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Citation
Navarrete, Eduardo, Bradford Z. Mahon, and Alfonso Caramazza. 2010. The cumulative semantic cost does not reflect lexical selection by competition. Acta Psychologica 134(3): 279-289.

Published Version
doi:10.1016/j.actpsy.2010.02.009

Published in final edited form as:
Acta Psychol (Amst). 2010 July ; 134(3): 279–289. doi:10.1016/j.actpsy.2010.02.009.

The cumulative semantic cost does not reflect lexical selection by competition[☆]

Eduardo Navarrete[a,*], **Bradford Z. Mahon**[a,b], and **Alfonso Caramazza**[a,c]

[a] Center for Mind/Brain Sciences (CIMeC), University of Trento, Italy

[b] Department of Brain and Cognitive Sciences, University of Rochester, USA

[c] Department of Psychology, Harvard University, USA

Abstract

The cumulative semantic cost describes a phenomenon in which picture naming latencies increase monotonically with each additional within-category item that is named in a sequence of pictures. Here we test whether the cumulative semantic cost requires the assumption of lexical selection by competition. In Experiment 1 participants named a sequence of pictures, while in Experiment 2 participants named words instead of pictures, preceded by a gender marked determiner. We replicate the basic cumulative semantic cost with pictures (Exp. 1) and show that there is no cumulative semantic cost for word targets (Exp. 2). This pattern was replicated in Experiment 3 in which pictures and words were named along with their gender marked definite determiner, and were intermingled within the same experimental design. In addition, Experiment 3 showed that while picture naming induces a cumulative semantic cost for subsequently named words, word naming does not induce a cumulative semantic cost for subsequently named pictures. These findings suggest that the cumulative semantic cost arises prior to lexical selection and that the effect arises due to incremental changes to the connection weights between semantic and lexical representations.

Keywords

Cumulative semantic cost; Semantic interference; Lexical access; Picture naming; Semantic access

1. Introduction

Across many areas of research within cognitive psychology, it has been observed that task-irrelevant stimuli that are semantically related to a target stimulus differentially affect target processing compared to semantically unrelated stimuli. Within the field of lexical access in speech production, semantic contextual effects have been observed in a number of different speech production paradigms, such as the picture-word interference paradigm (e.g., Rosinski, 1977; Schriefers, Meyer, & Levelt, 1990) and in the cyclic naming paradigm

[☆]The authors are grateful to Gary Dell and Gary Oppenheim for discussing the data reported in this manuscript. The research was supported in part by grant DC006842 from the National Institute on Deafness and Other Communication Disorders (AC) and by a grant from the Fondazione Cassa di Risparmio di Trento e Rovereto. EN was supported was supported by the Departament d'Universitats, Recerca i Societat de la Informació de la Generalitat de Catalunya. BZM was supported in part by an NSF Graduate Research Grant and an Eliot Dissertation Completion Grant, and is now at the Department of Brain and Cognitive Sciences, University of Rochester, Rochester, NY, USA.

[*]Corresponding author. Center for Mind/Brain Sciences, University of Trento, Corso Bettini, 31, I-38068-Rovereto, Italy. eduardo.navarrete@unitn.it (E. Navarrete).

involving picture naming and word translation tasks (e.g., Damian, Vigliocco, & Levelt, 2001; Kroll & Stewart, 1994; Bloem & La Heij, 2003). Semantic contextual effects in speech production tasks have been studied principally for their relevance to models of lexical access, as a number of authors have argued that the patterns of semantic interference and facilitation are relevant for understanding the dynamics of lexical access (e.g., La Heij, 1988; Schriefers et al., 1990; for reviews, see Mahon, Costa, Peterson, Vargas, & Caramazza, 2007; Roelofs, 2003).

One view is that interference effects on naming latencies induced by semantically related stimuli do not occur at the semantic level, but at the level at which the target lexical node is selected for production (e.g., Belke, Meyer, & Damian, 2005; Bloem and La Heij, 2003; Caramazza & Costa, 2000; Damian & Bowers, 2003; Damian & Martin, 1999; Hantsch, Jescheniak, & Schriefers, 2005; Humphreys, Lloyd-Jones, & Fias, 1995; Levelt, Roelofs, & Meyer, 1999; Roelofs, 1992, [1993], 2003; Starreveld & La Heij, 1995, 1996; Vigliocco, Vinson, Lewis, & Garrett, 2004). Models of lexical selection that are based on the principle of competition assume that the time required to select a target word is a function of the level of activation of non-target words: target selection is delayed proportionally to the level of activation of non-target words (e.g., La Heij, 1988; Levelt et al., 1999; Roelofs, 2003). However, recent findings (Finkbeiner & Caramazza, 2006; Janssen, Schirm, Mahon, & Caramazza, 2008; Mahon et al., 2007; Miozzo & Caramazza, 2003) have been argued to challenge the assumption that lexical selection involves competition. The alternative to lexical selection by competition is that the highest activated lexical node is selected (see e.g., Caramazza, 1997; Dell, 1986).

Recently, the issue of whether lexical selection is a competitive process has resurfaced in discussions of the cumulative semantic cost in picture naming. Howard, Nickels, Coltheart, and Cole-Virtue (2006; see also Experiment 4, Brown, 1981) asked participants to name a series of pictures that were drawn from multiple superordinate semantic categories (animals, fruit, vehicles, etc). Howard and colleagues found that naming latencies increased linearly as a function of ordinal position within-category. For instance, participants might name pictures in the sequence '…pig … house … sheep … apple … car … horse …etc'. It was found that naming latencies to the second animal in the sequence (e.g., 'sheep' above) were slower than naming latencies to the first animal; likewise, the naming latencies to the third animal (e.g., 'horse' above) were again slower, and by the same amount, than naming latencies to the second item. Those authors found that naming latencies were linearly related to ordinal position, at least out to the fifth (i.e., maximum tested) ordinal position.

1.1. Models of the Cumulative Semantic Cost

There are at present two detailed accounts of the cumulative semantic cost (Howard et al., 2006; Oppenheim, Dell, & Schwartz, 2007, 2010. Both accounts share the assumption that when naming a target picture, the connections between the concept and the name (lexical representation) corresponding to that picture are strengthened (see also Damian & Als, 2005). However, the two accounts differ in two important respects. First, the model of Oppenheim and colleagues assumes that semantic-to-lexical connections that are not used, but which originate from the same semantic level representations, will weaken in a given picture naming trial. Such a situation would arise for semantic category coordinates of a target response (i.e., in naming 'dog', the semantic-to-lexical connections for 'cat' would be weakened). Second, Oppenheim and colleagues demonstrated through computational simulation that the assumption of lexical selection by competition is not necessary in order to explain the cumulative semantic cost, while Howard and colleagues argued that that assumption is necessary.

Howard and colleagues' (2006) explanation of the cumulative semantic cost argued that the increased connection strengths between semantic and lexical level representations leads to greater competition for selection of a within-category coordinate lexical representation on a subsequent trial. Thus, according to Howard and colleagues, lexical competition is necessary in order to observe the cumulative semantic cost. Those authors also argued that two further assumptions are needed in order to explain the cumulative semantic cost. One is *shared activation*, which refers to the assumption that activation spreads to semantically related words when naming a target word. For instance, when producing the word 'table', the related words 'chair' and 'stool' will also become activated. The other, putatively necessary, property of the speech production system according to Howard and colleagues, is *priming. Priming* refers to the assumption that when a representation is activated, it will retain that activation for a certain (parameter dependent) amount of time. There are at least two possible ways of implementing the construct of priming: the first is by adjusting the strengths of the mappings from semantics to lexical nodes, and the second is by adjusting resting levels of activation of lexical nodes.

Oppenheim and colleagues (2010; see also Dell, Oppenheim, & Kittredge, 2008; Gordon & Dell, 2003; Oppenheim et al., 2007) presented a model in which lexical competition could be excluded from the model architecture, and the cumulative semantic cost still emerged from the process of incrementally adjusting connection strengths between semantic and lexical level representations. The basic premise of that account is that the production of a word (e.g., dog) strengthens the connections between semantic representations and the lexical representation of that word and, at the same time, weakens the connections between semantic representations and the lexical representation of semantic coordinates of the target (e.g., cat, horse). Thus, when on a subsequent trial, the word 'cat' must be produced, it takes relatively longer to produce because the mappings from semantics to lexical representations are relatively weaker. On the basis of their computational simulations 5 and 6, Oppenheim and colleagues (2010) concluded that weakening the mappings between semantic and lexical representations is sufficient to explain the cumulative semantic cost, without the need to also assume lexical selection by competition. Thus, Oppenheim and colleagues' computational work constitutes a demonstration that lexical selection by competition need not be assumed in order to explain the cumulative semantic cost.

More broadly, other types of explanations of the cumulative semantic cost may be envisioned. In particular, some or all of the effect may be due to the process of identifying/ categorizing target pictures. Our empirical approach in this article is to test specific predictions that are made by the two detailed models of Howard and colleagues (2006) and Oppenheim and colleagues (2010). We will return in the general discussion to consider the possible role of visual-to-semantic mappings in creating the cumulative semantic cost.

1.2. Scope of the Current Project

The hypothesis that the cumulative semantic cost is due to competitive lexical selection (Howard et al., 2006) predicts that the effect should be present when participants read target words accompanied by the associated gender marked determiners, instead of naming target pictures. In languages such as Italian, the form of gender-marked determiners depends on the grammatical gender of the referent noun (e.g., singular feminine: *la*, singular masculine: *il*). Because grammatical gender is a property of lexical representations (e.g., Caramazza & Miozzo, 1997; Levelt et al., 1999; Navarrete & Costa, 2009; Starreveld & La Heij, 2004; Vigliocco & Franck, 1999), it is necessary to retrieve the lexical node corresponding to the written word in order to perform this task. Previous research has used the same logic to argue that semantic effects in the cycling naming task have a lexical locus. Damian et al. (2001) reported that speakers are slower to name pictures blocked by semantic context than pictures in a semantically heterogeneous context (see also Kroll & Stewart, 1994). Damian and colleagues then showed that the same effect is observed when written words are presented instead of pictures, and participants must read the words preceded by gender marked determiners. On the basis of the interference effect with word targets, Damian and colleagues (2001) argued that the phenomenon had a lexical locus within speech production.

Thus, if the cumulative semantic cost arises at the level of lexical selection, then following the logic of Damian and colleagues (2001), the phenomenon should be observed both when participants name pictures of objects, and when they read words and produce the associated definite determiners.

1.3. Experimental overview

If the cumulative semantic cost has a lexical locus, then the effect should emerge equally in both picture naming (Experiment 1) and word reading (Experiments 2a and 2b) tasks. In contrast, if the cumulative semantic cost arises prior to lexical selection, then the effect should emerge only when participants name pictures of objects, but not during the determiner + word reading task. Because one predicted pattern of results is a null result (with respect to the cumulative semantic cost) in Experiments 2a and 2b, we also included the factor repetition in all experiments. Each participant named the entire set of pictures four times. Thus, even if no cumulative semantic cost is observed in the determiner + word production task, the presence of repetition priming effects will ensure that the experiments had sensitivity to detect response time effects.

To anticipate our basic finding, while the cumulative semantic cost is observed in picture naming (Experiment 1), it is not observed in determiner + word naming (Experiments 2). These data indicate that the cumulative semantic cost does not arise at the lexical level, and therefore, that lexical selection by competition is not required to account for the phenomenon. We then further explored the view that the cumulative semantic cost arises due to incremental (i.e., trial-by-trial) weakening of non-target semantic-to-lexical connections (Oppenheim et al., 2010). Critically, such an account of the data from Experiments 1 and 2 would be based on the assumptions that 1) determiner + word naming involves semantically driven access, and 2) that incremental weakening of non-target semantic-to-lexical mappings does not occur during a determiner + word naming task.

In order to test the assumption that word naming involves semantically driven lexical access but does not involve incremental learning, picture and word targets were intermingled in Experiment 3. Each stimulus (word or picture) was named along with its appropriate gender marked definite determiner. This experimental design first allowed us to replicate the findings from Experiments 1 and 2 within the same design. However, the critical manipulation of Experiment 3 was that the format of the stimuli (word or picture) was varied within each semantic category. If determiner + word naming involves semantically driven lexical access, then picture naming should induce a cumulative semantic cost for a subsequently named (within-category) word stimulus. In contrast, on the assumption that no incremental learning occurs for trials involving word naming, no cumulative semantic cost should be induced by word naming on a subsequently named picture. This was the pattern that was observed. We discuss the implications of this pattern of effects for an explanation of the cumulative semantic cost.

2. Experiment 1

In Experiment 1 we sought to replicate the basic phenomenon reported by Howard and colleagues (2006) and Brown (1981). In addition, we included the factor repetition, such that the entire set of pictures was named by each participant four times (each time in a different order). According to previous research we expect to observe a cumulative semantic cost as well as an effect of item repetition. It is an open empirical question as to whether the two effects interact.

2.1. Method

2.1.1. Participants—Twenty native Italian speakers (students at the University of Trento) took part in Experiment 1. All participants had normal or corrected to normal vision. Participants in this and subsequent experiments participated in only one experiment.

2.1.2. Materials—Ninety-four pictures (color photographs) were selected (most of them from the set used by Howard et al., 2006). Sixty of the 94 pictures belonged to 12 different semantic categories, with 5 items in each semantic category (see Appendix A). The rest of the pictures were filler items, and did not come from the same categories as those of the critical items.

2.1.3. Design—The ninety-four pictures were randomly inserted into a sequence with the following constraints. Pictures from each category were separated by lags of 2, 4, 6 or 8 intervening items. Twelve, of 24 (i.e., 4!) possible lag orderings were selected. Care was taken to ensure that each lag value (i.e., 2, 4, 6 and 8) was equally represented at each ordinal position (i.e., each lag value was presented a total of three times at each of the ordinal positions, from 2 to 5). The first 6 items of the sequence were filler items. Filler items and the order of the categories in the sequence were randomly assigned. This process was repeated nine times following the same constraints and structure, resulting in 10 experimental sequences. In generating the 10 experimental sequences, it was ensured that a specific category never occupied the same position across the 10 sequences. Finally, in order to avoid item specific effects, the five experimental items within each category were represented equally at each of the five ordinal positions within a category (i.e., across the 10 sequences each experimental item was presented twice in each ordinal position, 1 to 5).

Each participant received four different experimental sequences (referred to as blocks below). Each experimental sequence was used a total of eight times (across the 20 participants) and was used the same number of times as the first, second, third and forth block.

2.1.4. Procedure—An experimental trial involved the following events. A fixation cross was shown in the centre of the screen for 500 ms and was followed by a blank interval of 250 ms. The picture was presented for 1500 ms. After a blank screen of 700 ms the next trial started. Stimuli were presented against a white background. Response latencies were measured from the onset of the picture. Stimulus presentation, response times and response recording were controlled by the program DMDX (Forster & Forster, 2003).

Participants were seated approximately 60 cm from the screen. Participants were asked to name the pictures as fast and as accurately as possible. There was no familiarization phase. There was a short pause between each block. Participants were not corrected by the experimenter throughout the experimental session. The experiment lasted approximately 25 minutes.

2.1.5. Analysis—Three types of responses were excluded from the analyses of reaction times: a) production of clearly erroneous picture names (e.g., superordinates names, semantic coordinates); b) verbal dysfluencies (stuttering, utterance repairs, and production of nonverbal sounds that triggered the voice key), and c) naming latencies less than 350 ms or greater than 2.5 SD from a given participant's mean. A total of 8.7% of the data points were excluded following these criteria. Only responses on experimental items were included in the analysis.

Two within-subject factors, Ordinal Position Within-Category (five levels: 1 to 5) and Repetition (four levels: 1 to 4), and their interaction were included in the analysis. Following the protocol of Howard and colleagues (2006), separate analyses were carried out treating subjects and categories as random factors, yielding F1 and F2 statistics, respectively. For all analyses in this article, degrees of freedom were Greenhouse-Geisser corrected when the assumption of Sphericity was violated.

2.2. Results

Table 1 shows the mean naming latencies and error rates for each of the five ordinal positions, and for each of the four repetitions. The analysis of naming latencies showed a main effect of Ordinal Position Within-Category (F1 (4, 76)=22.57, p<.001, η^2=.54; F2 (4, 44)= 18.17, p<.001, η^2=.62), as well as a main effect of Repetition (F1 (1.66, 31.58)=23.58, p<.001, η^2=.55; F2 (3, 33)=37.38, p<.001, η^2=.77). The interaction between Ordinal Position Within-Category and Repetition was not significant (F1 (12, 228)=1.08, p=.37, η^2=.05; F2 (12, 132)=1.4, p=.17, η^2=.11). As can be seen in Table 1, inspection of the means by each cell of the design indicates that response times increased for each subsequent within-category item, while overall response times for the blocks decreased with repetition.

Fig. 1 plots response times in Experiment 1 against Ordinal Position Within-Category. As can be seen in ‘line a’ of the figure, response times increase linearly with each additional within-category item that is named (analysis of linear trend: F1 (1, 19)=91.37; p<.001; η^2=.82; F2 (1, 11)=45.97, p<.001, η^2=.8). The cumulative semantic cost on naming latencies remained when correcting for the presence of linear trends, on a subject by subject basis, across the entire block of items (see Fig. 1, line b)[1].

Furthermore, and as described by Howard and colleagues, there was no effect on response times of the number of items from different semantic categories that intervened between each subsequent within-category presentation (i.e., the factor ‘lag’). Two factors, Ordinal Position Within-Category (2 to 5) and Lag (2, 4, 6 and 8) were included in the analysis. In the analysis of naming latencies, the effect of Ordinal Position Within-Category was significant (F1 (3, 57)=9.7, p<.001, η^2=.33; F2 (3, 33)=10.65, p<.001, η^2=.49) while the effect of Lag was not significant (F1 (3, 57)=1.46, p=.23, η^2=.07; F2<1). The interaction between Lag and Ordinal Position Within-Category (Fs<1) was not significant. Lag analyses were not included in subsequent experiments.

Howard and colleagues (2006) analyzed error rates as a function of Within-Category Ordinal Position and did not observe any effects. In contrast, in this experiment, error rates patterned after the response time data. In the analysis of error rates there was a main effect of the factor Ordinal Position Within-Category (F1 (4, 76)=3.29, p=.02, η^2=.14; F2 (4, 44)=2.82, p=.04, η^2=.2), as well as a main effect of Repetition (F1 (3, 57)=37.17, p<.001, η^2=.66; F2 (1.3, 14.49)=11.65, p<.003, η^2=.51). The interaction between Ordinal Position Within-Category and Repetition was not significant (Fs<1). A direct test of the linear trend

[1]This analysis was conducted in order to ensure that the cumulative semantic cost was not merely an expression of the general tendency for pictures named early in the block to be named faster than pictures named later in the block. We observed an overall positive correlation between naming latencies and position within the entire sequence (across all semantic categories) (r values ranging from −0.2 to 0.4 for participants, with a mean of 0.2) (see Howard at al., 2006, for similar findings). Naming latencies were collapsed across the factor Repetition and linear trends were calculated for each subject individually. Individual subject data were then corrected on a subject by subject basis. The results of this linear trend correction are shown in Fig. 1 (line b, analysis of the linear trend: F1 (1, 19)=41.2; p<.001; η^2=.68; F2 (1, 11)= 30.27; p<.001; η^2=.73).

on error rates of Ordinal Position Within-Category was significant (F1 (1, 19)=21.42, p<.001, η^2=.53; F2 (1, 11)=6.32, p<.03, η^2=.36).

2.3. Discussion

The results of this experiment replicate Howard and colleagues (2006) and Brown (1981) and also indicate that the cumulative semantic cost does not interact with the factor repetition (at least as the latter factor has been manipulated herein). In the next experiment, Italian and German participants read target words preceded by the associated gender marked determiner. If the cumulative semantic cost arises at the lexical level, then the effect should emerge in the determiner + word naming production task in Experiment 2 (see Damian et al., 2001, for the same logic).

3. Experiment 2: Determiner + word naming

In this experiment Italian printed words (Experiment 2a) and German printed words (Experiment 2b) were presented and participants were asked to read them, preceded by the corresponding definite determiner (which was retrieved from memory). Experiment 2 was run in both Italian and German, because determiner retrieval in the two languages may be influenced by different types of information. Of particular relevance, determiner selection in Italian may depend on phonological properties of the head noun. There is evidence indicating that Italian determiner selection occurs after lexical selection has taken place (Caramazza, Miozzo, Costa, Schiller, & Alario, 2001; Miozzo & Caramazza, 1999), which is consistent with the view that the form of gender marked determiners is influenced not only by gender, but also by the phonological properties of the onset of the head noun (e.g., the determiner masculine form *il* becomes *lo* when masculine nouns begin with a consonant cluster of the form “s + consonant” or “gn”, or an affricate, as in *lo sgabello*, the stool). Furthermore, in Italian there is a high correlation between the phonological properties of the nouns and their grammatical gender; words ending in -*o* tend to be masculine while words ending in –*a* tend to be feminine. Thus, and because Italian is a transparent language (in terms of orthography-phonology mapping), it may be argued that Italian speakers could retrieve the correct determiner form based on orthographic information alone, without processing the word at the lexical level. In contrast, there is no relation between the form of gender marked determiners and the phonology of the head noun in German, and it has been argued that determiner selection in German occurs at a level of lexical access that is independent (or blind) to the phonological properties of words (e.g., Schriefers, 1993). Thus, the strongest test of whether the cumulative semantic cost has a lexical origin is to test whether the phenomenon is observed in German word naming with determiner production.

3.1. Methods

3.1.1. Participants, Materials and Procedure—Twenty native Italian speakers and twenty native German speakers (students at the University of Trento) took part in Experiment 2. The same items and experimental sequences (blocks) as in Experiment 1 were used, with the only difference that the pictures were replaced with their corresponding printed bare nouns. Those nouns were printed in Italian (Experiment 2a) or German (Experiment 2b). In both Experiments 2a and 2b, the words were presented in black upper case letters (Arial, Regular, 24 point) in the centre of the computer screen, against a white background. All other aspects of the procedure were the same as in Experiment 1.

3.2. Results

Following the same criteria as in Experiment 1, 2.7 % of the data points in Experiment 2a and 2.2 % in Experiment 2b were excluded from the analysis. The same analyses as in Experiment 1 were conducted here for each sub-experiment separately. Tables 2 and 3 show the mean naming latencies and error rates for all levels of the factors Ordinal Position Within-Category and Repetition for Experiments 2a and 2b, respectively.

3.2.1. Experiment 2a: Italian—In the analysis of naming latencies, the only significant effect was the main effect of Repetition ($F1\ (1.92, 36.51)=7.46$, $p<.003$, $\eta^2=.28$; $F2\ (1.77, 19.5)=45.37$, $p<.001$, $\eta^2=.8$); inspection of the means indicated that naming latencies decreased monotonically across blocks. The main effect of Ordinal Position Within-Category ($F1\ (4, 76)=1.03$, $p=.39$, $\eta^2=.05$; $F2\ (4, 44)=2.06$, $p=.1$, $\eta^2=.15$) was not significant, nor was the interaction between Repetition and Ordinal Position Within Category ($F1<1$; $F2\ (12, 132)=1.44$, $p=.15$, $\eta^2=.11$). As depicted in Fig. 2A, the analysis of the linear component did not show an increase in response times as a function of ordinal position ($Fs<1$). This pattern remained when correcting for the presence of subject specific linear trends (see Fig. 2A, line b, $Fs<1$).

The same pattern observed on naming latencies was observed on error rates. In the analysis of error rates there was a main effect of Repetition ($F1\ (3, 32.59)=14.42$, $p<.001$, $\eta^2=.43$; $F2\ (1.41, 15.58)=9.69$, $p<.005$, $\eta^2=.46$); inspection of the means indicated that error rates decreased with repetition. Neither the main effect of Ordinal Position Within-Category ($F1\ (4, 76)=1.39$, $p=.24$, $\eta^2=.06$; $F2\ (4, 44)=1.11$, $p=.36$, $\eta^2=.09$) nor the interaction between the two factors was significant ($F1\ (12, 228)=1.12$, $p=.34$, $\eta^2=.05$; $F2\ (12, 132)=1.17$, $p=.3$, $\eta^2=.09$).

3.2.2. Experiment 2b: German—In the analysis of naming latencies, the only significant effect was the main effect of Repetition ($F1\ (1.96, 36.78)=15.64$, $p<.001$, $\eta^2=.45$; $F2\ (1.19, 13.12)=49.64$, $p<.001$, $\eta^2=.81$): inspection of the means indicated that naming latencies decreased monotonically across blocks. The main effect of Ordinal Position Within-Category ($F1\ (2.53, 48.22)=1.87$, $p=.12$, $\eta^2=.09$; $F2\ (4, 44)=1.85$, $p=.13$, $\eta^2=.14$) was not significant, nor was the interaction between the two factors ($Fs<1$). As depicted in Fig. 2B, the analysis of the linear component did not show an increase in reaction times as a function of ordinal position ($Fs<1$). This pattern remained when correcting for the presence of subject specific linear trends (see Fig. 2B, line b, $Fs<1$).

In the analysis of error rates there was a main effect of Repetition ($F1\ (2.05, 39.06)=7.38$, $p<.001$, $\eta^2=.28$; $F2\ (1.64, 18.05)=5.36$, $p<.005$, $\eta^2=.32$); inspection of the means indicated that error rates decreased with repetition. Neither the main effect of Ordinal Position Within-Category ($F1\ (4, 76)=1.22$, $p=.3$, $\eta^2=.06$; $F2\ (4, 44)=1.05$, $p=.39$, $\eta^2=.09$) nor the interaction between the two factors was significant ($F1<1$; $F2\ (12, 132)=1.05$, $p=.4$, $\eta^2=.09$).

3.3. Discussion

The lack of a cumulative semantic cost in Experiment 2 contrasts with the results of Experiment 1, in which a reliable cost was obtained. Critically, everything about Experiments 1 and 2 was exactly the same, except for the use of pictures (Experiment 1) versus words (Experiment 2) as targets. Furthermore, in Experiment 2, as in Experiment 1, there was a reliable main effect of repetition, indicating that the experiment had sensitivity to detect effects on response times. In addition, the same pattern of results was observed in both the Italian and German versions of the determiner + word naming task (Experiments 2a and 2b, respectively).

The combination of findings from Experiments 1 and 2 indicates that the cumulative semantic cost does not arise at the level of lexical selection. Those data can be explained by the theoretical framework of Oppenheim and colleagues (2010) if two assumptions are made. First, it must be assumed that determiner + word naming involves semantically driven lexical access. That assumption would seem to be one that must be preserved on the basis of other findings in the literature (e.g., Damian et al., 2001). Second, the strong assumption must be made that no incremental weakening of non-target semantic-to-lexical connections occurs during determiner + word naming. Thus, on this account, the pattern of findings in Experiments 1 and 2 would be explained by assuming that while both incremental strengthening of target, and weakening of non-target, semantic-to-lexical connections occurs in picture naming (explaining repetition priming and the cumulative semantic cost, respectively), only strengthening of connections occurs in word naming.

There were two goals for Experiment 3. First we aimed to provide evidence that determiner + word naming task involves semantically driven lexical access (Damian et al., 2001, for relevant discussion). The second aim was to test the assumption that the determiner + word naming task does not lead to weakening of non-target semantic-to-lexical connections while picture naming does. In summary, Experiment 3 was designed to provide positive evidence for the claims that determiner + word naming involves semantically driven lexical access, and that there is no incremental weakening of non-target semantic-to-lexical representations in determiner + word naming.

3.4. Overview and predictions for Experiment 3

In Experiment 3 participants were presented with a sequence of words and pictures and instructed to name them together with the appropriate definite determiner. The presentation format (picture or word) of the target stimuli was varied within the semantic categories, so that it was possible to test for cumulative semantic costs in 1) picture naming induced by previously named pictures, 2) picture naming induced by previously named words, 3) word naming induced by previously named pictures, and 4) word naming induced by previously named words.

An account of the cumulative semantic cost consistent with the pattern of findings from Experiments 1 and 2 is that the effect is due to incremental weakening of non-target semantic-to-lexical connections (Oppenheim et al., 2010). As discussed above, this account would have to be supplemented with the assumptions that while 1) word naming is in part semantically driven, 2) there is no weakening of non-target semantic-to-lexical connections during word naming. Rather, there is only incremental strengthening of the target semantic-to-lexical connections. Motivation for this assumption may be that the identity of the target word is never in doubt as it is given by the stimulus input; in other words, in addition to semantically driven lexical access, there is also a “direct” lexical mapping from the visual input to the output lexical representation. Another way to think about why determiner + word naming may lead to relatively less weakening of non-target semantic-to-lexical mappings is within the context of the model of Oppenheim and colleagues (2010). On that model, weakening of non-target semantic-to-lexical connections is error driven. Thus, and on the assumption that picture naming leads to relatively more activation of within-category coordinates of the target than word naming does there will be relatively little evidence to drive error-based learning within the system for word naming.

On the basis of these considerations, the following four predictions can be framed for Experiment 3:

1. *Determiner + picture naming following determiner + picture naming.* The general logic of our article implicitly presupposes that there will be a cumulative semantic cost for determiner + picture naming trials that follow determiner + picture naming trials. The reason is that the explanation of the cumulative semantic cost is purely in terms of weakening of non-target semantic-to-lexical connections, and is thus not expected to be affected by determiner retrieval. This would therefore constitute

an extension of Experiment 1 but with determiner + noun utterances instead of bare noun production.

2. *Determiner + picture naming following determiner + word naming.* The explanation outlined above for the lack of a cumulative semantic cost in determiner + word naming generates the prediction that there will not be a cumulative semantic cost for picture naming following determiner + word naming trials. This prediction follows from the assumption that for determiner + word naming trials there is no weakening of semantic-to-lexical connections for coordinates of the target words. Thus, subsequent naming events over picture stimuli will not suffer a cost, as their corresponding semantic-to-lexical connections will not be differentially weaker.

3. *Determiner + word naming following determiner + picture naming.* If determiner + word naming implicates semantically driven lexical access (see Damian et al., 2001) then the critical prediction is made that there will be a cumulative cost induced for determiner + word naming trials that follow determiner + picture naming trials. This is because those previous picture naming trials will have led to a weakening of the semantic-to-lexical mapping for coordinates of those previously named pictures. Therefore, the semantic-to-lexical mapping for a subsequently named word will be slightly weaker, and hence naming latencies should be relatively slower. Of course, such an effect would be observed only if determiner + word naming involved semantically driven lexical access, and response times in word naming were constrained by the speed of semantically driven lexical access.

4. *Determiner + word naming following determiner + word naming.* On the basis of the findings from Experiment 2 we expect no cumulative semantic cost for determiner + word naming trials induced by previously named determiner + word naming trials. This would therefore constitute a direct replication of Experiment 2.

4. Experiment 3: Determiner + word and determiner + picture naming

In this experiment two types of targets were used, words and pictures, and participants were required to name them preceded by the corresponding definite determiner (which was retrieved from memory). The format of presentation of the stimuli was alternated between pictures and words within the semantic categories. Thus, for each semantic category, four items were presented within the same format (e.g., word format) and one item in a different (i.e., deviant) format (in this case, picture format). The deviant item was located at the third or at the fourth ordinal within-category position. For instance, for the category animal with the ordinal presentations *cat-horse-sheep-pig-donkey*, the deviant item could be *sheep* or *pig*. In this case, non deviant items would be the remaining items (*cat-horse-pig-donkey*, or *cat-horse-sheep-donkey*). Thus, when the deviant item was a picture, the rest of within-category items were words, and when the deviant item was a word the rest of within-category items were pictures.

The design of Experiment 3 allows us to explore whether there is cumulative semantic cost for picture and word naming trials, thus providing an internal replication of the previous two experiments (Level I analysis below). Furthermore, and as an extension on Experiment 1, this experiment permits confirmation of the expectation that there will be a cumulative semantic cost for picture naming (following picture naming) in the context of a determiner + word production task. The presence of such an effect would exclude an explanation of the differences in results between Experiments 1 and 2 in terms of whether (Experiment 2) or not (Experiment 1) target names were preceded by a determiner.

In the second level of analysis (Level II analysis below) we test whether a cumulative semantic cost is transferred from picture naming to word naming, and from word naming to picture naming. To test for these effects, two types of analyses were run. First, we compared naming latencies for deviant and non deviant trials, while holding ordinal position constant (Level II-a analysis, below). Second, (Level II-b analysis) we computed the difference in naming latencies between a deviant trial, and the previous ordinal position within category. Specifically, we asked whether 1) the cumulative cost for picture trials that follow word trials (i.e., deviant condition) are as slow (i.e., show as much cumulative cost) as picture trials that follow picture trials (i.e., non deviant condition), and 2) whether word naming trials that follow picture trials are slower (i.e., show more cumulative cost) than word trials following word trials. While these two analyses (Levels II-a and II-b) are not orthogonal, they represent two ways of testing, and demonstrating the effect of, the principal manipulation in Experiment 3.

4.1. Method

4.1.1. Participants, Materials and Procedure—Twenty native Italian speakers took part in this experiment. The same materials and lists as in previous experiments were used. For each list, six categories contained four word items (non deviant items) and one picture item (deviant item). In three of these categories the picture (i.e., deviant item) item was located at the third ordinal position within-category, while for the other three categories it was located at the fourth ordinal position within-category. The remaining six categories in each list contained four picture items (i.e., non deviant items) and one word item (i.e., deviant item). Word items (i.e., deviant items) were located at the third ordinal position within-category in three categories and at the fourth ordinal position within-category in the other three categories. In summary, there was 4 experimental conditions with respect to the format of the deviant items and the ordinal position of the deviant item within the category: a) *deviant word at 3rd* ordinal position (picture-picture-*word*-picture-picture); b) *deviant word at 4th* ordinal position (picture-picture-picture-*word*-picture); c) *deviant picture at 3rd* ordinal position (word-word-*picture*-word-word); and d) *deviant picture at 4th* ordinal position (word-word-word- *picture*-word). As in previous experiments, each participant was presented with 4 lists. Across the 10 experimental lists, semantic categories were assigned two or three times to each of the four experimental conditions, thus counterbalancing the design across the materials. However, because it is not possible to have all materials appear as both deviant and non deviant items (with a reasonable amount of participants), analyses were performed only treating subjects as a random factor. Finally, half of the 34 filler items in each list were presented as pictures and the other half as words. To simplify all analyses, we collapsed across, and did not analyze the factor Repetition, nor do we present analyses of error rates.

4.2. Results

Following the same criteria as in Experiment 1, 7.2% of the data points were excluded from the analysis (because of the large difference in overall response times for word and picture targets, naming latencies greater than 2.5 SD from a given participant's mean in each specific format condition (word or picture) were removed). Table 4 shows the mean latencies and error rates for the four experimental conditions in the five Within-Category Ordinal Positions (see also Fig. 3).

4.2.1. Level I analysis—In order to test for a cumulative semantic cost in determiner + picture naming (following picture naming trials), data points corresponding to word naming trials were excluded from the *deviant word at 3rd* and *deviant word at 4th* conditions. In other words, the analysis was performed on non deviant picture naming trials only. The main effect of Ordinal Position Within-Category ($F1\ (4, 76)=6.8$, $p<.001$, $\eta^2=.264$; F2 (4, 44)=4.23, p<.007, η^2=.278) was significant. The analysis of the linear component showed an increase in response times as a function of ordinal position (F1 (1, 19)=37.69, p<.001, η^2=.665; F2 (1, 11)=15.17, p<.003, η^2=.58), replicating the pattern observed in Experiment 1.

In order to test for a cumulative semantic cost in determiner + word naming (following word naming trials), data points corresponding to picture naming trials were excluded from the *deviant picture at 3rd* and *deviant picture at 4th* conditions. That is, the analysis was performed on non deviant word naming trials only. The main effect of Ordinal Position Within-Category was not significant (Fs<1). The analysis of the linear component did not show an increase in response times as a function of ordinal position (Fs<1), replicating the pattern observed in Experiment 2.

4.2.2. Level II-a analysis—In this analysis we tested whether the cumulative semantic cost is transferred from determiner + word naming to determiner + picture naming trials, and from determiner + picture naming to determiner + word naming trials. Ordinal position was held constant, and t-tests (two-tailed, paired) were performed between deviant trials and non deviant trials. This was done separately for picture- and word-naming targets, and restricted to those ordinal positions for which there were both deviant and non deviant naming trials (i.e., third and fourth ordinal positions within category).

For pictures, deviant trials were located in the third ordinal position in the *deviant picture at 3rd* condition (705 ms) and the fourth ordinal position in the *deviant picture at 4th* condition (705 ms) while non deviant trials they were located at the third ordinal position for the *deviant word at 4th* condition (724 ms) and the fourth ordinal position for the *deviant word at 3rd* condition (715 ms). The results indicated that for picture naming trials, the non deviant condition was slower than the deviant condition (t1 (1, 19)=−2.47, p<.03), indicating less transfer of cumulative semantic cost from word naming to picture naming trials than from picture naming to picture naming trials.

For word naming trials, deviant trials were located in the third ordinal position in the *deviant word at 3rd* condition (527 ms) and the fourth ordinal position of the *deviant word at 4th* condition (538 ms) while non deviant trials were located at the third ordinal position of the *deviant picture at 4th* condition (514 ms) and the fourth ordinal position of the *deviant picture at 3rd* condition (518 ms). The results indicated that the deviant condition was slower than the non deviant condition (t1 (1, 19)=2.72, p<.02), indicating the cumulative semantic cost in word naming trials that followed picture naming trials was greater compared to word naming trials that followed word naming trials. In fact, as described above (see Level I analysis and Experiment 2) there was no cumulative cost for word naming trials that followed word naming trials.

4.2.3. Level II-b analysis—In this analysis, we sought to confirm, with another analysis approach, the finding that the cumulative cost transfers from picture to word naming, but not from word naming to picture naming. To this end, we computed difference scores between each deviant item, and the preceding within category item (i.e., across ordinal positions). Thus, if a cumulative cost is transferred across format (picture to word, or word to picture) then the difference in milliseconds will be positive. For the purposes of this analysis, we collapsed together deviant items that appeared in the third and fourth ordinal positions. Specifically, for deviant picture targets, we a) averaged the naming latencies of the two deviant trials (i.e., third ordinal position of the *deviant picture at 3rd* condition, 705 ms, and the fourth ordinal position of the *deviant picture at 4th* condition, 705 ms), and b) averaged the latencies of the respective previous within-category picture trials (i.e., the second ordinal position of the *deviant word at 3rd* and *deviant word at 4th* conditions, 702 and 710 ms respectively, and the third ordinal position of the *deviant word at 4th* condition, 724 ms).

We then calculated the difference scores (deviant 'n' trials − non deviant 'n-1' trials) between those two averages. This was done on a subject-by-subject basis, such that error was calculated over subjects and degrees of freedom on the resulting statistical tests was number of subjects − 1.

The same procedure was used for determining the amount of cumulative semantic cost for the non deviant condition: a) we averaged the naming latencies of the two non deviant trials (i.e., the third ordinal position in the *deviant word at 4th* condition, 724 ms, and the fourth ordinal position in the *deviant word at 3rd* condition, 715 ms), and b) we averaged the latencies of the previously named within-category picture trials (as above, the second ordinal position in the *deviant word at 3rd* and *deviant word at 4th* conditions, 702 and 710 ms respectively, and the third ordinal position in the *deviant word at 4th* condition, 724 ms). We then calculated the difference scores between those averages in order to estimate the cumulative semantic cost (non deviant 'n' trials − non deviant 'n-1' trials). The corresponding analysis was performed for word targets. The difference scores obtained from this analysis are plotted in Fig. 4.

T-tests (two-tailed) were performed on the obtained difference scores for the deviant and non deviant conditions. In the analysis of target picture naming trials, the results showed that the cumulative semantic cost was larger in the non deviant condition than in the deviant naming condition ($t1\ (1, 19)=-2.48$, $p<.03$), indicating that deviant picture naming trials suffered less cumulative semantic cost than non deviant picture naming trials. In other words, this analysis confirms the finding that there was no cumulative semantic cost transferred from word naming to picture naming. In the analysis of target word naming trials, the results showed that the cumulative semantic cost was larger for the deviant word naming trials than for the non deviant word naming trials ($t1\ (1, 19)=2.68$, $p<.02$), indicating that deviant word naming trials suffered more cumulative cost than non deviant word naming trials. This finding substantiates the observation that a cumulative cost is transferred from picture naming to word naming.

In summary, both approaches to analyzing the critical manipulation within Experiment 3 (Levels II-a and II-b) converge to indicate that cumulative semantic costs are transferred from picture naming to word naming trials, but not from word naming to picture naming trials.

4.3. Discussion

Two sets of findings emerge from Experiment 3. First, the results replicate and extend the findings from the previous two experiments: a cumulative semantic cost was observed in determiner + picture naming trials that followed picture naming trials, and was not observed for determiner + word naming trials that followed word naming trials. These results support the expectations laid out in predictions 1 and 4 above. Second, the results of Experiment 3 also show that the cumulative semantic cost is transferred from picture naming to word naming, but is not transferred from word naming to picture naming. This pattern is as would be predicted if 1) determiner + word naming involves semantically driven lexical access, but 2) there is no incremental weakening of (non-target) semantic-to-lexical connections in determiner + word naming. These findings are consistent with predictions 2 and 3 above.

5. General Discussion

We have reported three experiments exploring whether the cumulative semantic cost (Brown, 1981; Howard et al., 2006) arises at the level at which target words are selected in speech production. The principal finding that emerges from our study is that while a cumulative semantic cost is observed in picture naming (Experiment 1), there is no effect in a determiner + word naming paradigm using the same materials. Thus, following the same logic that has been used to argue for a lexical locus of semantic effects in the cyclic naming paradigm (Damian et al., 2001) the lack of a cumulative semantic cost in determiner + word production indicates that the phenomenon does not occur at or after lexical selection. Furthermore, the lack of a cumulative semantic cost in the determiner + word production experiments cannot be dismissed on the grounds that those experiments did not have sensitivity to detect effects on naming latencies, because there was reliable repetition priming across blocks in all experiments (1, 2a, and 2b). In Experiment 3, the cumulative semantic cost was found to transfer from picture naming to word naming, indicating that determiner + word naming involves semantically driven lexical access. However, and consistent with the view that determiner + word naming does not involve incremental weakening of non-target semantic-to-lexical connections, the cumulative semantic cost does not transfer from word naming to picture naming.

5.1. Relation to other experimental paradigms inducing semantic costs

As discussed above, one assumption shared by current explanations of the cumulative semantic cost is that each time a picture is named, the connections between semantics and lexical representations are strengthened for that item (see also Damian & Als, 2005, for discussion). Convergent evidence for this assumption is provided by the studies of Vitkovitch and colleagues (Vitkovitch & Humphreys, 1991; Vitkovitch, Humphreys, & Lloyd-Jones, 1993; for discussion, see Oppenheim et al., 2010). Vitkovitch and Humphreys (1991) asked participants to name pictures in a sequence to a speeded deadline. Such a speeded picture naming task increases the possibility of making a mistake during the naming process, permitting analyses of the types of errors made by participants. Vitkovitch and Humphreys observed that participants often made related perseverative errors – that is, they misnamed target pictures by giving the name of a semantic coordinate to the target picture that was named in a previous phase of the experiment. In their second experiment, the related perseverative errors did not occur at a greater-than-chance rate, when during the previous phase pictures were categorized as depicting natural or manmade objects (instead of being named). Since the categorization task requires semantic but not lexical access, the lack of an effect in their second experiment would suggest that the origin of the related perseverative errors is at a post-semantic level of processing. In a subsequent experiment, the authors tested whether the locus of the effect was at the lexical level of processing by having participants read words corresponding to the related picture names in the initial phase (again, instead of naming the pictures). Critically, related perseverative errors did not occur at a greater-than-chance rate, suggesting that the locus of the phenomenon is pre-lexical. Taken together, the evidence from Vitkovitch and Humphreys suggests, as argued by the authors, that the origin of the related perseveration errors is at the level at which semantic representations interface with lexical representations. This is the same level of processing that has been implicated in explaining the cumulative semantic cost (for discussion and simulations, see Oppenheim et al., 2007, 2010).

The combined weight of the empirical evidence that we have reported in this article, together with previous findings and arguments, make it unlikely that the cumulative semantic cost reflects the process of lexical selection. This conclusion converges with recent arguments that there is no evidence to support the assumption of lexical selection by competition, and if anything, evidence against that assumption (Finkbeiner & Caramazza, 2006; Janssen et al., 2007; Mahon et al., 2007; Mahon & Caramazza, 2009; Miozzo & Caramazza, 2003). However, further empirical work is required in order to understand why there is a semantic interference effect observed in the cyclic blocking paradigm using a determiner + word naming task (for relevant findings and discussion, see Damian et al., 2001; Damian & Als, 2005; Dell et al., 2008; Oppenheim et al., 2007).

5.2. Implications for the relation between semantic and episodic memory systems

A well established phenomenon in the field of memory research is that access to information from memory is more difficult if related information has previously been retrieved. Perhaps the clearest demonstration of this is the phenomenon of retrieval-induced forgetting. This phenomenon bears certain surface similarities to the cumulative semantic cost. In the classical retrieval-induced forgetting paradigm, participants first study a list of category-exemplar pairs (e.g., FRUIT-apple, DRINK-beer, FRUIT-orange, DRINK-wine, etc). In a subsequent practice phase, half of the exemplars from half of the categories are practiced several times by presenting participants with a cued stem (e.g., when presented with 'FRUIT-a___' participants have to produce 'apple'). Finally, in the test phase participants are asked to recall all of the items that were originally presented in the study phase. As would be expected, items (e.g., apple) that were practiced in the second practice phase are recalled better at test than unpracticed items (e.g., beer). More surprising is that recall for unpracticed items from practiced categories (e.g., orange) is worse than recall of unpracticed items from unpracticed categories (e.g., wine) (Anderson, Bjork, & Bjork, 1994; Anderson & Spellman, 1995; for review, see Anderson, 2003; Levy & Anderson, 2002).

There are several interesting similarities between the cumulative semantic cost and retrieval-induced forgetting that merit further investigation (see Oppenheim et al., 2010, for discussion). At the broadest level, both phenomena are cumulative effects that are observed within semantic categories. More specifically, in the retrieval-induced forgetting paradigm, the proportion of retrieval successes in the last (test) phase declines in a systematic manner as a function of the total number of within-category retrievals that occurred (e.g., Johnson & Anderson, 2004); in the same line, the amount of cumulative semantic cost that a picture suffers depends on how many within-category pictures have been previously named. A second similarity refers to the observation that retrieval-induced forgetting is reported when in the practice phase participants are require to "actively" retrieve the name of category members, through for instance category-stem cues such as 'FRUIT-or___' (to cue the retrieval of 'orange'). By contrast, when the practice phase does not require "active" retrieval of the items, through for instance cues such as 'F___-orange' (for the category 'fruit') there is no 'retrieval-induced forgetting' of the category members of the category 'fruit' in the later test phase (Anderson, Bjork, & Bjork, 2000). This observation suggests that retrieval-induced forgetting depends on the specific mechanisms involved in retrieval attempts of the category member names ('FRUIT-or___'); when those mechanisms are not necessary because the member name is provided with the cue ('F___-orange) retrieval-induced forgetting is not observed. This aspect of the retrieval induced forgetting paradigm is strikingly similar to the pattern of findings we have observed, in which the cumulative semantic cost is not observed for word naming.

One issue for future research is whether the retrieval induced forgetting phenomenon and the cumulative semantic cost both reflect a process of individuating the target representation that is to be produced, and it is that process of individuation that is costly in terms of response times (see for instance, Wagner, Paré-Blagoev, Clark, & Poldrack, 2001; Brade & Wagner, 2002). The mechanism of incremental learning and the adjustment of the connection weights between semantic and lexical representations may be one way to implement that process of target individuation. However, it remains a largely open empirical issue whether such a mechanism may be successfully implemented at levels of processing prior to the interface between semantic and lexical representations. In particular, one possibility is that at least part of the cumulative semantic cost arises at the level at which higher order visual information interfaces with semantic information.

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6. Conclusion

The data that we have reported demonstrate that the cumulative semantic cost does not reflect lexical-level processes, and thus does not constitute support for the hypothesis of lexical selection by competition. We have presented evidence consistent with the view that the phenomenon is due to incremental adjustments to semantic-to-lexical connections. These data frame the importance of interactions between semantic and lexical level representations that are only recently coming under the focus of concerted study within the speech production community; similarly, issues concerning the dynamics of lexical access have received little attention within the fields of memory research. The cumulative semantic cost in picture processing will be an important paradigm to guide future research that bridges the empirical and theoretical insights that have been gained in those fields.

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Appendix A

Materials used in all Experiments organized by semantic category. Italian and German translations are provided after the English name.

Animals: cow (mucca, Kuh), donkey (asino, Esel), horse (cavallo, Pferd), pig (maiale, Schwein), sheep (pecora, Schaf).

Fruit: apple (mela, Apfel), banana (banana, Banane), lemon (limone, Zitrone), orange (arancia, Orange), pear (pera, Birne).

Musical instruments: drum (tamburo, Trommel), guitar (chitarra, Gitarre), piano (pianoforte, Klavier), trumpet (tromba, Trompete), violin (violino, Violine/Geige).

Tools: axe (scure, Axt), drill (trapano, Bohrer), hammer (martello, Hammer), saw (sega, Säge), screwdriver (cacciavite, Schraubenzieher).

Transportation: airplane (aereo, Flugzeug), bus (autobus, Bus), car (macchina, Auto), helicopter (elicottero, Hubschrauber), van (furgone, Lieferwagen).

Body parts: ear (orecchio, Ohr), eye (occhio, Auge), finger (dito, Finger), hand (mano, Hand), nose (naso, Nase).

Clothes: bra (reggiseno, Büstenhalter), jacket (giacca, Jacke), pyjamas (pigiama, Schlafanzug), skirt (gonna, Rock), sock (calzino, Socke).

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Tableware: cup (tazza, Tasse), fork (forchetta, Gabel), glass (bicchiere, Glas), knife (coltello, Messer), spoon (cucchiaio, Löffel).

Furniture: bed (letto, Bett), chair (sedia, Stuhl), desk (scrivania, Schreibtisch), stool (sgabello, Hocker), table (tavolo, Tisch).

White goods: dishwasher (lavastoviglie, Spülmaschine), fridge (frigo, Kühlschrank), microwave (forno microonde, Mikrowellenherd), stove (cucina, Ofen), washing machine (lavatrice, Waschmaschine).

Vegetables: broccoli (broccoli, Brokkoli), carrot (carota, Karotte), cauliflower (cavolfiore, Blumenkohl), onion (cipolla, Zwiebel), potato (patata, Kartoffel).

Buildings: castle (castello, Burg), church (chiesa, Kirche), house (casa, Haus), lighthouse (faro, Leuchtturm), windmill (mulino, Windmühle).

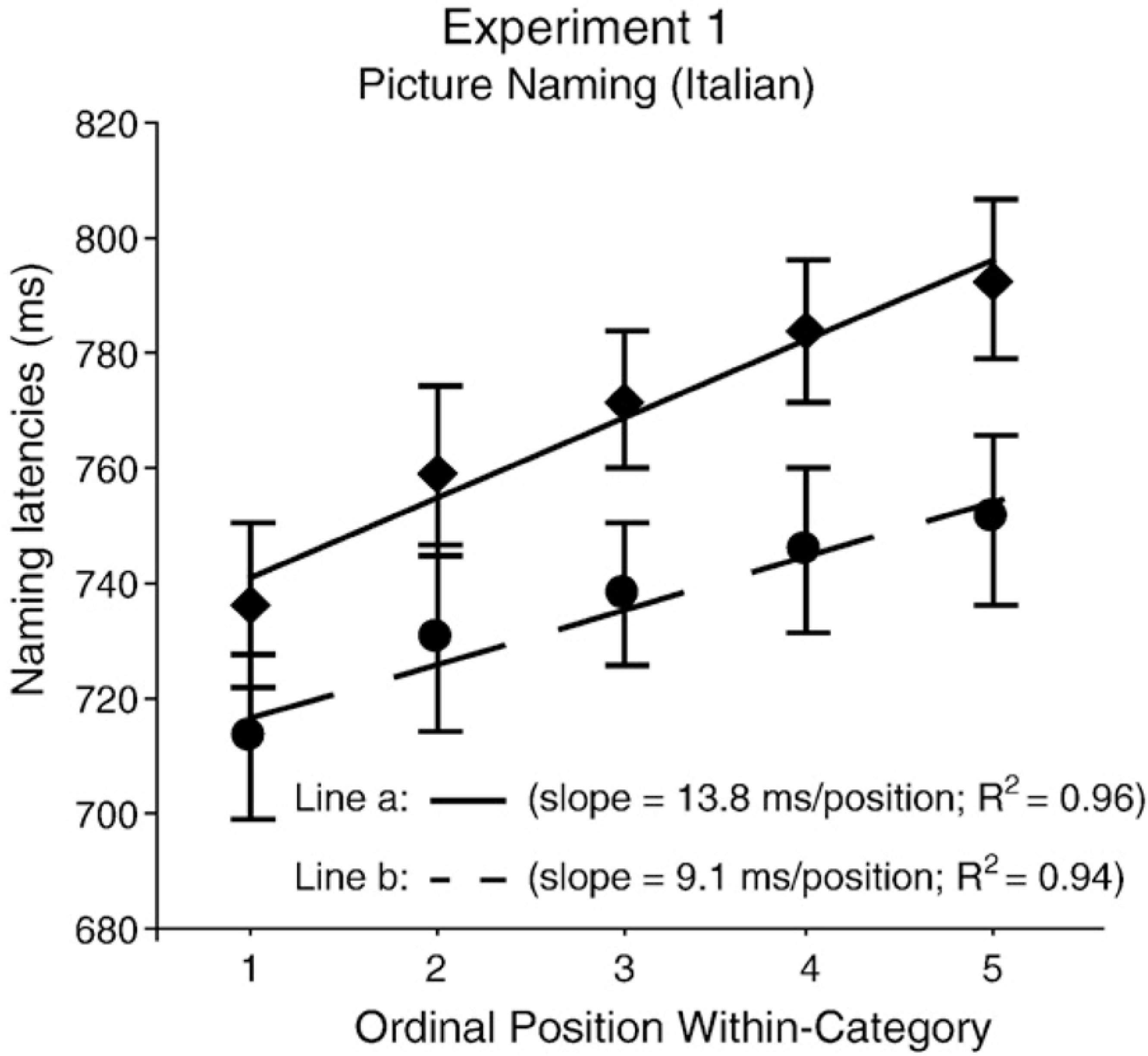

Fig. 1.
Mean naming latencies by Ordinal Position Within-Category collapsed across repetitions for Experiment 1. Line ‘a’ shows uncorrected naming latencies. Line ‘b’ plots the same data corrected for the presence of linear trends (see text for discussion).

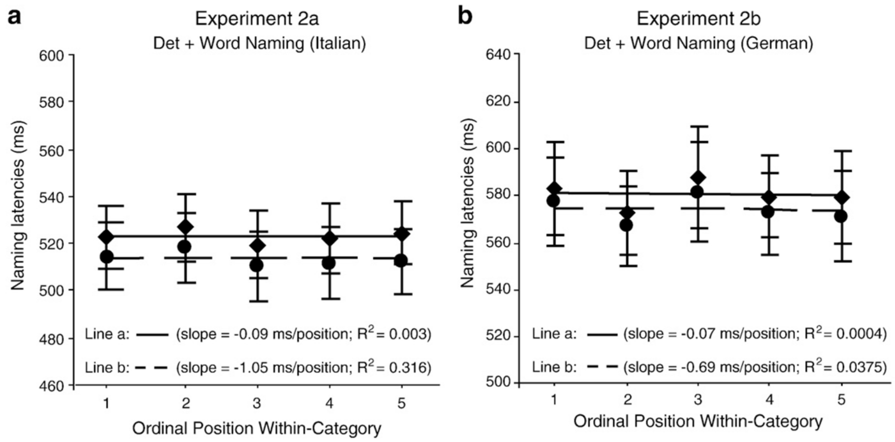

Fig. 2.

Mean naming latencies by Ordinal Position Within-Category collapsed across repetitions for Experiment 2a (Fig. 2A) and Experiment 2b (Fig. 2B). Line ‘a’ shows uncorrected naming latencies. Line ‘b’ plots the same data corrected for the presence of linear trends (see text for discussion).

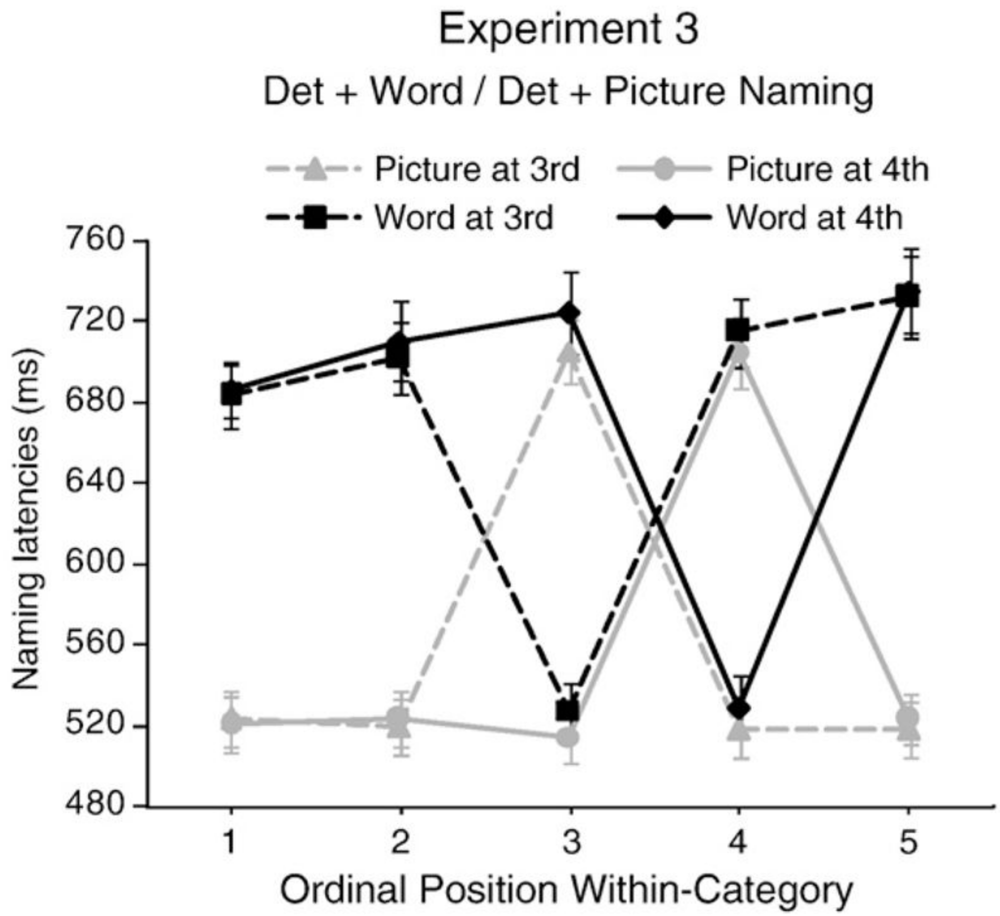

Fig. 3.
Mean naming latencies by Ordinal Position Within-Category and Condition collapsed across repetitions for Experiment 3.

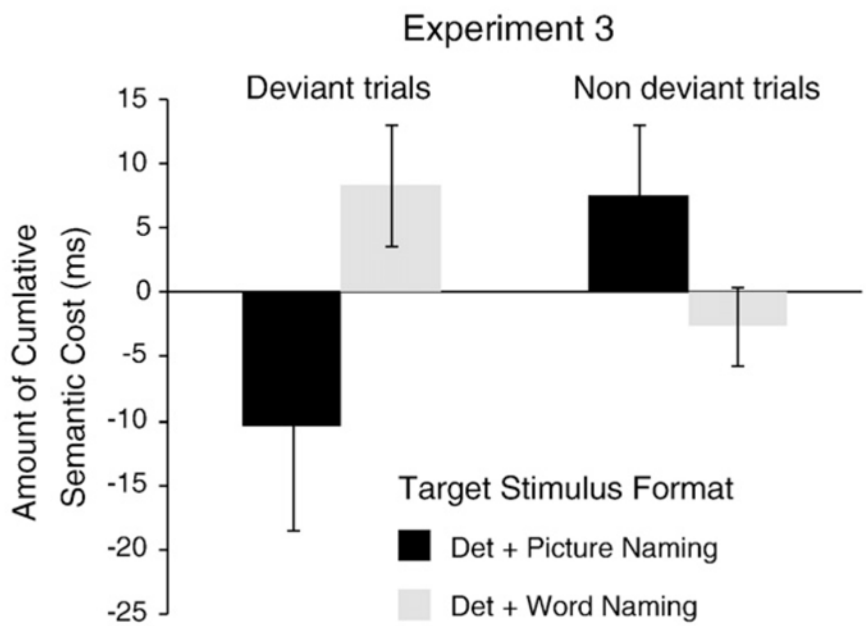

Fig. 4.
Mean differences in naming latencies representing the amount of cumulative semantic cost observed for deviant and non deviant trials, for picture and word targets (see text, Analysis II-b, for a description). A positive value reflects a cumulative semantic cost for consecutive ordinal positions within category. The conditions showing a cumulative semantic cost were the non deviant picture condition (determiner + picture following determiner + picture naming trials) and the deviant word condition (determiner + word following determiner + picture naming trials). No cumulative semantic cost was reported in the deviant picture condition (determiner + picture following determiner + word naming trials) and the non deviant word condition (determiner + word following determiner + word naming trials).

Table 1

Mean naming latencies (RT in ms), standard deviations (SD in ms) and percentage of error rates (E) by Ordinal Position Within-Category and Repetition in Experiment 1.

	Blocks													
	First			Second			Third			Fourth			Mean	
Position	**RT**	**SD**	**E**	**RT**	**SD**	**E**	**RT**	**SD**	**E**	**RT**	**SD**	**E**	**RT**	**E**
1	770	163	10.4	747	151	9.2	720	156	4.6	711	156	3.7	737	7.0
2	793	162	12.9	764	161	7.5	751	157	5.8	732	153	2.9	760	7.3
3	798	162	13.7	793	162	8.3	768	170	6.2	731	144	7.5	772	9.0
4	829	167	16.3	785	178	9.2	779	155	8.3	746	157	6.7	785	10.1
5	844	169	15	804	174	12.9	774	164	7.1	755	158	5.8	794	10.2
Mean	807		13.7	778		9.4	759		6.4	735		5.3		

Table 2

Mean naming latencies (RT in ms), standard deviations (SD in ms) and percentage of error rates (E) by Ordinal Position Within-Category and Repetition in Experiment 2a (Italian version).

	Blocks													
	First			Second			Third			Fourth			Mean	
Position	RT	SD	E	RT	SD	E	RT	SD	E	RT	SD	E	RT	E
1	557	108	10.3	519	84	4.4	509	90	4.9	504	87	3.4	522	5.7
2	551	106	8.1	533	92	3.7	514	95	3.0	509	90	1.9	527	4.2
3	545	100	7.9	522	81	4.4	513	102	5.0	498	77	3.4	520	5.2
4	544	101	6.3	522	92	4.8	515	99	3.4	507	91	2.6	522	4.3
5	551	102	4.2	523	84	3.7	511	100	3.4	511	90	1.9	524	3.3
Mean	550		7.4	524	4.2	512		4	506		5.6			

Table 3

Mean naming latencies (RT in ms), standard deviations (SD in ms) and percentage of error rates (E) by Ordinal Position Within-Category and Repetition in Experiment 2b (German version).

	Blocks													
	First			Second			Third			Fourth			Mean	
Position	**RT**	**SD**	**E**	**RT**	**SD**	**E**	**RT**	**SD**	**E**	**RT**	**SD**	**E**	**RT**	**E**
1	618	140	9.6	578	135	4.2	566	119	1.3	559	121	2.5	580	4.4
2	598	123	8.3	576	113	3.3	560	112	2.1	551	119	1.7	571	3.9
3	622	132	8.3	587	144	5.0	563	127	3.8	568	133	2.9	585	5
4	599	117	9.2	583	126	2.9	566	113	2.1	566	123	2.1	578	4.1
5	604	129	6.7	582	126	6.3	562	113	5.8	557	117	3.3	576	5.5
Mean	608		8.4	581		4.3	563			560		2.5		

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Table 4

Mean naming latencies (RT in ms), standard deviations (SD in ms) and percentage of error rates (E) by Ordinal Position Within-Category and Condition collapsed across repetitions in Experiment 3.

	Conditions													
	Picture at 3rd			Picture at 4th			Word at 3rd			Word at 4th			Mean	
Position	**RT**	**SD**	**E**	**RT**	**SD**	**E**	**RT**	**SD**	**E**	**RT**	**SD**	**E**	**RT**	**E**
1	523	85	4.2	520	89	2.9	683	156	6.3	687	142	9.6	603	5.7
2	519	88	2.5	523	90	5.4	702	162	9.6	710	164	9.2	613	6.7
3	705	156	11.7	514	85	2.9	527	90	1.7	724	175	12.5	617	7.2
4	518	84	2.5	705	160	12.1	715	164	14.2	538	92	1.7	616	7.6
5	517	87	1.7	523	82	1.3	732	159	19.6	735	168	12.9	627	8.9
Mean	556		4.5	557		4.9	672		10.3	677		9.2		