A joint investigation of facilitation and interference effects of semantic and phonological similarity in a continuous naming task

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Word count: 5,997 (main text, excl. references)

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Acknowledgements

This work was supported by the National Natural Science Foundation of China (No. 32171058, No. 31771212 and No. 62061136001), Youth Innovation Promotion Association (Chinese Academy of Sciences), and Youth Elite Scientist Sponsorship Program (No. YESS20200138, China Association for Science and Technology) to Qingqing Qu.

Abstract

Semantic and phonological similarity effects provide critical constraints on the mechanisms underlying language production. In the present study, we jointly investigated effects of semantic and phonological similarity using the continuous naming task. In the semantic condition, Chinese Mandarin speakers named a list of pictures composed of 12 semantic category sets with 5 items from each semantic category, while in the phonological condition, they named a list of pictures from 12 phonological sets of 5 items sharing a spoken syllable. Related pictures occurred on adjacent trials, or were separated by 2, 4, or 6 unrelated pictures. Similar results were found across the semantic and phonological conditions: naming was facilitated by the directly preceding production of a related picture. For non-consecutive related responses, naming latency increased linearly as a function of the number of preceding production instances of related pictures. Parallel patterns of facilitation and interference effects arising from semantic and phonological similarity suggest universal principles which govern language production. *(158 words)*

Key words: Word production; Semantic similarity; Phonological similarity; Continuous naming task; Incremental Learning

Introduction

Past experience influences ongoing speaking. Semantically related objects facilitate or interfere with subsequent picture naming, depending on various factors such as the interval between two related naming occurrences, and the closeness of semantic overlap (e.g., see Belke, 2013; Brown, 1981; Damian et al., 2001; Howard, Nickels, Coltheart, & Cole-Virtue, 2006; Mirman, 2011; Schnur, Schwartz, Brecher, & Hodgson, 2006; Scaltritti, Peressotti, & Navarrete, 2017 for evidence of semantic interference; see Vitkovitch, Rutter, & Read, 2001; Wheeldon & Monsell, 1994; Sperber, McCauley, Ragain, & Weil, 1979; Humphreys, Besner, & Quinlan, 1988; Lupker, 1988; Biggs & Marmurek, 1990; Hartsuiker, Pickering, & De Jong, 2005 for evidence of semantic facilitation). Similarly, phonological similarity between subsequent naming episodes also produces facilitatory and inhibitory effects (see Breining, Nozari, & Rapp, 2016; Qu, Feng, & Damian, 2021). Semantic and phonological effects in spoken word production are often studied in separation, and the mechanisms which generate facilitatory and inhibitory effects within each domain are not fully understood. In the present study, we jointly investigated effects of semantic and phonological similarity in a 'continuous naming' task, and we manipulated the lag between related naming episodes which (see below) is likely to be a key variable regarding the directionality (facilitation vs interference) of an effect.

Semantic facilitation and interference in spoken word production

Naming a picture is generally hampered by the presence of a semantically related item (see Roelofs, 2018 for a review). For instance, in the 'cyclic semantic blocking' task, objects which are repeatedly presented and named in the context of items from the same semantic category are named slower than the same objects presented in a different-category context (e.g., Abdel Rahman & Melinger, 2007; Belke & Stielow, 2013; Belke, Meyer & Damian, 2005; Crowther & Martin, 2014; Damian, Vigliocco & Levelt, 2001; Navarrete, Prato & Mahon, 2012; Python, Fargier, & Laganaro, 2018; Schnur, Schwartz, Brecher & Hodgson, 2006). The *semantic*

blocking effect was originally explained via co-activation of semantically related items and competition among co-activated items for lexical selection (e.g., Damian et al., 2001). However, subsequent research (Damian & Als, 2005) showed that the effect was essentially unaffected by the addition of intervening unrelated fillers, and the authors suggested that a slight but persistent change in the links between conceptual and lexical-semantic codes as a result of a picture naming episode ('incremental learning') might provide a better explanation than mere co-activation of related candidates. In a closely related paradigm, the 'continuous naming' task, participants name a series of objects drawn from several semantic categories. Objects are intermixed so that the number of unrelated items between same-category objects is varied. In this task, naming latencies increase linearly as a function of the number of preceding productions of same-category items. This *cumulative semantic interference* effect appears persistent across lags of two, four, six and even eight intervening unrelated objects (Alario & Moscoso del Prado Martín, 2010; Brown, 1981; Howard et al., 2006; Navarrete, Mahon & Caramazza, 2010). These findings motivated the incremental learning account (Oppenheim, Dell & Schwartz, 2010) according to which semantic features are connected to lexical nodes, and naming of an object triggers the modification of semantic-to-lexical links such that weights from semantically active features to target lexical nodes are increased whereas weights to all other lexical nodes are decreased. Oppenheim et al. used this principle of "competitive learning" to simulate both cumulative semantic inhibition and semantic blocking.

Under some circumstances, however, spoken responses are facilitated by semantic context. For example, some cyclic semantic blocking studies reported semantic facilitation on the very first presentation of items within an experimental block (Crowther & Martin, 2014; Navarrete, Prato, & Mahon, 2012; Python, Fargier, & Laganaro, 2018; Abdel Rahman & Melinger, 2007; Schnur, Schwartz, Brecher, & Hodgson, 2006). This pattern is often assumed to arise from short-lived conceptual facilitation on adjacent trials, which trades off with and

sometimes outweighs lexical competition (e.g., Abdel Rahman & Melinger, 2007). An alternative explanation is that in semantic blocking tasks, facilitation effects do not reside in the language system proper but instead arise outside the language system (e.g., from working memory, Belke, 2008; participant strategies, Belke et al., 2017).

Whether semantic context facilitates or interferes with subsequent picture naming hence critically depends on the interval between two related naming trials. Wei and Schnur (2019) reported that a spoken response was facilitated when a semantically related picture was presented on the previous trial, whereas a response was slowed down when two unrelated pictures were named between the related pictures. Similarly, Scaltritti, Peressotti, and Navarrete (2017) provided evidence that although both facilitation and interference were 'cumulative', the facilitatory effect disappeared with the presence of interleaved unrelated items, whereas the interference effect was unaffected. These findings suggest that both semantic facilitation and interference might emerge from within the language system but are due to different mechanisms. Semantic facilitation could arise from a transient and fast-decaying mechanism such as spreading activation from the preceding trial (Damian & Als, 2005; Navarrete et al., 2012); semantic interference appears with delays between related trials and might originate from persistent mechanisms such as the incremental modification of connection weights between semantic and lexical nodes (Oppenheim et al., 2010).

Phonological facilitation and interference in spoken word production

Investigations on the phonological manipulation of prior or co-occurring context inform critical theoretical questions about phonological encoding (Damian & Dumay, 2009; for a review). Earlier evidence showed that phonological similarity tends to speed up picture naming (Meyer & Schriefers, 1991; Roelofs, 1999; Damian & Bowers, 2003). For example, in studies using the picture-word interference paradigm, phonologically related distractor words facilitate naming of target pictures relative to unrelated distractors, presumably

reflecting coactivation of phonological segments of distractor words and target pictures (Starreveld, 2000). Damian and Dumay (2009) used a task in which speakers named coloured objecs with adjective-noun phrases, and segmental overlap between the two response words (e.g., “green goat”) produced faster naming latencies than non-overlapping phrases (“blue goat”). Another set of opposite effects of phonological manipulation derives from the “blocked cyclic naming” paradigm in which speakers name a small set of objects repeatedly, or report response words based on pre-memorised prompt words. Rather than blocking objects and responses by semantic category (see previous section), here they are grouped via overlapping phonological elements. As in the case of semantic blocked cyclic naming, the same responses are being produced in the baseline condition, but now with phonological overlap avoided. The key finding is that word-initial overlap facilitates responses and that the size of this effect grows with increasing overlap (Meyer, 1991). The most explicit computational account of the effect (Roelofs, 1997) attributes the facilitatory effect to partial planning of the response which is possible in overlapping but not in non-overlapping sets of responses. However, O’Seaghdha and Frazer (2014) highlighted attentional influences on the effect which raise the possibility that the effect resides outside the language system proper.

Contrary to the general finding that in the blocked cyclic naming task word-initial overlap generates facilitation, a recent intriguing study reported that responses were slowed down when shared segments were distributed across different word positions (Breining et al., 2016). Breining et al. suggested that the inhibitory effect of phonological similarity in their results could be accounted for by the same principle advocated for semantic effects (see previous passage), namely ‘incremental learning’, i.e. a slight and persistent modification of connections between representations. In a recent study, we (Qu et al., 2021) replicated the inhibitory effect of form overlap in the cyclic blocked naming task in both spoken and written production modalities. Critically, we examined one of the predictions which follow from the incremental

learning hypothesis, namely that the similarity-based interference effect should be relatively immune to manipulations of the time interval between successive trials. We showed that the phonological interference effect persisted across one or two unrelated filler trials, and argued that our results support the “competitive incremental learning” hypothesis according to which object naming elicits a slight and persistent modification of connections between lexical and phonological representations. For example, consider a scenario with only two phonologically related objects (“cat”-“cap”). Following naming of an object, all links between the target code and the phonological level are strengthened, whereas connections between other co-activated phonologically related lexical node and the phonological level are decremented. On subsequent trials, a naming response will be detrimentally affected when the phonological related item is to be named, because some of the lexical-to-phonological connections have been already weakened. In a computational model which implemented competitive incremental learning mechanism, we were able to generate the pattern of interference found in the behavioural results. The experiments and simulations hence provided further support for the incremental learning hypothesis (see also Breining et al., 2019, for relevant evidence from word learning).

In most of the studies reviewed above, effects of overlap in semantic and phonological processing were explored separately. To explore whether common principles might govern both domains, it is of particular interest to jointly manipulate semantic and form overlap in one and the same study. For instance, Nozari et al. (2016) reported results from a task which represents a variation on ‘cyclic naming’ reviewed above and also used in our experiments reported below. They constructed experimental blocks in which only two pictures were presented and named in spoken or written form in random order, which were either semantically or phonologically related. Results showed interference as a function of both semantic and (word-final) segmental overlap, for both written and spoken modalities. The findings reported by Nozari et al. underscore

the possibility that common principles might underlie language production across semantic and phonological (or orthographic) levels.

In summary, the studies reviewed above suggest that the manipulation of semantic or phonological similarity in spoken production can result in both facilitation and interference. It appeas that facilitatory effects are short-lived and mainly emerge when related stimuli are presented on adjacent trials and with a short time interval between repeated episodes. These types of effects are likely to arise from temporary co-activation of overlapping elements, or alternatively they could reside from response strategies outside the language system proper. Interference effects are longer-lasting and largely immune to the time interval between related trials, and these are best explained via a competitive incremental learning mechanism. The similarity of findings across semantics and phonology suggests universal principles of the language production system across semantic and phonological processing.

The present study

In the current study, we tested predictions derived from the universal principle hypothesis by exploring effects of semantic and phonological similarity in a single experiment in which we adopted the continuous naming task described above, commonly used to study semantic context (e.g., Alario & Moscoso del Prado Martín, 2010; Belke, 2013; Howard et al., 2006; Navarrete et al., 2010; Oppenheim et al., 2010; Rose & Abdel Rahman, 2016). We investigated both semantic and phonological effects by manipulating overlap between successive object naming responses at various lags. To examine short- and longer-lived effects, semantically or phonologically related objects were presented on adjacent trials, or they were separated by interleaved unrelated pictures (lags of 2, 4, or 6 unrelated trials). We tested three predictions which followed from the hypothesis that universal principles govern language production, according to which the same patterns of semantic and phonological effects should be observed. First, previous studies have shown that semantic

context facilitates or interferes with subsequent picture naming depending on the interval between two naming trials (Wei & Schnur, 2019). Thus, we expected to replicate semantic facilitation with successive trials and semantic interference when unrelated trials separated the related ones. Second, critically, the universal principle hypothesis predicts a similar pattern of results for the phonological context: phonological overlap should facilitate picture naming when related trials are presented successively, but interference should be found when related trials are separated by filler trials. Third, both semantic or phonological similarity based effects should be long-lasting and hence independent of the number of unrelated objects occurring between the related instances, i.e., the "lag" of 2, 4, or 6 unrelated pictures.

We varied semantic and phonological overlap within the same study. In the semantic context, speakers named a list of pictures composed of 12 semantic category sets with 5 items from the same semantic category. The manipulation of phonological overlap is less straightforward: if overlap is defined in terms of phonological segments, then it is very difficult to avoid repetition of phonemes across many naming instances because the inventory of phonemes within a given target language is so limited. The current study was conducted with native speakers of Mandarin Chinese, a language which is heavily oriented towards syllabic structure. We defined phonological overlap as the repetition of an atonal spoken syllable across successive responses. Speakers named a list of pictures from 12 phonological sets of 5 items sharing the same word-initial syllable. Related pictures were presented adjacently, or they were separated by 2, 4, or 6 unrelated pictures. The universal principle hypothesis predicts similar findings as a result of semantic and phonological overlap: for both types of relatedness, facilitatory effects should emerge on adjacent trials, whereas with unrelated trials separating the related instances and independent of the lag, interference should be found.

The continuous naming task we adopted here has several methodological strengths. Objects are never

repeated and several exemplars of each semantic category, or as in the study below, of a phonological type, are presented in a sequence which appears random to the participant. Therefore, participants are unlikely to form strategies and predictions, and effects arising outside the language system should be minimised. This contrasts with the blocked cyclic naming task in which participants repeatedly name items from a small set of pictures in each experimental block and (see above) it is possible that speakers hold all pictures of a set in working memory or form an attentional set (Belke, 2008, 2017; O'Seaghdha & Frazer, 2014). The continuous naming task has the additional advantage that the lag between related instances can be easily varied within-participants. By contrast, in blocked cyclic naming the interleaving of critical with filler trials leads to experiments which quickly reach unreasonable length (for instance, Experiment 5 by Qu, Feng & Damian, 2021, implemented a "lag2" manipulation by interleaving critical picture naming responses with two unrelated filler trials, and an experimental session took approximately 2 hours for a participant to complete).

Method

Transparency and Openness

In the following subsections, we report how our sample size is determined, all material selection and presentation, all measures and data exclusions in the present study. All materials, data, and analysis code are available from the corresponding author. Data were analyzed using R, version 4.0.0 (R Core Team, 2020) and the package ggplot2, version 3.3.5 (Wickham, 2016). This study's design and its analysis were not pre-registered.

Participants

We conducted a simulation-based power analysis using the R package simr (Green & McLeod, 2016) based on the pilot data of the phonological similarity effects from 10 participants. Results showed that to reach >

80% power, we would need at least 48 participants. Therefore, forty-eight native speakers of Mandarin Chinese from universities in Beijing were recruited in the experiment and were paid for their participation. They had normal or corrected-to-normal vision and no history of language disorders. This study was approved by the Ethics Committee of the Institute of Psychology, Chinese Academy of Sciences, and participants gave informed consent.

Materials and Design

For the "semantics" condition, 60 line drawings of common objects from 12 semantic categories were selected, so that five items were drawn from each of 12 semantic categories. For the "phonology" condition, another set of 60 objects with disyllabic names were chosen so that five items in each of 12 subsets shared an atonal spoken syllable in the word-initial position. Due to the large dissociation between phonology and orthography in Chinese, orthographic overlap between items was entirely avoided. In addition, two sets of 20 pictures (20 for the semantics and 20 for the phonology list) were selected as fillers to allow related items to be presented apart from each other.

Separate lists were formed for the semantics and the phonology context. In each list, a series of five pictures from the same set were randomly distributed into five positions (ordinal position: 1, 2, 3, 4, 5) and were interleaved by 0, 2, 4, or 6 different-category items or fillers (i.e., lag: 0, 2, 4, 6). In this way, the item at position 1 and the item at position 5 were separated by 15 items. At lag = 0, related pictures were presented adjacently, while at lags of 2, 4 or 6, related pictures were separated by unrelated pictures. Within each category, each lag was present once. The four types of lags formed 24 lag orders, 12 of which were randomly assigned to the first list and the other 12 to the second list. The position of the five items within a set was randomized. In each list, there were 80 trials (60 critical and 20 filler objects) and each list was replicated

twice.

Type of similarity (semantics vs. phonology) was manipulated as a within-participant and between-item variable, and lags (0, 2, 4, 6) was varied as a within-participant and within-item variable. The “semantics” and “phonology” lists were shown such that half of the participants received the “semantics” list first followed by the “phonology” list, whereas the other half received the opposite order. For each participant, the entire testing session included 320 trials (80 trials with 2 repetitions in each of 2 conditions).

Procedure

The experiment was conducted using DMDX (Forster & Forster, 2003). At the beginning of the experiment, participants were instructed that their task would be to name objects aloud as fast and accurately as possible. Before each list, participants were asked to familiarise themselves with all pictures, with the expected names printed underneath each picture. Subsequently, each trial started with a fixation (500 ms), and then a blank screen (500 ms) followed by an object (2,000 ms) in the center of the screen. The time interval between two successive trials was 1,000 ms. Filler objects were presented as the first three pictures of a list to familiarise participants with the task. The whole experiment lasted approximately 50 minutes per participant.

Results

Response times were obtained via Chronset, an automatic tool to detect speech onset (Roux, Armstrong, & Carreiras, 2017). Accuracy of each response was coded by the experimenter. Incorrect responses (2.59%) were relatively rare, and because previous studies of cumulative or long-lasting effects in spoken production (Howard et al., 2006; Belke, 2013; Wei & Schnur, 2019) have generally shown no relevant effects in errors, we did not analyse these further. Responses on incorrect trials, with latencies less than 200 ms or larger than

1800 ms (1.25%), beyond 3 *SD*s (1.0%) and recording failures (2.56%) were excluded from analysis. Linear mixed model analysis (Baayen, Davidson, & Bates, 2008; Bates, Maechler, Bolker, & Walker, 2015) was conducted on response latencies. The random-effect variables were determined by a maximal random-effect structure (Barr, Levy, Scheepers, & Tily, 2013). Separate statistical analyses were conducted for lag 0 and non-lag0 trials.

Lag0 trials. Picture naming for a target object on trial N was facilitated when a related object was presented and named on the preceding trial N-1, with naming latencies 16 ms shorter for phonologically related than unrelated pictures (803 vs 819 ms respectively), and 25 ms shorter for semantically related than unrelated pictures (799 vs. 824 ms). Linear mixed model analysis revealed that responses to N were significantly faster than N-1 (β = -10.27, *SE* = 3.47, *t* = -2.96, *p* = .003), and the main effect of type, and the interactions between position and type failed to reach any significance (all *p*s > .2). This pattern suggests that the facilitatory effect of overlap between successive trials was comparable across the semantics and phonology condition.

Non-lag0 trials. Table 1 shows naming latencies across lags and ordinal positions for the non-lag 0 trials. For these trials (lag 2, 4, 6), we first evaluated how response time changed linearly along with ordinal positions within a subset (cf. Howard et al., 2006). The final model included fixed effects of *ordinal position* and *type of similarity*, as well as the by-participant and by-item random intercepts and random slopes of ordinal position. As shown in Figure 1, there was a significant linear trend of ordinal position (β = 10.44, *SE* = 1.65, *t* = 6.34, *p* < .001) and interaction with type of similarity (β = -4.11, *SE* = 1.65, *t* = -2.50, *p* = .012). We conducted separate analysis for the semantics and the phonology conditions. Results showed significant linear trends of response time across ordinal position for both types (semantics: β = 12.62, *SE* = 2.02, *t* = 6.24, *p* < .001;

phonology: β = 5.95, *SE* = 2.18, *t* = 2.74, *p* = .006)[1], suggesting that participants were increasingly slower to name related pictures within a category in both types.

To examine whether the linear trend of ordinal position is affected by the lag between successive related instances, we additionally included the fixed factor "lag". The final model included the fixed effects of lags, ordinal position and type of similarity, as well as the by-participants and by-item random intercepts and random slopes of ordinal position. As expected, the model including lag also showed a linear trend of ordinal position (β = 7.00, *SE* = 2.74, *t* = 2.55, *p* = .011). Critically, the 2-way and 3-way interactions among ordinal position, lag and type failed to reach significance (all *p*s > .16), suggesting that the interference effect across ordinal position is not sensitive to lags between related trials. To test whether there is evidence in favor of a null effect of the interactions, we computed Bayes Factor between the models (i.e., interaction absent [null hypothesis] vs. interaction present [alternative hypothesis]). Bayesian analyses were carried out by a comparison between a model with the inclusion of all interactions and a simplified model by removing one interaction, in a stepwise backward elimination procedure. The Bayes Factors were ≥ 11.9, suggesting it is at least 11.9 times more likely that the null hypothesis is true than alternative hypothesis, and providing strong evidence for the null hypothesis, that is, the model without the interactions.

[1] Figure 1 suggests a possible non-linear component for the semantic condition which will be highlighted in the Discussion. We explored this via polynomial contrasts analysis but found neither a cubic trend, *t* = -1.51, *p* = .126, nor higher-order trends, *p*s ≥ .48.

Table1. Average naming latencies (in milliseconds, standard error of the mean in parenthesis) for each type of overlap (semantics vs. phonology), ordinal position (1-5) and lag between related instances (2, 4, 6).

Lags	Ordinal position					Mean
	1	2	3	4	5	
Semantics						
2		809 (15.2)	853 (15.4)	848 (15.2)	863 (15.5)	843 (7.7)
4		829 (14.6)	834 (15.9)	835 (14.0)	853 (15.0)	838 (7.4)
6		831 (14.6)	854 (16.1)	868 (15.5)	826 (14.3)	845 (7.6)
Mean	**795** (7.1)	**823** (8.5)	**847** (9.1)	**851** (8.6)	**847** (8.6)	
Phonology						
2		786 (12.9)	809 (14.9)	825 (14.9)	815 (14.6)	809 (7.2)
4		810 (14.9)	784 (13.9)	807 (14.6)	818 (13.4)	805 (7.1)
6		800 (13.7)	822 (14.2)	807 (15.7)	807 (15.2)	809 (7.4)
Mean	**791** (6.9)	**799** (8.0)	**805** (8.3)	**813** (8.7)	**813** (8.3)	

Table 2. Linear mixed model results for position and type on response times of non-lag 0 and lag 0 trials

Predictors	*Estimates*	*SE*	*t*	*p*
non-lag 0 trials				
(Intercept)	787.59	19.11	41.22	< .001
position	10.44	1.65	6.34	<.001
type	-2.99	11.58	-0.26	.796
position*type	-4.11	1.65	-2.50	.012
Lag 0 trials				
(Intercept)	812.63	18.55	43.80	< .001
position (N-1 vs. N)	-10.27	3.47	-2.96	.003
type	-1.10	10.19	-0.11	.914
position*type	4.26	3.42	1.25	.213

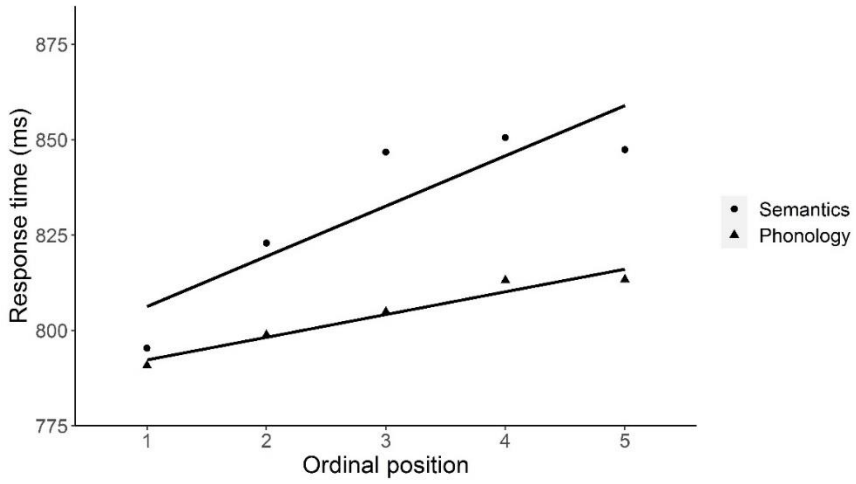

Figure 1. Observed response times and linear fitted trends along with ordinal positions for each type of overlap (semantics vs phonology), collapsed across lags 2, 4, and 6.

Discussion

In a continuous naming task performed with native Chinese Mandarin speakers, we demonstrated long-lasting interference and short-lived facilitation for semantically related pictures: when related pictures were separated by between 2 and 6 unrelated pictures, naming latencies of targets increased with each successive retrieval from the same semantic category, and this effect was independent of the lag length. However, when related pictures were named on adjacent trials (with zero lag), we found semantic facilitation on the target. In addition, we demonstrated that phonological similarity, defined as a shared spoken syllable between related picture names, produced a similar pattern: with lags 2-6, each successive production of a picture name which shared a syllable with an earlier picture was linearly slowed, but with pictures sharing syllables on adjacent trials, phonological facilitation was obtained. Hence we replicated previous findings of short-lived and long-lasting effects of semantic context (e.g., Wei, & Schnur, 2019), and we extended the general pattern to phonological context.

In the present study, the overlapping portion of responses was in word-initial position. With word-initial

overlap, we found that phonologically similar items elicited interference when related responses were separated by two or more unrelated trials. The finding, combined with the findings of recent studies, indicates that phonological interference effects do not exclusively occur when the phonological overlap was distributed at various position within a word (see Breining et al., 2016; Qu et al., 2021 for interference effects depending on the position of phonological overlap). The current finding demonstrated that phonologically related objects facilitate or interfere with subsequent picture naming, depending on the interval between two related naming occurrences, akin to the findings from semantic context. The similarity in patterns across the semantic and phonological context supports the hypothesis that in the language production system, similar and general universal principles govern access to semantics and to phonology.

For each successive retrieval from a given semantic category, picture naming latencies were slowed down on average by 13 ms. This estimate of the effect of ordinal position is somewhat lower than what was found in some previous studies. In their original report, Howard et al. (2006) estimated a slowdown of 30 ms for each successive retrieval, and Belke (2013, Experiment 1, object naming condition) reported a linear slowdown of 21 ms for each successive retrieval. Interestingly, in both previous studies, the effect of ordinal position was almost entirely linear (cf. Figure 1 in Howard et al., and Figure 2 in Belke), whereas in our own results the effect appeared largely confined to ordinal positions 2 and 3 (relative to position 1: 28 and 24 ms respectively), with very little additional increment for positions 4 and 5 (4 and -4 ms; see our Figure 1). The reason for the non-linear component of ordinal position in our results is not clear at present (but see Footnote 1). In the lag0 condition, we found a semantic facilitation effect of 25 ms. Wei and Schnur (2019) reported lag0 semantic facilitation effects of 34 ms (Experiment 1; English speakers) and 9 ms (Experiment 2; Mandarin speakers), hence the size of our own effect is located somewhere in between their findings. For phonologically related items, the linear effect of position for the non-lag0 trials was more subtle than in the

semantic case, but it was still highly significant: each successive retrieval of a form-related item slowed down naming latencies by a further 6 ms, and again this effect appeared unaffected by the lag varying between 2 and 6 unrelated items. Facilitation on lag0 items was also smaller for phonological (16 ms) than for semantic (25 ms) overlap in our results.

The general finding of smaller phonological than semantic effects mirrors results observed in our earlier experiments (Feng, Qu, & Damian, 2021) with a blocked cyclic naming task. One possible reason concerns differences in the degree of similarity among semantically and phonologically related items. In the present as well as our earlier study, phonologically similar words shared an atonal spoken syllable, while semantically similar words shared category membership and hence presumably overlapped in terms of semantic features. It is difficult to quantify phonological and semantic overlap, and the larger semantic effect might be caused by a stronger degree of similarity than for the form-related items. As far as the experimental task is concerned, our current study with the continuous naming paradigm may provide more compelling evidence for a persistent principle than the blocked cyclic naming task used in Qu et al. First, in the continuous naming task, objects are not repeated and related objects are not grouped into blocks, and thus participants' awareness about the experimental manipulation and expectancy strategies are likely to be minimal. By contrast, in the blocked cyclic naming task, a small set of objects (typically, only four or five exemplars) are repeatedly named within a block, a manipulation which is prone to the formation of strategies. Second, we implemented modest numbers of intervening unrelated trials in our current study, compared to the small number of lags in the blocked cyclic naming task (e.g., Qu et al., 2021). The observation of interference effects with long lags in the continuous naming task provides clearer evidence against an explanation in terms of residual activation. Third, Belke (2008; Belke & Stielov, 2013) reported a role of working memory in the blocked naming task, in which the number of items per experimental blocks is so small that speakers

maintain them in working memory as a “task set”, which curtails top-down modulation on semantic interference. By contrast, in the continuous naming task, no such formation of a task set is possible and hence interference accumulates with each additional retrieval instance from a given semantic category. This highlights the strength of the continuous naming task for investigating the long-lasting nature of effects.

In the semantic context, we replicated the cumulative semantic interference irrespective of lag length (Belke, 2013; Costa et al., 2009; Howard et al., 2006; Navarrete et al., 2010; Schnur, 2014). Because cumulative semantic interference remains persistent across modest numbers of unrelated trials, it is best explained via an incremental learning mechanism (Oppenheim et al., 2010). According to this view, semantic interference originates from slight but persistent changes in the strength of connections from semantic features to lexical representations. Following each naming, semantic-to-lexical links are modified such that weights from semantically active features to target lexical nodes are increased, whereas weights to all other lexical nodes are decreased, thus generating longer responses when these weakened lexical nodes are subsequently named. Likewise, we believe that persistent and cumulative semantic interference effects observed in our study are best explained by the competitive incremental learning.

Could the incremental learning mechanism be extended to lexical-phonological mappings? In the present study, we observed cumulative and persistent phonological interference effects. As described in the Introduction, inhibitory effects of phonological overlap have recently been reported in a blocked cyclic naming study which were immune to intervening trials between related naming responses (Qu, Feng & Damian, 2021). These effects were explained by the incremental learning mechanism and simulated in a computational model which implemented incremental learning between lexical and sub-lexical phonological representations. Specifically, the assumption is that naming a target object strengthens the connection between its the target word and its phonological nodes and weakens the connection between

phonologically similar words and shared phonological codes, which generates slower responses to these phonologically similar words in subsequent trials (Breining et al., 2016). Based on the findings from both cyclic blocked naming and the continuous naming task, we suggest (as previously done by Breining et al., 2018) that incremental learning constitutes a universal principle for both semantic-lexical and lexical-phonological mapping in the language production system.

Although we argue that incremental learning constitutes a universal principle for both semantic-lexical and lexical-phonological mappings, there are also considerable differences between the two types of links. Whereas the former involves mapping multiple semantic feature representations to a single lexical representation, the latter entails connecting one lexical representation to multiple phonological segments. If our account is correct, connections between representational layers are continually updated via slight and persistent modifications to weights; however, to generate interference, feedback is required in the case of phonological overlap but not of semantic overlap. Therefore, one should keep in mind that although both semantic and word-form similarity can lead to interference, the sources of this interference differ somewhat.

In the present study, we observed that object naming was accelerated when a semantically or phonologically related object had just been named on the preceding trial. The facilitatory effect was short-lived because facilitation was not found with a small number of unrelated trials between the related episodes. A similar pattern of semantic facilitation and interference was recently reported by Wei and Schnur (2019). In continuous naming tasks such as these, effects are likely to arise from within the language system proper, rather than from strategies and/or working memory constraints, as argued for instance by Belke (2008, 2017) for the blocked cyclic naming task. In the current study, facilitation still appeared when the probability of two related pictures being presented adjacently was quite low (~15%). These short-lived facilitation effects may

reflect residual activation arising from a preceding related trial. Critically, our results showed that these effects reversed to interference with lags of two or more unrelated trials. Hence, we argue that both spreading activation, and incremental learning between activated representations, constitute universal processing principles in language production. Hence both components co-modulate spoken word responses, with the polarity of observed effects resulting from a trade-off between the two. When related objects are presented on adjacent trials, it is plausible that residual activation-based facilitation is so strong that it outweighs inhibitory effects arising from the incremental learning mechanism, resulting in a net facilitative effect. On the other hand, when related trials are separated by unrelated instances, residual activation-based facilitation is likely to be weak or perhaps completely abolished, and inhibitory effects arising from competitive learning are likely to be dominant.

Throughout this article, we have highlighted the need for models of language production to incorporate mechanisms which allow long-lasting effects such as non-lag0 semantic and phonological effects in our results. We favoured an account in terms of 'incremental learning' (Oppenheim et al., 2010) but this is not the only possible explanation. Roelofs (2018) recently introduced a 'unified computational account' which does not rely on incremental learning, but rather employs a 'bias term' applied to lexical-conceptual nodes to account for long-lasting effects such as cumulative semantic, and semantic blocking, effects. In Roelofs' model, a production episode such as picture naming adds a persistent but slowly decaying bias to the selected lexical-conceptual node. As a result, on subsequent production of a semantically related picture, the previously biased node will constitute a more potent competitor, and hence naming latencies for the related picture will be slowed down. Extending this principle to the phonological domain, one could assume that not only lexical-conceptual nodes are subject to such persistent biases, but this is also the case for word form representations. Production of a given word involves the selection of sublexical representations (such

as syllables in the current study), and feedback from sublexical to lexical nodes would generate co-activation of phonologically similar items (cf Qu, Feng & Damian, 2021). However, one would have to assume an explicit principle of competition at the word form level in order to explain how production of a word could be inhibited by the previous instance of a phonologically related items, as shown in our data. Future simulations will have to show whether the bias principle could be extended to the phonological domain in order to account for the phonological inhibition effects shown in the current experiment.

In summary, our results showed that semantic and phonological context produced a similar pattern of results: both semantic and phonological overlap between objects and their names facilitated latencies when similar responses were produced adjacently; both semantic and phonological similarity slowed response latencies when related responses were separated by two or more unrelated trials. These results suggest that both facilitation and interference effects emerge within the language production system, and that spread of activation as well as incremental learning constitute universal principles of semantic and phonological processing in the language production system.

Declarations

Competing Interests

The authors declare that they have no competing interests.

Ethics approval

This study followed the ethical procedures for the protection of human participants in research and was approved by the ethics committee of the Institute of Psychology, Chinese Academy of Sciences. Informed consent was obtained from each participant prior to the experiment.

Availability of data and material

All data and analysis code have been made publicly available via the Open Science Framework and can be accessed at https://figshare.com/articles/dataset/Continuous_naming/14769702.

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