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Discussion

Set size and repetition matter: comment on Caramazza and Costa (2000)

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Abstract

Caramazza and Costa, 2000 (*Cognition 75*, B51–B64) report three picture-word interference experiments testing the response set mechanism of the WEAVER++ model of spoken word production. They argue that their findings are problematic for WEAVER++ and that the model's architecture needs to be changed. I show that there is no need to fundamentally modify the model. Instead, the findings of Caramazza and Costa, and all previous findings, are explained by assuming that only a limited number of responses can be kept in short-term memory and that memory improves with response repetition.

Caramazza and Costa (2000), henceforth C&C, report three picture-word interference experiments testing the WEAVER++ model of spoken word production (e.g. Levelt, Roelofs, & Meyer, 1999; Roelofs, 1992, 1993, 1997). Participants had to name pictured objects while simultaneously trying to ignore superimposed written words. In Experiments 1 and 2, semantic inhibition effects on picture naming latencies were obtained from distractor words that were not part of the response set and with one picture per semantic domain. In Experiment 3, the size of the semantic inhibition effect did not differ between response and non-response distractor words. According to C&C, these findings demand a fundamental modification of WEAVER++. "It is not obvious that minor changes to the model – that is, changes that do not alter the fundamental architecture of the model – would be successful in this regard" (C&C, p. B61). They conclude that "if one were willing to drop the response set principle used in WEAVER++, the *new* model would have to be able

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to account for the data reported here and the various other data that were previously used to support the old WEAVER++ model" (C&C, p. B61).

In this paper, I show that there is no need for a fundamental change of WEAVER++. Instead, the supposedly problematic findings of C&C, and all previous findings that support the model, are explained by assuming that "a response set is only marked in memory when the number of responses is small and can be kept in short-term memory" (Levelt et al., 1999, p. 62) and that response repetition helps establishing a response set in memory.

The mental lexicon is realized in WEAVER++ as a network that is accessed by spreading activation. In word retrieval, activation spreads from a conceptual stratum with concept nodes to a syntactic stratum with lemma nodes. A lemma node is selected when it reaches a critical difference in activation relative to the other lemma nodes. WEAVER++ has been tested on classical findings from the picture-word interference task, in particular, on semantic *inhibition* effects obtained with picture naming and semantic *facilitation* effects obtained with picture and word categorizing (i.e. Glaser & Düngelhoff, 1984). C&C do not mention the categorization data, but the performance assumptions made for WEAVER++ (and tested by C&C) cannot be understood without reference to these data. Picture naming (e.g. saying "dog" to a pictured dog) is slower with semantically related distractor words (e.g. "cat") than with unrelated distractor words (e.g. "tree"). However, when the pictured dog has to be *categorized* by saying "animal", then the distractor word "cat" speeds up the naming response relative to distractor "tree". A semantic facilitation effect (of over 150 ms) is also observed when the words have to be categorized and the pictures serve as distractors.

WEAVER++ explains the semantic inhibition effect with picture naming as follows. In saying "dog" to a pictured dog, the semantically related distractor word "cat" increases the response latency because the picture of a dog activates the distractor lemma *cat* via the connection between the concept nodes DOG(X) and CAT(X). Such "reverse priming" does not happen for semantically unrelated distractors such as "tree". Consequently, it takes longer before the target lemma *dog* reaches the critical difference in activation when the distractor is the word "cat" than when it is the word "tree". To account for the difference in semantic effect between naming and categorizing, *inhibition* versus *facilitation*, it was assumed that response selection can be limited to a restricted set of words. In particular, in a categorization task only hyperonyms such as "animal", "plant", and so forth, are considered for selection. In WEAVER++, this was achieved by marking the permitted responses in memory and applying the response criterion to these marked responses only. Consequently, in saying "animal" to a pictured dog, distractor "cat" primes the target lemma *animal* but *cat* is not a competitor because it is not a marked response. In contrast, distractor "tree" primes the competitor lemma *plant*. This causes the semantic facilitation effect in categorization. Computer simulations showed that the model quantitatively fits the semantic inhibition and facilitation effects and their exact time course (Roelofs, 1992). Furthermore, semantic facilitation effects have also been obtained from non-response distractors in *picture naming* in subsequent studies (Roelofs, 1992, 1993), confirming predictions of the model.

1. Explaining the findings of Caramazza and Costa (2000)

C&C obtained semantic inhibition rather than facilitation from distractors that are not responses, in contrast to what Glaser and Düngelhoff (1984), Glaser and Glaser (1989), and Roelofs (1992, 1993) observed. There are many differences between the earlier studies and the study of C&C, but two differences are especially salient. First, whereas the studies that observed semantic facilitation had 9 (Glaser & Düngelhoff, 1984), 3 (Glaser & Glaser, 1989), 9 (Roelofs, 1992), and 13 (Roelofs, 1993) responses, the number of responses in the experiments of C&C ranged from 21 (Exp. 1) and 20 (Exp. 2) to 40 (i.e. there were 20 target and 20 filler pictures in Exp. 3). Second, in the earlier studies the responses were produced many times (i.e. 12 to 54 times), whereas in the study of C&C there were only a few repetitions (i.e. 3 or 5). For the response set manipulation to work, it has to be assumed that C&C's

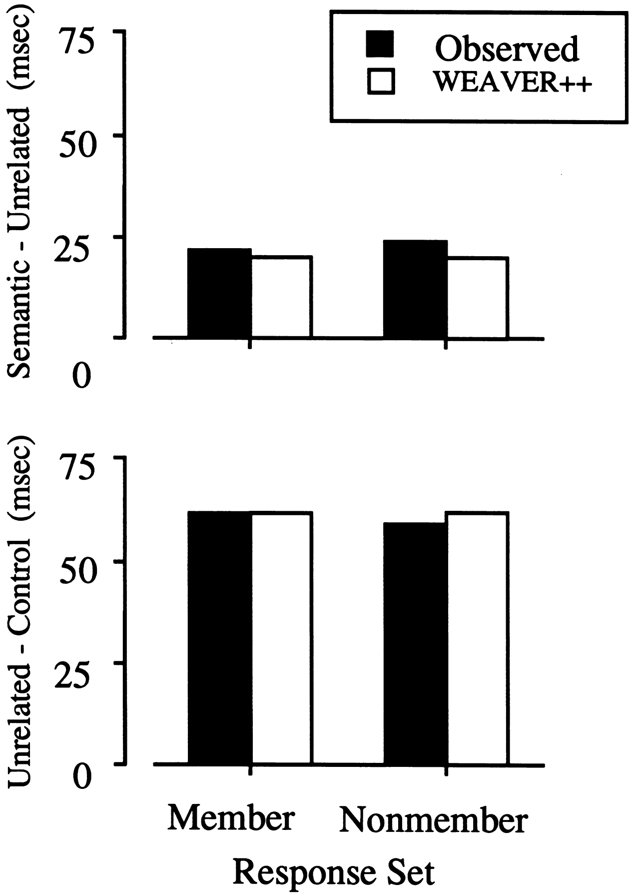

Fig. 1. Interference effects from distractor words in picture naming as a function of response set membership observed by Caramazza and Costa (2000) and in WEAVER++ simulations.

participants were able to keep 21, 20, or 40 different target names in short-term memory, which is much more than the 3 to 13 responses in the earlier studies. It is reasonable to assume, however, that when the number of responses is large (say, a dozen or more responses, but this is obviously an empirical parameter), participants cannot keep the response set in memory, and therefore the selection mechanism has to treat all words as potential responses. Furthermore, it is reasonable to assume that when responses are repeated many times, this helps establishing a response set in memory even when the number of responses slightly exceeds short-term memory capacity (say, with 12–16 responses).

If C&C's participants did not keep a response set in memory, semantic inhibition effects on picture naming are to be expected even when the distractor words are not permitted responses and when there is only a single picture per semantic domain. Fig. 1 displays the effects observed by C&C and WEAVER++ simulation results (to fine-tune the fit, parameter *cd*, the critical difference in activation, has been set to 2.0; all other parameter values and the network structure are identical to the simulations reported in Roelofs, 1992).

Furthermore, there should then be *no* main effect of response set membership *per se*. And this is exactly what C&C observed. In Experiment 3, the picture naming latencies with response distractors were almost identical to those with non-response distractors (respectively, 828 vs. 827 ms for the semantically related distractors, and 805 vs. 803 for the unrelated distractors). Compared to the control condition (a series of Xs) the effect of the unrelated condition was almost identical for distractors that were part of the response set and distractors that were not. Fig. 1 shows the effects observed by C&C and WEAVER++ simulation results. The absence of an effect from response set membership per se in C&C's data is surprising given that such effects are well established in the Stroop-like literature (e.g. MacLeod, 1991, for a review). This discrepancy can be explained, however, by taking into account that these response set effects were obtained with a limited number of responses (2 to 6) and many repetitions, which is typical of classical Stroop-like experiments.

2. Independent support for the set size and repetition analysis

Empirical support for the role of the number of responses and repetitions in establishing a response set in memory comes from picture-word interference experiments by La Heij and Van den Hof (1995). In their Experiment 1, response-set size was manipulated by testing 16 target pictures in 4 trial blocks with 4 pictures each (the small set condition) or testing all 16 pictures in a single trial block (the large set condition). The stimulus onset asynchrony (SOA) was +100 ms. La Heij and Van den Hof obtained no semantic effect at all in the small nor in the large set condition, replicating the results for SOA = 0 and +100 ms of Roelofs (1992, 1993) and the findings for picture categorizing of Glaser and Düngelhoff (1984), but contrary to what C&C observed. Compared to the control condition with Xs, the unrelated distractors yielded an inhibition effect, which was smaller for the small set condition than for the large set condition. Fig. 2 gives the observed effects and WEAVER++

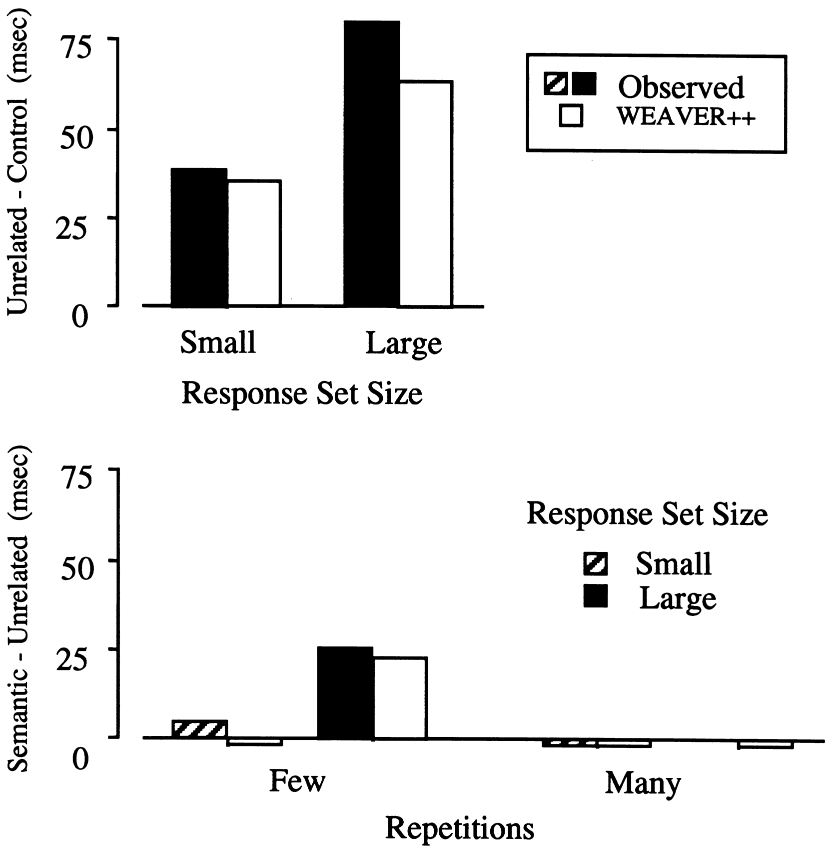

Fig. 2. Interference effects from distractor words in picture naming as a function of response set size and repetition observed by La Heij and Van den Hof (1995) and in WEAVER++ simulations.

simulation results (setting the parameter *cd* to 1.09, as in Roelofs, 1992, yields a set size effect but no semantic effect). The difference in inhibition effect between the small and large set conditions was greater in the first half of the experiment (after 16 repetitions of the responses) than in the second half of the experiment (after 32 repetitions), which was entirely due to a reduction of the inhibition effect for the larger set condition. This suggests that with really many repetitions (e.g. 32), even for a relatively large set of responses (i.e. 16), a response set (for most of the responses) can be established in memory.

In Experiment 2, La Heij and Van den Hof (1995) again manipulated the size of the response set, now concentrating on the semantic effect only. Response-set size was manipulated by testing 12 target pictures in 3 trial blocks with 4 pictures each (the small set condition) or testing all 12 pictures in a single trial block (the large set condition). The SOAs were 0, +50, and +100 ms, which were tested between participants. Now, a semantic inhibition effect was obtained but for the large set only. SOA had no effect. Furthermore, the semantic inhibition effect was only present in the first half of the experiment (with few repetitions, namely 6) and completely disappeared in the second half of the experiment (after many repetitions, namely 12). This suggests that for the small set (4 responses), a response set is created in memory without the need of response repetition. This explains why the non-response distractors yielded no semantic effect at all, replicating the findings for SOA = 0 and +100 ms of Roelofs (1992, 1993) and Glaser and Düngelhoff (1984). However, to hold the larger set of responses (12 responses) in short-term memory, help from response repetition is needed. Consequently, with few repetitions (when the response set still needs to be established in memory and thus all distractors are treated as competitors), a semantic inhibition effect is obtained. Later in the experiment (after a response set has been established in memory), the distractors are no longer treated as competitors, and the semantic inhibition effect completely disappears. Fig. 2 displays the observed effects and simulation results.

3. Explaining previous findings

The set size and repetition analysis also explains the earlier observed semantic inhibition effects from written and spoken distractors that were mentioned by C&C, which were typically obtained with over 20 responses (cf. Damian & Martin, 1999). I know of only two exceptions. Lupker (1979) had 11 (Exp. 1), 9 (Exp. 2), 10 (Exp. 3) and 20 different responses (Exp. 4), and 10 repetitions (except for Exp. 4, where the responses were produced 4 times), but he obtained semantic inhibition in all four experiments. However, the design of Lupker's experiments was somewhat peculiar, which may be responsible for the differing results. A single group of participants was first tested on the pictures of Experiment 1 (5 repetitions), then on those of Experiment 4, and then again on the pictures of Experiment 1 (again, 5 repetitions). Similarly, the participants of Experiment 2 (and 3) were first tested on all pictures of the experiment, then the participants took part in a new unrelated experiment, and finally they were tested for a second time on all pictures of Experiment 2 (and 3). This design places strong demands on short-term memory. It seems unlikely that testing 11 pictures 10 times in a trial block has the same effect on memory as testing 11 pictures 5 times, then testing 20 other pictures, and finally testing the 11 original pictures again. Thus, Experiments 1–3 had a relatively small number of responses but effectively only a few repetitions. Then, a semantic inhibition effect should be obtained, as empirically observed.

The second exception concerns findings of La Heij (1988), who tested 6 responses from 2 semantic domains (i.e. 3 responses per domain) in his Experiment 1 and 12 responses from 4 semantic domains (again, 3 responses per domain) in Experiment 2. Each response was repeated many times (e.g. 48 times in Exp. 1). La Heij factorially manipulated response set membership (member vs. non-member) and semantic relatedness (related vs. unrelated) and obtained main, additive effects of these variables. Elsewhere (Roelofs, 1992, 1993), I argued that these findings can be explained by assuming that the non-response distractors *indirectly* activated response set competitors and therefore yielded *mediated* semantic effects. For example, if the potential responses are "dog" and "cat" (but not "fish") and a pictured dog has to be named, then distractor word "fish" (which is not a response) may yield semantic inhibition by activating the lemma of "cat" (which is a response) via the conceptual network.

In deriving the predictions for their Experiment 3, C&C argued that such mediated semantic effects should be smaller than direct semantic effects (p. B58). However, this need not be the case. The semantic effect of the non-response distractor "fish" is assessed relative to an unrelated *non-response* distractor, whereas the semantic effect of the response distractor "cat" is assessed by comparing it to an unrelated *response* distractor. Thus, while non-response distractors yield less inhibition than response distractors compared to the control condition, the size of the semantic effect may be the same because the reduced effect holds for *both* the semantically related and unrelated non-response distractors. In WEAVER++ simulations (Roelofs, 1993), the size of the mediated semantic effect was the same as that of direct semantic effects.

Another possibility is that all distractor words are treated as competitors except that the size of the response threshold differs between response and non-response distractors. In particular, the critical difference in activation may be lower for non-response than for response distractors. In Experiment 1, La Heij (1988) observed a response set effect of 25 ms and a semantic inhibition effect of 12 ms, and together the effects were additive. WEAVER++ also produces additive effects of response set membership and semantic relatedness. For example, if the critical difference for non-response distractors is reduced from *cd* to 0.01 *cd*, then the response set effects for semantically related and unrelated distractors are 23 and 20 ms, respectively, and the semantic inhibition effects for response and non-response distractors are 22 and 19 ms, respectively. Thus, the model produces the effects of response set membership and semantic relatedness, and together the effects are additive, as empirically observed.

4. Conclusions

I have shown that the findings of C&C, and all previous findings that support the WEAVER++ model, can be accounted for by assuming that short-term memory for responses is of limited-capacity and that memory improves with response repetition (Levelt et al., 1999). The simulations that demonstrated the effects were run *without* a modification of WEAVER++'s architecture. The findings of C&C point to the need to further examine exactly under what conditions a response set is established in memory, but the data do not refute the response set mechanism in WEAVER++ per se.

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