ISSN 1512-1801

CROSS-MODAL STROOP INTERFERENCE BETWEEN TASTE AND ANAGRAMS

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Acknowledgements: The research reported in this paper was funded by the National Scientific and Technical Research Council (CONICET) of Argentina through the PIP-CONICET-11420100100139 granted to the first author.

Abstract
The purpose of this study is to evaluate the cross-modal Stroop effect between visually presented anagrams and gustatory stimuli. The working hypothesis states that cross-modal Stroop interference is increased by the level of inconsistency and reduced by the level of congruence between gustatory stimuli and linguistic visual stimuli whose order of syllables has been changed. 29 argentine subjects whose average age was 22 years old (SD = 3.024 years) participated in the experiment. A within-subjects repeated measures design was used. The independent variable was determined as the congruence of the stimulus and in it three levels were identified: congruent, incongruent and control stimuli. Two dependent variables were determined: reaction time and number of correct responses. The chosen paradigm was the cross-modal Stroop task. Gustatory stimuli were administered together with anagrams. The task required identifying a gustatory stimulus in the shortest possible time. It was concluded that in conditions of incongruent and control stimuli, subjects were not able to inhibit linguistic distractors to elaborate quick and effective responses concerning the identification of gustatory stimuli. In contrast, in the congruent anagrams condition the stimuli functioned as a key facilitator.

Keywords
Cross-modal stroop effect, taste, anagrams, working memory.

1. Introduction

The perception in humans is benefited from the temporary storage of environmental information (Baddeley, 1992). This storage allows a more comprehensive processing of information and, simultaneously, it facilitates elaborations that require different computational effort and processing times. Working memory is defined as a system that maintains and manipulates information temporarily (Baddeley, 1992). Thus, the organism perceives its ecological niche relying on certain regularities. The cognitive system discovers that sensory information has a high probability of being linked. The organism, therefore, is capable of working in the environment with some constants that make it possible to use the past as a predictor of the future (Baddeley, 1992). However, subjects are not always able to process two sources simultaneously (Roberts & Hall, 2008; Stroop, 1935). In this regard, Stroop (1935) designed an experiment in which words that referred to colors were presented to participants, written in colors that matched the meaning or were different. The instruction required naming the color in which the word was written in the shortest time possible. The results showed that when the stimuli were congruent, a greater number of correct responses were recorded and shorter reaction times were achieved (MacLeod, 1991). Congruency refers to the semantic

ISSN 1512-1801

coherence between the color of the stimulus and the meaning of the word. It is congruent when the word *red* is presented as a visual stimulus written in red. This test assesses executive aspects of intentional control required by selective attention (Banich et al., 2000; MacLeod, 1991, 1992). In the Stroop task there is an attentional resource competition in which both prosecutions require, on the one hand, processing the color of the word and, on the other, the linguistic processing of the meaning of the word which also refers to a color (Cho, Lien, & Proctor, 2006; Kahneman & Chajczyk, 1983; Kim, Cho, Yamaguchi, & Proctor, 2008; Mitterer, Laheij, & Van der Heijden, 2003). Thus, distractors must be inhibited in order to carry out the processing required by the experimental task (Kirn, Kirn, & Chun, 2005; Sreenivasan & Jha, 2007). In this sense, Stroop interference is evidenced as an increased reaction time and a lower number of correct responses due to the attention failure produced by the distractors that are inconsistent with the expected response.

Although the Stroop phenomenon has been studied initially in an isolated visual modality (Dyer, 1973; Houwer, 2003; McCown & Arnoult, 1981), it was later also studied in cross-modal situations (Allen & Schwartz, 1940; Börnstein, 1936; Gilbert, Martin, & Kemp, 1996; Pauli, Bourne, Diekmann, & Birbaumer, 1999; Prescott, Johnstone, & Francis, 2004; Roberts & Hall, 2008; Roelofs 2005; Rolls, 2004; Stevenson, & Boakes, 2004). White and Prescott (2007) gave participants olfactory stimuli together with gustatory stimuli and asked volunteers to identify taste as quickly as possible. Three experimental conditions were generated by presenting pairs of stimuli: 1) congruency: olfactory stimulation and gustatory stimuli belonged to the same object, 2) incongruity: the olfactory and gustatory stimulus did not belong to the same object, 3) control: olfactory stimulus was water. The data showed a lower reaction time and a greater number of correct responses in the congruent condition. Here it is important to highlight the anatomical entailment between olfactory and gustatory modalities through retronasal olfaction (Razumiejczyk, Macbeth & López Alonso, 2008) that functions as a biological bridge for fast and accurate discrimination of nutritive compounds as opposed to potentially toxic compounds before consumption (White & Prescott, 2007). Similarly, Razumiejczyk, Britos, and Grigera Monteagudo (2010), and Razumiejczyk, Jáuregui, and Macbeth (2012) have studied the cross-modal Stroop interference between taste and linguistic modalities of vision and hearing. In the gustatory-visual study Razumiejczyk et al. (2010) gave participants taste stimuli to be identified as quickly as possible while observing words written in black on a white background on a computer screen. In the gustatory-auditory study (Razumiejczyk et al., 2012) however, the words were presented in an auditory mode. The results were similar in both experiments. The Stroop interference was lower in the congruent condition, which is when the gustatory stimulus and the word presented visually or aurally coincided. In contrast, incongruent stimuli and control levels generated slower reaction times and more errors. These results are consistent with those observed by White and Prescott (2007).

The relevance of these findings lies in the ecological condition of visual and auditory stimuli used in the experiments. That is, stimuli were selected according to their presence in the natural environment in which experimental subjects operate. It is suggested here that the usual processing of language is part of the ecological adjustment of the individual to the environment. From such conjecture and based on the results obtained in previous studies (Razumiejczyk et al., 2010, 2012; White & Prescott, 2007) it is considered relevant to study how working memory functions with gustatory and visual linguistic representations such as anagrams. This study aims to extend the evaluation of cross-modal Stroop interference between taste and vision within the domain of language. Specifically, we intend to evaluate the cross-modal effect of visually presented anagrams with gustatory stimuli. The hypothesis presented here states that cross-modal Stroop interference is increased by the level of incongruency and reduced by the level of congruency between gustatory stimuli and visual stimuli. Visual stimuli are operationally defined as anagrams, i.e., written words in which the order of the syllables has been changed. This general hypothesis is justified by the tendency to adapt observed in previous experiments performed on different modalities.

2. Method

2.1 Participants

Twenty-nine Argentinean volunteers whose average age was 22 years old (SD = 3.024 years) participated in the experiment. All participants were enrolled in Social Science degree courses. The sample consisted of 20 women (69%) and 9 males (31%). The inclusion criteria for the sample were determined as in previous studies (Razumiejczyk et al., 2010, 2012): 1) the age of the participants should range between 20 and 40 years (West, 2004); 2) non smoking status, 3) not having eaten any food or drunk anything but water during the three hours prior to the experiment. In all cases, participation was free, voluntary and with informed consent. No financial, academic, or any kind of remuneration was distributed.

2.2 Materials

The taste stimuli were peach, plum, strawberry and orange in the form of pap liquefied at environmental temperature. The Cronbach´s α coefficient for the identification of these stimuli resulted in 0,536 (Razumiejczyk et al., 2010). As visual stimuli, anagrams written in black on a white background were presented on the screen of a computer using the PsychoPy software (Peirce, 2007). The criterion used to produce each anagram was to take a word and change the order in random syllables. This particular type of syllables anagrams was used instead of letter anagrams because of the difficulty to identify words that previous studies presented for single letters swap (Foley & Foley, 2007). The anagrams applied in this experiment were in Spanish as this is the native language of the experimental subjects. The congruent visual stimuli were: LLATIFRU (for the Spanish word *frutilla*, i.e. strawberry), RAZDUNO (*durazno*, i.e. peach), LACIRUE (ciruela, i.e. plum), and JANARAN (naranja, i.e. orange). The incongruent visual stimuli were: NABANA (for the Spanish word *banana*), NAANA (*ananá*, i.e. pineapple), DÍASAN (*sandía*, i.e. watermelon), and NAMANZA (*manzana*, i.e. apple). Control stimuli were DAMONE (*moneda*, i.e. coin), JOSOTEAN (*anteojos*, i.e. glasses), TACLECIBI (*bicicleta*, i.e. bicycle), and LOJRE (*reloj*, i.e. clock). All the utensils (spoons, glasses, and hygiene items) were discarded after use by each participant.

3.3 Design

A within-subjects repeated measures design was applied to study the effect of three different treatments of working memory interference using gustatory and visual linguistic (anagram) information. The congruence of stimuli was determined as an independent variable or factor. Three levels were identified for this factor, in accordance with previous studies (White & Prescott, 2007; Razumiejczyk et al., 2010, 2012): congruent, incongruent and control stimuli. The congruency levels were based on the relationship between gustatory and visual stimulation administered in the experiment: 1) congruent stimuli: the anagram matches the name of the gustatory stimulus, 2) incongruent stimuli: the anagram does not match the name of the gustatory stimulus, but it represents a random fruit, 3) control stimuli: the anagram and the gustatory stimulus do not match and the anagram does not represent an edible object. Two dependent variables were determined: REACTION TIME (RT) and number of correct responses. RT was measured in seconds with miliseconds precision. The number of correct responses is the cumulative score of successful identifications for each participant.

2.4 Procedure

The experiment was conducted by two volunteer experimenters who were unaware of the purpose of the study. The cross-modal Stroop task paradigm was selected (White & Prescott, 2007). The gustatory stimuli and the anagrams were administered simultaneously. The participants were asked to identify the taste stimulus in the shortest time possible. Three congruence factor levels were generated (congruent, incongruent and control stimuli) according to the relationship between the visual stimulus and the taste stimulus. As four taste stimuli were presented and each had 3 levels of congruence, 12 trials were generated for each participant. We measured the RT and the number of correct responses for each participant in each trial. During the experiment, the participant could only watch the computer screen as a result of a visual locking device, which prevented seeing the

ISSN 1512-1801

gustatory stimulus. This prevented the observation of color to influence gustatory stimulus identification (Morrot, Brochet, & Dubourdieu, 2001).
As part of the task, before each trial, participants had to wash their mouth with water. The pairs of stimuli (taste and anagram) were administered to each participant in random order.

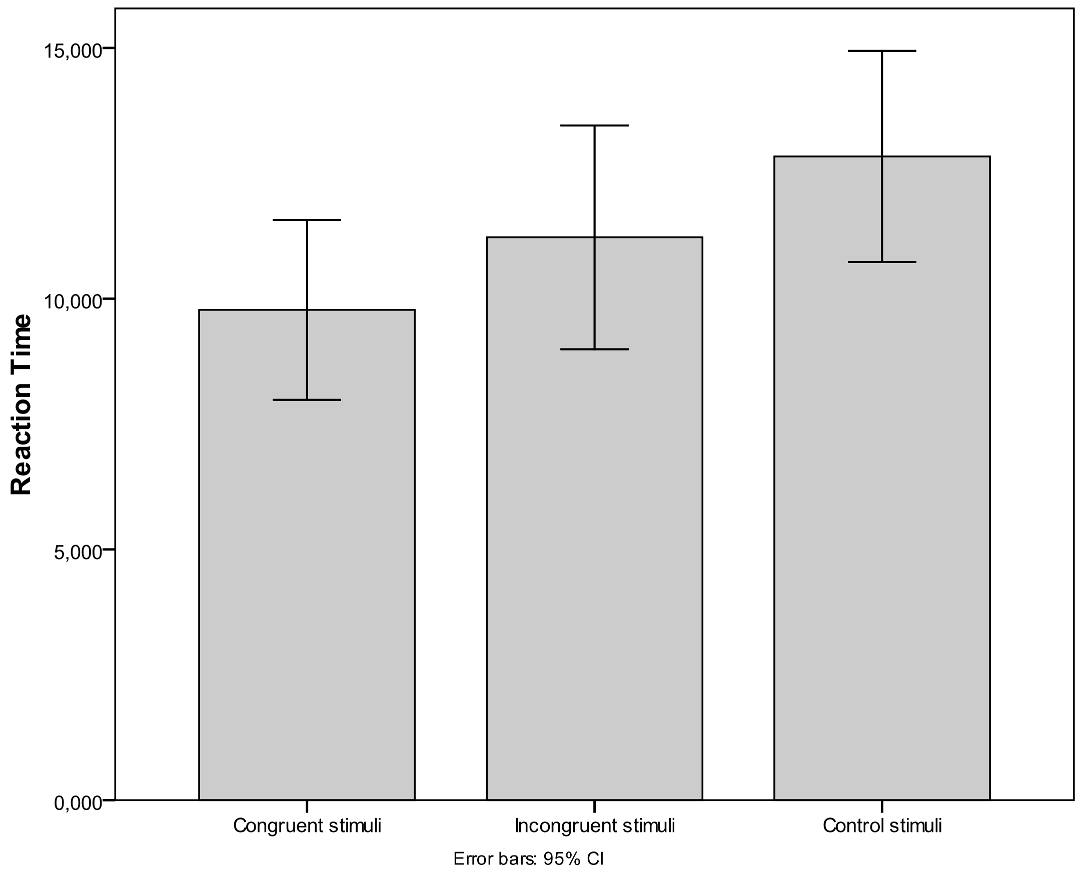
2.5 Results

In order to treat the sample as belonging to the same population, we evaluated potential gender differences in the dependent variables. No significant differences were found between men and women across the three levels of congruency factor as regards RT and number of correct responses with effects sizes close to zero (Cohen's d <0.10).
A within-subject analysis of variance was performed in order to compare the differences in RT between the three levels of congruency. We found a statistically significant difference between the congruent, incongruent and control stimuli´s RT ($F(2.28) = 11.575$, $p = 0.002$, = 0.3). Table 1 presents the Pairwise comparisons of within-subjects ANOVA.

Table 1. Pairwise comparisons for RT

	Pair 1		*Pair 2*		*Pair 3*	
	Congruent	*Incongruent*	*Congruent*	*Control*	*Incongruent*	*Control*
Mean	9.77	11.22	9.77	12.83	11.22	12.83
(*SD*)	(4,62)	(5.75)	(4.62)	(5.42)	(5.75)	(5.42)
t(28)	-2.306		-3.402		-1.929	
p	0.029*		0.002*		0.064	
Cohen´s d	0.278		0.608		0.288	

Note: * statistically significant difference (p-value < 0.05).
Below is Figure 1 which shows the RT in the three levels of the congruence factor.
Figure 1. Reaction time comparison in congruent, incongruent, and control stimuli



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Note: bars represent miliseconds measures for the three congruency conditions. The error bars represent a 95% confidence interval for the mean.

The number of correct responses achieved by the participants in the three conditions of congruency was studied through a within-subjects analysis of variance. We found a statistically significant difference between the number of correct responses in congruent, incongruent and control stimuli conditions (F(2.28) = 77.641, p <0.01, = 0.742). Table 2 presents the pairwise comparisons of within-subjects ANOVA.

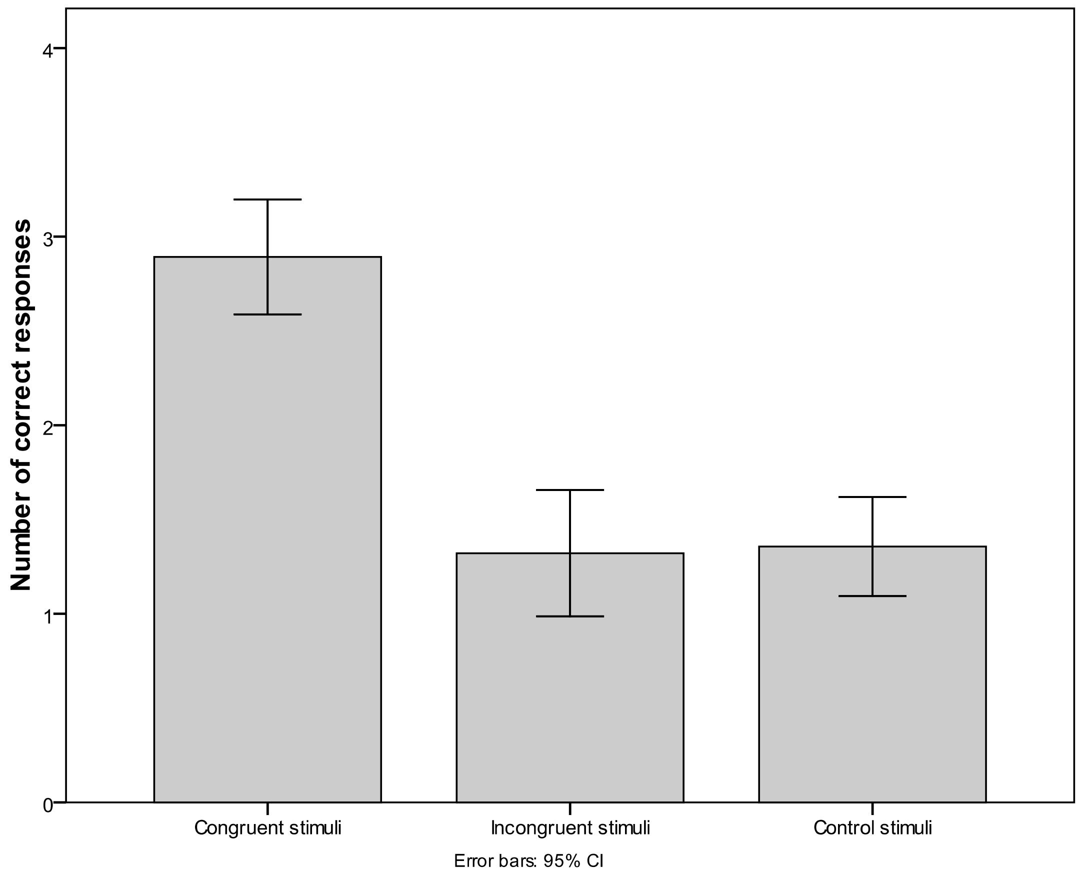
Table 2. Pairwise comparisons of number of correct responses

	Pair 1		*Pair 2*		*Pair 3*	
	Congruent	*Incongruent*	*Congruent*	*Control*	*Incongruent*	*Control*
Mean	2.89	1.32	2.89	1.36	1.32	1.36
(*SD*)	(0.786)	(0.863)	(0.786)	(0.678)	(0.863)	(0.678)
t(28)	6.6		8.811		-0.214	
p	0.001*		0.001*		0.832	
Cohen´s d	1.912		2.104		0.052	

Note: * statistically significant difference (p-value < 0.01).

Figure 2 shows the number of correct responses for congruent, incongruent, and control stimuli.

Figure 2. Average comparison between the number of correct responses for the three congruency conditions.



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Note: bars represent the number of hits or correct responses observed in each congruency condition. The error bars represent a 95% confidence interval for the mean.
All variables were normal and homoscedastic compared by the Kolmogorov-Smirnov and Levene tests, respectively, so parametric tests were applied to contrast the hypotheses.

3. Discussion

We have studied Stroop interference between taste and visual linguistic representations in working memory. The results evidenced that cross-modal Stroop interference was lower in congruent stimuli conditions, producing more correct responses and shorter RTs when the taste stimulus and the object referred to by the visual anagram coincided. Thus, competition between the two attentional modes, taste and visual linguistic anagrams, was lower in the congruent stimuli condition because the information converges.

These results have a double significance. On the one hand, subjects were not able to avoid the perceptive analysis of task-irrelevant attributes such as the perceived anagrams (Kahneman, 1997). It is possible to analyze this result considering that the materials used were environmentally friendly, i.e., the usual linguistic information in the environment of the experimental subjects. On the other hand, facilitating the identification of taste stimuli in the congruent stimulus shows the adaptation of the individual to the linguistic environment. These findings suggest that the individuals need to process visual information linguistically, even when it was not consigned in the task. Anagrams generated distractor effects, as expected. This led to attentional competition, which had already been found in previous studies (White & Prescott, 2007). This attentional competition was not identical in all cases. Incongruent and control stimuli worked as strong distractors, even while congruent stimuli were facilitators in identifying gustatory stimuli. Thus Stroop interference was observed in the incongruent and control conditions since they produced more errors and longer reaction times. In contrast, it is conjectured that in the congruent stimuli level anagrams worked as a key facilitator.

In this sense, the Stroop test involves selective attention processes (Cho et. al., 2006; Kahneman & Chajczyk, 1983; Kim et al., 2008; Mitterer et al., 2003) such as the processing of gustatory stimuli competing for resources with the processing of linguistic visual stimuli such as anagrams. In the incongruent stimuli and control stimuli conditions the results suggest that subjects were not able to inhibit linguistic distractors in tasks which required the quick and effective identification of gustatory stimuli (White & Prescott, 2007).

A contribution of this study that adds evidence to the current literature on linguistic cognition is that it provides a record of an inherent tendency to process simple anagrams. When viewing a succession of jumbled syllables, experimental subjects spontaneously tended to sort them so as to make a word. This inferential tendency of the human mind has been widely recorded in reasoning studies (Johnson-Laird, 2007). These data are inferred from the results that show significant differences in gustatory identification in the three levels of the congruence factor.

It is also interesting to link these results with those found in relation to the auditory processing of linguistic representations. Based on the results obtained here, it is pertinent to perform in the future a factorial study to compare the visual stimuli of words and the visual stimuli of anagrams with taste and compare the results with the processing of auditory stimuli. It is relevant to know if the cross-modal Stroop interference is greater in the visual or in the auditory modality in view of their survival ecological relevance related to the possible ingestion of toxic foods.

The data presented in this article were obtained from an experimental study in the laboratory. However, it is noted here that one should not lose sight of the natural relationship the individual has with the environment in which it operates. In this sense, these findings support the conclusion that the rapid and accurate identification of congruent stimuli corresponds to efficient adaptation to the environment and inconsistency requires further processing and generates more errors.

The experimental design was intended to be adapted to the natural relation between the subject and the environment, using natural taste stimuli. It is therefore considered that linguistic stimuli, though distorted, are usual visual stimuli in the natural ecological environment of the participants. We conclude that the experiment participants are well adapted to the environment in which they operate normally (Razumiejczyk & Jáuregui, 2012).

Two important limitations were revealed in this study: the use of a specific selection of taste stimuli and the application of a simple variant of anagrams. It is recommended in future studies to expand the collection of gustatory stimuli. This requires, however, the psychometric validation of the gustatory stimuli, as was done for this study (Razumiejczyk et al., 2012). This limitation implies therefore also a plus. All the tastes used are natural or ecological for the experimental subjects. The other important limitation of this study is the use of anagrams generated by the change of the sequence between syllables. It is possible that different results are obtained for anagrams generated by randomization of letters. However, we chose here to change syllables instead of letters because the latter option produces great difficulty to identify words. This difficulty could block the experimental uptake sought in the cross-modal interference. The use of anagrams by letters, instead of generating the Stroop phenomenon, could generate a problem-solving phenomenon (Foley & Foley, 2007). The evaluation of this conjecture is recommended in future studies.

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Article received: 2014-06-10