aproximaciones desde Latinoamérica [Mindsciences: Approximations from Latin America]*, (pp. 385-409). Santiago, Chile: JC Sáez.
- Worsham, R. W. (1975). Temporal discrimination factors in the delayed matching-to-sample task in monkeys. *Animal Learning & Behavior*, 3(2), 93-97.
- Wulfert, E., & Hayes, S. C. (1988). Transfer of a conditional ordering response through conditional equivalence classes. *Journal of the Experimental Analysis of Behavior*, 50(2), 125-144.