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# Face (and Nose) Priming for Book: The Malleability of Semantic Memory

**Jennifer H. Coane** and
Colby College

**David A. Balota**
Washington University in Saint Louis

## Abstract

There are two general classes of models of semantic structure that support semantic priming effects. Feature-overlap models of semantic priming assume that shared features between primes and targets are critical (e.g., *cat-DOG*). Associative accounts assume that contextual co-occurrence is critical and that the system is organized along associations independent of featural overlap (e.g., *leash-DOG*). If unrelated concepts can become related as a result of contextual co-occurrence, this would be more supportive of associative accounts and provide insight into the nature of the network underlying “semantic” priming effects. Naturally co-occurring recent associations (e.g., *face-BOOK*) were tested under conditions that minimize strategic influences (i.e., short stimulus onset asynchrony, low relatedness proportion) in a semantic priming paradigm. Priming for new associations did not differ from the priming found for pre-existing relations (e.g., *library-BOOK*). Mediated priming (e.g., *nose-BOOK*) was also found. These results suggest that contextual associations can result in the reorganization of the network that subserves “semantic” priming effects.

### Keywords

semantic priming; episodic priming; associative models; feature models

Semantic memory entails the general world knowledge individuals possess regarding concepts and their relations (see Balota & Coane, 2008, for a review). A classic paradigm for assessing the organization of semantic memory is the semantic priming task. In this task, responses to a target (e.g., *DOG*) are faster and more accurate when the prime is related (e.g., *leash* or *cat*), compared to when it is unrelated (e.g., *pen*). Semantic priming effects presumably reflect the similarity or proximity of concepts in semantic space. Since Meyer and Schvaneveldt’s (1971) seminal paper, there has been a wealth of findings regarding the parameters of the task and the nature of the underlying representations (see McNamara, 2005). Whether semantic priming reflects similarity at the level of shared features or lexical-level associations has been extensively examined (Hutchison, 2003; Lucas, 2000). However, one open question is how two items, such as *leash* and *dog*, become associated.

Within traditional network models of semantic priming, concepts are represented holistically, as nodes in a densely interconnected network (Collins & Loftus, 1975; Steyvers & Tenenbaum, 2005). Semantic knowledge is distributed across nodes, with each node

Address correspondence to: Jennifer H. Coane, Department of Psychology, Colby College, 5550 Mayflower Hill, Waterville, ME 04901, jhcoane@colby.edu, phone : (207) 859-5556, fax : (207) 859-5555.

representing a concept connected to related concepts via pathways. The distance in the network reflects the proximity of two concepts in semantic space. In these models, associations are due to semantic similarity, such as shared category membership, or to co-occurrence in the language (thus semantic similarity in terms of category membership is not necessary, such as in the concepts *dog* and *leash*).

Semantic network models can be contrasted with feature-overlap models, which assume that shared primitive features underlie semantic similarity (e.g., McRae, 2004).Feature-based models are attractive because one can quantify the amount of overlap in features between primes and targets, which affords a computationally explicit way of modeling priming (e.g., Plaut & Booth, 2000).

To examine whether simple co-occurrence can give rise to semantic priming effects, we examined priming for pairs of "unrelated" words, which have relatively recently become associated in the language. Here by "unrelated" we mean that there is not a clear pre-existing featural overlap between the concepts, such as that between *dog* and *cat*, which are both four-legged, furry pets. Consider, for example, *face* and *book*. These items do not have any obvious featural overlap and were probably not co-occurring before the advent of the popular internet networking site. These items are, thus, episodically associated (i.e., they are related in a specific episodic context). The question is whether such pairs yield priming effects similar to those observed for pre-existing associations (e.g., *cat-DOG*), thereby providing support for the notion that relatedness emerges as a function of experience in the absence of abstract featural overlap.

In earlier literature, priming for new associations has been investigated using the episodic priming paradigm (e.g., McKoon & Ratcliff, 1979). During a learning phase, unrelated word pairs are studied, followed by a test to measure priming for the new associations. The litmus test of "episodic priming" is demonstrating *automatic* priming for new associates, because this provides the strongest evidence that facilitation from newly learned associations reflects changes in the structure of the representation underlying such effects, rather than more strategic mechanisms (Neely, 1991). McKoon and Ratcliff (1979) obtained reliable priming for new associations using a stimulus onset asynchrony (SOA) of 300 ms in a lexical decision task (LDT), and later replicated this pattern at even shorter SOAs of 150 and 250 ms (McKoon & Ratcliff, 1986).

Several constraints on episodic priming have been identified. For example, Goshen-Gottstein and Moscovitch (1995a, 1995b) found that the preservation of the presentation modality and format between study and test modulated the effect. Pecher and Raaijmakers (1999) obtained episodic priming only when the same task (LDT or perceptual identification) was used during both encoding and the final test. In a more recent study, Pecher and Raaijmakers (2004) found priming for new associations in an animacy decision task only when the encoding task encouraged unitization of the words (e.g., by having participants find similarities between the two words in the pair), but not when the encoding task encouraged processing the words as separate units (e.g., by listing separate properties for each item). These constraints are noteworthy since semantic priming occurs across various tasks, and also across modalities.

Other studies have failed to obtain episodic priming. Carroll and Kirsner (1982) found reliable priming for pre-existing associations, but not for new associations. Den Heyer (1986) only obtained reliable priming for new associations at a long SOA (550 ms) but not at a short SOA (100 ms). The failure to find priming in these studies is intriguing because lexical decisions were made during both phases. Neely and Durgunoglu (1985) and Durgunoglu and Neely (1987) also failed to find priming when conditions minimized the use of strategic processing. Of course, one may be concerned that the initial encoding episodes were not sufficient to support priming at short SOAs. In support of this possibility, Dagenbach, Horst, and Carr (1990) presented word pairs over a 5-week period using a deep encoding manipulation (i.e., sentence generation). Even under these conditions, priming in a 200 ms SOA LDT was only obtained when the primes were very low frequency words (e.g., *drupe-cherry*), suggesting that, rather than forming new associations between existing items in the lexicon, new representations for these words were being established.

In summary, there is inconsistent evidence that new associations produce priming effects similar to pre-existing "semantic" prime-target pairs, under conditions that minimize strategic processing. However, the majority of studies provided limited exposure to the new word pairs and, with the exception of a few cases (Dagenbach et al., 1990, Pecher & Raaijmakers, 2004), meaningful encoding was rarely encouraged. More fundamentally, episodic priming studies have always used experimentally induced associations, in contrast to the naturally occurring associations that are used in semantic priming studies. Hence, the comparability to semantic priming is always going to be somewhat limited.

Another important limitation of the literature reviewed above is that there is little evidence that the new associations are integrated with pre-existing knowledge and hence do not simply reflect stimulus-response learning. If new associations were incorporated into semantic memory, new links would be formed between the prime's associates and the target, as well as between the two items directly. This would be analogous to mediated priming (i.e., priming for items that are semantically unrelated to one another but share a common associate, such as *lion* priming *stripes* through the mediated link *tiger*; Balota & Lorch, 1986). Obtaining automatic priming from pre-existing associates of one item (e.g., *nose*) to the newly learned associates (e.g., *book*) would provide compelling evidence for true integration of episodic knowledge into semantic memory (see Silberman, Miikkulainen, & Bentin, 2005). Pairs such as these were included in the experiment reported here.

We tested the integration of new associations within semantic memory by investigating priming between words that occurred in natural contexts in spaced, meaningful, and likely emotionally salient conditions, all of which should magnify the strength of the relationship (Crowder, 1976). Political discourse and movie titles provide the necessary structure for two items, such as *face* and *book*, to become "related", even though there are few, if any, overlapping features between the concepts of "faces" and "books" If new associations are fully integrated and incorporated into pre-existing knowledge, priming from *face* to *book* should be similar in magnitude to the priming observed from normatively associated primes (e.g., *library* for *book*). Importantly, the question is not whether participants are aware of a relationship between *face* and *book,* but whether the associations between these items result in *automatic* activation in a semantic priming paradigm. The absence of a learning phase in the present study and testing items that naturally co-occur eliminated the possibility that participants could engage in intentional or strategic retrieval of an earlier experimental context of learning the episodic pair. To assess whether the new associations also conferred a memory advantage, a surprise cued recall test was administered after the LDT.

## Method

### Participants

Seventy-two students from Washington University participated in exchange for course credit or $10. Four participants' data were omitted due to high error rates (over 40%) or RTs that exceeded the group average by more than 2.5 *SD*s.

### Materials

One-hundred and twenty prime-target pairs were initially developed. Sixty pairs referred to political events or concepts (the *political* targets) and 60 to media and entertainment concepts (the *pop culture* targets). The use of two distinct domains provides generality to the effects. See Table 1 for lexical characteristics of the targets.

Each target was paired with four prime types: a pre-existing associate prime (hereafter, semantic primes, e.g., *library-BOOK*), a "new associate" prime (e.g., *face-BOOK*), a mediated prime (e.g., *nose-BOOK*), and an unrelated prime (e.g., *inch-BOOK*). Mediated primes were strong associates of the semantic primes, but were not related to the target. The four types of primes were matched along relevant lexical variables (i.e., length, frequency, orthographic neighborhood size, i.e., the number of words that can be generated by changing a single letter; Coltheart, Davelaar, Jonasson, & Besner, 1977), and LDT response latencies from the English Lexicon Project (http://elexicon.wustl.edu; Balota et al., 2007). For each prime/target pair, a measure of association strength from the Nelson, McEvoy, and Schreiber (1998) database was obtained. Forward associative strength (FAS) refers to the probability that a prime elicits the target in a free association task, and is a predictor of priming in LDT (Hutchison, Balota, Cortese, & Watson, 2008). In addition, the semantic similarity measure derived from the Latent Semantic Analysis (LSA; Landauer & Dumais, 1997) database (http://lsa.colorado.edu) was computed for the prime-target pairs.

To obtain current measures of the associative strength of the prime-target pairs, a norming study ($N$ = 88) was conducted. Each participant was presented with 120 cues (i.e., one prime for each of the 120 targets; 30 cues for each prime type) and told to write the first word that came to mind. The targets in the unrelated condition were never produced, and the target was given as a response most often with the semantic prime.

In the analyses reported below, we omitted 21 prime-target pairs in which the new associate elicited the target more than 25% of the time, as well as four pairs in which the mediated prime elicited the target. An additional 25 pairs were omitted from the analyses because there was some concern that these items shared features (e.g., *princess-BRIDE*, *war-TERROR*). These 50 items were removed from all conditions. The characteristics of the remaining 70 pairs (34 in the political condition, 36 in the pop culture condition) are presented in Table 2. As was the case for the full stimulus set, the different prime types did not differ from one another on any of the lexical variables (all $p$s > .09). Importantly, targets were produced less frequently in response to the newly associated primes than to the semantic primes, $t(119) = 2.3$, $p = .02$; thus, one would expect different magnitudes of priming effects in these conditions. Of course, the fact that the targets were produced at all in the new associate condition indicates that these new associations are indeed present in the population.

As shown in Table 2, the primes differ in the associative strength measures to the target: Unrelated pairs have very low relatedness scores in any of the measures; the newly associated and mediated pairs have significantly lower FAS and LSA values than the semantic pairs ($p$s < .001).

One hundred and twenty pseudohomophonic nonwords (e.g., *brane*) matched in length and orthographic neighborhood to the targets were paired with primes matched in length, frequency, and orthographic neighborhood to the word primes.

### Procedure

Participants were tested individually or in groups of five or six. Participants were given a 32-item practice list and were told to respond as quickly and as accurately as possible. In both the practice and critical phases, each trial began with a 1000 ms blank screen, followed by the prime (in lower case) for 200 ms. After a 50 ms blank interval, the target appeared (in upper case). Targets remained visible until participants responded by pressing one of two keys (“A” for words, “L” for nonwords). The prime-target SOA of 250 ms was expected to minimize the likelihood of intentional or strategic processes (e.g., Neely, 1977). The two critical conditions (the new association and mediated conditions) each only occurred on 25% of the word trials (12.5% of the total trials), further minimizing the likelihood that strategic generation would occur (e.g., Hutchison, 2007; Stolz & Neely, 1995; see McNamara, 2005, Neely, 1991 for reviews). After the LDT, a surprise cued recall task was administered. The 120 primes used in the four priming conditions were presented and participants were instructed to recall the target with which each prime was presented during the LDT. This task was self-paced and participants were told to skip the trials in which they could not remember the target.

## Results

### Response Latencies

Analyses were performed on correct responses within 250 and 2000 ms and that did not deviate from each subject’s average by more than 2.5 SDs. Overall, 3.5% of trials were excluded. Data were submitted to a 2 (target type: political vs. entertainment) × 4 (prime type) repeated measures ANOVA.

Facilitation was observed in the related prime conditions relative to the unrelated condition (Figure 1), as reflected by a significant main effect of prime type, $F(3,201) = 15.5$, $p < .001$, partial $\eta^2 = .19$. All three conditions produced significant priming, all *t*s > 2.5, all *p*s < .005. Priming effects for newly associated primes ($M = 37.5$) were equivalent to those observed with semantic primes ($M = 35$), $t < 1.0$. Although overall responses to political targets were slower than to pop culture targets, $F(1,67) = 42.1$, $p < .001$, partial $\eta^2 = .39$, there was no evidence of an interaction between prime type and target type, $F < 1.7$. Consistent with Balota and Lorch (1986), the average mediated priming effect ($M = 19.5$) was approximately half the size of the priming effect for newly associated primes, and was significantly smaller than both the new associate priming effect, $t(67) = 4.8$, $p < .001$, and the semantic priming effect, $t(67) = 3.6$, $p = .001$.

It is likely that, even with the relatively low proportion of newly associated pairs (25% of word trials), participants became aware of the fact that these pairs referred to common expressions in the media or movie titles and television shows. In fact, there is evidence that the strength of priming effects can depend on the type of relations between prime-target pairs in the lexical decision task (Becker, 1980; McKoon & Ratcliff, 1995). This, in turn, might have resulted in a post-lexical checking strategy (Neely, 1991). To examine this issue, priming effects were examined as a function of list half: If awareness of the type of specific relations drove the effects, one would expect more priming in the second half. One might have also expected reduced semantic priming, because the newly associated pairs were quite salient (although inhibitory priming effects generally do not emerge with short SOAs). However, the effect of list half was not significant, nor did it interact with prime type ($F < 1$), suggesting that the list context effect was not driving the priming effects for newly associated pairs.

### Error Data

Error rates were submitted to the same analyses as the RT data. Both the main effect of target type and that of prime type were significant: $F(1,67) = 18.4$, $p < .001$, partial $\eta^2 = .22$, and $F(3,201) = 3.6$, $p = .01$, partial $\eta^2 = .05$, respectively. The interaction was not significant, $F < 1.9$. Political targets resulted in more errors than pop culture targets. New associates resulted in reliable reduction in errors relative to unrelated primes, $t(67) = 1.8$, $p < .05$ (one-tailed; see Figure 2). Neither the mediated condition nor the semantic condition differed from the unrelated condition in error rates, both *t*s < 1.5, *p*s > .14.

### Cued Recall Data

The proportion of correct responses was submitted to a target type by cue type ANOVA. The effect of target type was significant, $F(1,67) = 61.5$, $p < .001$, partial $\eta^2 = .48$, with more targets recalled in the pop culture condition than in the political condition. The effect of cue type was also reliable, $F(3,201) = 193.1$, $p < .001$, partial $\eta^2 = .74$. All three related conditions resulted in better recall than the unrelated condition, all *p*s < .05. The target type by cue type interaction was also reliable, $F(3,201) = 15.02$, $p < .001$, partial $\eta^2 = .18$. As can be seen in Figure 3, correct recall in the unrelated and mediated conditions did not differ as a function of target type, both *t*s < 1.1, *p*s > .3. In both the newly associated and semantic conditions, large and equivalent advantages were observed for recall of pop culture targets relative to political targets, $t(67) = 4.2$, $p < .001$, and $t(67) = 7.04$, $p < .001$, respectively.

## Discussion

The results are straightforward: Newly associated primes resulted in equivalent facilitation as semantic primes in response latencies and errors, under conditions in which strategic mechanisms were unlikely to be operating. Mediated priming effects were found in RTs, albeit not in errors. In cued recall, newly associated and semantic primes resulted in equivalent recall rates. These effects were found for pairs from two distinct domains. The norming study results and the FAS and LSA measures suggested that, because the newly associated primes were weaker associates than the semantic primes, the magnitude of priming should have been smaller than that observed for semantic pairs. However, this was clearly not the case. Thus, it appears that the new associations used here are indistinguishable from pre-existing associations in semantic memory.

The critical mediated priming effect (i.e., *nose-BOOK*) suggests that the new associations are integrated into pre-existing semantic networks, thereby allowing activation to spread from *nose* to *book*, via *face*. Perhaps participants were able to strategically “guess” what the mediator was. However, three arguments suggest this is unlikely. First, the SOA was only 250 ms, which is quite short to generate expectancies, especially for items that do not share a direct relationship. Second, only 12.5% of trials were mediated pairs, making this strategy generally unhelpful. Third, the effortful processing of generating the mediator should result in a stronger memory trace. However, the mediated items results in much lower correct recall than both the new associate (by 30%) and the semantic (by 32%) and were only slightly better than the unrelated pairs (by 5%).

There may be some special characteristics of the items used in the present study that modulate priming but are due to a different mechanism than the standard semantic primes. For example, the stimuli may be analogous to phrasal associates. We believe the mediated priming effect indicates that we are tapping into something more than phrasal associates (because the mediated prime never actually occurs with the target). Another consideration is that the stimuli have specific referents (e.g., the title of a movie or television show). In this sense, these items might be considered “unitized” through their referent rather than completely unrelated. However, the short SOA, relatively low proportion of newly associated trials, and the mediated priming again suggest the involvement of semantic/ conceptual level information as well. The mediated priming effect, in particular, supports the idea that, even if the newly associated prime-target pairs are unitized, the individual items in the pair can result in independent activation of one another.

As reviewed earlier, prior evidence of automatic priming for episodic associations has been inconsistent (Durgunoglu & Neely, 1987; Neely & Durgunoglu, 1985). Of course, building episodic associations within single or even multiple experimental contexts (as in earlier experiments) would pale in contrast to the lifelong experience of more traditional semantic pairs (e.g., *library-BOOK*). Here, we capitalized on naturally occurring associations in political discourse or pop culture. An important advantage of these stimuli is that no extensive study phase is required within the experiment, thereby reducing intentional strategies, and making the comparison to more standard “semantic” priming stimuli possible. Exposure to the prime-target pairs occurred in a variety of contexts, across time, and in multiple modalities and media (e.g., radio, internet). The mnemonic benefits of spacing and encoding variability are well documented (Crowder, 1976). Using these naturally occurring associations provides strong evidence supporting the flexibility in the underlying networks that support “semantic” priming (Pecher & Raaijmakers, 2004). If conceptual representations were stored in semantic systems in flexible and non-abstracted forms, one would expect recent experience or novel contextual associations to have persistent effects on the representation of a concept. However, if the representations were abstracted and amodal, they should be more static. Clearly, the present results are more consistent with accounts that underscore the flexible and adaptive nature of semantic memory.

In feature-based models of semantic priming, the representation consists of sets of primitive features, which combine to give rise to concepts (e.g., McRae, 2004; McRae, Cree, Seidenberg, & McNorgan, 2005). The more features are shared between two concepts, the more similar they are. When the prime is presented, its features are activated. If the target has some of the same features, target recognition will be faster. While these models can readily explain priming for semantic coordinates that do not share lexical-level associations, they have more difficulty explaining priming for new associations when the prime-target pairs have little feature overlap (e.g., *guitar-hero*). Thus, such models would predict little or no facilitation, or at the very least strongly reduced priming compared to “semantic” associates. Of course, there might be episodic features that help bind representations together due to co-occurrence. So, feature models may ultimately be able to accommodate the present results, although further specification of the nature of the features is required. Clearly, traditional notions of primitive semantic features have difficulty accommodating these results.

In this light, the results are consistent with associative accounts of priming (Hutchison, 2003): Co-occurrence of unrelated words in naturalistic environments gave rise to relatedness effects similar to those that support priming from pre-existing, semantic relationships. Because the new associations shared few, if any, features with the targets, lexical level co-occurrence was the primary driving mechanism (see Balota & Paul, 1996; Hutchison & Balota, 2005).

Some models of semantic memory make explicit predictions concerning how new information might become incorporated into a pre-existing semantic structure. Among these are the high-dimensional semantic space models such as Landauer and Dumais’ (1997) LSA and Burgess and Lund’s (1998) Hyperspace Analogue to Language (HAL), and the recent combination of the two models called BEAGLE (Jones, Kintsch, & Mewhort, 2006). These models emphasize the role of experience with the language as the basis for the acquisition and organization of semantic memory. Although the models differ in the implementations and details, they share the assumption that concepts that occur in similar contexts (e.g., *car, vehicle*) have similar representations in memory and that repeated co-occurrence in similar contexts will increase the similarity and the relatedness among items. These models derive measures of semantic similarity from large-scale databases, so, as long as they were based on recent and contextually relevant language databases, they might predict priming for new associations. A critical factor in these models, however, is that the similarity between items is based on a measure of global co-occurrence (i.e., the fact that each word in the pair occurs with the same other words in various contexts) rather than local co-occurrence (i.e., the co-occurrence of two items with each other). Thus, a necessary assumption is that the primes and targets would have to occur in similar contexts for similarity to emerge. Because these models can accommodate associative priming effects, it seems plausible that new associations, over time, would give rise to similar effects. However, these accounts might have some difficulty explaining the equivalent priming for newly associated and semantic pairs. Specifically, how can recent experience and exposure to pairs of concepts have the same relative influence as a lifetime of linguistic experience? Because the semantic relations are laid down earlier and more frequently across the lifetime, these models should predict *more* priming for semantic than new associations. Extra-linguistic factors (i.e., the newly associated pairs are rich in emotional salience, occur in a multitude of contexts and modalities, and may have more personal relevance.) might be able to account for the equivalent strength of the traces. In addition, the newer associations might be equivalent in strength to the pre-existing ones because of recency factors: Compared to the pre-existing associations, new relations might be less subject to decay or interference, even if they are of lower overall frequency. Thus, these models would need to include extra-linguistic influences and/or measures of decay and interference to account for variability in associations.

To examine the role of pair frequency and local co-occurrence, for the 70 prime-target pairs included in the analyses we computed a measure of dyad frequency using the Google frequency norms, which contain English word n-grams (i.e., clusters of words ranging from unigrams, or single tokens, to five-grams, or sequences of five words in a particular order). The frequency of tokens (i.e., individual words) or combinations of tokens is based on text included in publicly accessible websites through January of 2006. This measure thus provides an estimate of usage similar to when the current study was conducted. The log-transformed frequency estimates indicated that the new associate pairs did occur more frequently ($M = 5$) than the semantic pairs ($M = 2.8$), $t(69) = 9.3$, $p < .001$, confirming that the new pairs do have higher local co-occurrence than semantic pairs. However, the dyad frequency measure did not predict priming effects for either new associates ($r = -.1$, $p = .39$) or semantic primes ($r = .15$, $p = .23$), suggesting that simple local co-occurrence was not driving the effects, although it should be noted that the dyad frequency measure we computed only captures immediately adjacent word pairs and is directional in nature. Perhaps a more thorough examination of co-occurrence within larger units (e.g., within a five token window) would be more a sensitive measure and could predict priming effects. However, for present purposes, these results support our argument that the priming for new associations is not simply due to unitization or phrasal associations.

In sum, these results provide compelling evidence that a standard measure of semantic memory structure (priming in lexical decision with a short SOA) is quite sensitive to words that primarily share recent associations in the media. This finding is most consistent with the notion of an ever-changing storehouse of knowledge that readily incorporates new associations of previously unrelated concepts and points to the flexible and dynamic nature of semantic knowledge. One implication of these results is that the definition of “related” and “unrelated” words is far from static and researchers need to attend to the possibility that events in the media can strongly influence the strength of associations between items.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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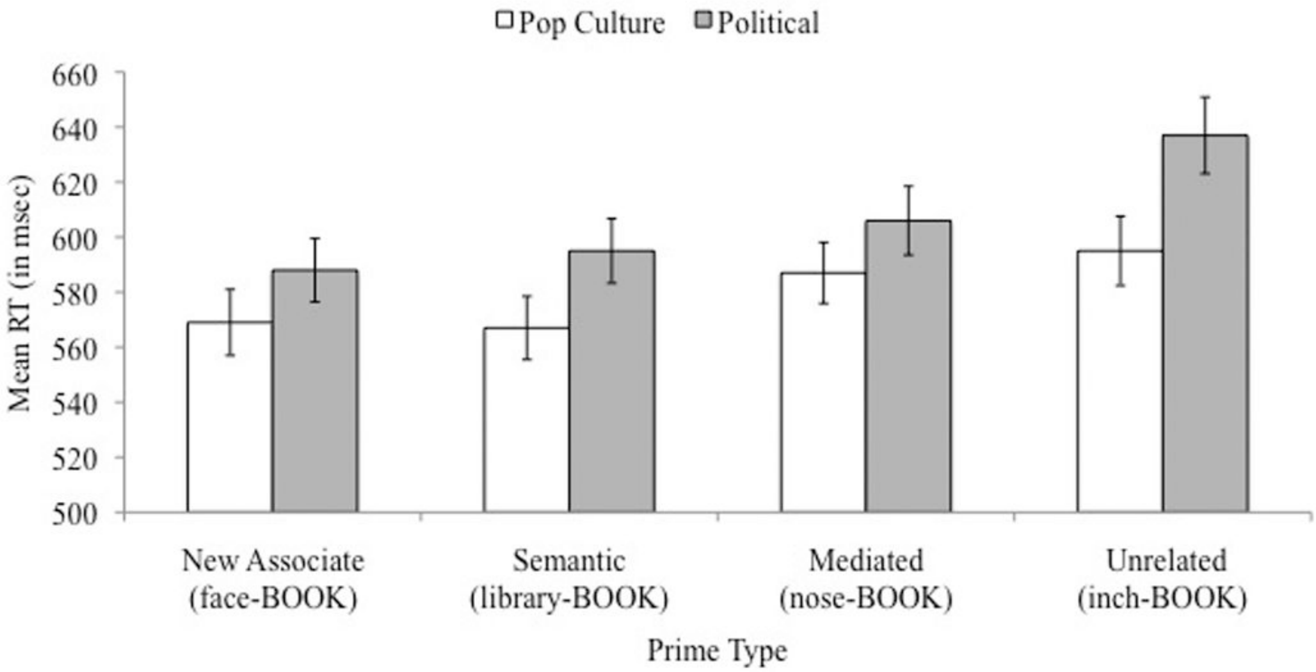


**Figure 1.**
Average response latency as a function of prime type and target type.

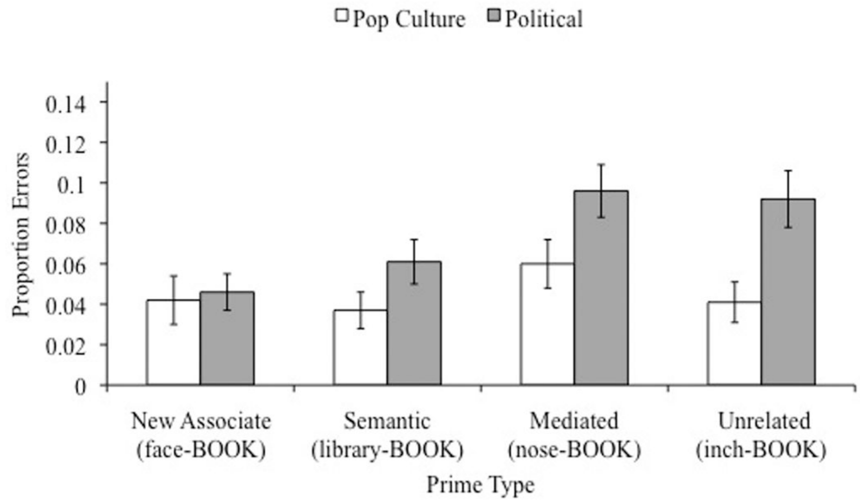


**Figure 2.**
Error rates as a function of prime type and target type.

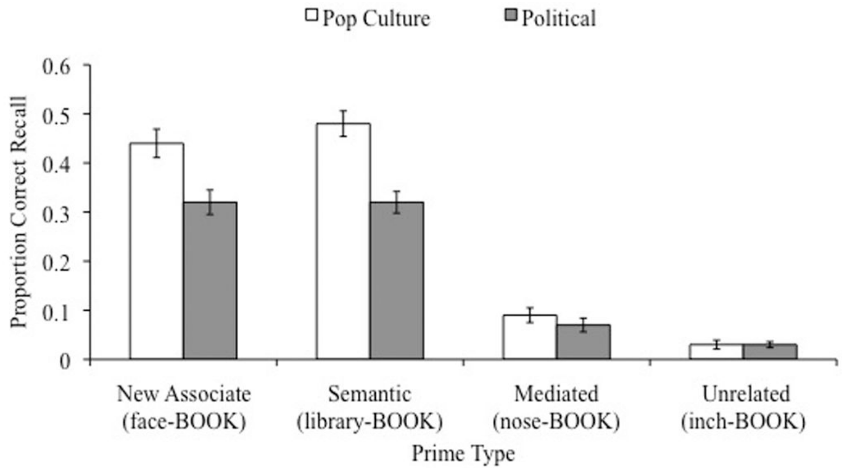


**Figure 3.**
Average correct recall rates as a function of prime type and target type.

**Table 1**

Lexical Characteristics of Targets

| Target Type | Length | Orthographic N | HAL Log Frequency |
|---|---|---|---|
| Pop Culture | 5.75 (2.01) | 6.63 (7.06) | 9.55 (1.87) |
| Political | 6.82 (2.44) | 3.93 (5.64) | 9.70 (1.46) |
| Nonwords | 6.28 (1.62) | 5.21 (4.82) | |

**Table 2**

Lexical Characteristics of Primes and Measures of Associative Strength between Primes and Targets

| Prime Type | Length | HAL LOG frequency | Ortho N | Mean RT[1] | Mean Accuracy[1] | LSA Similarity | FAS[2] | FAS-N[3] |
|---|---|---|---|---|---|---|---|---|
| Mediated | 6.1 | 9.1 | 4.3 | 645 | .97 | .11 | 0 | 0 |
| New associate | 5.7 | 9.7 | 5.3 | 629 | .98 | .14 | .003 | .08 |
| Semantic | 6.2 | 9.1 | 4.8 | 645 | .97 | .39 | .28 | .21 |
| Unrelated | 6.1 | 9.3 | 5.7 | 641 | .97 | .07 | 0 | 0 |

[1]Value from ELP

[2]Value from Nelson et al. (1998) Free association norms

[3]Value from norming study