Cognitive style modulates semantic interference effects: evidence from field dependency

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Abstract

The so-called semantic interference effect is a delay in selecting an appropriate target word in a context where semantic neighbours are strongly activated. Semantic interference effect has been described to vary from one individual to another. These differences in the susceptibility to semantic interference may be due to either differences in the ability to engage in lexical-specific selection mechanisms or to differences in the ability to engage more general, top-down inhibition mechanisms which suppress unwanted responses based on task-demands. However, semantic interference may also be modulated by an individual's disposition to separate relevant perceptual signals from noise, such as a field independent (FI) or a field dependent (FD) cognitive style. We investigated the relationship between semantic interference in picture naming and in a STM probe task and both the ability to inhibit responses top-down (measured through a Stroop task) and a FI/FD cognitive style measured through the Embedded Figures Test (EFT). We found a significant relationship between semantic interference in picture naming and cognitive style -with semantic interference increasing as a function of the degree of field dependence- but no associations with the semantic probe and the Stroop task. Our results suggest that semantic interference can be modulated by cognitive style, but not by differences in the ability to engage top-down control mechanisms, at least as measured by the Stroop task.

Keywords: Lexical Retrieval, Semantic Interference, Cognitive Styles, Field Dependence

1 Introduction

Presenting semantically related stimuli close in time and space (semantic context) can interfere with target selection (Belke et al. 2005; Howard et al. 2006; Navarrete et al. 2010). This is because the presentation of a cohort of semantically related, alternative responses (competitors), making selection of the right target more difficult, a so-called semantic interference effect (Oppenheim et al. 2010; Belke and Stielow 2013). Semantic interference has been observed in different experimental paradigms manipulating the context in which stimuli are presented (Damian & Bowers 2003; Piai et al. 2012). A good example is the continuous picture naming task (Howard et al. 2006), in which participants name a sequence of pictures and embedded within this sequence there are sets of semantically related items. Typically, participants naming speed increases with presentation of each new category member in the sequence, in the order of roughly 30ms (Navarrete et al. 2010). Other studies have highlighted the strong influence of semantic context in short-term memory (Hamilton and Martin 2007; Atkins et al. 2011). For example, Atkins et al. (2011) investigated the performances of healthy volunteers with a paradigm (semantic probe task) in which semantic relatedness was manipulated in a recent-probe task (Berman et al. 2009). Participants were given a list of four semantically related or unrelated words. Then, immediately afterwards, a single probe word was shown which could also be either related to the words in the list or unrelated. Participants had to decide whether the probe was one of the words in the preceding list. Results showed strong effects of interference: participants made more false alarms and showed higher correct rejection latencies with lists where items were semantically related.

In conditions of high lexical/semantic interference (i.e. an exceedingly high activation of both the target and its semantic neighbours), control mechanisms must be engaged to inhibit the activation of competitors. These mechanisms may be either internal to the lexicon or more general operating across domains to inhibit the activation of interfering responses be they linguistic or non-linguistic (e.g., Thompson-Schill et al. 1999; Novick et al. 2009). These latter mechanisms may be tapped chiefly by a task like the Stroop, but they may also be operating in naming tasks (i.e., Picture-Word-Interreference, cyclic blocking naming) and STM tasks in condition of high interference (e.g., Nigg 2000; Hamilton and Martin 2007; Whitney et al. 2011; Shao et al. 2013; Krieger-Redwood and Jefferies 2014; Shao et al. 2015).

There is already some evidence that the mechanisms which control interference in lexical selection tasks are different from mechanisms which apply top-down to suppress task irrelevant responses based on task demands, as in an experimental task like the Stroop. In a continuous naming task, suppressing irrelevant names is an automatic process which is not under strategic control. This is very different from the Stroop which is an experimental task where responses need to be under strict control of the participant. In the Stroop, the names of written words (irrelevant to the task) are automatically activated and top-down control is needed to bias the activation of task relevant information (i.e. the ink color, see Khng and Lee 2014). Consistently with this description, the Stroop engages prefrontal cortex areas (Banich et al. 2000; Milham et al. 2001; Milham et al. 2002; Milham et al. 2003) while naming tasks -even those with high semantic competition- engage temporal brain areas such as the superior or the middle temporal gyrus (de Zubicaray et al. 2001; de Zubicaray et al. 2013; de Zubicaray et al. 2014). Another piece of evidence comes from a study of Dell'Acqua et al. (2007) which investigated the locus of interference in Stroop and Picture-Word Interference (PWI) tasks by assessing the effects of a psychologically refractory period on these tasks. In the PWI task, participants are instructed to ignore a distractor word whilst naming a picture. In critical conditions, the distractor and picture name are semantically related, and this makes responses slower and less accurate compared to an unrelated condition. Dell'Acqua et al. (2007) combined a PWI task and a Stroop task with a second task where participants had to give a speeded manual response to an auditory stimulus followed, at a varying stimulus onset asynchrony (SOA), by a PWI trial/Stroop trial. A strengthening of interference effects at shortest SOA has been explained with limitations of response selection operations when two tasks must be performed in rapid succession (see Fagot and Pashler, 1992 for results with the Stroop task). In contrast, Dell'Acqua et al. (2007) reported that the magnitude of semantic interference decreased in the PWI task decreased instead of increasing at shortest SOA. They interpreted this result as showing that semantic interference in the PWI task originates prior to the top-down selection mechanisms engaged by the Stroop task.

In spite of some suggestive results, evidence regarding the nature of control mechanisms across tasks remain limited. Moreover, we know little of what determines individual differences in susceptibility to interference (e.g. Ridderinkhof et al. 2005). They may be due to differences in the ability to engage in lexical-specific selection mechanisms or to more general, top-down mechanisms as discussed above. Still alternatively, differences in the size of the interference effect may be due to a general cognitive style which affects the ability to discriminate stimulus-specific information from a general background. The semantic context created by the previous presentation of a series of semantically related items may make it more difficult to focus on the individualizing feature of an item. Thus, individuals who are more focused on shared features could be more prone to semantic interference, due to a higher co-activation of both the target and its related representations. Conversely, individuals who focus on item-specific information may show reduced interference.

In our study, we are particularly interested in the hypothesis that semantic interference may be related to a cognitive style linked to the ability to separate signal from noise such as the field independent/field dependent (FI/FD) cognitive style (see Witkin et al. 1977). This style identifies two modalities of interaction with the environment. Highly FI individuals focus on discrete parts/dimensions of a perception independently of context. Highly FD individuals find more difficult to isolate discrete dimensions without being influenced by the context in which they are embedded and, thus, find more difficult to overcome or restructure a contextual organization when needed.

The early works on FI and FD made use of experimental paradigms such as *the rod-and-frame test*, *the body-adjustment test*, and *the embedded figures test* (EFT; see Witkin et al. 1977). These paradigms allowed computing a quantitative index of the extent to which the surrounding field influences a person's perception of an item. The rode-and-frame task assesses identification of the upright dimension in space. Participants are placed in a dark room, in which they can see only a luminous square framework with a luminous rod pivoted at its centre. Both the framework and the rod are shown in a tilted position, but the rod can be rotated clockwise or counter clockwise independently of the framework. The participants' task is to adjust the rod to a perceived upright position, while the framework remains in its original position. People perform the task differently, with some being strongly influenced by the surrounding frame (FD) and others not (FI). Witkin stated that: "They [FI individuals] evidently apprehend the rod as an entity discrete from the prevailing visual frame of reference…" (pp. 5). In the body-adjustment task, participants are seated on a tilted chair located inside a small tilted room. Both, the chair and the room can be independently tilted clockwise or counter-clockwise by means of a rotating centrifuge arm. In this setting, the participants' task is to adjust the chair (and thus the body) to a perceived upright position. Finally, in the embedded figures test, participants must locate a simple geometric figure embedded in a complex one (see Figure 1 in the method section). The simple figure is concealed because its lines are used in various sub-parts of the complex design. This hides the simple figure. Results show that some people quickly recognise the simple figure in the complex design (FI), while others struggle (FD; Witkin et al. 1971). These different paradigms are reported to be consistent in identifying individuals as FI/FD (Witkin 1977; see also Witkin and Goodenough 1981).

The degree to which a semantic context (negatively) influences target selection may be related to field dependency. Highly FD individuals may be more sensitive to the influence of a general semantic field created by the features shared between a target picture and other pictures recently presented. This would make picture naming more difficult for two reasons: 1. It would be more difficult to focus on the perceptual identifying feature of the target and 2. It would increase the activation of semantically related items. In the first case, field dependency may modulate degree of interference in a picture naming task. In the second case, it would modulate it across picture naming and STM tasks (where words but not pictures are presented).

FI and FD cognitive styles have been report to correlate with a broad range of cognitive processes. Poirel et al. (2008) showed that an individual's disposition toward a global-local bias in a Navon task (where a larger shape is made of copies of a smaller different shape and the participant has to name either the larger or the smaller shape; see Navon 1977) was largely explained by FI/FD cognitive styles. The preference for the global shape linearly increased with the degree of field dependence. Other studies have reported correlations between field dependency and a variety of visuospatial tasks such as the road learning task (Mitolo et al. 2013), the visual pattern test (Borrella et al. 2007), the Minnesota Paper Form Board (a spatial orientation test, Likert and Quasha 1941), and a task involving the spatial transformation of a perceived object (Boccia et al. 2016). Finally, FI/FD cognitive styles have been shown to correlate with learning abilities (St Clair-Thompson et al. 2010; Nozari and Siamian 2015) and working memory capacity (Rittschof 2010), with FI individuals performing better (see Evans et al. 2013 for a review). However, to our knowledge, there is no evidence of whether cognitive styles can modulate semantic interference.

In our study, we explored the nature of interference effects by assessing inter-relations among tasks including a task assessing field-dependency. We assessed semantic interference in a continuous picture naming task and put the size of this effect in relation with interference effects in other tasks such as: a) a Stroop task which measures top-down control mechanisms related to inhibition abilities, b) a probe short-term memory task which measures interference not in lexical selection, but in recognition and, finally, c) an embedded-figure test which measures field-dependency. We predicted the following:

1. If semantic interference is controlled exclusively by lexical-specific selection mechanisms, there should be no relation between interference in picture naming and other tasks. Alternatively, if semantic interference is controlled by top-down inhibition mechanisms, we should see a relationship between interference in the Stroop task on one side and interference effects in picture naming and probe tasks on the other side, since all these tasks require task-dependent inhibition to an extent (see above).

2. If cognitive style -related to field dependency- modulates interference effects, performance in the embedded figures test may contribute to explain individual differences in semantic interference in picture naming and, possibly, in probe tasks since in both of these tasks a stimulus needs to be distinguished from a semantic background. Moreover, if this effect is

perceptually mediated, we should see it only more strongly in Picture Naming than in the Probe task where words rather than picture are presented. Moreover, if an association is present at all in the Probe task is should be modulated by the number of semantically related distractors which are presented. We should see a stronger association with a higher number of distractors which contribute to create a shared semantic context. We expect instead no relation at all between a measure of field dependency (EFT scores) and the Stroop task since the Stroop is based on inhibiting an unwanted, automatic response rather than on discriminating the identifying features of a stimulus in a confusing background.

2 Method

2.1 Participants

52 participants were recruited from the University of Rome "Sapienza" student community (23 males; mean age = 26; SD = 3). Sample size was determined by means of G*Power software (Faul et al. 2009) with the following parameters (effect size= .20, α= .05, Power (1-β)= .80). Participants were all monolingual Italian native speakers. They were naïve to the purpose of the study. All claimed to have normal or corrected to normal vision and had no language impairment. All participants signed a consent form before the study began. This study was approved by the local ethics committee, in agreement with the Declaration of Helsinki (2013).

2.2 Materials and procedure

2.2.1 Cognitive style: The Embedded Figures Test (EFT).

Version A of EFT was used. It consists of a set of 12 cards depicting coloured, complex geometric figures and of a set of 8 cards with simple shapes (Figure 1; Witkin et al. 1971; Italian adaptation: Fogliani, Messina et al. 1984). Participants were first shown a complex figure for 15 seconds. This figure was then removed from sight and the simple shape was shown for 10 seconds. Finally, the complex figure was presented again, and participants were asked to locate the simple shape embedded in it and trace it with a pen. A practice trial was administered to familiarize participants with the task. Time was recorded with a stopwatch. Errors and very long responses were arbitrarily assigned a maximum time of 180 seconds (Fogliani, Messina et al. 1984). The score of each participant was computed by averaging the times needed to correctly identify the simple shapes. This score was taken as an index of individual field independence/field dependence. The higher the score, the higher the field dependence.

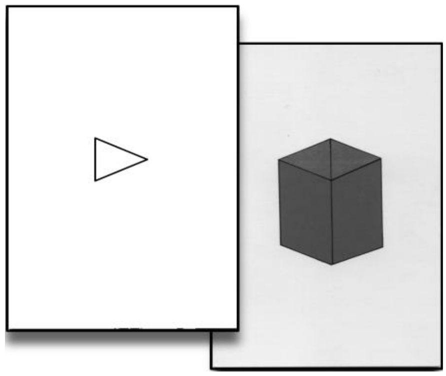

Fig.1 An example of cards used for the Embedded Figure Test

2.2.2 Continuous Picture Naming.

Stimuli. Participants had to name pictures. They were 82 line-drawing pictures (300x300 pixel dimensions) drawn from a variety of sources. 60 pictures were experimental and 22 were "fillers" (see *Appendix 1*). Experimental pictures were drawn from 12 semantic categories, with 5 exemplars for each category (Figure 2). Presentation of the stimuli followed Howard et al. (2006). The first and last five items were filler items; each category was presented in a sequence that separated category members by 2, 4, 6, or 8 intervening items (lag), which were either fillers or pictures from other categories; each category was assigned one of the 24 possible lag order sequences (4x3x2=24) and category members were assigned ordinal positions (i.e., 1 to 5) in the corresponding lag sequence. In the literature, this structure is well known to induce a linear increase of both reaction times (Howard et al. 2006) and errors (Navarrete et al. 2010) as a function of ordinal position (cumulative semantic interference). The size of the lag in this range does not affect the degree of interference. In other words, during this task, the previous naming of a picture (e.g. dog) will make the naming of a successive related picture (e.g. cat) slower and more prone to errors, but the number of intervening items (up to 8) does not matter. To make sure that positional effects were not confounded with lexical variables, items were matched across each ordinal position for frequency and word length (CoLFIS database; Goslin et al. 2014; see *Appendix 2*).

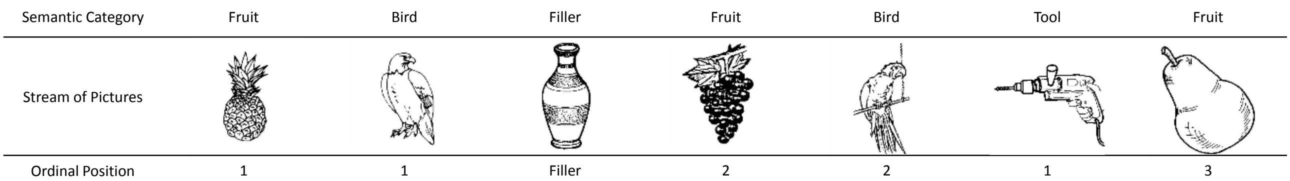

Fig.2 Schematic representation of a sequence of trials in the Continuous Picture Naming Task

Procedure. For this and the following tasks, participants were seated in a dark and noise-isolated room and stimuli were provided at the centre of a 21-inch LCD computer monitor with a resolution of 1024x768 pixels, 120Hz. The presentation of the stimuli and response times were controlled by means of SuperLab 4.0 software. Each naming trial started with the presentation of a fixation cross for 1000ms followed by a blank screen for 250ms. A picture was then presented and remained on the screen until the participant made a verbal response. RTs were taken using a Cedrus SV1 voice key.

The naming trial finished with a blank screen presented for 500ms and, then, the next trial started. Participants were instructed to name the pictures as fast and accurately as possible using bare, subordinate category nouns (e.g., a correct response to ant is “ant”, not “insect”). A brief practice session preceded the experimental task. Naming responses were scored off-line using a tape recorder. Responses were scored as incorrect if the name was incorrect or no response was given. Near-synonyms (e.g., “mule” instead of “donkey”) were scored as correct.

2.2.3 Stroop Task.

Stimuli. Participants had to name the ink colour of words. Stimuli consisted of four colour words (BLUE, RED, YELLOW and GREEN) and strings of Xs (i.e. “XXXX”) printed in one of four colours (blue, red, yellow and green). There were three main conditions: neutral, congruent and incongruent (24 trials for each condition). In the neutral condition, a string of Xs was shown in one of the four possible colours. In the congruent condition, colour words were shown in their corresponding colours. Finally, in the incongruent condition, colour words were presented in a different colour (e.g. “RED” written with green ink). Participants were instructed to name the ink colour of the stimuli as fast and accurately as possible.

Procedure. Each trial started with a fixation cross presented at the centre of the screen for 1000ms, followed by either a word or a string of Xs. Stimuli remained on the screen until the participant gave a verbal response which triggered a Cedrus SV1 voice key. Words were displayed in uppercase, 56-point Times New Roman font. A brief practice session preceded the experimental task.

2.2.4 Semantic Probe Task.

Stimuli. Participants were asked to recognize whether a probe word was present in a list of immediately preceding words. In each trial, five words were presented one at a time on a computer screen, followed by a probe word. All words were concrete nouns. Participants were asked to respond affirmatively if the probe was one of the previous five words (positive/yes trials) or negatively if not (negative/no trials). Lists were never repeated. There were 120 trials, overall, half positive and half negative. The negative trials included: a. No-Associated trials, where the words of the list were semantically related to each other and to the probe (e.g. cat, dog, mouse, rabbit, goat: probe: cow; N=20); b. No-Combined trials, where the words of the list were unrelated to each other but the combined meanings of two of them were related to the probe (e.g. vehicle, *lobe*, lizard, *jewel*, hostage: probe: *earring*; N=20); and c) No-Unrelated trials where the words of the list were neither related to each other nor to the probe (N=20). Positive trials were subdivided into a) Yes-related trials (words in the lists were semantically related to each other and to the probe; N=30) and b) Yes- unrelated trials (words were not drawn from the same semantic category; N=30). Figure 3 provides an illustration of the negative and positive trials.

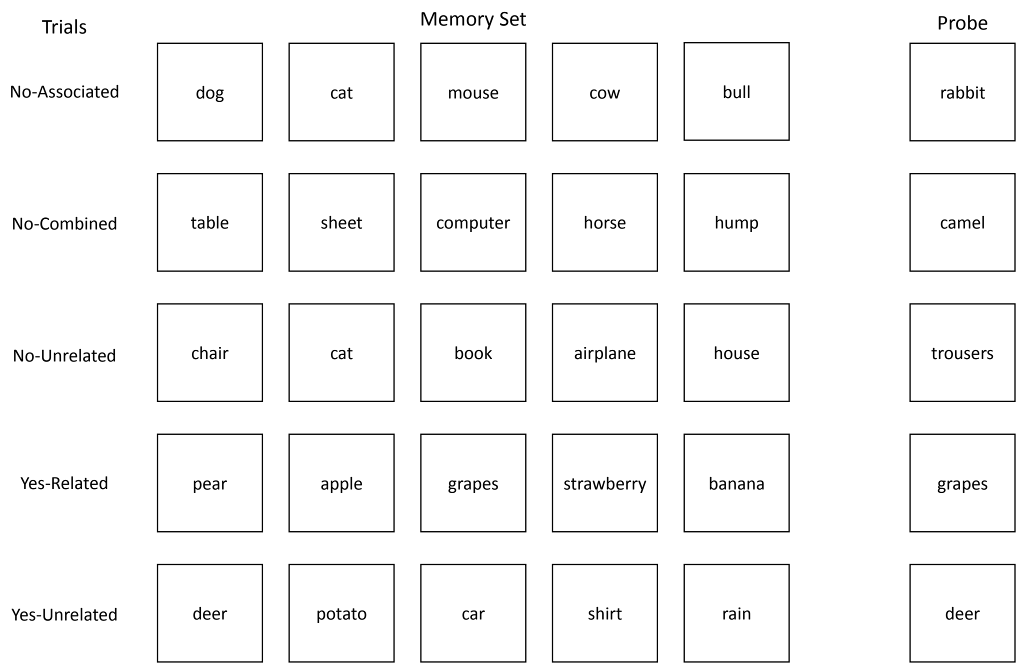

Fig.3 Schematic illustration of the conditions in the Semantic Probe Task

We wanted to contrast a ***no-associated*** condition with a ***no-combined*** condition with the expectation that field dependency may be related to the first but not to the latter. In the associated condition the categorical (and visual similarity) between the items may strongly activate a semantic field where common features are more salient than the distinguishing features of the target. This may make especially difficult for field-dependent individuals to distinguish the probe from other items in the list (thus producing a correlation between field-dependency and degree of interference). In contrast, in the combined condition, it is only the meaning of the (lure) probe which is strongly activated by the overlapping meanings of two words in the list. Therefore, degree interference in this condition may relate STM abilities and/or to lexical abilities in activating selective representations and inhibiting competitors, but not to field dependency.

We have not distinguished associated and combined conditions in the case of positive trials. Here, a degree of association between related words may actually make a positive, correct response more likely. Results from the literature generally either do not report results for yes trials or report non-significant results compared to neutral conditions (Hamilton and Martin 2007; Atkins and Reuter-Lorenz 2008; Atkins et al. 2011).

Procedure. At the beginning of each trial, a fixation cross was presented in the centre of the screen for 1000ms, followed by five words presented one at a time. Each word stayed on the screen for 400ms and was separated from the following word by a blank screen for 250ms. The five words were followed by the probe word that remained on the screen until the participant gave a response. Participants gave "yes" and "no" responses by pressing the "g" and "j" keys, respectively. They were asked to respond as quickly and accurately as possible with the index finger of their dominant hand.

2.3 Data analyses

For each task, errors, responses below 250ms (false triggers) and above 3 standard deviations over the mean (outliers) were removed. All analyses were carried out on RTs. Errors were not analysed because they were too few.

In order to investigate the inter-relation among tasks, different indices of interreference were computed as follow:

a) for the continuous picture naming, we averaged the RTs in the first two (hereafter "1+2") and the last two (hereafter "4+5") ordinal positions and then calculated the difference between them ((4+5)-(1+2); Cumulative Picture Naming Interference or CPNI);

b) for the semantic probe, we computed the difference between 1. No-Associated and No-Unrelated trials (Interference No Associated), 2. No-Combined and No-Unrelated trials (Interference No Combined), and 3. Yes-Related and Yes Unrelated trials (Interference Yes). Additionally, in order to make a possible effect more reliable, we computed 4. an Associated + Combined interference index by averaging the RTs in the No-Associated and No-Combined trials and subtracting them from those in the No-Unrelated trials (Interference No Associated + Combined);

c) for the Stroop task, we computed the difference between the incongruent and the congruent condition (Stroop Interference).

The mean and SD for each index and the EFT score are reported in Table 1.

Table 1 Mean scores and variability (standard deviation) for each interference index and EFT

	CPNI	Interference Associated	Interference Combined	Interference Associated+Combined	Interference Related	EFT
Mean	93 ms	86 ms	119 ms	102 ms	9 ms	35 sec
Standard Deviation	128	117	125	108	58	22

These indices were submitted to a Pearson bivariate correlations along with the EFT score. A Bonferroni correction for multiple comparisons was applied.

In addition, to explore relationships between our tasks, we also used more sophisticated linear mixed model analyses where interference effects were measured not with a single averaged index, but considering modulations of individual reaction times according to ordinal position in continuous picture naming or type of condition in probe and Stroop task. In this kind of analysis, the dependent variable is modelled as linear combination of both fixed and random effects, with the latter contributing only to the covariance of the data (Baayen et al. 2008; Bates et al. 2015a; Bates et al. 2015b). Modelling relies on single trial data rather than the averages by subject (or other factors) which potentially leads to more accurate predictions.

We carried out two main types of analyses:

1. To investigate the association between interference effects in picture naming and other tasks we created a global model where this effect was predicted by EFT, the interference effects in the probe task, and the interference effect in the Stroop;
2. To investigate the effects of EFT on interference effects, we created three models for each task (continuous picture naming and probe task): a) a baseline model (m1), intended to test the main effect of interference. Here, experimental conditions were conceived as the main source of observed variance in RTs; b) a second model (m2), investigating the main effect of both task condition and cognitive style on participants' performance. This model assumed an amount of unexplained variance in the first model accounted for by FI/FD styles; c) a third model (m3), investigating the interaction between task condition and cognitive style as another source of variance in RTs. It assessed whether FI/FD styles modulated the size of interference. These models were compared in their fit of the data. If cognitive style modulates performance in our tasks, the third model would explain the data better. For all the created models, participants and items were entered as random factors.

Linear mixed models were built by means of the “lme4” package (Bates et al. 2015a) implemented in R (R Development Core Team). Statistics for each model were computed by using the “lmertest” package for R (Schaalje et al. 1997). The function provides p-values calculated from F statistics. Furthermore, Kenward-Rogers approximation for degrees of freedom was computed. The KR method works reasonably well when sample sizes are moderate to small and the design is reasonably balanced (Schaalje et al. 1997). Finally, we run the “r.squaredGLMM” command (MuMln package) to calculate conditional and marginal coefficient of determination for generalized mixed-effect models. This command gives two main outputs, namely the marginal coefficient of determination (the variance explained only by fixed factors) and the conditional coefficient of determination (variance explained by both fixed and random factors) (Nakagawa and Schielzeth 2013).

3 Results

3.1 Associations among experimental tasks

Correlational analysis showed that there was a significant relation between the interference effect in continuous picture naming and the EFT (Pearson r= .46, p=.01). There was also a significant relation between Interference Associated and Interference Combined (Pearson r= .61, p < .001). There were no other significant correlations (Table 2).

Table 2. Pearson correlations among the tasks and Bonferroni-corrected p-values. Significant correlations are in bold.

		CPNI	Interference Associated	Interference Combined	Interference Associated+ Combined	Interference Related	Stroop Interference	EFT
CPNI	Correlation coefficient	1	- .10	.005	- .05	- .06	- .10	**.46**
	p		.48	.97	.70	.66	.48	**.01**
Interference Associated	Correlation coefficient	- .10	1	**.61**	**.90**	.005	.19	.14
	p	.48		**< .001**	**< .001**	.97	.21	.34
Interference Combined	Correlation coefficient	.005	**.61**	1	**.89**	- .06	.06	.23
	p	.97	**< .001**		**< .001**	.65	.69	.11
Interference Associated+Combined	Correlation coefficient	- .05	**.90**	**.89**	**1**	- .03	.14	.21
	p	.70	**< .001**	**< .001**		.82	.35	.16
Interference Related	Correlation coefficient	- .06	-5	- .06	- .03	1	.26	- .13
	p	.66	.97	.65	.82		.08	.36

Stroop Interference	Correlation coefficient	- .10	.19	.06	.14	.26	1	.01
	p	.48	.21	.69	.35	.08		.91
EFT	Correlation coefficient	**.46**	.14	.23	.21	- .13	.01	1
	p	**< .001**	.34	.11	.16	.36	.91	

3.2 Modelling the semantic interference in the continuous picture naming task

With the global model, we considered interference in the Stroop and probe tasks and EFT scores as predictors of interference effects in picture naming. For the probe task, we considered the more general Associated + Combined interference score. To place EFT scores, the Stroop interference and the probe interference scores on an equal footing, we converted them in z-scores. These scores were submitted to a linear mixed modelling together with the ordinal positions as fixed factors. Participants were treated as random effect.

Results highlighted only a main effect of the Ordinal position ($F_{1,172}$=53.32, p< .001) and a significant Ordinal position by EFT interaction ($F_{1,172}$=4.63, p= .03). No other effects were significant (Table 3).

Table 3. Linear mixed models: Global model (GM). Table shows information and statistics about the model.

Model	Fixed Factor	Fixed Factor Statistics		Model Statistics			
		F	p	AIC	BIC	r^2_m	r^2_c
GM	Ordinal Position	53.32	< .001	2832	2894	.30	.70
	Ordinal Position x EFT	4.63	.03				
	Ordinal Position x Stroop Interference	.25	.61				
	Ordinal Position x Semantic Probe Interference	.45	.50				
	Ordinal Position x EFT x Stroop Interference	.21	.64				
	Ordinal Position x EFT x Semantic Probe Interference	.70	.40				
	Ordinal Position x EFT x Stroop Interference x Semantic Probe Interference	1.01	.31				

3.3 The role of cognitive styles in modulating semantic interference: Continuous picture naming task and Semantic probe task

3.3.1 Continuous picture naming.

Incorrect responses (2%) as well as false triggers and outliers (2%) were excluded from analysis. Remaining RTs were log transformed to reduce skewness and to approach a normal distribution and were submitted to linear mixed modelling (see Runnqvist et al. 2012). In the first model (CPN-m1) ordinal position was treated as a fixed factor. Participants and items were entered as random factors. Results reported a significant effect of Ordinal position ($F_{1,896}$= 48.81, $p < .001$; Figure 4). In the second model (CPN-m2) EFT scores were added as a fixed factor. Results confirmed the significant main effect of Ordinal position ($F_{1,896}$= 48.78, $p < .001$), but also showed a significant main effect of EFT score ($F_{1,50}$= 10.50, p= .002). This indicates that individuals who are more field-independent have faster naming latencies. The third model (CPN-m3) investigated the interaction between Ordinal position and EFT as a fixed factor. This model showed a significant effect of Ordinal position ($F_{1,1503}$= 13.87, p< .001), no significant effect of EFT score ($F_{1,86}$= 1.16, p= .28), but a significant Ordinal position by EFT interaction ($F_{1,2765}$= 12.63, p< .001; Figure 5). That is, the higher the FD the higher the semantic interference effect.

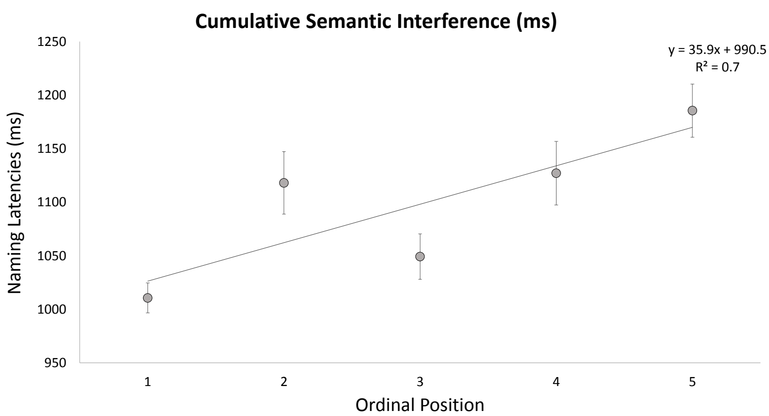

Fig.4 Linear increase of naming latencies in function of ordinal positions. Error bars report the standard error. Continuous lines depict the linear trend. The equation of linear trend as well as the R^2 have been reported.

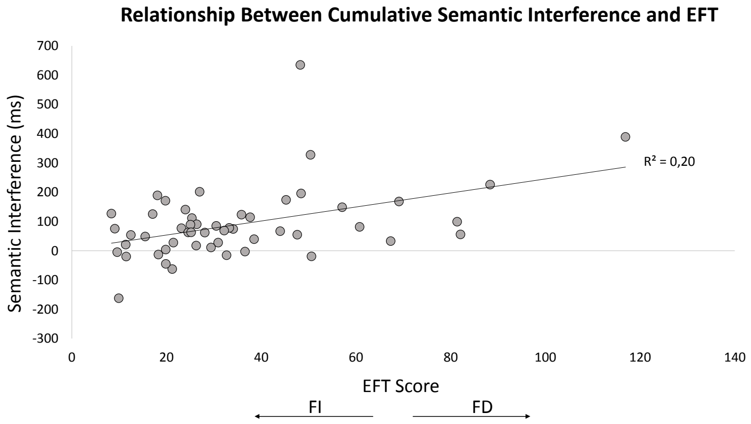

Fig.5 Scatterplot. The EFT score is reported on x-axis, whereas on y-axis is represented the cumulative semantic interference index computed as the difference of the averaged reaction times in the last vs the first two ordinal positions ((4+5)-(1+2). R^2 shows the size of their positive linear relationship.

A formal comparison of these models showed that the third model's fit was better than CPN-m1a ($\chi^2_{(1)}$ = 9.80, p= .001; see table 4 for details) and CPN-m2 ($\chi^2_{(1)}$ = 12.61, p< .001). Subsequently, to test the reliability of our results, another version of the same three models were created (CPN-m1b, CPN-m2b and CPN-m3b), with the slope of the ordinal position allowed to be different for each participant. These models replicated our previous results (Table 4).

Table 4 Linear mixed models: Continuous picture naming (models a and b). Table shows information and statistics for each model.

Model	Fixed Factor	Fixed Factor Statistics		Model's Statistics			
		F	p	AIC	BIC	r^2_m	r^2_c
CPN-m1a	Ordinal Position	48.81	< .001	-808	-778	.04	.43
CPN-m2a	Ordinal Position	48.78	< .001	-816	-780	.07	.43
	EFT Score	10.50	.002				
CPN-m3a	Ordinal Position	13.87	< .001	-826	-785	.08	.43
	EFT Score	1.16	.28				
	Ordinal Position x EFT Score	12.63	< .001				
CPN-m1b	Ordinal Position	43.31	< .001	-801	-759	.04	.43
CPN-m2b	Ordinal Position	42.41	< .001	-791	-744	.06	.43
	EFT Score	6.22	.01				
CPN-m3b	Ordinal Position	12.35	<.001	-783	-729	.08	.43
	EFT Score	1.43	.23				
	Ordinal Position x EFT Score	10.16	.002				

Note. CPN-m1a investigates the main effect of ordinal position (1 to 5). CPN-m2a probes the main effect of both ordinal position and cognitive style (FI/FD). CPN-m3a tested the interaction between ordinal position and cognitive style. CPN-m1b, CPN-m2b, CPN-m3b are similar to the previous models, but in these models the ordinal position was allowed to be different for each participant.

3.3.2 Semantic probe.

Errors (7%) as well as false triggers and outliers (3%) were excluded from analysis. The remaining data were log transformed and submitted to a linear mixed model analysis. Interference effects for the following conditions were analysed separately: No-Associated, No-Combined, No-Associated + Combined, Yes-related (each effect established from relevant control condition: unrelated no or unrelated yes). Each of these interference effects were submitted to three types of models as before. For example, for the No-Associated condition, the first model (SPna-m1) tested the significance of the interference effect; the second model (SPna-m2) added EFT, and the third model (SPna-m3) considered the interaction between interference and EFT scores. For all models, participants and items were treated as a random factor.

In the Associated condition, the first model (SPna-m1) showed significant effects of interference ($F_{1,38}$= 11.84, p = .001). The second model (SPna-m2) confirmed significant interference effects ($F_{1,38}$= 11.84, p= .001) and a marginally significant effect of EFT ($F_{1,45}$= 3.73, p= .06). A formal comparison of SPna-m1 and SPna-m2 showed a significant improvement in the model fit ($\chi^2_{(1)}$ = 3.73, p= .05). Finally, the third model confirmed significant effects of interference ($F_{1,86}$= 7.14, p= .008), but showed neither a main effect of EFT ($F_{1,55}$= 3.60, p= .06) nor any interactions between interference effect and EFT ($F_{1,1702}$=.04, p= .82; Figure 6A). A formal comparison between SPna-m2 and SPna-m3 showed no improvement in fit ($\chi^2_{(1)}$ = .04, p = .82). Similar results were obtained for the No-Combined condition (see Figure 6B) and in the No-Associated + Combined condition, where interference effects were averaged between the two conditions. There were no significant interference at all (positive or negative) with the Yes-related condition (see table 5 for additional information about the models).

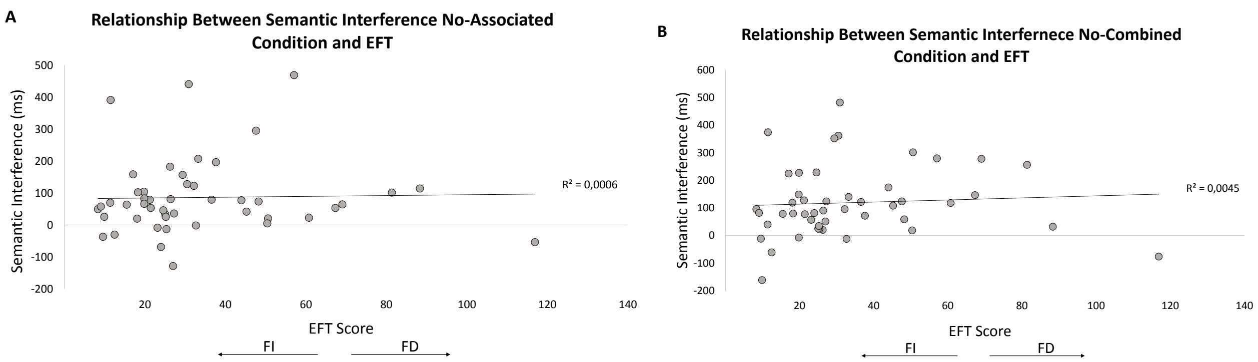

Fig.6 Scatterplot. The EFT score is reported on x-axis, whereas on y-axis is represented: (A) the semantic interference in No-Associated trials computed as the difference between No-Associated and No-Unrelated conditions (<u>Interference No Associated</u>); (B) the semantic interference in No-Combined trials computed as the difference between No-Combined and No-Unrelated conditions (<u>Interference No Combined</u>). R^2 shows the size of their positive linear relationship.

Table 5 Linear mixed models: Semantic Probe. Table shows information and statistics for each model.

Model	Fixed Factor	Fixed Factor Statistics		Model Statistics			
		F	p	AIC	BIC	r^2_m	r^2_c
SPna-m1	Negative Probe Condition	11.84	< .001	181.77	209.22	.01	.45
SPna-m2	Negative Probe Condition	11.84	< .001	209.06	247.49	.04	.45
	EFT Score	3.73	.10				
SPna-m3	Negative Probe Condition	7.14	.003	209.06	247.49	.04	.45
	EFT Score	3.60	.10				
	Negative Probe Condition x EFT Score	.04	.82				
SPnc-m1	Negative Probe Condition	22.56	< .001	197.86	225.22	.03	.44

SPnc-m2	Negative Probe Condition	22.56	<.001	195.22	228.02	.06	.44
	EFT Score	4.68	.03				
SPnc-m3	Negative Probe Condition	11.48	.001	196.38	234.68	.06	.44
	EFT Score	5.34	.02				
	Negative Probe Condition x EFT Score	.83	.36				
SPn$_{A+C}$-m1	Negative Probe Condition	20.68	< .001	381.90	411.27	.02	.44
SPn$_{A+C}$-m2	Negative Probe Condition	20.68	< .001	379.72	414.95	.05	.44
	EFT Score	4.20	.04				
SPn$_{A+C}$-m3	Negative Probe Condition	11.68	.008	381.39	422.50	.05	.44
	EFT Score	4.37	.04				
	Negative Probe Condition x EFT Score	.32	.56				
SPp-m1	Positive Probe Condition	.17	.67	- 20.28	8.78	.0002	.48
SPp-m2	Positive Probe Condition	.17	.67	- 20.20	14.67	.01	.48
	EFT Score	1.88	.17				
SPp-m3	Positive Probe Condition	.02	.87	-19.11	21.58	.01	.48
	EFT Score	.05	..81				
	Positive Probe Condition x EFT Score	.90	.34				

Note. SPna-m1, SPnc-m1, SPn$_{a+c}$-m1, investigate the main effect of negative probe conditions (respectively Associated, Combined and Associated+Combined vs Unrelated). SPna-m2, SPnc-m2, SPn$_{a+c}$-m2 probe the main effect of negative probe conditions (see above) and cognitive style. SPna-m3, SPnc-m3, SPn$_{a+c}$-m3 tested the interaction between negative probe conditions (see above) and cognitive style. SPp-m1, SPp-m2 and SPp-m3 tested respectively the main effect of positive probe conditions (related vs unrelated), the main effect of both positive probe conditions and EFT, the interaction between positive probe conditions and cognitive style.

4 Discussion

Our study investigated the nature of individual differences in semantic interference effects during lexical access. Semantic interference effects arise within the lexical system and are modulated by the efficacy of mechanisms which operate *within* the lexicon, such as mechanisms of lateral inhibition (Gurd and Oliveira 1996; Brown et al. 2005) which suppress the activation of competing words during lexical access, or alternatively by mechanisms which make the activation of selected representations return to baseline with passage of time (e.g. Schnur 2014). The question is whether interference effects are mediated mostly or exclusively by these in-house mechanisms or whether other mechanisms contribute as well. Interference could also be controlled by top-down inhibitory mechanisms which operate across modalities and tasks. Additionally, it is possible that some supra-modal individual characteristics -that can be referred to as cognitive styles- modulate the strength of interference effects across modalities. Our study addressed these possibilities.

The hypothesis that interference effects are controlled exclusively within the lexicon predicts that the strength of semantic interference in picture naming will be unrelated to the strength of interference effects in other tasks such as STM tasks and the Stroop. In the case of STM probe tasks, the effects of semantic interference will be controlled by mechanisms which efficiently clear the buffer of previous information and by the presence of a good phonological record which will counteract any semantic interference effect. These mechanisms/resources will be unrelated to mechanisms that control lexical selection among competitors. In the case of the Stroop, this task taps into the ability to respond to specific task demands by suppressing top-down more automatic responses. This ability can be strategically controlled and is also unrelated to the automatic mechanisms of selection operating within the lexicon.

Alternatively, it has been argued that top-down inhibitory control can also play a role in controlling interference across tasks and, particularly, in picture naming in conditions of high elevated interference. For example, Schnur et al. (2006) stated that, “in line with the executive selection hypothesis, we now suggest that ‘‘too much excitation’’ among lexical-level competitors constitutes a signal that engages the executive selection mechanism; and that the latency effect [semantic interference] is due, in whole or in part, to the time needed for this mechanism to come on-line and/or affect the outcome of the competition” (pp. 220).

Our results support the hypothesis that effects of semantic interference are mostly lexically mediated. We have found no correlation between interference effects in picture naming and in STM probe tasks. In addition, we found no evidence that supra-modal inhibitory mechanisms modulate interference effects across tasks. We have found no correlation between interference in the Stroop task and interference in picture naming and probe tasks nor between interference in the Stroop task and scores on the embedded figures task (EFT). These results are consistent with an accumulating body of evidence arguing against overarching mechanism of inhibitory control (Lang et al. 1995; Miyake et al. 2000; Friedman and Miyake 2004; Aron 2007; Munakata et al. 2011; Noreen et al. 2015; Shao et al. 2015). Different research lines supporthe different nature of control mechanism which operate within the lexicon and top-down for task-specific control. We have already mentioned in the Introduction the different neuro-imaging correlates of interference effects in the Stroop and naming tasks and experiments by Dell’Acqua et al. (2007) indicating that control in lexical selection and the Stroop arises at different processing stages. Another example of a study showing differences between the interference effects in naming and in the Stroop is the study by

Shao et al. (2015). These authors assumed that since selective inhibition takes time to deploy, it would operate more efficiently in trials where processing is slower, thus reducing interference for longer RTs (progressively less interference across RTs quartile; see also Ridderinkhof et al. 2005). They showed evidence of this reduction in interference in cyclic blocking and picture-word interference tasks, but not in the Stroop task. Discussing reasons for this difference is beyond the scope of this paper, but their results are consistent with ours in highlighting differences between the inhibitory mechanisms at play in picture naming and the Stroop task.

Finally, our results provide some support for the hypothesis that a general cognitive style related to the ability to separate stimuli from the background -field-dependency- influences semantic interference. We found a significant correlation between performance in an embedded figures task (measuring FI/FD) and semantic interference in the continuous picture naming task, and linear mixed models confirmed a contribution of field dependence/independence in accounting for variability in the interference effect in picture naming. This is an interesting and perhaps surprising result. It suggests not only that some individuals are more influenced by the context/reference framework, but that these effects are general enough to encompass a visuo-spatial context (a figure embedded in a larger figure) and a semantic context (a picture which is part of a series of semantically related pictures). We know that semantic similarity modulates the size of semantic interference in naming tasks (Vigliocco et al. 2002; Vigliocco et al. 2004; see also Alario and Martín 2010 for a similar conclusion). Field-dependent individuals would be more sensitive to this similarity. They would find difficult to overcome the perceptual context in which a simpler figure is embedded, but also to overcome the semantic context provided by a sequence of semantically related pictures in picture naming. FD individuals may adopt a “spectator approach” (Witkin et al. 1977) where, with each new stimulus of a category, the constant features of the category gradually become more salient, making it progressively more difficult to distinguish the identifying features of an item from ‘background noise’.

The relationship between field dependency and semantic interference may be perceptually mediated. Visual similarity between items of the same category rather than more abstract shared semantic features may be responsible for interference effects. Field dependent individuals may be more susceptible to this shared visual similarity and activate more strongly common features which, in turn, would make more difficult to select the specific features which identify the target. This explanation is consistent with our finding of a relationship between field dependency and the interference effect in picture naming, but not in the probe task. In the probe task, the stimuli are words rather than picture, making visual similarity less salient. On the other hand, there is evidence that semantic interference in picture naming is not just a perceptual phenomenon, because it is also reported when items of the same category are visually distinct from one another (Rose and Abdel Rahman 2017), and for associative as well as for categorical relationships (Rose and Abdel Rahman 2016). Another possibility would be that field dependent individuals activate semantic fields where representations share features which are both perceptual in nature and more abstract. To assess these alternatives, one could run a continuous naming task where the semantic categories include items which do or do not share visual similarity and see whether associations with measures of field dependency differ.

In conclusion, our results highlight the possibility that cognitive styles rather than general top-down executive control mechanisms modulate semantic interference effects in naming. We have shown that interference effects in picture naming are related to a cognitive style like field-dependency, but not to more general inhibitory mechanisms tapped by the Stroop task. Whether or the relationship between field-dependency and semantic interference effects is perceptually mediated should be investigated by further studies.

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Figure Captions

Fig.1 An example of cards used for the Embedded Figure Test

Fig.2 Schematic representation of a sequence of trials in the Continuous Picture Naming Task

Fig.3 Schematic illustration of the conditions in the Semantic Probe Task

Fig.4 Linear increase of naming latencies in function of ordinal positions. Error bars report the standard error. Continuous lines depict the linear trend. The equation of linear trend as well as the R^2 have been reported.

Fig.5 Scatterplot. The EFT score is reported on x-axis, whereas on y-axis is represented the cumulative semantic interference index computed as the difference of the averaged reaction times in the last vs the first two ordinal positions ((4+5)-(1+2). R^2 shows the size of their positive linear relationship.

Fig.6 Scatterplot. The EFT score is reported on x-axis, whereas on y-axis is represented: (A) the semantic interference in No-Associated trials computed as the difference between No-Associated and No-Unrelated conditions (Interference No Associated); (B) the semantic interference in No-Combined trials computed as the difference between No-Combined and No-Unrelated conditions (Interference No Combined). R^2 shows the size of their positive linear relationship.

Appendices

Appendix 1 Stimuli for Continuous Picture Naming.

Body Parts: arm (braccio), ear (orecchio), foot (piede), hand (mano), leg (gamba)

Clothing Items: dress (vestito), shirt (camicia), skirt (gonna), sweater (maglione), trousers (pantaloni)

Fruits: banana (banana), pineapple (ananas), strawberry (fragola), grapes (uva), pear (pera)

Furniture: chair (sedia), sofa (divano), desk (scrivania), table (tavolo), bed (letto)

Insects: butterfly (farfalla), spider (ragno), fly (mosca), ant (formica), mosquito (zanzara)

Instruments: drum (tamburo), trumpet (tromba), violin (violino), guitar (chitarra), piano (pianoforte)

Kitchen Utensil: pan (padella), knife (coltello), fork (forchetta), spoon (cucchiaio), plate (piatto)

Plants: flower (fiore), leaf (foglia), palm tree (palma), tree (albero), cactus (cactus)

Tools: hammer (martello), pliers (pinze), saw (sega), drill (trapano), screwdriver (giravite)

Transport: aeroplane (aereo), car (auto), train (treno), motorbike (moto), boat (barca)

White Goods: toaster (tostapane), blender (frullatore), refrigerator (frigorifero), washing machine (lavatrice), radio (radio)

Zoo Animals: elephant (elefante), panda (panda), monkey (scimmia), gorilla (gorilla), giraffe (giraffa)

Appendix 2 Stimulus statistics for the continuous picture naming tasks; frequency and length from CoLFIS database (Goslin et al. 2014).

	Position										Total	
	1		2		3		4		5		M	SD
	M	SD	M	SD	M	SD	M	SD	M	SD		
Frequency	51	40	52	74	70	70	50	49	64	60	58	59
Length	7	2	6	2	7	2	7	2	7	2	7	2