

## RESEARCH REPORT

# Reassessing Critiques of the Independent Probe Method for Studying Inhibition

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Inhibitory processes have been proposed to play an important role in resolving interference during retrieval (M. C. Anderson, 2003; M. C. Anderson & Spellman, 1995). Supporting this view, retrieval induces a negative aftereffect on competing items known as retrieval-induced forgetting (M. C. Anderson, Bjork, & Bjork, 1994). Retrieval-induced forgetting often generalizes to novel cues used to test the forgotten items, and this cue independence is considered diagnostic of inhibition. This interpretation of cue independence assumes, however, that these novel cues (i.e., independent probes) are truly independent of the original cues. Challenging this assumption, Camp, Pecher, Schmidt, and Zeelenberg (2009) reported that extralist cuing test performance can be influenced by increasing the accessibility of other nonpresented cues. Here we consider this evidence for nonindependence and the conditions under which it occurs. We present two experiments demonstrating that this *cue enhancement effect* arises exclusively whenever independent probes have uncontrolled semantic relationships to the study cues of the sort that are specifically proscribed by the method—relationships not at all detected by association norms. When such relationships are controlled, as they are in many studies of inhibition, cue enhancement effects disappear. These findings highlight the importance of carefully controlling probe–cue relatedness in research on cue-independent forgetting and suggest that cue independence is diagnostic of inhibition.

*Keywords:* retrieval-induced forgetting, independent probe method, inhibition, interference, memory retrieval

People often need to retrieve particular memories from cues that are related to many traces. How do we selectively retrieve a desire memory in the face of competition from related memories? Over the last 2 decades, evidence has accumulated implicating a role of inhibitory control in facilitating selective retrieval. By this view, retrieval competition triggers an inhibition process that suppresses competing traces, rendering them less accessible. Consistent with this hypothesis, repeated retrieval practice of some memories associated to a cue induces forgetting of other memories sharing that cue. This aftereffect, known as *retrieval-induced forgetting* (RIF; M. C. Anderson, Bjork, & Bjork, 1994), suggests the involvement of inhibition in selective retrieval, especially considering the functional properties of the phenomenon. In one important property, items suffering RIF are often less accessible from a variety of cues, not just when tested with the cue used for retrieval practice—a property known as *cue independence* (M. C. Anderson & Spellman, 1995). Cue independence was predicted by inhibitory accounts of RIF, providing distinctive support for inhibition (M. C. Anderson & Spellman, 1995). Noninhibitory accounts of RIF

predict cue-dependent forgetting (J. R. Anderson, 1983; McGeoch, 1942; Mensink & Raaijmakers, 1988).

Recently, a key assumption of the method establishing cue-independent RIF—the *independent probe method* (M. C. Anderson & Spellman, 1995)—has been questioned, suggesting that cue independence may not be diagnostic of inhibition. Camp, Pecher, Schmidt, and Zeelenberg (2009) observed that when people study cue–response word pairs and are later given extralist cues to independently probe recall of the responses, recall is also influenced by the accessibility of the original study cues. Quite simply, making the study cues more accessible by repeatedly presenting them (earlier in the experiment) alters independent probe recall of the response, even though those study cues are not provided at test. We refer to this herein as the *cue enhancement effect*. The cue enhancement effect suggests that independent probe recall may not merely assess the state of the probed item, but also may be influenced by participants' covert efforts to identify other cues. If correct, this interpretation raises the possibility that covert cuing renders independent probes nonindependent, and thus perhaps not a clear measure of inhibition.

Here we examined why the cue enhancement effect occurs. On the one hand, presentation of the extralist probe may trigger a strategic search of all the cues from the study context, which should benefit from increased accessibility of the repeated cues (hereinafter the strategic search hypothesis). On the other hand, putative independent probes may accidentally elicit retrieval of related study cues via uncontrolled semantic associations between

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probes and cues (hereinafter the semantic association hypothesis). The semantic association hypothesis was prompted by our impression that Camp et al.'s (2009) independent probes were related to their matched cues, despite their use of free-association norms to control for probe–cue relationships. Such hidden relationships may underlie cue enhancement effects. To distinguish these hypotheses, we examined whether this effect depended on verifiable relations between probes and cues. If so, it would support the semantic association hypothesis. It would further illustrate the importance of meeting the prescribed conditions of the independent probe method and argue that association norms are insufficient in establishing unrelatedness (M. C. Anderson et al., 1994; M. C. Anderson & Spellman, 1995).

### The Goal of the Independent Probe Method

The basic finding of RIF is that retrieving some members of a studied category (e.g., retrieving *Fruit Orange* via *Fruit Or\_\_*) facilitates recall for the practiced items (*Fruit Orange*) but impairs later retention of competing, unpracticed items (e.g., *Fruits–Banana*), compared with recall from nonpracticed baseline categories (M. C. Anderson et al., 1994; for reviews, see M. C. Anderson, 2003; Levy & Anderson, 2002). Why? On the one hand, competitors may be recalled more poorly on the final test because they have been inhibited during retrieval practice. By this view, activation of competitors during retrieval practice triggers their suppression by inhibitory control processes. Alternatively, competitors may suffer because, on the final test, practiced items are too strong. Repeatedly retrieving *Fruit–Orange* during retrieval practice may lead *Orange* to spring to mind persistently when *Fruit* appears on the test, blocking access to *Banana*. This blocking mechanism does not assume that *Banana* is inhibited, rather that *Fruit* elicits *Orange* too easily. The independent probe method was introduced to distinguish inhibition from interference accounts such as blocking (M. C. Anderson & Spellman, 1995).

The insight behind the independent probe method is that blocking should be eliminated if different cues are provided on the test—cues that could access the competing item (e.g., *Banana*) but that, if well designed, should not elicit retrieval of the practiced items. So, for example, to avoid eliciting *Orange* (a practiced item), one could replace *Fruit* with an independent test cue uniquely related to *Banana* and not *Orange*, like *Monkey B\_\_*. If retrieval practice inhibits competing items, inhibition should remain even when the competitor is tested from such a distinctive cue. Thus, independent probes may isolate the activation state of the competing item uncontaminated by blocking. If RIF generalizes to independent cues—that is, is cue independent—this would be strong evidence for inhibition. A broad base of findings supports cue independence under many conditions in both episodic and semantic memory (e.g., M. C. Anderson & Bell, 2001; M. C. Anderson, Green, & McCulloch, 2000; M. C. Anderson & Spellman, 1995; Aslan, Bäuml, & Grundgeiger, 2007; Camp, Pecher, & Schmidt, 2005; Levy, McVeigh, Marful, & Anderson, 2007; MacLeod & Saunders, 2005; Saunders & MacLeod, 2006; Shivde & Anderson, 2001; for exceptions, see Camp, Pecher, & Schmidt, 2007; Perfect et al., 2004; Williams & Zacks, 2001). Thus, retrieval often appears to induce RIF that reflects changes to the state of the competitor, consistent with inhibition.

### The Covert Cuing Hypothesis and the Cue Enhancement Effect

Although cue-independent forgetting has broad support, some authors have questioned whether it reflects inhibition. Of main concern is whether putatively independent test cues are truly independent of practiced items. Perhaps participants do not limit themselves to independent probes when searching memory. For example, if cued with *Monkey B\_\_* for the retrieval of *Banana*, perhaps participants augment their search by retrieving studied categories like *Fruits* (for discussions, see M. C. Anderson, 2003; M. C. Anderson et al., 2000; M. C. Anderson & Spellman, 1995). Because practiced categories (e.g., *Fruit*) were seen more often than baseline categories (e.g., *Drinks*), practiced categories will be more accessible. If so, independent probe recall may be influenced by access to the practiced categories even though they are not provided overtly at test. The nature of this influence, at present, is unclear. On the one hand, Perfect et al. (2004) and Camp et al. (2005) argued that covertly recalling the practiced category may trigger recall of practiced items (e.g., *Orange*) that would then block unpracticed items (e.g., *Banana*). If so, blocking could explain independent probe impairment, albeit with complex assumptions about the cues participants use. On the other hand, covert cuing may mask evidence for cue-independent forgetting by providing additional cues that may overcome inhibition (M. C. Anderson, 2003; see also General Discussion). In either case, nonindependence may compromise inferences about the presence of inhibition.

No study has tested how covert cuing affects cue-independent RIF, but the occurrence of covert cuing has been studied in a non-RIF paradigm. Camp et al. (2009) had participants encode pairs like *Concert–Piano* to see whether later recall of *Piano* from an extralist category (e.g., *Instrument*) would be influenced by how accessible *Concert* is. If the recall of *Piano* from *Instrument* depends on how accessible *Concert* is, then *Instrument* may not be independently accessing *Piano*. Participants were presented with 24 pairs (e.g., *Concert–Piano*) on an incidental encoding task. Prior to pair encoding, 12 cues (e.g., *Concert*) were preexposed twice, rendering those cues (hereinafter the extra exposure cues) more accessible than the others (hereinafter the control cues). An extralist independent probe test followed encoding in which each target (e.g., *Piano*) was probed with a category (e.g., *Instrument*). Crucially, Camp et al. selected these probes to have low associations to studied cues ( $M = 0.001$ , using the Dutch category production norms), to ensure that the probes would be independent of the cues—a critical feature of the independent probe method. Interestingly, Camp et al. found better recall of items whose study cues had received extra exposure than control responses. Thus, independent probes may not be truly independent of studied cues because cue accessibility influences performance, complicating interpretation of cue-independent forgetting as evidence for inhibition.

### Mechanisms Underlying the Cue Enhancement Effect

The cue enhancement effect suggests that Camp et al.'s (2009) participants may have searched covertly for cues beyond the extralist probe. A question remains, however: How do participants covertly recollect exactly the correct cue from the appropriate study pair that is linked with the sought-after response? This

hypothesized cue retrieval must depend on whether independent probes are unrelated to the study cues. Take, for example, a pair from the M. C. Anderson and Green (2001) stimuli: *Gate–Daisy*. The independent probe for *Daisy* is *Flower*, which is unrelated to *Gate*. To use covert cuing on this item, participants must use the extralist cue *Flower* to recall *Gate*, which is not possible, because no association links them. Rather, to find *Gate*, participants would have to free-recall cues from the study context; and for each cue recalled, they must recall its target response, because the cue itself is not related to the independent probe and provides no diagnostic information; only when subjects recall the target could they discern whether the recalled cue was related. Thus, when independent probes are unrelated to study cues, covert cuing takes the form of a *strategic search* of the original list context (i.e., recalling every cue and probing memory to come up with the target), together with a categorical decision applied on each recalled target.

Does strategic search underlie Camp et al.’s (2009) cue enhancement effect? Perhaps. Camp et al. characterized their independent probes as *unrelated* to the study cues. If so, then covert cuing would necessarily be achieved by strategic search. According to the strategic search hypothesis, the cue enhancement effect arises because repeating the extra exposure cues increases their accessibility from the study context. There are reasons to doubt that strategic search accounts for Camp et al.’s cue enhancement effect, however. It seems implausible that participants could search the study context and find, amid 24 pairs, the right cue to access the critical target. Even if participants focused only on the 12 repeated cues, this mechanism seems improbable. Finding the right cue amid 12 pairs, though possible, seems unlikely given the short retrieval times (e.g., 5 s) used in Camp et al.’s later studies.

Matters are different, however, if independent probes are related to study cues. Indeed, inspection of Camp et al.’s (2009) stimuli reveals that despite using association norms to minimize probe–cue relationships, their probes and cues appear related. For example, for the pair *Beak–Duck*, the independent probe was *Bird* (see Figure 1). By calling *Bird* an independent probe for *Duck*, Camp et al. claimed that *Bird* is unrelated to *Beak*. In another example, the probe for *Zoo–Tiger* was *Animal*, which seems related to *Zoo* (Appendix A illustrates that these are not isolated examples). In contrast, M. C. Anderson and Green’s (2001) stimuli are more consistently unrelated. For instance, for *Gate–Daisy*, the probe was *Flower* (see Figure 1), and for *Tattoo–Uncle*, the probe was *Relative* (see Appendix A). The higher probe–cue relatedness in the Camp et al. stimuli suggests that the conditions of the independent probe method were not met; the method requires probes to be unrelated to the practice cue and practiced items (M. C. Anderson et al., 1994; M. C. Anderson & Spellman, 1995). If probes and cues were related, nonindependence is to be expected. For example, when probed with *Bird* for the recall of *Duck*, perhaps participants sometimes recalled the cue *Beak* and used this to help recall *Duck*. According to this semantic association hypothesis, participants need never have been using a covert cuing strategy, and may have recalled cues accidentally as a by-product of uncontrolled associations.

### The Present Studies

In the present studies, we sought to distinguish the strategic search and semantic association hypotheses. Experiment 1 evalu-

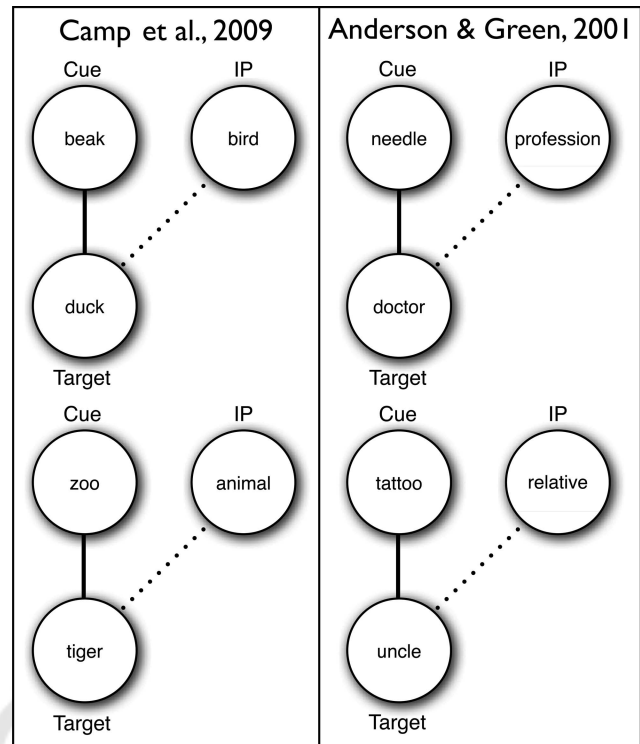


Figure 1. Examples of problematic cue–target pairs and independent probes (IPs) from Camp et al. (2009), contrasted with typical stimuli from M. C. Anderson and Green (2001). A solid line indicates an episodic association formed during encoding in the experiment. Dotted lines indicate preexisting categorical relationships between the independent probes and targets. Note that in the examples of problematic stimuli from Camp et al., the independent probes are highly related to the study cues. The greater frequency of related pairs such as these in the Camp et al. stimuli (see Figure 2 and Appendix A) illustrate the potential reason why Camp et al. found independent probes to be nonindependent.

ated whether Camp et al.’s (2009) probes were more related to cues than the norms might suggest. We paired the cue and probe for each item from three stimulus sets (M. C. Anderson & Green, 2001; M. C. Anderson et al., 2004; Camp et al., 2009) and asked participants to rate their relatedness. Like Camp et al.’s materials, these latter sets are composed of unrelated pairs, each with a categorical independent probe. Importantly, these materials have been used to establish cue-independent forgetting in nearly 1,300 subjects (M. C. Anderson & Huddleston, 2011). We corroborated participant ratings with latent semantic analysis (Dumais, Furnas, Landauer, Deerwester, & Harshman, 1988). Latent semantic analysis, based on automatic analysis of interword distances in large corpora of text, provides a more sensitive metric of semantic distance between words than association norms, and so may reveal probe–cue relatedness. In Experiment 2, we replicated Camp et al.’s procedures to evaluate whether the effect depended on uncontrolled associations. If the semantic association hypothesis proves correct, even though probes and cues are unrelated by association norms, it would serve as a cautionary tale in the design of independent probes to isolate the role of inhibition in retrieval.

F1

AQ: 2

AQ: 3

## Experiment 1

### Method

**Participants.** Sixteen native English speakers participated for payment.

**Design.** We manipulated stimulus set within subjects on three levels: Camp et al. (2009), M. C. Anderson and Green (2001), and M. C. Anderson et al. (2004). Participants received the cue-independent probe pairs from all studies, intermixed. Half the pairs presented the cue, then the probe (e.g., *Beak-Bird*), and the other half, the reverse (e.g., *Bird-Beak*). A given pair's order was counterbalanced across subjects. We measured the average relatedness on a 5-point scale with anchors *unrelated*, *moderately related*, and *highly related* linked with 1, 3, and 5, respectively.

**Materials.** We used stimuli from Camp et al. (2009), M. C. Anderson and Green (2001), and M. C. Anderson et al. (2004). The stimuli were triplets composed of cue-target pairs (e.g., *Beak-Duck*), with an extralist independent probe. The probes were the semantic categories for the targets (e.g., *Bird* for *Duck*). Camp et al. used Dutch stimuli but provided translations. Seven of their probes that consisted of multiple words (e.g., *Four-Footed Animal*) were truncated (e.g., *Animal*), maintaining the meaning but making them similar to probes in prior studies. The average word length of the cues in the Camp et al., M. C. Anderson and Green, and M. C. Anderson et al. sets was 5.3, 5.2, and 5.2, respectively, and the average length of the probes was 7.5, 6.1, and 6.7. The average word frequency (Kučera & Francis, 1967) of the cues in the Camp et al., M. C. Anderson and Green, and M. C. Anderson et al. sets was 46, 25, and 22, respectively, and the frequency of the probes was 143, 90, and 44.

Further details of stimulus characteristics in these studies can be found in the original articles. Because Experiment 1 entails collecting judgments on probe-cue relatedness, only the cue and independent probes were rated. The total numbers of probe-cue pairs in the Camp et al. (2009), M. C. Anderson and Green (2001), and M. C. Anderson et al. (2004) stimulus sets were 24, 40, and 36, respectively. According to the University of South Florida Free Association Norms (Nelson, McEvoy, & Schreiber, 1998), virtually none of the cues were listed in the associations generated for its respective probes, showing that they are unrelated by this standard.

**Procedure.** Participants viewed each cue-independent probe pair for 4 s and indicated on a 5-point scale how related they thought the two words were. For example, participants rated *Bird-Beak* to determine how related the independent probe (*Bird*) for a pair (*Beak-Duck*) was to the cue (*Beak*). The next pair appeared 1 s after participants made their response.

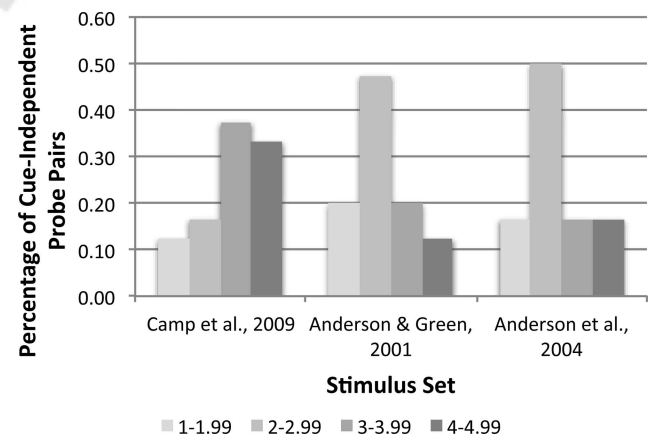
### Results and Discussion

Did the stimulus sets differ in how related independent probes were to cues? The stimulus sets differed reliably,  $F(2, 47) = 34.15$ ,  $p < .001$ ,  $MSE = 3.79$ . Follow-up analyses indicated that participants viewed the probes from Camp et al. (2009) to be more related ( $M = 3.61$ ) to their cues than they did the probes of either the M. C. Anderson and Green (2001;  $M = 2.70$ ),  $t(15) = 13.79$ ,  $p < .001$ , or the M. C. Anderson et al. (2004;  $M = 2.87$ ) stimulus sets,  $t(15) = 11.87$ ,  $p < .001$ . Thus, despite Camp et al.'s cues and

probes being unrelated by association norms, participants judged them to be more than moderately related ( $M = 3.61$ , where a rating of 3 is *moderately related*).

To further characterize these items, we computed the percentage of probe-cue pairs that participants viewed as unrelated (average rating from 1.00 to 2.99, or less than moderately related) or related (average rating of 3.00–5.00, or more than moderately related). Participants judged 71% of the items in the Camp et al. (2009) stimuli to be related, but only 33% of the M. C. Anderson and Green (2001) and M. C. Anderson et al. (2004) stimulus sets. As Figure 2 illustrates, most items in Camp et al.'s stimuli fell into the highest two relatedness bins (3.00–4.00 and 4.01–5.00). Examples of related probe-cue pairs from the Camp et al. set include *Animal-Zoo*, *Bird-Beak*, *Instrument-Concert*, and *Fruit-Jam*. Thus, the clear majority of Camp et al.'s probes violate the conditions of the independent probe method. Importantly, this procedure also identified instances of uncontrolled relatedness (e.g., *Mob-Crime*) in our own stimuli, though as Figure 2 illustrates, this was much less frequent. Importantly, Figure 2 vividly illustrates that very large differences in the distribution of relatedness values are possible, even when stimuli have no associations, by free-association norms.

A highly similar pattern arose when we quantified probe-cue relatedness with latent semantic analysis. The pairwise comparison tool at <http://lsa.colorado.edu> was used to generate a similarity comparison for each probe-cue pair, under the topic space "general reading: up to 1st year college (300 factors)." There was a main effect of stimulus set,  $F(2, 96) = 6.55$ ,  $p = .002$ ,  $MSE = 0.125$ . Probe-cue relatedness for Camp et al.'s (2009) stimuli ( $M = 0.23$ ) was greater than it was for M. C. Anderson and Green's (2001;  $M = 0.11$ ),  $t(28.11) = 2.81$ ,  $p = .001$ , or M. C.



**Figure 2.** Percentage of probe-cue pairs that have been binned in each of four relatedness rating ranges (1–1.99, 2–2.99, 3–3.99, 4–4.99). As suggested by Figure 1, these findings confirm that the materials of Camp et al. (2009) contain a much higher frequency of independent probes that were related to their cues than do stimulus sets often used to study inhibitory processes. This validates concerns that evidence for nonindependence observed in Camp et al. may arise from lack of control over these relationships (i.e., cue enhancement effects). More generally, the large difference in relatedness distributions between Camp et al. and the other stimulus sets illustrates how much probe-cue relatedness can vary, even when association norms say that no such relationships exist.

Anderson et al.'s (2004;  $M = 0.12$ ),  $t(35.48) = 2.03$ ,  $p = .05$  (both tests correcting for unequal variances, as Mauchly's Test of Sphericity revealed unequal variances between the groups). Thus, by two independent measures, we established that probe-cue relatedness is higher in Camp et al.'s stimuli than in other stimulus sets often used to test cue independence. Strikingly, although Camp et al.'s independent probes and cues were not associated by association norms, over 70% were viewed by participants as moderately to highly related. Thus, it is unlikely that the necessary conditions of the independent probe method were met.

## Experiment 2

Does the probe-cue relatedness established in Experiment 1 influence subjects' recall on independent probe tests? On the one hand, these relationships may be irrelevant if subjects strategically search for cues by recalling the list context. By this strategic search hypothesis, cue enhancement effects should arise regardless of whether probe-cue relatedness is high or low. On the other hand, according to the semantic relatedness hypothesis, cue enhancement effects should be specific to materials with high probe-cue relatedness. In Experiment 2, we examined these predictions by replicating Camp et al.'s (2009) procedure and manipulating whether probes had high or low probe-cue relatedness. We conducted several experiments to test these hypotheses, which we describe here once, for succinctness, as they were similar.

In Experiment 2A, we compared two stimulus sets from Experiment 1 (M. C. Anderson & Green, 2001; Camp et al., 2009) to determine whether observed differences in probe-cue relatedness predicted the cue enhancement effect. Comparing these stimulus sets allowed us to assess whether stimuli widely used to study cue-independent forgetting (M. C. Anderson & Green stimuli) produce cue enhancement effects. In Experiment 2B, we asked a similar question by experimentally manipulating probe-cue relatedness with new stimuli. Using the same probes and targets across two groups, we (a) varied the cues that were studied with targets to manipulate probe-cue relatedness, (b) matched the number of pairs (24), and (c) eliminated cue-target and probe-cue associations, according to association norms. These measures allowed us to generalize the findings of Experiment 2A, while matching the stimuli closely. In Experiment 2C, we modified Experiment 2B to "go the extra mile," controlling our stimuli on both objective (the association norm standard used by Camp et al., 2009) and subjective (participant ratings) measures to ensure that the stimuli matched Camp et al.'s (2009), except for the absence of probe-cue relatedness. We ensured that (a) probe-cue relatedness was low according to association norms and subjective relatedness, matching the subjective relatedness to that in M. C. Anderson and Green (2001), and (b) cue-target associations were absent, according to association norms, but matching the subjective relatedness in Camp et al.'s stimuli. If the semantic association hypothesis is correct, we should be able to make cue enhancement effects either appear or disappear depending on whether probe-cue relations are present; this variation should arise though all probe-cue pairings are ostensibly unrelated by association norms.

## Method

**Participants.** In Experiments 2A–2C, respectively, 36, 88, and 32 native English speakers participated for pay.

**Design.** Experiments 2A and 2B employed a  $2 \times 2$  mixed design, with cue exposure (extra exposure vs. control) and probe-cue relatedness manipulated within and between subjects, respectively. Participants received two extra exposures on half the cues prior to pair encoding, with participation of stimuli in the extra exposures and control conditions counterbalanced. The related group received items in which probe-cue relatedness was strong, whereas the unrelated group received one in which it was weak, according to pilot ratings. In Experiment 2A, the related and unrelated groups received the Camp et al., 2009 or M. C. Anderson and Green (2001) stimuli, respectively. In Experiment 2B, the stimulus sets were designed to vary probe-cue relatedness. Experiment 2C was identical to Experiment 2B but used tailored cue-target pairs matched in subjective relatedness (on top of ensuring unrelatedness according to norms) to those used by Camp et al., while matching subjective probe-cue relatedness to that present in M. C. Anderson and Green. The percentage of items correctly recalled to the extralist cues was measured.

**Materials.** Experiment 2A used Camp et al.'s (2009) and M. C. Anderson and Green's (2001) stimuli. In Experiment 2B, we created stimulus sets with high and low probe-cue relatedness, composed of 24 triplets (i.e., cue-target pairs plus probe). Design of the related and unrelated stimuli was guided initially by experimenter impressions. A pilot rating experiment (procedurally identical to Experiment 1) confirmed that the unrelated and related sets differed in perceived relatedness. Probe-cue relatedness in the related set ( $M = 3.98$ ) resembled that of Camp et al.'s stimuli ( $M = 3.61$ ). Relatedness was weaker in the unrelated ( $M = 1.79$ ) than in the related set ( $M = 3.98$ ),  $F(1, 15) = 557.42$ ,  $p < .001$ ,  $MSE = 38.37$ , in Camp et al.'s set ( $M = 3.61$ ),  $t(45) = 13.70$ ,  $p < .001$ , and in M. C. Anderson and Green's stimuli,  $t(45) = 6.83$ ,  $p < .001$ . The targets and probes were based on Camp et al.'s stimuli. The cues in the unrelated and related sets had similar length ( $M = 5.4$  and  $5.5$ , respectively), frequency ( $M = 58$  and  $35$ , respectively), concreteness ( $M = 5.18$  and  $4.71$ , respectively; all  $ps > .2$ ), and unrelatedness to their responses, according to association norms (no responses were listed as associates for their cues). Experiment 2C replaced cues from Experiment 2A with ones with high subjective cue-target relatedness ( $M = 3.79$ ) and low probe-cue relatedness ( $M = 2.85$ ). Cue-target relatedness was comparable to pairs used by Camp et al. ( $M = 3.79$ ), and probe-cue relatedness was comparable to M. C. Anderson and Green's stimuli ( $M = 2.7$ ).

**Procedure.** As in Camp et al.'s (2009) Experiment 3, the cues from half the word pairs were preexposed twice prior to pair encoding. Cues were rated for pleasantness and frequency in Rounds 1 and 2, respectively. Each trial presented a 1-s fixation cross, followed by the cue for 4 s, along with a 5-point Likert scale. During pleasantness ratings, the anchors *unpleasant*, *neutral*, and *pleasant* appeared above the 1, 3, and 5 ratings, respectively; during the frequency task, *infrequent*, *average*, and *frequent* appeared instead, and participants judged how frequently the word occurred in English. Participants indicated their responses within the 4 s that each cue appeared.

Cue-target encoding followed cue preexposure. Experiment 2A asked participants to indicate, for each pair, how related they thought the words were on a 5-point Likert scale. The anchors *unrelated*, *moderately related*, and *highly related* appeared over the numbers "1," "3," and "5" for the 4-s trial. In Experiments 2B

and 2C, participants intentionally linked cue–target pairs, and rated how difficult it was on scale of 1–5, with the anchors over “1,” “3,” and “5” being *easy*, *moderate*, and *difficult*.

On the final test, participants received a probe (e.g., *Bird*) for each target and recalled aloud, within 5 s, which studied target was a member of the category (e.g., *Duck*).

## Results and Discussion

**Experiment 2A.** A cue enhancement effect was observed with Camp et al.’s (2009) materials, with target recall higher in the extra exposure ( $M = 46\%$ ) than in the control condition ( $M = 34\%$ ),  $F(1, 14) = 4.25$ ,  $p = .058$ ,  $MSE = 0.027$ . M. C. Anderson and Green’s (2001) stimuli, in contrast, showed no such effect ( $M = 38\%$  and  $41\%$  for extra exposure and control conditions, respectively;  $F < 1$ ). This reduction in the cue enhancement effect was significant,  $F(1, 30) = 4.87$ ,  $p = .035$ ,  $MSE = 0.017$ . Thus, the variations in probe–cue relatedness documented in Experiment 1 influenced recall. Importantly, with materials often used in studies of cue-independent forgetting, no cue enhancement effects arose.

**Experiment 2B.** The interaction between cue exposure and relatedness was significant,  $F(1, 84) = 4.07$ ,  $p < .05$ ,  $MSE = 0.016$ . We replicated the cue enhancement effect in the related condition ( $M = 64\%$  and  $55\%$  for extra exposure and control conditions, respectively),  $F(1, 42) = 11.88$ ,  $p < .01$ ,  $MSE = 0.013$ , but no such effect was found in the unrelated condition ( $M = 40\%$  and  $39\%$  for extra exposure and control conditions, respectively;  $F < 1$ ).

**Experiment 2C.** As in unrelated conditions of Experiments 2A and 2B, no cue enhancement effect was observed, with extra exposure ( $M = 53.5$ ) and control items ( $M = 50.3$ ) showing comparable recall,  $F(1, 31) = 1.21$ ,  $p = .28$ ,  $MSE = 0.01$ .<sup>1</sup>

**Combined analysis.** Would a cue enhancement effect occur in the unrelated condition if we combined the data of Experiments 2A–2C? We pooled the related conditions ( $N = 60$ ) and compared them to the pooled unrelated conditions ( $N = 92$ ) in an uneven sample size mixed-subjects analysis of variance. Although caution must be exercised in comparing overall performance across the related and unrelated conditions (which differ in materials), if cue enhancement effects were general, they should emerge in the combined unrelated condition. Whereas a robust cue enhancement effect occurred in the related condition,  $F(1, 59) = 14.23$ ,  $p = .001$ ,  $MSE = 0.019$ , no trace of an effect arose in the unrelated condition ( $F < 1$ ). The interaction of cue exposure with relatedness was highly significant,  $F(1, 150) = 7.87$ ,  $p = .006$ ,  $MSE = 0.016$ . The straightforward result established in Experiments 2A–2C appears in Figure 3, illustrating that the differences in perceived relatedness, evident in Figure 2, but not measured by association norms, determines the cue enhancement effect observed by Camp et al. (2009).

## General Discussion

The present experiments strongly favor the semantic association account of the cue enhancement effect. Experiment 1 confirmed that the probes used by Camp et al. (2009) were more related to their respective cues than association norms might lead one to believe. Indeed, 71% of the probes used by Camp et al. were

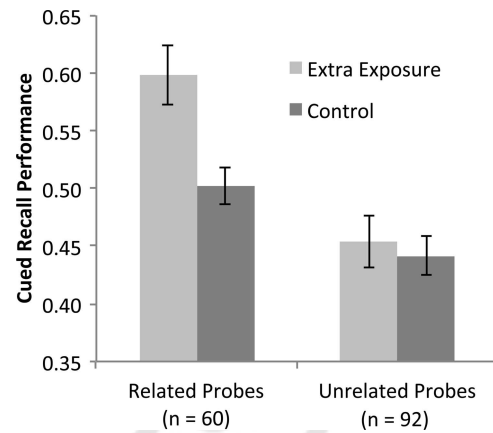


Figure 3. Cued recall performance for extra exposure and control items in two samples in which study cues are either related or unrelated to independent probes. As suggested by the differences in independent probe relatedness established in Figure 2, the cue enhancement effect only occurs when independent probes are related to cues. Thus, independent probes are nonindependent of original study cues when semantic relationships between probes and cues are incorporated into the materials, highlighting a general constraint that must be carefully honored in designing independent probes.

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judged to be more than moderately related, and 33% to be highly related. This increased relatedness was established by ratings of probe–cue relatedness, but also by latent semantic analysis.

Experiments 2A–2C showed that the relationships established in Experiment 1 were sufficient to cause cue enhancement effects. When relationships were reduced, cue enhancement effects vanished. In Experiment 2A, we used M. C. Anderson and Green’s (2001) stimuli, widely used to isolate inhibition (see M. C. Anderson & Huddleston, 2011). In Experiment 2B, we crafted special stimuli using (nearly) the same probes and responses as Camp et al. (2009), differing only in the study cue paired with the response and its relatedness to the probe. Cue enhancement effects only arose with high probe (e.g., *Bird*) to cue (e.g., *Beak*) relatedness, disappearing when the probe (e.g., *Bird*) and cue (e.g., *History*) were unrelated. Again, these variations occurred for stimuli that, by association norms, were unrelated. Even when we went the extra mile, going beyond association norms (the standard used by Camp et al., 2009) to equate the subjective cue–target relatedness to that in the Camp et al. stimuli—while matching the subjective

<sup>1</sup> Overall recall was higher in Experiment 2C than in the unrelated condition of Experiment 2B (as it was in the related condition of Experiment 2B), indicating that independent probe recall of a response can be influenced by which study cue it is paired with. This likely reflects variations in how people encode the response when it is paired with a related cue (e.g., *Zoo–Tiger*) or a less related cue (e.g., *Gift–Tiger*)—that is, encoding specificity. Using less related study cues (as had occurred in the unrelated probe–cue condition of Experiment 2B, but not in Experiment 2C) is likely to alter the response’s (*Tiger*) match to the probe (*Feline*), lowering performance. Note, however, that this dependency of independent probe recall on study cues is not a violation of cue independence, as the latter refers to whether the independent probe accesses the cue at test. Given the lack of a cue enhancement effect in Experiment 2C, this dynamic is unlikely.

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relatedness of probe-to-cue associations to those of M. C. Anderson and Green—no cue enhancement effect arose (Experiment 2C). Thus, in three samples with differing materials, cue enhancement effects vanished when probe–cue associations were low.

### Accounts of Cue Enhancement Effects

Our findings indicate that the cue enhancement effects observed by Camp et al. (2009) did not arise from a global scanning of all the cues in the list. Cue enhancement effects vanished with low probe–cue relatedness, indicating that it was not possible to take advantage of a cue scanning strategy without help from probe-to-cue associations. The dependency of this effect on probe–cue relationships is, however, consistent with a limited covert cuing account. According to this strategic compound-cuing hypothesis, participants search the study list with both the list context and the probe to identify the most related cue. Using both the context and the probe ought to focus search effectively. This strategy is only useful, however, if the probe is related to one of the cues and so can constrain search. Thus, in marked contrast to the strategic search hypothesis, strategic compound cuing works only for stimuli that do not adhere to the conditions of the independent probe method, and would not be a general criticism.

Strategic compound cuing makes unnecessary assumptions, however. One need not assume that participants intentionally search for cues. When searching for a target, participants may accidentally retrieve the related cue from the independent probe. For example, given the probe *Bird*, it would be unsurprising if participants accidentally recalled the cue *Beak* before recalling *Duck*, sometimes, because *Bird* and *Beak* are related. In effect, participants are in an A–B, A–B situation, where the probe (i.e., A; e.g., *Bird*) is linked to two related items (i.e., the cue, *Beak*, and the target, *Duck*). If participants recall the target *Duck*, retrieval will stop; but if they recall the cue (*Beak*) first, the activation of *Bird* and *Beak* can act as a spontaneous compound cue for *Duck*. As such, strategic efforts to generate secondary cues are not needed to explain this effect. Because this account explains the data with fewer assumptions, it should be preferred over strategic compound cuing. Thus, cue enhancement effects do not provide clear evidence that covert cuing strategies are prevalent in the independent probe method.

### Implications for Research on Inhibition

The present findings have significant implications for the value of the independent probe method as a tool for studying inhibition. The main concern motivating Camp et al.'s (2009) investigation was the possibility that independent probes may not access target items independently of their associated cues, and may thus introduce associative interference. Given that the chief evidence for nonindependence was the cue enhancement effect, our findings reduce such concerns. Evidence for nonindependence is limited to material sets with probe–cue relationships, the opposite condition required by the method. Because many studies supporting cue-independent RIF or retrieval suppression use probes lacking relationships to studied cues, concerns about nonindependence in most existing data are unclear at best, particularly given the wealth of other evidence supporting cue independence that is not subject to

covert cuing such as deficits in item recognition and lexical decision for inhibited items.

Concerns over covert cuing may still remain for some findings. For instance, M. C. Anderson and Spellman (1995) found that retrieval practice on some category exemplars (e.g., *Red–Blood*) induced forgetting of other members studied under that category (e.g., *Red–Tomato*), but also other red items studied and tested under another cue (e.g., *Food–Strawberry*). This *cross-category inhibition* reflects cue-independent forgetting because the cue (e.g., *Food*) used to test *Strawberry* was not used for retrieval practice on *Red–Blood*. However, only six categories were used. Thus, if participants received the cue *Food*, they could have strategically searched through all categories, even without semantic associations between them. Moreover, two of the six category pairs used in those earlier studies arguably had hidden relationships of the sort studied here (e.g., *Loud* and *Tool*, *Cotton* and *Leather*), prompting concerns about whether covert cuing-induced blocking might have caused cross-category inhibition.

Though such concerns are reasonable, recent data indicate that covert cuing-induced blocking does not underlie these effects. Hulbert, Shivde, and Anderson (2011) used the cross-category inhibition paradigm and materials and manipulated whether participants received retrieval practice or extra study exposures on items like *Red–Blood*. Strengthening of practiced items above baseline occurred for both retrieval practice (23%) and extra study (24%) items. Does this strengthening cause cross-category inhibition? According to the covert cuing hypothesis, cuing with *Food* for the recall of *Strawberry* should lead to covert recall of the practiced *Red* category; as a result, the practiced item *Red–Blood* should cause blocking and thus cross-category forgetting. If so, cross-category forgetting should occur whenever there is a strong practiced item. Yet, Hulbert et al. found significantly more impairment in the retrieval practice (9%) than in the extra study condition (0%), despite closely matched strengthening. Moreover, with all 96 subjects, the predicted correlation between practiced-item strengthening and cross-category inhibition was absent ( $r = .06$ ). These findings indicate that strengthening practiced items is unrelated to cross-category inhibition, contrary to the predictions of the covert cuing hypothesis. These findings cast serious doubt on the covert cuing account of those data.

We do not wish to argue that covert cuing is not a concern in general. Over the years, we have considered this factor seriously (M. C. Anderson, 2003; M. C. Anderson & Bell, 2001; M. C. Anderson et al., 2000; M. C. Anderson & Spellman, 1995) and made efforts to reduce it, including minimizing subjective relatedness between probes and cues (as illustrated in Experiment 1). Our view, however, is that covert cuing does not *cause* cue-independent forgetting but rather *masks* it (M. C. Anderson, 2003). If a participant tries to recall the item *Duck* given *Bird* as a cue and, in the process, retrieves *Beak* as a second cue, recall of *Duck* should increase, not decrease. Adding cues generally improves recall, and sometimes superadditively (e.g., Rubin & Wallace, 1989). If so, and if practiced categories are more accessible, covert cuing should reduce cue-independent forgetting. This has not been tested, however. Thus, controlling this behavior is central if the independent probe method is to isolate inhibition. The present findings underscore how important it is to carefully screen probe–cue relationships with measures more stringent than free-association norms to achieve this control.

## Concluding Remarks

Cue-independent forgetting has been interpreted as evidence for the role of inhibition in RIF. This interpretation assumes that novel test cues for a putatively inhibited item access the trace directly, without involvement of nonpresented retrieval cues. Here we considered a challenge to this assumption that we termed the cue enhancement effect, which has been argued to reflect covert cuing. The current findings, however, show that the cue enhancement effect does not reflect strategic covert cuing, but rather uncontrolled relationships between putative independent probes and study cues. Such relationships should not arise when the method is implemented as prescribed.

The present findings are instructive about pitfalls investigators may confront in using the independent probe method to isolate inhibition. Establishing independence between probes and cues requires more than documenting nonassociation in association norms. Although all of Camp et al.'s (2009) probes and cues were clearly unrelated by this standard, we still found strong evidence for relatedness. These findings recommend that investigators interested in using the independent probe method to study inhibition should carefully scrutinize probes to eliminate the subjective sense of relatedness and, preferably, characterize probe–cue relatedness by ratings or latent semantic analysis. Indeed, even with focused efforts to create well-controlled stimuli, ratings revealed cases in our own stimuli that should have been more controlled than they were.

It remains to be seen what effect covert retrieval of study cues has on cue-independent forgetting. Some have argued that covert cuing causes cue-independent forgetting, others that it eliminates it (M. C. Anderson et al., 2001). Regardless of the effect's direction, it is important to control the influence of cuing, which may arise. Fortunately, as illustrated here, covert cuing can be circumvented with proper materials design and procedural controls (see M. C. Anderson, 2003, for a detailed discussion). These conditions have been honored in many studies of inhibition. As such, we argue that the independent probe method remains a theoretically diagnostic tool in research on inhibition.

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### Appendix A

#### Materials From Camp et al. (2009), Anderson and Green (2001), and Anderson et al. (2004)

Camp et al., 2009			Anderson & Green, 2001			Anderson et al., 2004		
Cue	Target	Independent probe	Cue	Target	Independent probe	Cue	Target	Independent probe
Jam	Cherry	Fruit	Planet	Blue	Color	Dough	Salt	Spice
Gate	Palace	Dwelling	Slander	Roach	Insect	Glow	Ghost	Supernatural
Chair	Grandfather	Relative	Gate	Daisy	Flower	Journey	Pants	Clothes
Zoo	Tiger	Animal	Ambition	Ballet	Dance	Stumble	Clown	Circus
Beak	Duck	Bird	Relief	Bourbon	Alcohol	Relax	Bed	Furniture
Pen	Letter	Reading-material	Fuss	Poodle	Dog	Vitamin	Lemon	Fruit
Concert	Piano	Instrument	Flag	Sword	Weapon	Crack	Lobster	Seafood
Bang	Pistol	Weapon	Ticket	Flute	Instrument	Antler	Knife	Weapon
Illness	Doctor	Occupation	Vice	Cigar	Tobacco	Crumb	Toaster	Appliance
Ball	Wool	Kind-of-cloth	Fault	Sadness	Emotion	Picnic	Hill	Landform
Medal	Bronze	Metal	Haven	Falcon	Bird	Soil	Tomato	Vegetables
Dessert	Spoon	Kitchen-utensil	Errand	Hour	Time	Diet	Cream	Dairy
Fireplace	Coal	Fuel	Greed	Penny	Money	Pet	Mouse	Rodent
Rope	Sailing	Sport	Orphan	Lamb	Animal	Pipe	Wrench	Tool
Toddler	Blocks	Toy	Mob	Robbery	Crime	Nail	Picture	Art
Bottle	Milk	Beverage	Snag	Cotton	Fabric	Surprise	Snake	Reptile
Stump	Carrot	Vegetable	Tattoo	Uncle	Relative	Lawn	Beef	Meat
Sole	Foot	Body-part	Peg	Oak	Tree	Pump	Oil	Fuel
Bar	File	Tool	Lever	Steel	Metal	Officer	Blue	Color
Swamp	Mosquito	Insect	Kiln	Hammer	Tool	Beach	Africa	Continent
Sunflower	Yellow	Color	Tribe	Valley	Land-form	Libery	Eagle	Bird
History	Century	Unit-of-time	Position	Chair	Furniture	Steam	Train	Vehicle
Station	Bus	Vehicle	Custom	Tomb	Burial	Tape	Radio	Media
Winter	Coat	Clothing	Mulch	Gopher	Rodent	Hug	Rose	Flower
			Alarm	Cobra	Snake	Jaw	Gum	Candy
			Wedge	Cheddar	Cheese	Lens	Physics	Science
			Apron	Nutmeg	Spice	Broom	House	Building
			Moss	North	Direction	Needle	Doctor	Profession
			Pity	Goldfish	Fish	Leap	Ballet	Dance
			Braid	Doll	Toy	Mixture	Jar	Container
			Rim	Granite	Rock	Cradle	Parent	Relative
			Thud	Football	Sport	Accident	Snow	Weather
			Arch	Sandal	Footwear	Rug	Wool	Alcohol
			Reflex	Bicycle	Vehicle	Candle	Wine	Fabric
			Paste	Tomato	Vegetable	Breath	Nose	Bodypart
			Jargon	Physics	Science	Decay	Carbon	Element
			Belt	Shirt	Clothing			
			Pollution	Sulfur	Chemical			
			Spine	Lobster	Seafood			
			Cluster	Necklace	Jewelry			

(Appendices continue)

## Appendix B

### Stimuli Used in Experiment 2B

Cue			
Related	Unrelated	Target	Independent probe
Ice	Sinus	Vodka	Alcohol
Beak	History	Duck	Bird
Pocket	Treaty	Jacket	Clothing
Gate	Dance	Mansion	Dwelling
Napkin	Fault	Spoon	Eating-utensil
Zoo	Gift	Tiger	Feline
Fall	Cube	Gravity	Force
Burn	Ambition	Coal	Fuel
Leaf	Slander	Rake	Garden-tool
Evidence	Humor	Passport	Identification
Swamp	Bump	Mosquito	Insect
Concert	Sand	Piano	Instrument
Information	Finger	Television	Media
Alloy	Rainbow	Steel	Metal
Desk	Slot	Engineer	Occupation
Clan	Dentures	Uncle	Relative
Venom	Cushion	Snake	Reptile
Tentacle	Grave	Squid	Seafood
Condiment	Pulpit	Salt	Seasoning
Rope	Spine	Wrestling	Sport
Beauty	Canal	Lotion	Toiletry
Stump	Stump	Carrot	Vegetable
Station	Arch	Bus	Vehicle
Bang	Errand	Rifle	Weapon

*Note.* The independent probe for each target word was a semantic category into which the target fit. Each target was paired with a cue in the encoding phase. In the related condition, these cues were selected that were semantically related to the respective independent probes; in the unrelated condition, cues were selected that were unrelated to the independent probe. Due to an error, the cue *Stump* was used in both the strong and weak stimulus sets. This item was omitted from analyses in both conditions.

## Appendix C

### Stimuli Used in Experiment 2C

Cue	Target	Independent probe
Russia	Vodka	Alcohol
Bread	Duck	Bird
Breeze	Jacket	Clothing
Rich	Mansion	Dwelling
Baby	Spoon	Eating-utensil
Stripe	Tiger	Feline
Balloon	Gravity	Force
Diamond	Coal	Fuel
Autumn	Rake	Garden-tool
Holiday	Passport	Identification
Bump	Mosquito	Insect
Bench	Piano	Instrument
Boredom	Television	Media
Frame	Steel	Metal
Calculator	Engineer	Occupation

(Appendices continue)

Appendix C (continued)

Cue	Target	Independent probe
Dentures	Uncle	Relative
Mouse	Snake	Reptile
Ink	Squid	Seafood
Ocean	Salt	Seasoning
Spine	Wrestling	Sport
Sunburn	Lotion	Toiletry
Horse	Carrot	Vegetable
Tourist	Bus	Vehicle
Deer	Rifle	Weapon

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