The activation–selection model of meaning: Explaining why the son comes out after the sun

DAVID S. GORFEIN

University of Texas, Arlington, Texas

VINCENT R. BROWN

Hofstra University, Hempstead, New York

AND

CHRISTIAN DEBIASI

Adelphi University, Garden City, New York

The activation–selection model (ASM) of determining the meaning of an ambiguous word is unique in that it is able to account for the long-term effects of meaning selection without an explicit mechanism for suppressing the representation of the nonselected meaning. The model assumes that a meaning is selected when a threshold number of attributes associated with that particular meaning are activated. When a meaning is selected, the ASM assumes that the weights of the attributes that are associated with the chosen meaning are increased. This two-phase process (transient activation followed by long-term weight changes) provides a mechanism by which meaning selection at one time can affect meaning selection at a much later time. The ASM can explain the results of the presently reported experiments, in which the meaning selected for a homophone presented in an unbiased context is affected by multiple previous presentations of the homophone in different contexts. In particular, although participants who are initially oriented toward the secondary meaning of a homophone show an increased proportion of dominant responses when next primed by the dominant meaning of the homophone, the proportion of dominant responses decreases to below baseline levels when the homophone is later presented in a neutral context, indicating the lasting influence of the initial secondary meaning context.

Prior to the late 1980s, research on the semantic ambiguity of single words had focused on the process of lexical access. Although various researchers favored different forms of access (exhaustive, context-dependent, ordered; see Simpson, 1984, for a review), the common tendency was to treat each occurrence of an ambiguous word as an independent event. A more recent trend in the ambiguity processing literature has been to examine the effect of the repetition of an ambiguous word in situations in which the appropriate meaning of the ambiguous word varies across occurrences. Changing the contextually appropriate meaning of a homograph across trials in a task can result in large decrements in performance, such as when an individual is required to decide if *seal* is related to *walrus* after earlier deciding that *seal* is related to *glue*. Maintaining the same meaning context generally facilitates performance, for example, deciding that *seal* is related to *walrus* shows a benefit if earlier the participant had decided that *seal* is related to *dolphin* (for reviews of this literature see Gorfein, 2001a; Simpson & Kang, 1994). Although Simpson and Kang (1994) have argued that in normal discourse, words are often repeated and therefore the long-term effects of processing each occurrence of an

ambiguous word need to be understood, surprisingly little theoretical work has addressed the issue.

Simpson and Kellas (1989) reported that once a homograph had been used as a prime for a word related to one of its less common meanings (e.g., *bank* as a prime for *river*), a target word related to the dominant meaning of the homograph (e.g., *bank* followed by *money*) showed a prolonged naming time in comparison with a neutral baseline, even after a lag of 12 intervening trials. Simpson and Kang (1994) concluded that “Processing one meaning of a homograph and responding to that meaning results in the *active and specific inhibition of competing meanings*” (p. 376, italics added), thus extending the idea of transient suppression of the nonselected meaning of an ambiguous word to a longer term inhibitory process that endures over a period of time. From a theoretical perspective, Simpson and Kang (1994) suggested that the observed decrement is a form of negative priming (see, e.g., Tipper, 1985), but did not present a specific model. Simpson and Adamopoulos (2001) reemphasized the inhibition interpretation of negative priming (but cf. Neill & Valdes, 1996, for a noninhibitory explanation of negative priming).

D. S. Gorfein, dgorfein@yahoo.com

Gernsbacher, Robertson, and Werner (2001) reported that for sentence sensibility judgments, there is a large cost of changing the meaning of a homograph on consecutive sentence trials. Participants are slower and less accurate in deciding that the sentence *She blew out the match* made sense after deciding that the previous sentence, *She won the match*, was sensible. However, in contrast to the cost found in the naming task used by Simpson and Kang (1994) over 12 intervening trials, Gernsbacher et al. found that after four intervening sentences, there was no cost associated with the meaning change. The duration of the decrement associated with meaning change appears to vary with the way that the local meaning context is presented, and perhaps also with the methodology used to assess the effects. Gernsbacher et al. suggested that their data could not be accounted for by models that do not involve mutual inhibition or suppression between alternative meanings (such as the episodic-retrieval model of Neill & Valdes, 1996).

Gernsbacher (1990) proposed a *structure-building* model as an explanation of the immediate effects of processing words in a sentence context. This model includes active suppression of inappropriate-to-the-context meanings during initial processing of a homograph, and a signal transmitted by activated "memory cells" that promotes the facilitation of related-to-the-context interpretations. Gernsbacher and St. John (2001) presented a *connectionist* model of meaning selection in which top-down suppression is a major component. The model includes four levels of representation, each of which has moderately inhibitory feed-forward connections to the immediately subsequent layer and strongly inhibitory feedback connections to the immediately prior layer. Thus, at each stage of sentence processing, alternative meaning representations are assumed to directly inhibit each other. The interpretation of a sentence corresponds to the stable pattern of activations achieved by the network after each word in the sentence has been processed in sequence. Gernsbacher et al. (2001) argued that the structure building framework extends naturally to homograph repetition effects.

Two other recent models of ambiguity processing also postulate inhibition between competing meanings of ambiguous words (Erickson & Allred, 2001; Twilley & Dixon, 2000). Twilley and Dixon (2000) explicitly reported that their *independent activation* model cannot reproduce the results of studies like those of Simpson and Kang (1994) that show decrements due to meaning change over the lag of several intervening trials. They suggested a change in the resting levels in their model as a possible solution, but have not explored the viability of this solution. In reviewing the homograph priming literature, Erickson and Allred (2001) concluded that "To our knowledge, no model in the literature, including ours, has the ability to account for long-term priming data."

The *reordered access* model described by Rayner and his colleagues (e.g., Duffy, Kambe, & Rayner, 2001; Duffy, Morris, & Rayner, 1988) is a model that does not include explicit suppression and/or inhibitory mechanisms. The reordered access model was originally proposed to account for the interactive effects of disambiguating context and relative dominance of homograph meanings on reading fix-

ation times in what is known as the *subordinate-bias effect* (Duffy, Morris, & Rayner, 1988).¹ Duffy et al. (2001) employed the constraint satisfaction architecture of Spivey and Tanenhaus' (1998) competitive integration model to create a computational version of the reordered access model. Two sets of constraints are employed: the balance of the homograph, which is a measure of the relative frequency of alternative meanings, and the weight of the semantic context. These constraints combine to produce a candidate meaning for the homograph. The weights of these "provisional interpretations" feed back to the constraint representations, resulting in the re-weighting of both constraints. The re-weighting continues until a threshold is reached and a meaning is selected. The number of cycles to reach threshold determines the reading time for each combination of homograph and context. The reordered access model is not formulated to account for long-term effects of meaning selection over many intervening trials or long time intervals, but we believe it could be modified to do so. Although not explicitly stated by the authors, the re-weighted meaning frequency values could be employed in a subsequent encounter with the homograph, thus producing a long-term effect of choosing a particular meaning. (Since the model is designed to account for processing times, it would also have to be modified to account for response proportions.)

Another recent model of ambiguity processing, the *activation-selection* model, or ASM (Gorfein, 2001b), was specifically designed to explain the long-term effects of meaning selection without postulating inhibition between meaning representations. A two-stage process—transient activation followed by long-term weight changes in meaning representations—provides a mechanism by which meaning selection at one time can affect meaning selection at a much later time, even across intervening occurrences of an ambiguous word. The ASM is based on an earlier model (Gorfein, 1987; Gorfein & Bubka, 1989) that assumes that the meaning of a word is based on a set of weighted attributes (Bower, 1967). An attribute is a hypothetical construct for representing the various (semantic, graphemic, acoustic, etc.) features associated with a word. All words have many nuances, and the activation of different subsets of attributes at different times and under different conditions is one way that the multiple senses of a word could be represented. During each encounter with a word, a sufficient number of attributes are activated to meet task demands (different tasks may require activation of different numbers of attributes). In the absence of a biasing semantic context, the probability of activating any single attribute is a function of its current weight. The current version of the model focuses on changes in attribute weights when a meaning is selected for an ambiguous word. Although transient activation of an attribute decays fairly quickly to a resting level, the weights of active attributes representing the selected meaning are increased. The result of the process of meaning selection is an altered (re-weighted) configuration in which the selected meaning becomes more available and, as a consequence, unselected meanings become relatively less available.

An analogous process of long-term changes in connection weights was utilized by Becker, Moscovitch, Berh-

men, and Joordens (1997) in their *attractor neural network* model to account for long-term semantic priming effects. Note that no inhibitory network connections were used in the Becker et al. model. At that time, few studies showing long-term effects of the ambiguity resolution existed in the literature, so the model was not tested with ambiguous words, and it is possible that some form of inhibition between meaning representations would need to be added to the model account for the effects of priming ambiguous words (Steve Joordens, personal communication, February 5, 2007). Note also that two-stage models of the formation of memory representations—short-term activation followed by longer term weight changes—are not new, going back at least to Hebb's (1949) notions of reverberatory circuits and cell assemblies.

According to the ASM, initial processing of a word activates a small number of the more highly weighted attributes of the word; then, additional attributes are activated as needed to meet the requirements of the task within the processing time available. The *set principle* is the assumption that processing a word in the context of an already active attribute (e.g., from a prime word or biasing context) results in the selection of that attribute if the current word possesses it. When an ambiguous word is preceded by a related word, active attributes of the prime word will contribute to the determination of the ambiguous word's meaning. The success of the prime depends on both the overlap of the attributes associated with the prime and the attributes associated with the ambiguous word, and the weights of the attributes associated with other meanings of the ambiguous word.

An impetus for the present study was the study by Gorfein, Berger, and Bubka (2000) in which participants were asked to produce free associates to homographs on three separate occasions. The context for a homograph was manipulated by presenting a word related to one meaning of the homograph (either dominant or secondary) just prior to the homograph on its first occurrence, and a word related to a different meaning of the homograph just prior to its second occurrence. On its third occurrence, the homograph was presented following a word unrelated to either meaning. In three experiments, this procedure resulted in a greater mean priming effect on the first occurrence of the homograph (.17 above baseline) than when the homograph was primed by an alternative meaning at second exposure (.05 above baseline), indicating a lingering influence of the first prime. Later, in the unrelated context, performance was significantly different from baseline by .05 in the direction of the first primed meaning. This *primacy effect* was obtained even when the lag between the primed second occurrence and the unbiased third occurrence was as few as three intervening items.

The primacy effect obtained by Gorfein et al. (2000) does not appear to be predicted by any published model of ambiguity processing. With the assumption that the inhibition of the nonselected meaning carries over across presentations of an ambiguous word, the variety of suppression and/or inhibitory mechanisms postulated in the literature can account for the reduction in priming that is obtained when the second presentation of the homograph occurs in a meaning context different from that of the first

presentation. However, the same mechanism would seem to predict that the inhibition of the unselected meaning during the second occurrence of the homograph will be carried over and will thus lead to a lower-than-baseline proportion of responses following the unbiased third presentation of the homograph (or if suppression is transient, prior experience would have no effect on the third occurrence of the homograph). The primacy effect is therefore a major focus of the present article.

We report a set of experiments designed to differentiate between models like ASM that postulate long-term facilitation of selected meanings, but no suppression or inhibition of nonselected alternatives and models that require suppression/inhibition mechanisms to account for the costs associated with changing the appropriate meaning of an ambiguous word across occurrences. Specifically, the present study was designed to achieve the following conditions: an initial biasing of an ambiguous word—in this case, a (heterographic) homophone (e.g., *sun-son*)—toward the non-dominant meaning (*son*) (Phase 1), after a reasonable delay (5–10 min), the subsequent placement of the homophone in a context intended to prime its dominant meaning (*sun*) (Phase 2) and, finally, a test of the lasting effect of these contrasting conditions in an unbiased context (Phase 3).

In two experiments, we extended a technique used by Gorfein and Walters (1989) in which word associations to, and the spelling of, homophones (e.g., *sun-son*) were shown to be influenced by a task in which participants were required to remember the location of pictures on a page. Pictures were placed in each quadrant of a page depicting homophones that were given an auditory label (e.g., *son, hare, nun, tale*). In the present study, we used a combination of words and pictures as to-be-remembered items. A sample stimulus page is shown in Figure 1.

In the orienting phase (Phase 1) of the present experiments, participants were asked to remember both the location on the page and the form of presentation (picture or word). It seemed likely that the pictures would result in greater changes in the internal representation of the homophones than presentation of the written words. Specifically, many of the pictures we created were complex (see Figure 1), and some depth of processing is necessary to see why the picture represents the word given as its auditory label. In almost every case, the pictures could be labeled with many words (e.g., the picture of the nun in Figure 1 could be described by the homophones *pray* and *holy*, as well as by many nonhomophones, e.g., *devout, saint*, etc.). The ambiguous auditory stimulus (homophone) presented with the ambiguous picture requires the participant to disambiguate the internal representations by selecting the attributes of the homophone needed to make sense of the label for the picture. On the other hand, the auditory presentation of the homophone (e.g., “nun”), along with the same homophone in its unambiguous written form (*nun*) would seem to require less processing. Therefore, the presentation of the written word should result in a minimal activation of attributes, whereas the more difficult picture is expected to activate more attributes and, as a consequence, a greater number of attributes will have increased weights. Furthermore, the ASM posits that the greater the change in

Figure 1. A sample page from the Phase 1 stimulus booklet. From top left to bottom right: *son, hare, nun, tale*. This figure is reprinted with permission from D. S. Gorfein & C. M. MacLeod (Eds.), *Inhibition in Cognition*. Copyright 2007 by the American Psychological Association.

the current representation of a word, the less likely it would be for the processing of a subsequent occurrence of the word to return the representation to its initial form. This is because weight increases in a greater number of attributes associated with one meaning of an ambiguous word would require a greater number of presentations of the word in an alternative meaning context to restore the weights of the attributes to their initial relative balance.

Experiment 1 allowed us to directly assess the effects of the orientation manipulation (words vs. pictures) by comparison with the baseline responses and test the hypothesis that pictures would have the greater influence on subsequent spelling or word-association responses. Experiment 2 utilized a three-phase procedure similar to that of the Gor-

fein et al. (2000) study. In Phase 1, the picture-location task designed to bias the homophones' secondary meanings was administered. In Phase 2, the homophones were immediately preceded by words that were chosen to bias their dominant meaning. In Phase 3, the homophones occurred in an unbiased semantic context. As a control condition, some homophones were not presented in the orienting phase of the experiment and occurred only twice, first in the dominant meaning context (Phase 2 of the experiment) and second in a neutral context (Phase 3). Phase 2 of this experiment allowed us to look at the influence of the earlier orienting task on the priming effect of a local context (a word related to the dominant meaning of the homophone). Most crucially, Phase 3 allowed us to assess the long-term

Table 1
Design of the Study

	Phase 1		Phase 2	Phase 3
	Secondary Meaning Picture/Word Orienting Task	Word-Association/ Spelling Test	Dominant Prime (Word-Association/ Spelling Test)	Neutral Prime (Word-Association/ Spelling Test)
Experiment 1	X	X		
Experiment 2	X		X	X
Experiment 2 (Control condition)			X	X

Note—Experiment 1 provides a direct measure of the effect of the orienting tasks. Experiment 2 measures the long-term effects of the orienting tasks. Most importantly, Phase 3 measures whether the carryover effects of a dominant prime (presented in Phase 2) are mitigated by the earlier orienting toward the secondary meaning (presented in Phase 1).

effect of prior experience on the homophone presented in a neutral context. The question is whether the effects of secondary meaning orienting in Phase 1 will still be apparent following dominant meaning priming in Phase 2. The overall design of the study is given in Table 1.

Note that there was no direct measurement of the effects of the Phase 1 picture-word orienting task in Experiment 2. This was to guard against the possibility that an additional presentation of and response to the homophones would additionally influence future encounters with the homophones, complicating the interpretation of the effects of the orienting phase on the subsequent phases. Indeed, the ASM assumes that each and every encounter with an ambiguous word in which a meaning is selected results in an altered representation. Thus, the direct effects of the orienting task were measured separately in Experiment 1 with different participants.

We derived theoretical predictions for performance in the unbiased Phase 3 context. Models that postulate a transient suppression of the inappropriate-to-the-context meaning (e.g., Gernsbacher & St. John, 2001) predict little carryover from Phase 1 (secondary meaning context) to Phase 2 (dominant meaning context), and essentially baseline performance in Phase 3 (unbiased context). Models that postulate that the inhibition of the nonselected meaning persists across trials would seem to predict some difficulty in switching meanings between Phase 1 and Phase 2, but more critically, to the degree that the dominant meaning of the homophone is selected in Phase 2, that dominant choice should persist into Phase 3 (since the secondary meaning would have been inhibited in Phase 2 and would continue to be inhibited in Phase 3) (e.g., Simpson & Kang, 1994).

In contrast, ASM predicts a small carryover of the Phase 1 experience to Phase 2 in the direction of the Phase 1 prime (carryover effects are reduced by the fact that the disambiguating context precedes the homophone in Phase 2, which allows the local context to set the attributes of the homophone representation). Critically, ASM predicts that performance in Phase 3 will show more secondary responses than were made in the baseline measurement, indicating a long-term carryover of the secondary bias induced in Phase 1. Furthermore, this primacy effect should be greater for homophones that were presented as pictures in Phase 1: Homophones that are associated with the pictures in Phase 1 should show a greater proportion of secondary responses in Phase 3

than homophones that are associated with their written representations in Phase 1.

Although the present study is an extension of Gorfein et al. (2000), it differs in a number of important ways. The use of the expanded Gorfein and Walters (1989) picture/word orienting task instead of a more standard semantic priming manipulation makes the local context in Phase 1 of the present study entirely different from that in the critical Phase 3: Both the stimuli serving to prime the meaning of a homophone and the required response differ. Because task similarity is an important contextual variable influencing retrieval (Morris, Bransford, & Franks, 1977; Roediger & Blaxton, 1987), the change of response from memory for location in Phase 1 of Experiment 2 to word association or spelling in Phases 2 and 3 makes it unlikely that in Phase 3, participants will episodically retrieve any implicit associates that may have been formed in Phase 1 (a potential confound in the Gorfein et al., 2000, experiments that is further discussed in Note 2). Indeed, the use of homophones instead of homographs means that the meaning of a word was primed in the Phase 1 picture condition without the participant ever having seen either graphemic form of the word, knowledge of which is of course required for the written spelling responses in Phases 2 and 3.

Baseline Measurements of Word-Association and Spelling Responses

We first established baseline responding to the items that we employed in the two subsequent experiments. We chose two dependent tasks that could be implemented with the same auditory stimuli. One of these tasks, word association, required participants to give the first word to come to mind in response to each word presented via audiotape, whereas the second task, spelling, required the participant to spell each word presented on the audiotape. Britton (1976) speculated that homophone spelling is a direct indicator of meaning. To the degree that Britton's view is correct, we would expect to obtain equivalent performance in the word-association and spelling tests. This would translate into a substantial correlation between the spelling and word-association performance.

Method

Participants. Thirty-two Adelphi University students participated in this study to fulfill a course requirement. Half of the participants were randomly assigned to the spelling condition, and the other half were assigned to the word-association condition.

Materials. Forty-two (heterographic) homophones were selected from the Adelphi norms (Gorfein & O'Brien, 1985). The normatively most-frequent spelling of the homophone was labeled the *dominant* spelling. The second most frequent spelling was labeled the *secondary* spelling. The selected homophones met the constraint that whatever the normative frequency of the secondary spelling, more than 75% of the participants from the Adelphi norms could spell the word appropriately within a secondary context. For example, one homophone was spelled *air* out of context by 100% of the Adelphi norm participants, but nevertheless, given the context of inheritance, better than 75% of the Adelphi norm participants produced the appropriate contextual spelling, *heir*. Based on the Adelphi norms, the 42 homophones employed in the present study were spelled in the secondary direction 24% of the time when presented out of context, but when presented with a cue associated with the secondary meaning, they were spelled in the secondary direction 94% of the time. The 42 homophones used in the present study are listed in Appendix A.

These 42 homophones and 23 nonhomophonic filler words were tape recorded in random order. Words were read at a rate of one word every 6 sec, and each word was preceded by its number in the sequence.

Procedure. Participants were tested individually in a small laboratory cubicle. They were supplied with a numbered answer sheet. Participants in the spelling group were told simply to write each word they heard alongside its number on the answer sheet. Participants assigned to the word-association condition were asked to write the first word to come to mind on the appropriate line of the answer sheet.

Results and Discussion

In this and the subsequent experiments, each item was scored as to which meaning of the auditory stimulus was indicated by the participant's response. In the case of spelling, the participant's written response was tallied except for a small proportion (less than 1%) of trials in which the response indicated that the participant had misheard the tape—for example, writing *pull* instead of *poll* or *pole*. For word association, two experimenters independently classified the written responses as to which meaning they represented. In the event of a rare disagreement (less than 2% of the responses), a third rater was employed and the majority decision prevailed. The proportion of responses in the most frequent (dominant) direction was computed for each homophone in each condition. The mean dominance score for spelling was .725, and for word association, it was .756. These values are used as the baseline comparison for Experiments 1 and 2.

Across words, the correlation between the proportion of dominant responses for the spelling and word-association tests was .77. In short, the two techniques seem to be measuring closely related underlying processes, and the results are supportive of Britton's (1976) suggestion that homophone spelling is a direct indicator of meaning.

In this baseline study, the scored proportion of dominant responses was .50 or below for seven of the homophones that were originally indicated to be dominant in the Adelphi norms (Gorfein & O'Brien, 1985). However, we chose to continue to use those items because—as discussed previously—the normative data gave us the confidence that the participants would be able to provide the correct spelling when the specific meaning of the homophone was indicated. Nevertheless, in each of the two following experiments, in addition to analyzing the full data set, we also analyzed the data from only the 35 homophones whose proportion of dominant responses in the baseline

study was above .5. In no case did the analyses indicate different patterns of statistical significance between the full 42-item set and the 35-item subset (although the mean response proportions differed, of course). Appendix A reports the results for each individual homophone, with the seven homophones whose baseline proportion of dominant responses was at or below .5 marked with an asterisk.

EXPERIMENT 1

Effect of the Location Memory Orienting Task

In the orienting phase of Experiments 1 and 2, participants were asked to remember both the location on the page and the form of presentation (picture or word) of the visual item accompanying each homophone. The direct effect of this orienting task was measured in Experiment 1 by having participants subsequently respond by spelling or providing an associate to the homophones (see Table 1). As described previously, we hypothesized that the pictures would result in greater changes in the internal representation of the homophones than the written words. This should result in a greater proportion of secondary responses in a subsequent spelling or word-association test to homophones initially accompanied by a picture than to homophones initially accompanied by a written representation.

Method

Participants. Forty-eight Adelphi University students participated in this study and were assigned to either the spelling or word-association condition in a counterbalanced order. None of the participants in Experiment 1 had participated in the baseline study.

Materials. The 42 homophones presented in the baseline study were used. The homophones were randomly divided into two subsets of 21 items. Two stimulus booklets of 42 items each were created. One booklet was created by assigning one of the two subsets of items to the picture condition and the second subset to the word condition. The second booklet reversed the assignments (if a homophone was represented by a picture in one booklet, it was represented by a word in the other booklet, and vice versa). Thus, across the two booklets, each homophone appeared once as a printed word and once as a picture meant to illustrate that word. Both pictures and printed words represented the normative secondary meanings/spellings of the homophones. Homophones were randomly assigned four to a page, one homophone as either a picture or a word in each quadrant of the page, as shown in Figure 1. Two filler homophones were added to each booklet, one as a word and one as a picture, to fill an 11-page booklet.

Procedure. Participants were individually tested in a small laboratory cubicle. They were instructed that they were to participate in several studies. In the first of these, they were to learn the form and location of some items presented in a booklet. They were told that each page of the study booklet would contain four items, a mixture of pictures and words, and that the experimenter would read aloud each word and name each picture as they went through the booklet. For example, for the page represented in Figure 1, the experimenter would read "son," "hare," "nun," "tale." The participant was asked to point to each item as the experimenter labeled it and to try to remember whether the item was a picture or a word and in which quadrant on the page the item was presented. The experimenter illustrated the procedure with a one-page example containing nonhomophonic words and pictures. After the practice trial, the experimenter clarified the instructions and proceeded to go through the booklet in order, naming the items on each page from Quadrant 1 to Quadrant 4. The test phase followed immediately, and the experimenter read each of the 44 words in a predetermined random order. The participant re-

Table 2
Mean Proportions (and Standard Deviations) of Dominant Spelling and
Word-Association Responses to Homophones Presented As Pictures
or Words in the Phase 1 Orienting Task

Phase	Picture		Word		None		<i>M</i>	Baseline
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>		
Phase 1 (Experiment 1)								
Spelling	.503	.141	.609	.136			.556	.725
Word Association	.534	.134	.618	.097			.576	.756
Mean	.519		.613					.741
Phase 2 (Experiment 2)								
Spelling	.711	.141	.724	.163	.798	.122	.744	
Word Association	.769	.098	.782	.095	.812	.128	.788	
Mean	.740		.753		.805			
Phase 3 (Experiment 2)								
Spelling	.579	.126	.676	.176	.749	.127	.668	
Word Association	.639	.154	.743	.123	.783	.156	.722	
Mean	.609		.710		.766			

corded responses in that order by checking the appropriate response on their answer sheet. Participants were supplied with numbered answer sheets containing spaces for a location response and a place to indicate whether the stimulus had been a picture or word. The top of the answer sheet contained the outline of a page with the numeral 1 in the top left quadrant, the numeral 2 in the top right quadrant, the numeral 3 on the lower left, and the numeral 4 at the lower right. This part of the experiment took approximately 10 min to complete.

Following the completion of the memory task, participants were given instructions to listen and respond to a list of words presented by audiotape. The same audiotape used in the baseline assessment was used. The tape contained each of the homophones from the booklet, presented in a random order. Half of the participants for each booklet were told to write each word they heard on the answer sheet provided (spell condition), whereas the remaining participants were told to write the first word to come to mind on the appropriate line of the answer sheet (word-association condition). The experimenter left the room while the participant responded to the tape. This part of the experiment took approximately 6.5 min to complete. Thus, the mean time from the initial presentation of an item in the orienting task to its test presentation was slightly longer than 8 min.

Results and Discussion

Scorers were blind to the orienting condition (picture-word) of the items being scored. Each item was scored as to which meaning of the auditory stimulus was indicated by the participant's response. As occurred in the baseline study, for the spelling test, the participant's written response was tallied except for a small proportion of trials (again, less than 1%) in which the response indicated that the participant had misheard the tape. For word-association responses, two scorers independently classified written responses on the basis of which meaning they represented. In the rare event of a disagreement, a third rater was employed, and the majority decision prevailed (as was the case in the baseline study, disagreements occurred for less than 2% of the responses). For convenience of comparison across the phases of the two experiments, we report the proportion of items that were classified as responses indicating the normative dominant meaning/spelling of the homophone.

Table 2 reports the mean proportion of responses in the dominant direction for each condition. These results, collapsed across type of test, are also graphed as Phase 1 in Figure 2. Because the stimuli in the orienting task represented the secondary meaning of the homophones, lower scores in-

dicate greater priming. To the extent that priming occurred, the proportion of dominant responses would be less than the baseline proportion of .725 for the spelling task and below the baseline proportion of .756 for the word-association task. Separate analyses of variance were conducted using participants and items as the source of error variance. For all analyses, Type I error rates were set at .05.

A mixed-model ANOVA tested the effect of orienting format (picture vs. word) as a within-groups effect and type of test (spelling vs. word association) as a between-groups variable. There was no significant difference between the proportion of dominant responses obtained under the word-association test (.576) and the spelling test (.556) [$F < 1$ for participants, and $F(1,41) = 3.59$, $MS_e = 0.092$, $p = .07$, for items]. The test type by orienting format interaction was also not significant ($F < 1$) for both participants and items. Pictures were more effective in priming the secondary meaning of the homophones, producing a smaller proportion (.519) of responses in the dominant direction than did word stimuli (.613) [$F(1,46) = 12.29$, $MS_e = 0.0178$, for participants, and $F(1,41) = 8.36$, $MS_e = 0.042$, for items].

Additional *t* tests using variability between items as the source of error were conducted to compare the proportions of dominant responses obtained in Experiment 1 to the baseline. Collapsing across form of test, the proportion of dominant responses to both the picture and word conditions differed significantly from baseline by two-tailed *t* tests, indicating positive priming for both pictures [$t(41) = 6.56$] and words [$t(41) = 5.27$].

There was a significant priming advantage for pictures, as expected. An important feature of this finding is that this advantage manifested itself in test conditions that occurred several minutes after the initial priming manipulation, indicating a stable change in the interpretation of the homophones, an effect not predicted by most models of ambiguity processing.

The long-term carryover effects of the Phase 1 picture-word location orienting procedure across multiple presentations of the homophones were explored in Experiment 2. In Experiment 2, the initial assessment of the Phase 1 orienting task was omitted, since the addi-

Figure 2. Proportion of dominant responses to homophones as a function of form of presentation in the Phase 1 orienting task. The data are averages of the word-association and spelling responses. The horizontal line represents the baseline performance of .74. Error bars indicate one standard error of the mean. This figure is reprinted with permission from D. S. Gorfein & C. M. MacLeod (Eds.), *Inhibition in Cognition*. Copyright 2007 by the American Psychological Association.

tional meaning selection required by the word-association and spelling responses could potentially alter the effects of the subsequent Phase 2 dominant context and Phase 3 neutral context.

EXPERIMENT 2

Long-Term Effects of Meaning Selection

Method

Participants. Forty-eight Adelphi University students participated in this experiment and were assigned to either the spelling or word-association condition in a counterbalanced order. None of the students participating in Experiment 2 had participated in Experiment 1 or the baseline study.

Design. In Experiment 2, the homophones were presented on three separated occasions. The first presentation (Phase 1) was intended to bias participants toward selecting the secondary meaning of each homograph using the same picture-word orienting procedure used in Experiment 1. Homophones were represented visually as either a picture or word during this phase of the experiment. To avoid unwanted carryover effects of the measurement procedure, the test of spelling or word association was not conducted following the location test, as had been done in Experiment 1. Instead, the long-term effects of secondary orienting were assessed in Phases 2 and 3 of Experiment 2. In Phase 2, participants either spelled or associated to the Phase 1 homophones, which were presented immediately following a word related to their dominant meaning. Participants were then presented the same set of homophones a third time (Phase 3) in a neutral context (each homophone was immediately preceded by an unrelated word) and again responded by either spelling the word or giving the first word to come to mind. Experiment 2 also included a control condition in which participants responded in Phases 2 and 3 to homophones not included in the Phase 1 secondary orienting task.

Materials. The same 42 homophones that were used in the baseline study and in Experiment 1 were randomly divided into three

subsets of 14 items to create the Phase 1 stimulus booklets. Three stimulus booklets were created by assigning two of the subsets to a booklet. The third subset was reserved as control items. Each subset appeared in two booklets. Each homophone appeared in one booklet as a printed word, and in a second booklet as a picture meant to illustrate that word. Each homophone was left out of a third booklet (control items). Each booklet contained 28 items. As occurred in Experiment 1, the homophones were presented four to a page.

For each homophone a prime word was selected that—in the judgment of the experimenter (D.S.G.)—was related to the dominant meaning of the homophone, but was a low-frequency associate of that homophone. For example, the word *star* is related to the dominant meaning of *sun*, but the most common response to *sun* in word-association norms is *tan*, whereas *star* is a low-frequency (.02) response (Nelson, McEvoy, & Schreiber, 1994). Selection of a low-frequency associate as the prime served to reduce the probability that the prime for the homophone would be given as the associative response to the homophone.

To create the Phase 2 stimuli, we added 26 filler words to the homophones and their primes, resulting in a total of 110 stimuli. The 42 prime-homophone pairs and the 26 filler words were randomly ordered, with the requirement that a homophone was always preceded by its prime. For Phase 3, the same 65-item list that was employed in the baseline study and in Experiment 1 was added as Trials 111–175. In this portion of the list, each of the 42 homophones was preceded by an unrelated item. A tape recording was made of the 175-item list. Thus, Phases 2 and 3 were presented as part of a continuous stream of 175 trials, with each word being read by the same voice. Thus, from the participants' points of view, there was no clear demarcation between Phase 2 and Phase 3 of the study. Each phase simply constituted a separate presentation of the set of homophones.

Procedure. Participants were individually tested in a small laboratory cubicle, and they were instructed that they were to participate in several studies. In the first phase, they were to learn the form and location of some items presented in a booklet. The procedure was identical to that of Experiment 1, with the exception that the Phase 1

booklet contained only 28 items. Thus, the picture-word orienting task was somewhat shorter than that in Experiment 1, lasting approximately 7 min.

Following the completion of the picture-word location memory test, the experimenter gave the participant a numbered answer sheet. The participant was then given instructions for a "second experiment," either the spelling test or the word-association test. The experimenter left the room as the participant listened and responded to the 175-item audiotape. The same tape was used for all participants. The Phase 2 portion of the tape lasted approximately 11 min, and the Phase 3 portion of the tape lasted approximately 6.5 min. Thus, the mean time between a homophone being presented in Phase 2 and being presented again in Phase 3 was just under 9 min. No mention was made of the homophones or the purpose of the study.

Results

The Phase 2 and Phase 3 results are presented in Table 2 along with the Phase 1 data from Experiment 1. The word-association and spelling responses are combined for all three phases in Figure 2. The Phase 2 and Phase 3 data were analyzed with a mixed-model ANOVA. One between-subjects factor, task (spelling or word association), was crossed with two within-subjects manipulations: orienting task (picture, word, or no orienting) and phase (primed Phase 2 and neutral Phase 3). For this overall analysis, separate ANOVAs were conducted using participants and items as the source of error variance. Additional separate ANOVAs with participants as the source of error were conducted for Phases 2 and 3. For all analyses, Type I error rates were set at .05.

The overall analysis showed a small but significant effect of form of testing [$F(1,46) = 4.93$, $MS_e = 0.0346$, for participants, and $F(1,41) = 6.36$, $MS_e = 0.0309$, for items] in the same direction as that in the baseline study and Experiment 1, with the proportion of dominant responses being slightly higher for the word-association test (mean difference = .048). However, none of the interactions involving form of test approached significance for either the participant or item analyses. Therefore, the data shown in Figure 2 are averaged over form of test. As was anticipated, there was a significant interaction of experimental phase with the form of exposure in the picture-word location memory task [$F(2,92) = 7.27$, $MS_e = 0.0087$, for participants, and $F(2,41) = 3.64$, $MS_e = 0.2354$, for items], with the decrease in the proportion of dominant responses from Phase 2 to Phase 3 being greater for homophones presented as pictures during the Phase 1 orienting task than for homophones presented as words.

In Phase 2, form of test (spelling vs. word association) did not interact with the orienting task (picture vs. word) ($F < 1$). The effect of the orienting task was significant [$F(2,92) = 5.08$, $MS_e = 0.011$]. The priming scores (condition - baseline) were in the predicted direction (control > word > picture), with only the control group (no orienting) showing significant priming [.065 above baseline, $t(41) = 3.02$]. The word and picture conditions did not differ significantly from each other or from their normative baselines (all $ts < 1$). Thus, processing the homophones in the secondary direction in the orienting phase reduced the effectiveness of the subsequent dominant meaning prime.

Additional t tests using variability between items as the source of error were conducted to compare the performance following the secondary meaning orienting task alone (Experiment 1) to that of Phase 2 of the present experiment, in which word association and spelling were tested in the presence of dominant meaning primes. These tests showed that the effect of the presence of the dominant biasing context in Phase 2 was significant. Both picture and word responses were more in the dominant direction than they were in Experiment 1 (see Table 2), in which the spelling and word-association tests took place in an unbiased context [$t(41) = 7.22$ for picture orientation; $t(41) = 5.28$ for word orientation]. Clearly, the presence of a dominant-related prime just before the critical homophone offset the effects of the secondary-meaning orienting task somewhat, but did not increase the frequency of dominant responses above baseline. This result was consistent with predictions of the ASM.

The ANOVA of the unprimed Phase 3 performance indicated a significant effect of form of test [$F(1,46) = 4.05$, $MS_e = 0.0256$], but no interaction of test form with form of exposure in the orienting phase ($F < 1$). The effect of orienting task was significant [$F(2,92) = 16.03$, $MS_e = 0.0188$]. A comparison of condition means employing Tukey's HSD procedure with $\alpha = .05$ showed that all three conditions (picture orienting, word orienting, no orienting) differed significantly from one another; importantly, both picture and word orienting led to a decreased proportion of dominant responses in comparison with the no-orienting control (see Table 2).

T tests, with variability between items as the source of error, indicated that both picture and word orienting in Phase 1 resulted in the proportion of dominant responses in Phase 3 being significantly below the baseline proportion, indicating significant primacy effects [$t(41) = 5.72$ for picture orientation; $t(41) = 2.14$ for word orientation]. The control condition did not differ significantly from baseline in Phase 3 [$t(41) = 0.57$].

Discussion

As expected, priming the dominant meaning of a homophone in Phase 2 increased the proportion of dominant spellings and word associations from their levels in Phase 1. However, the proportion of dominant responses was significantly below the control condition, which was not exposed to the Phase 1 secondary-orienting task. The effect of the dominant prime was reduced for those homophones previously oriented to their secondary meaning. The ASM explains this as being the result of an increase in the weight of secondary-meaning attributes activated during Phase 1. This change of weights leads to an increase in the probability of selecting secondary-meaning attributes during subsequent phases, which has the effect of reducing the effectiveness of the Phase 2 dominant prime. The Phase 2 results are also consistent with the assumption that the inhibition of the dominant meaning during Phase 1 persists over several minutes and many intervening items, thereby reducing the effectiveness of the Phase 2 dominant prime. The reduced priming effect observed in Phase 2 would appear to be

inconsistent with a short-term suppression model, which assumes that the suppression of the nonselected dominant meaning in Phase 1 decays relatively quickly.

When the homophones are presented again in Phase 3, this time in a neutral context, not only is the proportion of dominant responses to homophones presented in the secondary-meaning orienting task (on average, about 15 min prior) below that for control homophones not presented in the orienting task, but the proportion of dominant responses is significantly below the initial baseline level. This significant influence of having selected the secondary meaning of a homophone prior to being exposed to the same homophone in a dominant context is not easily explained by models that assume that inhibition of the nonselected meaning persists across occurrences of an ambiguous word: The residual inhibition of the nonselected secondary meaning in Phase 2 should lead to an above baseline proportion of dominant responses in Phase 3. On the other hand, ASM explains the persistent influence of the Phase 1 secondary orienting task by postulating that each occasion of deciding on the meaning of an ambiguous word results in a long-term change in the word's representation. Following the choice of the secondary sense of the homophones in Phase 1, a number of the underlying attributes representing that meaning are assumed to increase in weight. This means that on subsequent encounters with the word, secondary attributes will have an increased probability of being activated; thus, the secondary meaning will have an increased probability of being selected (and therefore the dominant attributes will have a decreased probability of being selected). (The "weight" of an attribute can be thought of as a representation of its probability of being selected in comparison with other attributes.) Thus, in Phase 2, the secondary meaning is chosen a higher proportion of times than it would have been without recent prior exposure to the secondary meaning, and more crucially, the increased secondary weights from Phase 1 will also carryover to Phase 3. Although the weights of a number of the dominant attributes will increase in Phase 2 when the dominant meaning is chosen, those increases will not be sufficient to completely offset the recent increase in the weights of secondary attributes (i.e., the weight distribution will not be immediately returned to its initial level). Thus, the proportion of dominant responses made in the neutral Phase 3 context will remain below the initially measured baseline level.

GENERAL DISCUSSION

Summarizing the important results: (1) As measured in Experiment 1, Phase 1 of the study showed a carryover of secondary-meaning orienting to subsequent word-association and spelling responses; (2) this carryover effect is disrupted somewhat, but not completely, in a different meaning context in Phase 2 (measured in Experiment 2); (3) most crucially, a primacy effect (a return toward the secondary meaning of Phase 1) is obtained in the neutral context of Phase 3 of Experiment 2, and (4) this primacy effect is larger for the task (picture memory) that showed the larger initial Phase 1 orienting effect.

The carryover influence of the visually based first phase picture-word location memory task to the Phase 2 and 3 spelling and word-association tests shows that the influence of meaning context is not only a within-task effect. The disambiguation of a homophone has quite a robust effect on subsequent encounters with that homophone minutes later. The results obtained in the biased second phase list are consistent with the conclusion that the prior selection of one meaning of a homophone makes it more difficult to access another meaning, but the results do not distinguish between inhibitory explanations and models such as ASM, which explain the results as the consequence of long-term changes in the word's representation. These findings with homophones extend previous results of changing the prime context for homographs (Gorfein et al., 2000; Simpson & Kang, 1994) to all ambiguous words.

According to suppression/inhibition views, inhibition is necessary in the service of discourse processes whenever there is a conflict between the interpretation of the ambiguous word and the context, and in general, the greater the conflict, the greater the need to inhibit the competing meaning (Simpson & Adamopolous, 2001). It follows, therefore, that the priming of the dominant meaning in Phase 2 would result in inhibitory processes acting on the secondary meaning produced in the Phase 1 picture-word task. Pictures were shown to produce greater priming than words in Experiment 1, and should therefore produce the greater conflict. Consequently, the secondary meaning of homophones represented by pictures should be more strongly inhibited in subsequent phases. Therefore, according to inhibitory theories, the picture-orienting condition should not show a larger primacy effect in Phase 3.

One might also consider whether the primacy effect observed here could be explained strictly as a memory-retrieval phenomenon. Aspects of the local context in Phase 1 could become associated with the selected secondary meaning of the homographs and later serve as (direct or indirect) cues for retrieving the secondary meaning of the homographs when they are presented in Phases 2 or 3 (see, e.g., Tulving & Thomson, 1973). However, the experiments were designed so that the entire local context of Phases 2 and 3 differed as much as possible from the Phase 1 context. Again, in Phase 1, auditory presentation of the homophones was accompanied by a visual picture or word representing the homophone, and participants were simply asked to remember the location and form of the accompanying visual representation. Participants made no response involving the meaning of the homophones in Phase 1. In Phases 2 and 3, the homophones were presented auditorially in a different voice and were accompanied by no other auditory or visual stimuli, and participants were asked to either interpret the meaning of the homophone (by indicating the closest semantic associate to come to mind) or spell the homograph. Thus, the secondary-meaning orienting phase, Phase 1, differed from subsequent phases both in terms of the organization and presentation of the stimuli and in terms of the cognitive operations required to generate the different responses (see, e.g., Blaxton, 1989). On the other hand, the local contexts of Phases 2 and 3 (which were presented as

a continuous list) were quite similar, the only difference being that in Phase 2, each homophone was preceded by a word related to its dominant meaning, and in Phase 3, the word preceding each homophone was unrelated to either meaning of the homophone. Thus, essentially, only the semantic context differed between Phases 2 and 3; all other aspects of the context were nearly identical. Importantly, Phases 2 and 3 also occurred more closely in time than did Phases 1 and 3, so any local temporal aspects of the context would have been more similar between Phases 2 and 3 as well. Thus, the most straightforward prediction from an episodic retrieval perspective is that responses to the homophones in Phase 3 should more closely resemble the Phase 2 responses, since Phases 2 and 3 were contextually much more similar and occurred more closely in time than Phases 1 and 3. The observed primacy effect—a significant decrease in the number of dominant responses in comparison with the control condition in the neutral Phase 3—seems inconsistent with this prediction.

The results of the present experiments as well as those of Gorfein et al. (2000)² are consistent with the predictions of the activation–selection model. The results of a computer simulation of the model are depicted in Figure 3. In the computer implementation of the model, a “word” is defined as a two-part vector of attributes (equal numbers of attributes are associated with the dominant and secondary meanings of the words). Higher weights are initially assigned to the dominant attributes. (Here, the initial weights are selected to approximate the observed baseline proportion of dominant responses of .74.) A “prime” is represented by “activating” a small number of attributes associated with the primed meaning, either the dominant or secondary meaning of the word. Meaning “selection”

takes place after a fixed number of attributes are activated: The meaning associated with the majority of activated attributes is the meaning that is selected. (Different selection rules would be defined for different tasks; e.g., relatedness judgments might use a procedure that counts the overlap in attributes between two words.) For the present purposes, “activation” consists of randomly sampling from the weighted vector of attributes. The probability of “activating” a given attribute is simply the weight of the attribute divided by the sum of the weights of all of the attributes associated with the word in question. In simulating the experiments described here, the probability of a dominant or secondary word-association or spelling response is represented by the probability that the majority of activated attributes are associated with that meaning of the word. The activated attributes associated with the selected meaning are then increased in weight by a constant amount. We assume that the time between reoccurrences of the homophone (greater than 5 min with many intervening presentations of other items) allows for the complete decay of activation between phases. The activation and selection procedure is carried out with the revised weights in each of the three phases of the simulated experiment. (A flowchart for the computer implementation of the model is given in Figure 4, and more details regarding the simulation are presented in Appendix B.)

In Phase 1 of the study, participants were oriented toward the secondary meaning of a homophone by being asked to remember the location and form of the accompanying picture or word. Because participants are required to generate their own interpretation of the drawing, the picture-orienting task is more difficult and is assumed to lead to the activation of more attributes in the representation of the

Figure 3. Results of the simulation of the activation–selection model. The parameters of the simulation are given in Appendix B. The graph represents the average of 100,000 simulation runs. This figure is reprinted with permission from D. S. Gorfein & C. M. MacLeod (Eds.), *Inhibition in Cognition*. Copyright 2007 by the American Psychological Association.

homophone than the word-orienting task. In the computer simulation, a greater number of secondary attributes are pre-activated in the picture-orienting condition than in the word-orienting condition. Because more attributes are activated, the picture-orienting task leads to increases in the weights of more secondary attributes than does the word-orienting task. The greater number of secondary attributes reweighted leads to more secondary responses in the picture-orienting condition when the homophones are presented for a word-association or spelling test in Phase 1, as seen in Figure 3. Furthermore, it is these reweighted representations that are used for selecting the meaning of the homophones presented in Phase 2. The increased weights of the secondary attributes lead to a reduced effect in the computer simulation of the dominant primes that preceded each homograph in Phase 2, because the dominant prime is now competing with word representations whose secondary meaning attributes have increased in weight. An example can be seen in Figure 3, where the proportion of dominant responses in both the picture and word orienting conditions, although near baseline, is below—that is, in the direction of more secondary responses—the control condition, which was not subject to Phase 1 orienting and thus did not have the weights of its secondary attributes increased. The weights of activated dominant attributes are, of course, increased following dominant meaning selection in Phase 2, but this change in the representation does not completely overcome the increase in the weights of secondary attributes that took place in Phase 1. Thus, when the homophones are presented once again in Phase 3, this time preceded by a word unrelated to either of their meanings, a residual effect of the meaning selection from Phase 1 remains. Figure 3 shows the effect of these still higher weighted secondary attributes: The simulation predicts that the proportion of dominant responses will drop back below baseline for the homophones that were subject to secondary-meaning orienting in Phase 1. Furthermore, the increase in secondary responses in Phase 3 is greater for the picture-orienting condition, which was simulated to have the initially greater number of preactivated secondary attributes in Phase 1. The control condition, which was not subject to Phase 1 secondary orienting, but was subject to dominant priming in Phase 2 (which led to increases in the weights of the dominant attributes) remains above baseline in Phase 3.

Of particular note is that through its postulation of circumstances that produce changes in the attribute weights of ambiguous words, the activation-selection model can account for effects over long intervals and across different experimental tasks. A major implication of this line of research is that we may no longer consider each occurrence of an ambiguous word as an independent event. Our understanding of a word is influenced not only by the immediate context in which it appears, but can also be influenced by a context that is no longer in conscious awareness. The temporal durations involved in this study, as well as the influence of meaning manipulations across rather dissimilar tasks, suggest to us that the locus of the effect is at the item representation level. Whether extensions of other models might succeed in capturing the results presented here is something that needs to be explored.

Figure 4. Flowchart for simulations of the activation selection model.

Finally, the set principle predicts that when an item appears in a biasing local context, the potential carryover effects of previous meaning selection will be reduced, as observed in Phase 2 of Experiment 2. This result is important to investigators of ambiguity in that it indicates that even in circumstances in which there are large differences in the strengths of the representations of alternative meanings of ambiguous words, these differences may be obscured by presenting the word in a disambiguating context. Thus, the subsequent shift from the biasing context in Phase 2 to an unbiased context in Phase 3 reveals the long-term carryover of the Phase 1 context. It is this observation that leads us to conclude that although the sun may temporarily eclipse the son, in the end, the son comes out after the sun.

AUTHOR NOTE

Some of the data reported here were presented at the 1995 meeting of the Psychonomic Society in Los Angeles. The authors are grateful to Susan Petry and Andrea Spata for creating the drawings of the homophone, and to Will Schweinle, who assisted with the figures. Kay Erusu contributed critical editing to the manuscript. We wish to thank Greg Simpson, James Erickson, and Kristin Weingartner, who were an immense help in our attempts to better communicate our ideas. Written correspondence may be sent to D. S. Gorfein, 3804 Summercrest Dr., Fort Worth, TX 76109 (e-mail: dgorfein@yahoo.com).

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NOTES

1. The *subordinate-bias* effect refers to differential gaze durations observed on balanced and unbalanced homographs as a function of the presence or absence of a disambiguating context prior to the homograph. For example, when the unbalanced homograph *diamond* (the gemstone meaning is much more common than the baseball infield meaning) is presented without prior disambiguating context, as in *The diamond was . . .*, the initial eye fixation duration is about equivalent in time to an unambiguous word of equal frequency. However, when disambiguating context for the secondary meaning of diamond occurs earlier than the homograph, as in *The umpire checked the dimensions of the diamond . . .*, the fixation time on the word *diamond* is significantly increased. On the other hand, when the homograph is relatively balanced, for example, *match* (the fire meaning is only slightly more common than the contest meaning), and the homograph is not preceded by a disambiguating context, gaze duration is prolonged as compared with an unambiguous control word of equal frequency. But when the disambiguating context precedes *match*, as in *The wrestling match . . .*, the gaze duration to *match* is significantly reduced.

2. Another possible explanation of the results in the Gorfein et al. (2000) word-association study of homographs is that they are artifactual. If we look at the word-association test employed in that study as a repeated test of implicit conceptual memory (Roediger, 1990), one can conceive that at least some of the responses to the homograph *organ* following *piano* are associates to *piano* that occurred either explicitly (the response) or implicitly (other words that came to mind when *piano* was presented). It is a well-established finding that explicit prestudy of potential associates can lead to their production as responses in a word-

association task (see Cofer, 1967, for a review of what he labeled *direct priming*). If an implicit form of direct priming occurs in this case, then on second occurrence, when *organ* is preceded by *liver*, there might be competition between associations to *liver* and *organ* and the earlier associations to *piano* and *organ*. This competition could lead to the decrease in the magnitude of priming reported on second occurrence. Indeed these two occurrences are not unlike an A-B A-C paired-associate task known to produce retroactive interference (see, e.g., Keppel, 1968). Under such circumstances, the absence of a biasing context on a third occurrence of the ambiguous word *organ* might lead to recovery of the first associated response, yielding the observed primacy effect. In the Gorfein et al. (2000) study, there is no way to distinguish between the explanation of the effect as an artifact of the design and the theoretical explanation of a

true primacy effect. To do this, we sought to design, a study that would minimize the role of implicit responses on performance.

In the present design, no word response is required in the picture-word location memory task and, as a consequence, there could be no implicit recall of a word response to produce the observed effects of the orienting task. Thus, the findings of this study are inconsistent with the possibility that the results of Gorfein et al.'s (2000) study were an artifact of implicit conceptual memory. Furthermore, the absence of any interaction in the present study of the form of the test (spelling or word-association) with the form of exposure in the orienting task (picture or word) implies that the effect of prior processing of a homophone is not simply the retrieval of a specific response, which in the spelling test would have led to an advantage for words in comparison with pictures.

APPENDIX A

Proportions of Dominant Responses for Each Homophone Averaged Over Spelling and Word-Association Responses

Homophone (Dom-Secondary)	Baseline	Phase 1 (Experiment 1)		Phase 2 (Experiment 2)			Phase 3 (Experiment 2)		
		Picture	Word	Picture	Word	Control	Picture	Word	Control
AIR-HEIR	0.966	1.000	0.800	1.000	1.000	0.938	1.000	0.938	1.000
BEAR-BARE	0.893	0.583	0.923	1.000	1.000	0.938	0.875	0.670	0.938
BEAT-BEET	0.920	0.385	0.700	0.866	0.938	1.000	0.857	0.762	0.804
BORED-BOARD	0.833	0.692	0.727	1.000	0.813	0.741	0.929	0.795	0.834
BREAK-BRAKE	0.844	0.500	0.692	0.750	0.750	0.875	0.625	0.804	0.845
DAZE-DAYS*	0.333	0.400	0.583	0.188	0.563	0.536	0.250	0.313	0.473
FAIR-FARE	0.967	0.308	0.818	0.688	1.000	1.000	0.729	0.938	0.938
FLEA-FLEE	0.679	0.273	0.417	0.500	0.813	0.616	0.550	0.402	0.792
FLOWER-FLOUR	0.969	0.917	0.769	0.813	1.000	1.000	0.688	1.000	1.000
GREAT-GRATE	1.000	0.545	0.545	1.000	0.938	1.000	0.838	0.938	1.000
GROWN-GROAN	0.852	0.500	0.667	0.786	1.000	1.000	0.670	0.813	1.000
HAIR-HARE	0.968	0.750	0.750	0.938	0.938	1.000	0.750	0.854	1.000
HEAL-HEEL	0.655	0.273	0.500	0.340	0.500	0.563	0.333	0.350	0.479
HEAR-HERE	0.933	0.583	0.833	1.000	0.850	0.813	0.750	0.804	0.598
HIM-HYMN	0.714	0.143	0.273	0.563	0.402	0.866	0.429	0.845	0.729
KNOW-NO*	0.222	0.250	0.167	0.500	0.268	0.313	0.143	0.292	0.536
LOAN-LONE	0.586	0.750	0.900	0.929	0.729	1.000	0.661	0.575	0.900
MAIL-MALE*	0.207	0.083	0.182	0.518	0.500	0.334	0.188	0.259	0.000
MEAT-MEET	0.679	0.778	0.714	0.792	0.938	0.929	0.227	0.741	0.713
NIGHT-KNIGHT	0.885	0.455	0.667	0.792	0.786	0.938	0.834	0.786	0.845
NONE-NUN	0.786	0.231	0.500	0.762	0.857	0.757	0.548	0.854	0.838
PAIN-PANE	0.968	0.909	0.667	1.000	0.938	1.000	0.838	0.857	0.938
PAIR-PEAR	0.667	0.667	0.385	0.625	0.584	0.813	0.786	0.732	0.688
PEACE-PIECE	0.844	0.750	0.692	0.875	0.625	0.741	0.750	0.750	0.804
PLANE-PLAIN	0.750	0.636	0.615	1.000	1.000	1.000	0.732	0.500	0.775
POLE-POLL	0.857	0.750	0.875	0.750	1.000	0.900	0.584	0.286	0.667
POOR-POUR	0.885	0.692	0.667	0.857	1.000	0.875	0.732	0.857	0.938
PRAY-PREY	0.871	0.545	0.833	0.938	1.000	0.917	0.750	0.929	1.000
REAL-REEL	0.867	0.615	1.000	0.938	0.938	1.000	0.875	0.854	1.000
RIGHT-WRITE	0.750	0.417	0.615	0.584	0.741	0.675	0.625	0.857	0.866
ROLL-ROLE	0.750	0.667	0.625	0.709	0.670	0.774	0.545	0.813	0.854
SEA-SEE*	0.406	0.364	0.167	0.750	0.563	0.866	0.250	0.584	0.590
SELL-CELL	0.762	0.250	0.889	0.688	0.702	0.857	0.548	0.729	0.750
SOAR-SORE*	0.500	0.333	0.308	0.762	0.354	0.417	0.515	0.375	0.334
STEAK-STAKE	0.769	0.583	0.538	0.854	0.938	0.813	0.795	0.813	0.750
STEAL-STEEL	0.690	0.462	0.643	0.688	0.513	0.875	0.375	0.545	0.563
SUN-SON	0.968	0.615	0.750	0.938	0.938	0.938	0.875	0.813	0.938
TAIL-TALE	0.875	0.917	0.769	0.929	0.732	1.000	0.750	0.929	0.938
TOE-TOW	0.903	0.750	0.846	0.813	0.875	0.857	0.813	0.732	0.813
WAIT-WEIGHT	0.655	0.417	0.462	0.500	0.268	0.429	0.188	0.545	0.661
WEEK-WEAK*	0.200	0.091	0.167	0.292	0.197	0.500	0.197	0.188	0.250
WHOLE-HOLE*	0.240	0.400	0.154	0.125	0.417	0.375	0.415	0.584	0.415
Mean of all 42 items	0.740	0.529	0.614	0.746	0.752	0.804	0.615	0.691	0.757
Mean of 35 items	0.827	0.580	0.688	0.806	0.820	0.870	0.682	0.755	0.834

Note—Asterisk indicates seven homophones with anomalous baseline proportion of dominant responses of .50 or below.

APPENDIX B

Simulation Details

A flowchart of the simulation sequence is given in Figure 4. For the simulation graphed in Figure 3, a vector of 50 attributes, each with an initial weight of .57, was assigned to represent the dominant meaning of a homograph and a vector of 50 attributes, each with an initial weight of .43, represented the secondary meaning. The initial weight values were chosen to produce a baseline proportion of dominant responses of .74. The simulations did not distinguish between word-association and spelling responses. Nineteen attributes were sampled in each phase of the simulation and the meaning associated with the majority of the sampled attributes determined the response. The weights of the active attributes associated with the selected meaning (regardless of whether or not it was the primed meaning) were increased by .6. The probability of a given attribute i being sampled (i.e., "activated") is given by the weight of the attribute divided by the sum of the weights of all attributes, $p_i = w_i / \sum w_j$ ($j = 1$ to number of attributes).

Thus, given the arbitrary choice of 50 attributes to represent each meaning of a homophone and 19 attributes as the number sampled in response to the presentation of the homophone, the initial attribute weights were chosen to reproduce the baseline proportion of dominant responses of .74. The remaining parameters were selected by inspection to approximate the mean proportion data of Experiments 1 and 2 (see Figure 2). There are essentially four remaining free parameters for simulating the remaining eight data points in Figure 2: the number of attributes preselected in each of three priming situations (Phase 1 picture orienting, Phase 1 word orienting, and the dominant priming in Phase 2), and the size of the weight increment of active attributes following meaning selection. Although no formal attempt was made to find a set of best-fitting parameters, the simulation appears to capture the trends in the data quite well (cf. Figures 2 and 3).

If the parameters of the model are simply counted, there are seven parameters to account for nine data points (the initial weights of the dominant meaning and secondary meaning attributes were constrained to add to one, so the initial attribute weights are counted as a single parameter). However, the parameters of the model are not completely independent. The number of attributes sampled ("activated") following the presentation of an ambiguous word needs to be a small enough subset of total attributes so that random sampling will lead to a variety of outcomes (technically, so that the activation process approximates random sampling from a binomial distribution), but large enough so that there is the possibility of preactivating a range of attributes to simulate different degrees of priming (e.g., if only five attributes were activated in response to the presentation of a homophone, there would be very little room to vary the number of prime attributes, whereas with 19, there is room to distinguish the effects of the various priming situations in the current study). This means that the total number of attributes associated with a word needs also needs to be large enough for random sampling to be effective.

In simulating Phase 1, the orienting phase, eight secondary attributes were preselected to simulate the effects of the picture orienting task and four secondary attributes were preselected to simulate the effects of the word orienting task. The greater effort required to disambiguate the picture-homophone pairs was assumed to lead to a greater change in the representation of the homophones paired with pictures than in the representation of the homophones paired with printed words. Attributes associated with both meanings of the homophone were then randomly sampled to bring the total "active" attributes to 19. The weights of the active attributes associated with the meaning represented by the majority sample (usually the primed secondary meaning) were increased by .6. Since the word-association/spelling test in Experiment 1 did not take place for several minutes, and several intervening trials followed the orienting task, attributes activated by the orienting task are assumed to be no longer active at test. Thus, in order to simulate the word-association/spelling test that followed the picture-word orienting task, 19 attributes were randomly selected on the basis of the revised weights from the orienting process. The meaning associated with the majority of active attributes determined the simulated response proportions graphed as Phase 1 in Figure 3.

In simulating Phase 2, an average of 2.5 dominant attributes were preselected to simulate the effects of the dominant prime (half of the time, two attributes were selected and the other half, three attributes were selected). This was the number that visually gave the closest approximation to the Phase 2 and Phase 3 data from Experiment 2. In this case, since the homophone was presented immediately following its prime, the attributes activated by the prime are assumed to still be active during the presentation of the homophone. Thus, 16 or 17 additional attributes were randomly selected on the basis of the revised weights from Phase 1. Again, the meaning associated with the majority of active attributes determined the response. The weights of activated attributes associated with the chosen meaning were then increased by .6. In simulating Phase 3, no attributes were preselected, consistent with the presentation of a neutral prime. In this case, 19 attributes were randomly selected on the basis of the revised weights from Phase 2.