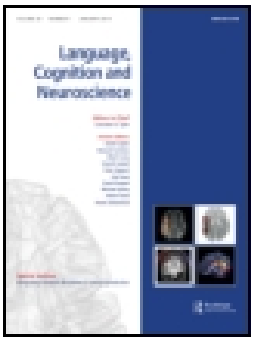

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Semantic similarity promotes interference in the continuous naming paradigm: behavioural and electrophysiological evidence

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ABSTRACT
We investigated within-category semantic distance effects in the continuous naming paradigm with reaction times (RTs) and event-related potentials (ERPs). Cumulative semantic interference and ERP effects were observed only for closely related members of basic level categories with high feature overlap (e.g. apes: orangutan, chimpanzee), indicating that shared broad semantic category membership (e.g. animals: orangutan, donkey) without considerable semantic feature overlap is insufficient to induce semantic interference. ERP modulations were characterised by an enhanced P1 at about 100–150 ms, that may reflect early co-activation of visual-conceptual feature information, and a relative posterior positivity starting at about 250 ms that was positively correlated with RTs, reflecting lexical selection. Furthermore, a posterior negativity between 450 and 600 ms was observed and associated with semantic-lexical calibration processes. These findings suggest early conceptual and lexical loci of semantic interference and underline the importance of converging activation spread triggered by shared semantic features during speech planning.

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Language production; semantic distance; semantic interference; continuous naming; electrophysiology

Introduction

According to most models of language production, semantic processing during early planning stages involves the co-activation of meaning-related representations at the conceptual planning level and in turn, the co-activation of related lexical representations (e.g. Bloem, van den Boogaard, & La Heij, 2004; Caramazza, 1997; Dell, 1986; Levelt, 1992; Levelt, Roelofs, & Meyer, 1999). For instance, in the course of picture naming not only the conceptual and lexical representations of the target word are activated, but also – via semantic activation spread – those of related items. The number of co-activated lexical representations and their activation levels are determined by the degree of semantic activation spread that propagates between related concepts according to their semantic distance or feature overlap (e.g. Navarrete, Del Prato, & Mahon, 2012; Vigliocco, Vinson, Damian, & Levelt, 2002; Vigliocco, Vinson, Lewis, & Garrett, 2004).

Evidence for the crucial role of lexical-semantic activation of related items during speech planning stems from different semantic context effects such as observations of semantic interference in the picture word interference (PWI; e.g. Damian & Bowers, 2003; see also Geng, Kirchgessner, & Schnur, 2013; Glaser & Dungelhoff, 1984; Glaser & Glaser, 1989; Hantsch, Jescheniak, & Schriefers, 2005; Schriefers, Meyer, & Levelt, 1990) or cyclic blocking paradigm (e.g. Belke, Meyer, & Damian, 2005; Damian & Als, 2005; Damian, Vigliocco, & Levelt, 2001; Kroll & Stewart, 1994; Schnur, Schwartz, Brecher, & Hodgson, 2006; Vigliocco et al., 2002). In the PWI task a picture (e.g. dog) is paired with a simultaneously presented semantically related or unrelated distractor word (e.g. cat vs. pen). In the blocking paradigm, pictures (e.g. dog) are named in homogenous blocks consisting of related items from a common semantic category (e.g. animals: cat, wolf, lizard, etc.) or in heterogeneous blocks consisting of unrelated objects (e.g. wolf, pan, car, etc.). Naming times are longer in the context of related compared to unrelated stimuli.

According to lexical competition models, semantic interference reflects the competition of the target lexical candidate with simultaneously co-activated and semantically related lexical representations for selection (Levelt et al., 1999; Roelofs, 1992). These models further assume that the size of semantic interference should be affected by the degree of semantic distance between target and context stimuli because the extent of semantic feature overlap determines the strength and extent of co-activation of semantically related concepts and their lexical representations. In line with this assumption, Vigliocco and colleagues (2004) found that

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semantic interference in the PWI task linearly increases with increasing levels of semantic similarity between target and distractor. Thus, closely related distractors sharing many semantic features with targets yield stronger interference than more distantly related words (see also Vigliocco et al., 2002 for comparable results in cyclic blocking).

However, empirical evidence on such graded effects is mixed and inconclusive. Whereas some studies could replicate graded semantic interference in the PWI (Aristei & Abdel Rahman, 2013; Vieth, McMahon, & de Zubicaray, 2014a, Experiment 2) and cyclic blocking paradigm (with interleaved symbols; Navarrete et al., 2012, Experiment 3a and b), there are also studies that failed to find a modulation of interference by semantic distance beyond the mere effects of semantic categories (Hutson & Damian, 2014; Navarrete et al., 2012, Experiment 2; Vieth et al., 2014a, Experiment 1). Furthermore, Mahon and colleagues reported a reversed pattern for semantic distance in the form of stronger interference for distantly compared to closely related distractors in the PWI paradigm (Mahon, Costa, Peterson, Vargas, & Caramazza, 2007, Experiment 7). Even though the pattern of longer naming times for distant relative to close word distractors has not been replicated thus far (cf. Aristei & Abdel Rahman, 2013; Hutson & Damian, 2014; Vieth et al., 2014a), Mahon et al.'s findings (2007), together with other observations that not all semantic contexts yield interference (e.g. association or part-whole relations in the PWI (e.g. Alario, Segui, & Ferrand, 2000; Costa, Alario, & Caramazza, 2005; La Heij, Dirkx, & Kramer, 1990) or the first cycle in the cyclic naming paradigm (Abdel Rahman & Melinger, 2007; Navarrete et al., 2012, 2014; but see Crowther & Martin, 2014)), has sparked a debate on the plausibility of lexical competition models. Several alternative accounts for context effects in different paradigms have been proposed, and while competition models typically assume lexical selection as the origin of interference in all paradigms (plus additional task-specific mechanisms) (e.g. Abdel Rahman & Melinger, 2009a, 2009b), non-competitive accounts have proposed different mechanisms in different paradigms, rejecting the assumption of competitive lexical selection. Specifically, Mahon and colleagues (2007) locate interference in the PWI task at the level of the articulatory output buffer to which words have privileged access and must be removed. Removal times depend on their response relevance which is determined by broad category membership, and relevant words are removed more slowly. Semantic relations in this paradigm are assumed to induce priming, and close relations should induce stronger priming (and thus faster naming) than distant relations. For the cyclic blocking task non-competitional models make different assumptions, suggesting that the retrieval of one item includes the inhibition of related items. When these appear in subsequent trials, they are named more slowly (Navarrete, Del Prato, Peressotti, & Mahon, 2014; Oppenheim, Dell, & Schwartz, 2010). In general, some authors take semantic facilitation, rather than interference, as the typical and expected pattern in the PWI and the cyclic blocking task (Mahon et al., 2007; Mahon, Garcea, & Navarrete, 2012; Navarrete & Mahon, 2013). For a detailed discussion of semantic effects in the continuous naming task, see below.

A potential problem of many studies on semantic distance cited above, and a possible factor that may explain the heterogeneity of these findings, is related to the use of feature generation norms (Hutson & Damian, 2014, Experiment 1; Mahon et al., 2007; Vieth et al., 2014a, Experiment 2; Vigliocco et al., 2002) or similarity ratings (Cree & McRae, 2003; Hutson & Damian, 2014, Experiment 2; Mahon et al., 2007; Vieth et al., 2014a, Experiment 1). Employing these measures, items may be classified as closely related on the basis of some shared features irrespective of their semantic category membership (e.g. colour: strawberry and lobster). Furthermore, similarity ratings may overestimate shared relative to distinct features (Aarts & Dijksterhuis, 2002; Kaplan & Medin, 1997; Medin, Goldstone, & Markman, 1995): two stimuli sharing many features (e.g. horse and zebra: equine animal, has legs, has a tail, etc.) but differing essentially concerning some features (e.g. zebra has stripes) are rated as more similar than stimuli sharing the same amount of features but only differing modestly (Vieth, McMahon, & de Zubicaray, 2014b). In the present study, we aimed to avoid these problems by systematically investigating semantic distance within taxonomic hierarchies (cf. Aristei & Abdel Rahman, 2013; Navarrete et al., 2012). Specifically, we manipulated semantic distance on the basis of feature information that objects share either with closely related members of a basic level category or with more distantly related members of the broader main category. For instance, the orangutan shares many features with other apes or monkeys but less – and more global features – with other animals as cow, pig, etc. Thus, semantic feature overlap is varied while keeping broad semantic category membership constant.

Recently, Abdel Rahman and Melinger (2009a, 2009b) have proposed a variant of lexical competition models, the swinging lexical network, arguing that semantic context effects are the result of a trade-off between conceptual facilitation (priming) and lexical competition, and that semantic interference is only observed when context induced lexical competition outweighs conceptual facilitation. This is typically the case when a lexical cohort of sufficient size is active, that is, when a number of simultaneously co-activated items contributes to the overall competitive activation, delaying the selection of the target entry accordingly. (Abdel Rahman & Melinger, 2007; Melinger & Abdel Rahman, 2013). It is furthermore assumed that lexical selection times are a function of the target activation relative to the sum activation of all other co-activated items. Thus, there are two related forces that modulte semantic context effects: the activation strength of lexical competitors and the number of competing items. In order to account for faster naming in the context of close relative to distant distractors in the PWI task (Mahon et al., 2007), Abdel Rahman and Melinger have hypothesised that distant relations within broad superordinate categories sharing mostly general features (e.g. animals: bee and horse) may induce stronger interference because target and distractor co-activate a big cohort of items belonging to the broad category, while closely related distractors co-activate only a small number of highly related members of the small category that has fewer members (e.g. insects: bee and ant). As a result, a bigger cohort would be active for distant relative to close distractors, and the competition induced by a bigger number of active competitors, even though they may be relatively weakly activated, may be stronger than the competition induced by few strongly active competitors. However, lexical competition may also be determined primarily by the activation strength of co-activated competitors (see above), which should be stronger for closely related cohorts mutually co-activating each other, even though smaller in number. Additionally, the two factors of cohort size and activation strength are closely related and should strongly influence each other: a bigger number of active competitors should induce stronger competition not only because each competitor contributes to the overall competition, but also because the mutual co-activation should increase the activation strength of individual competitors. Here, we employ the continuous naming task to isolate effects of activation strength from effects of cohort size, as explained below.

Semantic similarity in the continuous naming paradigm

Until now, most studies on semantic similarity effects employed the PWI (Aristei & Abdel Rahman, 2013; Hutson & Damian, 2014; Vieth et al., 2014a; Vigliocco et al., 2004) or cyclic semantic blocking task (Navarrete et al., 2012; Vigliocco et al., 2002). However, semantic interference can also be observed in the continuous naming paradigm in which semantic category members are presented in a seemingly random sequence separated by 2, 4, 6 or 8 unrelated items (Howard, Nickels, Coltheart, & Cole-Virtue, 2006). Irrespective of the lag, semantic interference increases linearly each time a new member of the semantic category is named (e.g. Belke, 2013; Belke & Stielow, 2013; Costa, Strijkers, Martin, & Thierry, 2009; de Zubicaray, McMahon, & Howard, 2013; Howard et al., 2006; Navarrete, Mahon, & Caramazza, 2010; Runnqvist, Strijkers, Alario, & Costa, 2012).

This task could contribute to a better understanding of semantic similarity effects because it includes lexical-semantic access while differing from the other context paradigms concerning the involved cognitive sub-processes. Specifically, naming performance is less prone to working memory load or top-down control mechanisms because – in contrast to cyclic blocking – participants cannot anticipate whether a stimulus will be semantically related to a previously presented stimulus due to unrelated intervening items (Belke, 2008; Belke & Stielow, 2013; Riès, Karzmark, Navarrete, Knight, & Dronkers, 2015). While in the cyclic version task-relevant stimuli can be easily identified after the first presentation cycle, this distinction cannot be made in the continuous naming paradigm, and predictions about upcoming stimuli – that may depend in their concreteness on the semantic similarity – are unlikely (Belke, 2008; Belke & Stielow, 2013; de Zubicaray et al., 2013; Riès et al., 2015). Moreover, it has been criticised that the visual similarity between semantically related objects in homogenous blocks of the cyclic blocking task may affect naming performance independent of lexical-semantic factors, for example, in the form of higher fine-grained visual discrimination effort to identify visually similar items when they are successively presented (Hocking, McMahon, & de Zubicaray, 2009; Lotto, Job, & Rumiati, 1999). Semantic distance effects in the PWI task might be influenced not only by the degree of shared features but also by the importance of these feature for identifying the target concept (Vieth et al., 2014a, 2014b). These problems can be circumvented in the continuous naming paradigm because visual similarity should not significantly affect object naming times due to the lags of variable size between related items, and because no direct context stimuli are presented.

The long-lasting and cumulative nature of semantic interference has been explained with learning mechanisms altering the activation levels of previously selected lemmas (Belke, 2013; Howard et al., 2006; Oppenheim et al., 2010). Specifically, in the context of lexical competition models it is assumed that competition is proportionally enhanced by strengthened connections between concepts and lemmas (Howard et al., 2006) or between semantic features and concepts (Belke, 2013) of previously named objects. Because these models presume that the extent of competition is influenced by shared activation between related concepts, increasing levels of semantic similarity should be reflected in steeper slopes of cumulative semantic interference across ordinal positions. Alternatively, Oppenheim and colleagues (2010; see also Navarrete et al., 2014) propose a learning mechanism (e.g. Anderson, 2003; Anderson, Bjork, & Bjork, 1994; Anderson, Bjork, & Bjork, 2000; Johansson, Aslan, Bauml, Gabel, & Mecklinger, 2007) that not only induces enhanced activation levels of targets but also inhibition of co-activated non-targets in the form of retrieval-induced forgetting (RIF). Implementing this mechanism, cumulative interference can be explained without the assumption of lexical selection by competition. Instead, lexical selection is based on a booster amplifying the activation of lexical entries until one reaches a selection threshold. Because the connection weight changes during learning are also assumed to be proportional to the extent to which lexical representations have received activation from their corresponding concepts, the predictions from this non-competitive model for semantic distance effects in the continuous naming paradigm are similar to those derived from competitive models, with stronger cumulative interference for closely related relative to more distantly related objects.

Crucially, the continuous naming paradigm allows for an investigation of the effects of lexical activation strength of competitors independent of the size of the active lexical cohort, as these factors usually influence each other in the PWI task (cf. Melinger & Abdel Rahman, 2013). The cumulative interference in this task – and the activation of a lexical cohort that increases in size with each newly named member of the category – is determined by the previous naming experience and the number of (more) active competitors increases systematically with each new category member that is named. This is in contrast to the PWI paradigm in which cohort size is directly influenced by the relation and semantic feature overlap between target and distractor (see above). Therefore, we can use the continuous naming task to directly compare effects of the activation strength of competitors due to semantic feature overlap independent of increasing lexical cohort size (Abdel Rahman & Melinger, 2009a, 2009b).

By now, semantic distance has not been explicitly manipulated in the continuous naming task. In fact, most continuous naming studies employed closely related stimuli derived from small basic level categories, for example, reptiles, farm animals, fruits, deserts, etc. (cf., e.g. Costa et al., 2009; de Zubicaray et al., 2013; Howard et al., 2006; Navarrete et al., 2010). For instance, the stimulus set used by Howard and colleagues (2006) consists of 16 (of 24) closely related sets (basic level categories: bugs, birds, fish, computer equipment, vegetables, fruits, etc.). Thus, even though most accounts suggest modulations of the slope of semantic interference by semantic distance, it remains unclear to which extent distantly related stimuli elicit (more or less) cumulative semantic interference. Alario and Moscoso del Prado Martín (2010) investigated in a re-analysis of Howard et al.'s (2006) data whether cumulative interference can be found across categories, for instance, when objects from basic level categories presented at the beginning and ending of the experiment (e.g. farm animals and zoo animals) are regrouped into broader (main) categories (e.g. animals with four legs). Critically, while the overall naming latencies of basic level categories were slower after members of related basic level categories had been named, this additional interference effect did not modulate the slope of cumulative interference effects within basic level categories, as would have been predicted.

For the present study and the manipulation of semantic distance within taxonomic hierarchies, we expect the slope of the cumulative effects to vary as a function of semantic similarity/activation strength, predicting stronger cumulative increases for closely related items sharing many specific semantic features relative to distantly related items.

To gain insight into the temporal dynamics of cumulative semantic distance effects and for functional localizations within the speech planning process, we extracted event-related potentials (ERPs) from the electroencephalogram (EEG) acquired during overt naming. Even though articulation related artefacts are an unresolved issue (Piai, Riès, & Knight, 2015; Ouyang et al., submitted), recent EEG studies with overt naming responses have shown that particularly early ERPs well before articulation onset can be employed without massive contaminations under certain conditions (e.g. Aristei, Melinger, & Abdel Rahman, 2010; Blackford, Holcomb, Grainger, & Kuperberg, 2012; Costa et al., 2009; Dell'Acqua et al., 2010; Greenham, Stelmack, & Campbell, 2000; Hirschfeld, Jansma, Bölte, & Zwitserlood, 2008; Janssen, Carreiras, & Barber, 2011; Janssen, Hernandez-Cabrera, van der Meij, & Barber, 2015; Llorens, Trebuchon, Ries, Liegeois-Chauvel, & Alario, 2014; Maess, Friederici, Damian, Meyer, & Levelt, 2002; Piai, Roelofs, & van der Meij, 2012; Piai, Roelofs, Jensen, Schoffelen, & Bonnefond, 2014; Strijkers, Costa, & Thierry, 2010). Concerning cumulative interference, Costa and colleagues (2009) have reported ERP modulations in the form of an enhanced positivity at posterior electrodes between 200 and 380 ms that was positively correlated with reaction times (RTs) and taken to reflect lexical competition. Additionally, the authors reported a modulation in the N400 time window that was not correlated with the semantic interference effect (but see Llorens et al., 2014). We expected to replicate these findings in the present study, and to observe relatively early ERP modulations starting at around 200 ms. The predicted larger increase of cumulative interference as function of feature overlap in naming times should be reflected in augmented posterior ERP modulations (bigger amplitudes of the posterior positivity starting around 200 ms and of the N400 starting in a later time window), as described above.

Material and methods

Participants

Twenty-four right-handed participants, aged 20–39 years ($M = 27.4$, $SD = 4.87$) were paid for their participation in the experiment or received partial fulfilment of a curriculum requirement. All participants were native German speakers and had normal or corrected-to-normal visual acuity and normal colour vision. Two participants were replaced because of excessive EEG artefacts and/or weak naming performance.

Materials

Two hundred and sixteen colour photographs of objects were selected. The objects were equally distributed across 6 broad main categories (animals, clothes, tools, groceries, furniture and means of transportation) that could be subdivided into 36 basic level categories with 6 members each (e.g. vermin, headgear, kitchen utensils, fruits, seating furniture, ships; see Appendix A). While stimulus sets of the close condition consisted of different basic level category members (e.g. monkeys: chimpanzee, baboon, gorilla, mandrill, etc.), the sets of the distant condition consisted of six members from the six basic level categories belonging to the particular main category (e.g. animals: chimpanzee (monkey), ostrich (birds), ray (fish), bug (bugs), donkey (hoofed animals) and cobra (reptiles)). In total 36 sets for the distant condition were constructed and all objects were in the close and in the distant sets. Eighty-four additional pictures of objects from different categories were selected as filler stimuli that could appear between target pictures. All photographs were scaled to 3.5 cm × 3.5 cm and edited for homogeneity of background colour.

Design and procedure

Using the programme "Mix" (van Casteren & Davis, 2006), stimulus lists were created with the constraint that objects are separated randomly by a minimum of two and a maximum of eight items that could be either fillers or target items from different categories. By doing so, lag position was randomly assigned, and each exemplar of a stimulus set was presented at least three to four times at each ordinal position across participants (cf. Costa et al., 2009; Llorens et al., 2014; Runnqvist et al., 2012). For each participant this procedure was repeated three times (3 lists) to obtain a sufficiently large number of EEG segments per condition (54 segments for each ordinal position per semantic distance condition). After presentation of each list, short breaks were introduced.

To control for systematic variations of cumulative semantic interference from regrouping basic level categories into a main category, as shown by Alario and Moscoso del Prado Martín (2010), and from regrouping different exemplars of a main category into a basic level category across the experimental list, we applied several constraints.

First, within each list, an object (e.g. orangutan) was either presented in a sequence of members from its basic level category (semantically close condition; see participant n°1 in Figure 1) or in a sequence of members from its broad main category (semantically distant condition; see participant n°7 in Figure 1). Importantly, a participant viewed an object only in one semantic distance condition to control for potential confounds within one participant, for example, in the form of carry over effects, when gorilla is seen successively in both conditions. Still, each participant named all exemplars of the stimulus material, only that one half of the participants named exemplars (e.g. orangutan) in the semantic close condition while the other half named them in the distant condition. The assignment was counterbalanced across participants. Second, the stimulus sequence was divided, unnoticeable for participants, into six different blocks such that the presentation of objects in sequences of basic level, or main categories, did not overlap. This presentation order was balanced across participants such that each category appeared equally often in each of the six blocks. For example, subject n°1 (see Figure 1) named gorilla in a sequence of other basic level category members (e.g. orangutan, chimpanzee, etc.) in the first block, while in the second block it named ant in a sequence of other insects (e.g. fly, bug, etc.). In contrast, subject n°2 named insects in the first block and apes in the second block. The same holds for the presentations of the semantic distant condition.

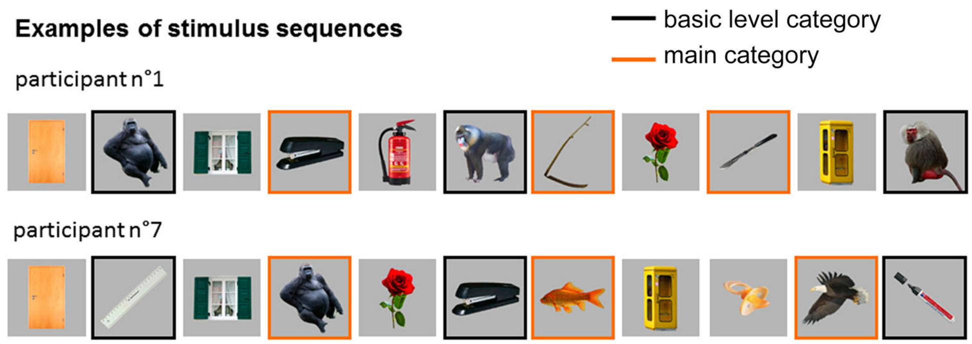

Figure 1. Example of hypothetical stimulus sequences for two participants. Participant n°1 named the gorilla in a sequence with other apes, whereas participant n°7 named the gorilla in a sequence with other animals (but not with other apes).

Subject n°7 saw gorilla in a sequence with other animals from the main category (e.g. gold fish, eagle, etc.) in the first block, and named the orangutan in sequence with other different animals (e.g. shark, owl, etc.) in the second block. However, Subject n°8 saw the orangutan and the animals of corresponding set in the first block, and so on. Please note here, that the presentation order of the exemplars within their set was randomised.

Prior to the main experimental session participants were familiarised with the objects as follows: all photographs and the written names were presented randomly on sheets of paper and participants were asked to study each picture and its corresponding name. In the main session each trial began with a fixation cross displayed in the centre of a grey screen for 500 ms. Then a picture was presented for 2 s, followed by a blank screen for 1.5 s. Participants were instructed to name each picture as fast and accurately as possible. Naming latencies were measured with a voice key during the entire duration of picture presentation. After the naming response was registered the picture disappeared and the next trial followed after the blank screen period of 1.5 s.

EEG procedure

The continuous EEG was recorded with 62 Ag/AgCl electrodes arranged according to the extended 10/20 system. An electrode over the left mastoid was used as reference. The sampling rate was 500 Hz. To register eye movements and blinks we used electrodes near the left and right canthi of both eyes and above and beneath the left eye. Electrode impedance was kept below 5 kOhm. Offline the EEG was re-referenced using the average reference transformation and low-pass filtered (high cutoff = 30 Hz, 24 dB/oct). Eye movement and blink artefacts were removed employing BESA software by deriving an estimate of the spatial distribution of eye movement artefacts to be corrected from the EEG. Afterwards, EEG data were segmented in epochs of 2100 ms, starting 100 ms before the onset of the target (baseline interval). Remaining artefacts were eliminated with a automatic artefact rejection and segments with potentials exceeding 50 µV and a threshold of 200 µV were excluded. Finally, segments were averaged for each ordinal position within the semantic distance condition.

Results

Naming latencies

RTs for each ordinal position within a category in the semantically close and distant condition are presented in Figure 2 and Table 1. A 6 (ordinal position) × 2 (semantic similarity) repeated measures analysis of variance (ANOVA) with participants (F_1) and categories (F_2) as random variables revealed a main effect of semantic similarity, $F_1(1, 23) = 6.6$, $p < .05$, $\eta^2_p = .22$; $F_2(1, 35) = 5.3$, $p < .05$, $\eta^2_p = .13$, and a main effect of ordinal position, $F_1(5, 115) = 13.3$, $p < .00$, $\eta^2_p = .36$; $F_2(5, 175) = 8.3$, $p < .001$, $\eta^2_p = .19$. Additionally, an interaction of the two

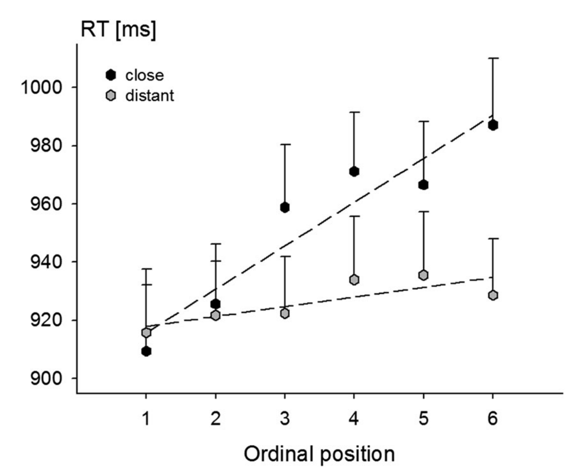

Figure 2. Means and one-tailed errors bars of naming latencies in milliseconds for each ordinal position in the semantically close and distant condition.

Table 1. Mean naming latencies in milliseconds, mean error rates in percent and the corresponding standard deviations of means for each ordinal position.

		Ordinal position					
Semantic relatedness		1	2	3	4	5	6
Close	Naming latencies	909 (111)	925 (100)	958 (105)	971 (98)	966 (105)	987 (112)
	Error rates in %	9.1 (6.4)	9.9 (6.1)	11.0 (5.9)	9.4 (6.8)	12.1 (6.8)	13.3 (7.8)
Distant	Naming latencies	915 (107)	921 (91)	922 (95)	933(106)	935 (106)	928 (94)
	Error rates in %	10.6 (8.0)	12.2 (7.1)	9.1 (4.5)	9.4 (5.0)	10.4 (6.8)	11.1 (8.3)

factors was observed, $F_1(5, 115) = 5.9$, $p < .001$, $\eta^2_p = .20$; $F_2(5, 175) = 5.5$, $p < .001$, $\eta^2_p = .13$. Planned comparisons revealed an effect of ordinal position for closely related objects, $F_1(5, 115) = 17.6$, $p < .001$, $\eta^2_p = .43$; $F_2(5, 175) = 15.9$, $p < .001$, $\eta^2_p = .31$, but not for distantly related objects, $F_{1/2} < 1.2$. Moreover, there was a significant linear trend for closely related items, $F_1(1, 23) = 97.5$, $p < .001$, $\eta^2_p = .80$; $F_2(1, 35) = 52$, $p < .001$, $\eta^2_p = .6$, indicating that RTs increased linearly with ordinal position. No linear trend was found for distantly related items, $F_{1/2} < 3.5$.[1]

An ANOVA of mean error rates (cf. Table 1) revealed a significant main effect of ordinal position, $F_1(5, 115) = 3.1$, $p < .05$, $\eta^2_p = .12$; $F_2(1, 175) = 2.9$, $p < .018$, $\eta^2_p = .07$ and an interaction of semantic similarity and ordinal position over participants only, $F_1(5, 115) = 2.7$, $p < .05$, $\eta^2_p = .1$; $F_2(1, 175) = 2.1$, $p < .1$. Further analysis revealed that the interaction in the subject analysis was driven by a significant ordinal position effect in the semantically close condition, $F_1(5, 115) = 5.3$, $p < .001$; $\eta^2_p = .19$. This effect reflected a linear increase in error rates, as confirmed by a significant linear trend, $F_1(1, 23) = 14.6$, $p < .001$; $\eta^2_p = .38$.

Electrophysiology

Based on visual inspection and previous reports of ERP effects in the continuous naming paradigm (cf. Costa et al., 2009) we selected a posterior region of interest with the electrodes Cp3, Cp4, P5, P3, Pz, P4, P6, PO3, POz, PO4 for repeated measures ANOVAs on mean amplitudes of consecutive 50 ms time windows, starting from the onset of the target picture until 900 ms after target onset.

The ANOVAs with the factors semantic similarity (2), ordinal position (6) and electrode (10) revealed a significant interaction of ordinal position and semantic distance between 250 and 400 ms and between 500 and 600 ms (Table 2).[2] Separate analyses for the semantic similarity conditions (Table 3) revealed that the interaction is due to an effect of ordinal position only in the semantically close condition, mirroring the behavioural effects. The linear trend analysis in this condition showed that in every significant 50 ms time window the ordinal position effect for objects with large semantic overlap showed a linear trend, indicating a linear increase of mean amplitudes for the factor ordinal position. As can be seen in Figure 3(b), the linear increase over ordinal position in the semantically close condition was characterised by an increased posterior positivity between 250 and 400 ms and by an increased posterior negativity in the time window between 450 and 600 ms.

Additionally, we observed an enhanced amplitude of the P1 between 100 and 150 ms in the semantically close condition (Figure 3(c), and Tables 2 and 3), as also reported in other language production ERP studies (cf. Clarke, Taylor, Deveurex, Randall, & Tyler, 2013; Dell'Acqua et al., 2010). This effect appeared as a statistical trend in the ANOVAs with the factors semantic distance and ordinal position, and reached significance in the analyses of semantically close condition (Tables 2 and 3). However, in contrast to the ERP effects between 250 and 400 ms and 450 and 600 ms, there was no indication of a linear modulation of P1 amplitude by ordinal position. The effect was most pronounced between the first and second ordinal position, $F(1, 23) = 10.5$, $p < .01$,

Table 2. Results of the repeated measures ANOVAs for the factors semantic distance and ordinal position.

Time window	Semantic distance		Ordinal position		Semantic distance × ordinal position	
	F	η^2_p	F	η^2_p	F	η^2_p
df	1, 23		5, 115		5, 115	
0–50 ms	ns.		ns.		ns.	
50–100 ms	ns.		ns.		ns.	
100–150 ms	ns.		ns.		2.1^{+}	.08
150–200 ms	ns.		ns.		ns.	
200–250 ms	ns.		ns.		ns.	
250–300 ms	ns.		ns.		2.5*	.10
300–350 ms	ns.		ns.		2.6*	.10
350–400 ms	ns.		ns.		2.5*	.09
400–450 ms	ns.		ns.		ns.	
450–500 ms	3.2^{+}	.12	ns.		ns.	
500–550 ms	3.5^{+}	.13	ns.		2.7*	.10
550–600 ms	ns.		ns.		2.9*	.12
600–650 ms	ns.		ns.		ns.	
650–700 ms	ns.		ns.		ns.	
700–750 ms	ns.		ns.		ns.	
750–800 ms	ns.		ns.		ns.	
800–850 ms	ns.		ns.		ns.	
850–900 ms	ns.		ns.		ns.	

Note: Reported values are Huynh-Feldt corrected if necessary.
$+p < .09$.
$*p < .05$.
$**p < .01$.

Table 3. Results of the separate ANOVAs for both semantic distance conditions and results from the linear trend analyses.

Time window	Semantically distant condition				Semantically close condition			
	Ordinal position		Linear trend		Ordinal position		Linear trend	
	F	η_p^2	*F*	η_p^2	*F*	η_p^2	*F*	η_p^2
df	5, 115		1, 23		5, 115		1, 23	
0–50 ms	ns.		ns.		ns.		ns.	
50–100 ms	ns.		ns.		ns.		ns.	
100–150 ms	ns.		ns.		2.7*	.11	ns.	
150–200 ms	ns.		ns.		ns.		ns.	
200–250 ms	ns.		ns.		ns.		ns.	
250–300 ms	ns.		ns.		2.9**	.11	7.7**	.25
300–350 ms	ns.		ns.		2.1*	.08	5.1*	.18
350–400 ms	ns.		ns.		2.5*	.09	6.2*	.21
400–450 ms	ns.		ns.		ns.		ns.	
450–500 ms	ns.		ns.		2.8**	.11	6.6*	.22
500–550 ms	ns.		ns.		3.3**	.12	8.3*	.26
550–600 ms	ns.		ns.		3.4**	.13	14.7*	.39
600–650 ms	ns.		ns.		ns.		ns.	
650–700 ms	ns.		ns.		ns.		ns.	
700–750 ms	ns.		ns.		ns.		ns.	
750–800 ms	ns.		ns.		ns.		ns.	
800–850 ms	ns.		ns.		ns.		ns.	
850–900 ms	ns.		ns.		ns.		ns.	

Note: Reported values are Huynh-Feldt corrected.
*$p < .05$.
**$p < .01$.

$\eta_p^2 = .31$, and all other comparisons between positions failed to reach significance, *F*s < 3.7.

Finally, we calculated point-by-point correlations for every 2 ms time window (according to our sampling rate of 500 Hz) to test whether the ERP modulations are associated with naming latencies. We correlated mean RTs and mean ERP amplitudes for the six ordinal positions over all participants (cf. Costa et al., 2009). By employing this analysis we found positive correlations between ERP and RT data from 268 to 352 ms and from 370 to 413 ms ($r = [0.73–0.87]$, $n = 6$, $p < .05$), and negative correlations between ERP and RT data from 458 to 586 ms ($r = [−0.73$ to $−0.95]$, $n = 6$, $p < .05$). Thus, increases in naming latencies were associated with an augmented positivity in the ERP between 270 and 410 ms and with a negative shift between 460 and 590 ms. The early ERP effect in the 100–150 ms time window was not correlated with RTs. Please note, however, that the correlations between RTs and ERPs concerning the magnitudes of cumulative effects in the form of difference measures – as more direct measures of semantic interference than raw RTs and ERP amplitudes – did not reach significance ($r = [−0.34–0]$, $n = 2$, $p > .05$).

Discussion

In this study we investigated semantic distance effects in the continuous naming task with behavioural and electrophysiological measures. In contrast to many studies investigating semantic distance using feature generation norms or similarity ratings (e.g. Mahon et al., 2007; Vigliocco et al., 2002; Vigliocco et al., 2004) we manipulated this factor systematically within taxonomic hierarchies. This allowed us to manipulate semantic distance by varying semantic feature overlap between category members while keeping broad category membership constant and by controlling for influences of cohort size on semantic distance effects. This was achieved by the choice of the continuous naming task in which the cohort increases systematically with each named member of the category independent of semantic similarity and activation strength.

In line with several recent reports using different context manipulations to induce semantic interference (e.g. Aristei & Abdel Rahman, 2013; Costa et al., 2005; Damian et al., 2001; Navarrete et al., 2012; Vieth et al., 2014a; Vigliocco et al., 2002; Vigliocco et al., 2004), but in contrast to the report by Mahon and colleagues (2007) that more distantly related items yield longer naming times than closely related items in the PWI paradigm, we find stronger interference for close relative to distant relations. More precisely, cumulative interference was only found in the semantically close but not in the distant condition. Thus, even though some studies have reported semantic interference for items with moderate semantic overlap in the PWI (Aristei & Abdel Rahman, 2013; Vigliocco et al., 2004) and cyclic blocking paradigm (Navarrete et al., 2012; Vigliocco et al., 2002), here we only found significant effects for sub-categorical relations sharing a comparatively big number of semantic features. Interestingly, this is in contrast to a PWI study using the same materials in terms of semantic relations that shows gradually increasing interference with increasing levels of semantic similarity, and interference for distantly related relative to unrelated distractors (Rose, Aristei, Melinger, & Abdel Rahman, submitted), but in line with a study manipulating the same semantic relations in the cyclic blocking paradigm where again interference was only found for close relations (Abdel Rahman et al., in preparation).

Recently, Abdel Rahman and Melinger (2009a, 2009b; but see Mahon & Caramazza, 2009) have argued that lexical cohort activation is a major factor for observing semantic interference, and that faster naming times associated with close relative to distant distractors in the PWI task might be due to the activation of smaller competitive lexical cohorts (see above). However, effects of semantic activation strength and cohort size cannot easily be disentangled because they influence each other in the PWI task. In contrast, in the continuous

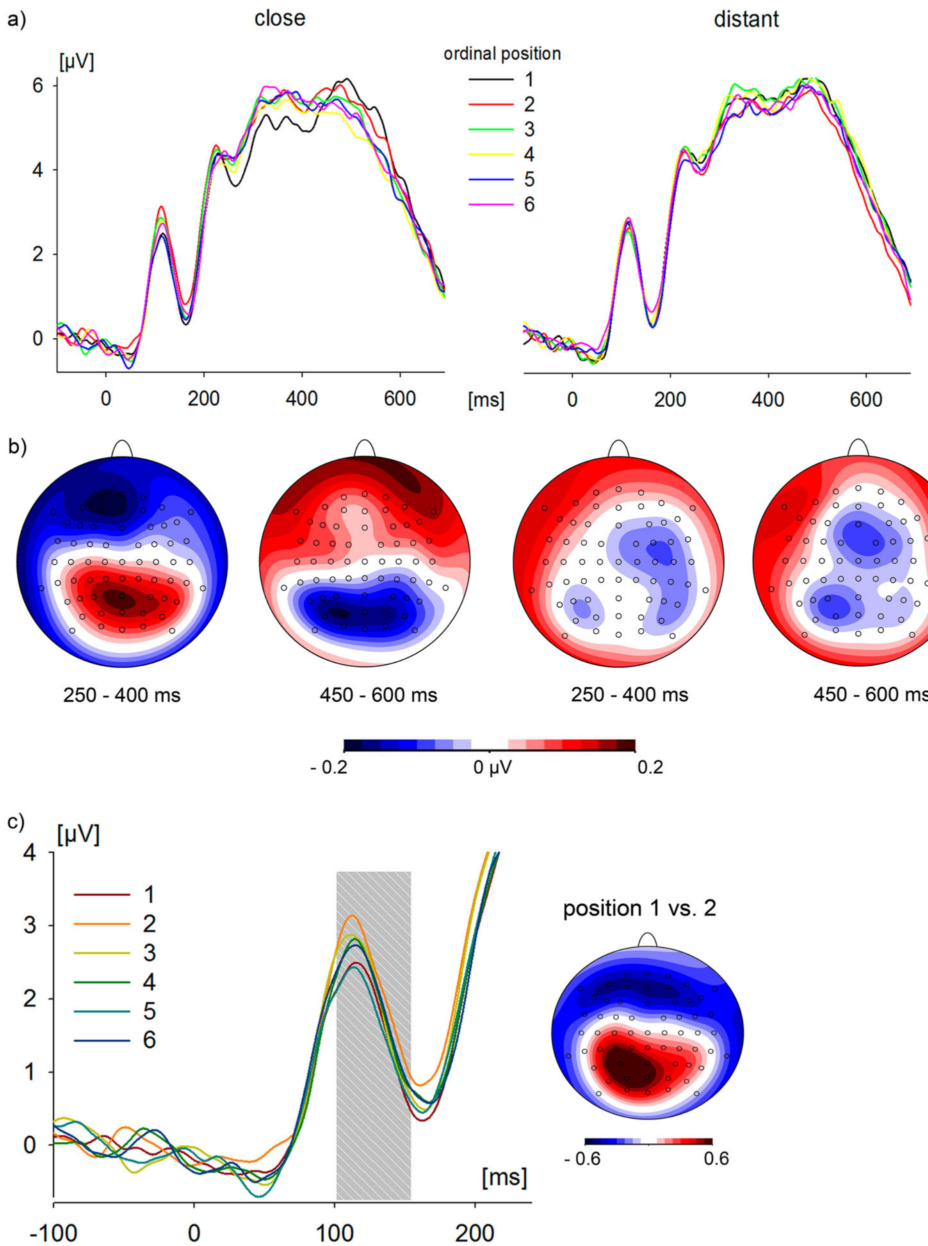

Figure 3. Effects of ordinal position on ERPs (a) and topographical scalp distributions (b) separately shown for the semantically close (left) and distant condition (right). ERPs are pooled over the electrodes of interest. Scalp distributions depict average differences across all ordinal positions. (c) ERPs (pooled over the electrodes of interest) and scalp distributions of the P1 effect between 100 and 150 ms. The scalp topography show the average difference waves between the first and second ordinal position.

task the size of the cohort is determined by the previous naming experience and is identical for close and distant relations, allowing us to isolate genuine effects of activation strength due to semantic feature overlap. The present findings show that the degree of feature overlap plays an important role for the emergence of cumulative semantic interference. Closely related objects (e.g. orangutan, chimpanzee, etc.) share many and specific features (e.g. has fur, has legs, lives in jungle), whereas distantly related objects belonging to the broad main category share more global class features (e.g. animal) (Belke, 2013). Here, the activation from shared features concentrates on strongly related and highly active lexical representations, intensifying lexical competition or inhibition of previously co-activated items (Howard et al., 2006; Oppenheim et al., 2010). In contrast, class features induce a relatively unspecific activation spread on loosely connected concepts and lexical competitors that is not strong enough to induce cumulative interference. Please note that his finding does not exclude additional effects of cohort size that may even interact with semantic distance/activation strength (e.g. Rabovsky, Schad, & Abdel Rahman, 2016; Rose & Abdel Rahman, 2016).

In ERPs cumulative interference in the close condition was reflected in posterior amplitude modulations between 250 and 400 ms and between 450 and 600 ms. The early effect starting around 250 ms consists of a relative positivity increasing with each newly named member of a basic level category and is positively correlated with RTs. The onset latency of this modulation is in line with several ERP studies exploring the time course of lexical retrieval (e.g. Aristei et al., 2010; Christoffels, Firk, & Schiller, 2007; Costa et al., 2009; Llorens et al., 2014; Maess et al., 2002; Piai et al., 2012; Strijkers et al., 2010), and most likely represents the selection of a lexical entry for further production. However, our effect starts about 50 ms later than has been reported, for example, by Costa and colleagues (2009) or estimated in a meta-analysis by Indefrey and Levelt (2004; see also Indefrey, 2011). This difference is most likely due to additional processing costs during visual and early semantic lead-in processes (object identification), because we presented complex photographs of real objects (e.g. a carp) instead of typically presented simple black-and-white drawings of basic level objects (e.g. a prototypical line drawing of a fish). The identification of complex and (photo)realistic objects can be assumed to be more demanding and time consuming. Accordingly, our RTs are about 100 ms longer then the RT reported by Costa and colleagues. Yet, both studies revealed longer duration estimates than about the 75 ms as upper boundary for lexical retrieval proposed by Indefrey and Levelt (2004; see also Indefrey, 2011) derived from non-overt naming and bottom-press paradigms. Comparable with Costa et al. (2009), our correlation analysis revealed significant correlation with overall RT between 268 and 413 ms, suggesting a duration of about 145 ms (and about 180 ms in Costa et al., 2009).

The later effect between 450 and 600 ms is most likely one of the N400 family (e.g. Kiefer, 2002; Kutas & Federmeier, 2011). Such effects reported at frontal electrodes in PWI tasks have been interpreted as co-activations of target and distractor representations at the interface between conceptual and lexical stages (Blackford et al., 2012; Greenham et al., 2000) and lexical selection processes (Piai et al., 2014). The modulation in the N400 with ordinal position found here at posterior sites might represent the postulated calibrations of connection weights between concepts and lexical representations or between concepts and their semantic features in the continuous naming paradigm (Belke, 2013; de Zubicaray et al., 2013; Howard et al., 2006; Oppenheim et al., 2010). Accordingly, and as the negative correlations between the ERP and RT effects indicate, this calibration may be intensified with each item that is named from a semantic category and manifest after the selection of the appropriate lexical candidate succeeded around 250 and 400 ms.

Additionally, we found an ERP effect in the P1 component between 100 and 150 ms for closely related items that is due to differences between the first and second ordinal position.[3] Modulations in this early time window can be taken to reflect basic perceptual processes, attention allocation, and/or early interactions between perceptual and semantic processes during visual object recognition (Abdel Rahman & Sommer, 2008; Dell'Acqua et al., 2010; Di Russo, Martinez, Sereno, Pitzalis, & Hillyard, 2002; Luck, Woodman, & Vogel, 2000). For example, the depth of semantic knowledge associated with an object modulates P1 amplitude (Abdel Rahman & Sommer, 2008), and a recent magnetoencephalography study found that objects having more shared then distinctive semantic features induce an enhanced P1, indicating a very early state of conceptual ambiguity in which many semantically related concepts are co-activated via shared visual features (Clarke et al., 2013; see also Moss, Rodd, Stamatakis, Bright, & Tyler, 2005). Alternatively, the P1 effect could also be a manifestation of feature-based attentional mechanisms (cf. Bensafi et al., 2002; Hillyard & Anllo-Vento, 1998; Theeuwes, 2013). In the context of a naming task, attention may enhance the visual processing of features that are important to distinguish and correctly name objects in the closely related condition. The P1 effect could thus be interpreted as early co-activation of visual/semantic feature information that may trigger the activation of related semantic-lexical representations. Future studies are needed to precisely determine the functional significance of this effect. In contrast to the later ERP modulations, P1 amplitude was not correlated with RT, and influences of visual factors on naming latencies are thus unlikely (cf. Hocking et al., 2009; Lotto et al., 1999). However, please note that RTs are influenced by many different processes and facilitatory and inhibitory effects that may be entirely unrelated to the presumed facilitation associated with the processes reflected in P1 amplitude modulations. Thus, traces of facilitation related to early perceptual-semantic processes might be hidden and undetectable in the correlation analyses.

The RT and posterior ERP modulations are in line with competitive accounts of semantic interference, but also with the non-competitive model suggested by Oppenheim and colleagues (2010). Precisely, they argue that a learning mechanism that includes weakened links of co-activated non-target lexical representations – in the form of RIF (Anderson, 2003; Anderson et al., 1994; Anderson et al., 2000; Johansson et al., 2007) – is sufficient to explain semantic interference without the assumption of lexical competition. RIF effects are commonly associated with activity in the right inferior gyrus and anterior cingulate cortex and can be detected in ERPs as an enhanced frontal positivity starting around 250 and 400 ms after target-cue onset (Hellerstedt & Johansson, 2014; Johansson et al., 2007; Spitzer, Hanslmayr, Opitz, Mecklinger, & Bauml, 2009). Thus, we conducted additional ANOVAs on mean amplitudes in the time windows of our effects at frontal sites (F3, Fz, F4; cf. Hellerstedt & Johansson, 2014; Spitzer et al., 2009). In line with recent findings (cf. de Zubicaray et al., 2013, for similar fMRI results), this additional analyses revealed no significant frontal ordinal position effect, $F(5, 115) < 1.7$. Therefore, though theoretically conceivable, we find no direct evidence for this account (see also Riès et al., 2015). Either via competitive or inhibitory mechanisms, semantic similarity has a strong influence on lexical selection that can be found independent of possible additional effects of the size of active cohorts.

To conclude, by manipulating semantic distance via semantic feature overlap within broad semantic categories we observed cumulative semantic interference only for closely related objects from basic level categories. This can be viewed as a consequence of activation spread triggered by high feature overlap, resulting in the activation of a well-defined cohort of highly co-active and strongly inter-related lexical items hampering the selection of the target. This effect was accompanied by posterior ERP modulations of positive and negative polarity that are correlated with behaviour and can be taken to reflect lexical selection and subsequent calibration processes. Additionally, these effects were preceded by a P1 amplitude modulation that may represent activation of specific visual/semantic features at early points in time during object identification. The present findings are in line with other reports of inhibitory effects of semantic similarity and demonstrate similar mechanisms in the continuous naming task, suggesting a common basis of semantic context effects during lexical-semantic processing besides paradigm-specific differences.

Notes

1. We also conducted an ANOVA with the factor repetition of list. Overall, naming latencies decreased significantly over repetition, $F_1(2,46) = 70.3$, $p < .001$, $\eta_p^2 = .75$; $F_2(2,70) = 245.0$, $p < .001$, $\eta_p^2 = .87$. However, as has been reported before (Costa et al., 2009; Navarrete et al., 2010; Rose & Abdel Rahman, 2016), this factor did not influence the ordinal position effect ($Fs < 1$). As the purpose for including repetitions was to increase the number of EEG segments, we will not discuss these data any further.
2. We also conducted an ANOVA over all 62 electrodes that supports the results of the ROI analysis, except of the time windows between 450 and 500 ms and between 550 and 600 ms that show a statistical trend in the overall analysis, $p < .07$.
3. Interestingly, a similar P1 modulation has been found by Costa et al. (2009, not reported) and interpreted as a repetition effect that should be strongest for the first vs. second presentation (personal communication).

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