What's so funny?:

Investigating the time-course of lexical access in the processing of puns

Jenna Zeigen

Brown University

Author Note:

Jenna Zeigen, Department of Cognitive, Linguistic, and Psychological Sciences, Brown University.

Any questions or concerns regarding this report should be addressed to Jenna Zeigen at jenna_zeigen@brown.edu

Abstract

Two experiments that examine the time-course of lexical access in processing of puns are reported. Subjects heard sentences and subsequently performed a lexical decision on a visual probe. Experiment 1 was a cross-modal priming experiment utilizing four types of context—dominant, subordinate, neutral, and pun— to investigate pun processing. Experiment 2 was a norming study performed to ensure that the results obtained from Experiment 1 were valid. The sentences heard in Experiment 1 ended in a lexically ambiguous term while the sentences in Experiment 2 ended in a control term. Results show that the dominant meaning of puns is processed in the same manner as the dominant meaning when found in a context that solely supports that meaning and the subordinate meaning of puns is processed in the same manner as if it were present in a context that solely supports that subordinate meaning. Furthermore, it was found that lexical access in processing of puns differs from that in processing of neutral context sentences. The data lend support to a general exhaustive access model.

Keywords: lexical ambiguity, lexical ambiguity resolution, puns, cross-modal lexical decision

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1. Introduction

A great deal of attention in cognitive science, specifically in psycholinguistics, has been paid to *lexical ambiguity*, the phenomenon in which words have multiple meanings, and *lexical ambiguity resolution*, the process by which we we select the appropriate meaning for that multiple meaning word. However, not much work has been done to investigate what happens when we encounter and process puns, which are crafted such that multiple threads of meaning in the discourse converge to support multiple meanings of a single lexical item. We frequently encounter ambiguous words but do not notice that the words are ambiguous because the language processing mechanism is quite skilled at using probabilistic and contextual clues to resolve potential ambiguities. With puns however, the context supports both meanings, providing the language processor with a particular surprise and challenge. It is also this dual meaning that makes puns clever, and to many enjoyable and funny. The current experiment investigates the time-course of the lexical access and activation of two meanings of an ambiguous word in puns in an attempt to uncover how the language processor deals with such discourse, provide further insight into the nature of lexical ambiguity resolution, and perhaps cast some light on what makes puns funnier than other ambiguity-containing discourse.

2. Puns and Lexical Ambiguity

2.1 Lexical Ambiguity

Many puns take advantage of the phenomenon of *lexical ambiguity,* in which words of different meanings have the same form— in phonology, orthography, or both. Ambiguous words with the same phonology, those that sound the same, are termed *homophones*. A homophonous set may or may not be spelled the same way (i.e. “pare,” “pear,” and “pair”). The term *homograph* refers a word that has the same orthography, or spelling, as another word. A classic example of such a word is “bank,” which refers to either the financial institution or the land beside a river, among other things. A set of two words that are homographs with each other could have different phonology, such as is the case with “bass,” changing pronunciation whether the word refers to the fish or to the low-pitched sound or stringed instrument.

Ambiguous words are said to be either *balanced* or *biased* depending on the relative frequencies of the meanings. The meanings of a *balanced* homograph occur relatively equally, making one meaning as likely to be attached to the word as the other. *Biased* ambiguous words have *dominant* and *subordinate* meanings. The most frequently occurring meaning is said be the dominant meaning, and all remaining meanings are referred to as subordinate. Furthermore, some ambiguities are cross-category: some meanings are verbs and other meanings are nouns, for example. This is the case with homographs, such as “construct” in which the noun meaning and the verb meaning have different pronunciations but not different spellings. Other ambiguities, such as “mole,” are within-category, since all of its meanings are nouns.

2.2 Lexical Ambiguity Resolution

The fact that an ambiguous word has multiple meanings poses an interesting problem for comprehension of that word. If someone were to say the word “plane” outside of any context whatsoever, it is unclear whether that the word was meant to mean “airplane” or “flat surface.” Though most discourse contains ambiguous words, we are not frequently confused about the meanings of these words because we rarely encounter words devoid of contextual connections. When we encounter ambiguities in a rich context, the ambiguity goes unnoticed because the language processor is skilled in determining the meaning appropriate for the discourse at hand through taking into account context clues that reveal the ambiguous terms’ intended meaning or meanings. Such clues can be syntactic, such as in the case when the word in question is a cross-category ambiguity, as is the case for the word “judge.” For example:

a) Joshua was excited to be a *judge* in a pie-baking competition.

b) Joshua found a job in which he would *judge* weekly pie-baking competitions.

These contextual clues can also be purely semantic, as is necessary when the meanings are within-category. Such clues are integral in words such as “mole,” in which both meanings are nouns. For example:

c) The dermatologist spotted the *mole* on Joshua’s leg.

d) While at the park, Joshua spotted the *mole* peeking out of its hole.

This process by which the proper meaning is found for the word form through information both intrinsic and extrinsic to the word, is called *lexical ambiguity resolution*. Lexical ambiguity resolution is of interest to many psycholinguists because it provides insight into the nature of *lexical access,* the process of selecting the appropriate word or meaning from the mental lexicon. A word is said to be accessed when all of its phonological, syntactic, semantic, and pragmatic information becomes available after the word has been recognized (Harley, 2008).

Models of lexical ambiguity resolution tend to disagree most strongly on the effect of context on the resolution process, but there is no doubt that context plays *some* role. For example, selective access models (i.e. Simpson & Krueger, 1991) suggest that context has an early effect in the process, narrowing which meanings are even accessed. While our experience encountering ambiguous terms might support the selective access model and suggest that we only access the meaning of an ambiguity that is relevant to the context, this has been found to not be case. A body of research conducted over the past 40 years indicates instead that all meanings of an ambiguous word are accessed upon encountering the lexical item; this is called *exhaustive access.* In other words, the context and frequency of ambiguous words do not affect which meanings are accessed in the earliest stages of processing. These factors do, however, modulate the relative activation of the multiple meanings over time, helping to guide the processor, in most cases, to settle on a single meaning.

Exhaustive access was first shown by studies implementing a cross-modal priming paradigm (i.e. Tanenhaus, Leiman, & Seidenberg, 1979; Swinney, 1979). In such experiments, subjects listen to a sentence containing an ambiguous word and then must perform a task related to a visual probe word, such as a lexical decision or naming task. This visual probe word is either related or unrelated to one of the meanings of the ambiguous word. The assumption is that the levels of activation of the related meanings will wax and wane over time, creating a distinct time-course of activation and revealing the nature of the lexical access of the ambiguous terms.

Through presenting subjects with these probe words at various points in time, this paradigm allows for the collection of snapshot-like data about multiple meanings of a homograph over a specific window of time with respect to a single sentence. Taking these samplings of the processing patterns also allows for comparison between activation of dominant and subordinate meanings. The data from such experiments show that there is no difference in activation between the dominant and subordinate meanings when the probe word is shown coincidental with the ambiguous target (at an stimulus onset asynchrony— SOA— of 0 ms), demonstrating that both of these meanings are indeed activated regardless of the meaning that the context supports. However, when the probe is offset by 200 ms, the contextually appropriate meaning shows facilitation over the inappropriate meaning (i.e. Tanenhaus et al., 1979). This is the resolution process in action, as the access phase is followed by a selection phase in which only the meaning — or, presumably, meanings in the case of puns— that fits into the context of the discourse is selected as the proper meaning. The mechanics of these access and selection processes have been the focus of most lexical ambiguity resolution research.

Recent studies employing eye-tracking while reading have provided more insight into the nature of the access process, lending support to the exhaustive access type of model, but allowing for its differentiation into two models: the *reordered access model* (Duffy, Morris, & Rayner, 1988) and the *integration model* (Rayner & Frazier, 1989). The data provided by the majority of these studies converge upon the *reordered access model* of lexical ambiguity resolution *(*Dopkins, Morris, & Rayner, 1992; Sereno, O'Donnell, & Rayner, 2006; Sheridan, Reingold, & Daneman, 2009). This model says that both meaning frequency and contextual information play a role in the access process, determining the order in which the meanings are accessed. Because the model is an exhaustive access model, neither of these pieces of information restrict the access of certain meanings, only modulates it. On the other hand, the integration model suggests that context only has an effect in the post-access selection phase; meaning frequency alone determines the order of lexical access.

One of the great strengths of the reordered access model is that it robustly explains a phenomenon in lexical ambiguity resolution called the *subordinate bias effect*, which occurs when the subordinate meaning is biased by the context but the dominant meaning is not. In this situation, the dominant meaning receives a processing boost simply by being the more frequent meaning while the subordinate meaning receives a processing boost from being supported by the sentential context. Eye tracking while reading studies find that subjects fixate longer on a biased homograph when the preceding context supports the homograph's subordinate meaning (i.e. Dopkins et al., 1992; Sereno et al., 2006). This is surprising under a selective access model because it would predict that the context would select for the subordinate meaning and there would be no processing delays. The reordered access model explains this by saying that the intersection between these two factors causes two meanings to be accessed at approximately the same time; the two meanings compete with each other, causing delays in processing. However, the subordinate meaning fits into the context and is therefore selected. In addition, the reordered access model posits that activation is purely facilitatory, not inhibitory (for such a model, see Tanenhaus at al., 1979)— a boost in the activation of one meaning does not inhibit the activation of another.

2.3 Intentional Ambiguity and Puns

Puns differ from most other language we encounter that contains ambiguities. In most of our communication, we seek to avoid outright ambiguity (Kittay 1987). To this end, we most regularly encounter discourse containing ambiguity that can be smoothly resolved to a single meaning through contextual constraints. However, in some discourse the meaning intended for the ambiguity *cannot* be narrowed to a single word. Sometimes this occurs because we unintentionally fail to provide sufficient context clues. In other cases, we purposefully exploit ambiguity for the sake of being creative with our language— for example, to be humorous or metaphorical, to grab people's attention, or to curry favor with a conversational partner; this requires skill and forethought (Kittay, 1987; Nerlich & Clarke, 2001). Kittay (1987) dubs this usage "purposive ambiguity." Such language is used in punning, in which multiple threads of meaning in the discourse converge to a single point at an ambiguous word, which, due to its inherent ambiguity, is able to carry multiple meanings. Upon encountering the ambiguity, the processor is able to find support for those multiple meanings. Thus, there is no resolution, at least in the classical sense. In the case of puns, it appears that this lack of resolution contributes to the humor of the discourse (or to the desire to groan upon hearing the pun). The question remains, then, if the ambiguity in puns can ever be said to be resolved; this paper will attempt, in part, to answer this question.

Humor studies, in conjunction with linguistic analysis, have provided some insight into the structure and expectation violation that might be driving the humor behind punning (Kittay 1987; Brône, Feyaerts, & Veale, 2006). However, despite the popularity in the psycholinguistics world of studying lexical ambiguity resolution, there is a gap in the psycholinguistics literature studying the processing of puns. Only a handful of studies have been performed using puns, and none of them have investigated the time-course of lexical access in the processing of puns on a psycholinguistic level, as the current study does. Sheridan et al. (2009) used puns in an eye-tracking while reading study in an effort to distinguish between the integration and reordered access models, finding evidence in support of the reordered access model. Their “pun” sentences were dual-context sentences in which multiple meanings of a homograph were supported in the word’s preceding context, but the homograph was resolved after its presentation in a disambiguating region to its subordinate meaning. The puns in the current study, however, are never resolved, as the ambiguity is presented in the sentence final position. Furthermore, while Sheridan et al. used research on puns as a means rather than an end, the current study’s purpose is to investigate the nature of pun processing in itself. In an ERP study, Coulson & Severens (2007) found that there are initial hemispheric asymmetries when processing puns, but that these asymmetries eventually resolve. Subjects heard puns and were subsequently presented with either a strongly or weakly related visual probe in either their left or right visual field. Stimulus presentation was at an SOA of 0 or 500 ms. The data show that both meanings are initially active in the left hemisphere while the stronger is the only meaning active in the right hemisphere; by 500 ms, however, both meanings seem active in both of the hemispheres. This is some of the only data to date on the time-course of the processing of puns.

2.4 Present Study

The present study uses two experiments to investigate the time-course of pun processing, how the mind processes the simultaneous contextual support of multiple meanings of ambiguous words. As mentioned before, the current models of lexical ambiguity resolution posit exhaustive access, in which all meanings of an ambiguity are accessed, but only the appropriate meaning is selected through being successfully integrated into the discourse context. Under this view, when neither of the meanings is explicitly supported (i.e. in "neutral" contexts, as they will be called in this study), both meanings could theoretically be integrated into the discourse, but the dominant meaning is selected because it is more probabilistically the intended meaning. This model of lexical ambiguity resolution leaves open the question of how lexical access proceeds when both meanings are supported explicitly in the context, as in the case of puns. Specifically, the current study asks:

a) How does the mind proceed when it is able to successfully integrate both meanings into contextually rich discourse that actively supports multiple meanings? Does this differ from processing when the discourse does not actively support either meaning?

b) How do the levels of activation of these multiple, supported meanings rise and fall over time? Do the meanings compete with each other or do they remain activated independently of each other?

To answer these questions, we examined the time-course of the processing of the meaning of homographs in puns, and compared it to their processing in three other types of context:

1. Dominant: The context only supports the dominant meaning of the homograph

2. Subordinate: The context only supports the subordinate meaning of the homograph

3. Neutral: The context actively supports neither meaning of the homograph

Examples of the four types of sentences in their forms for both Experiment 1 and Experiment 2 can be seen in Table 1.

Table 1

Example Complete Stimuli Set

Condition	Sentence	Ambiguous target (Exp. 1)	Unambiguous control target (Exp. 2)	Probes
Pun	The geometry whiz who wanted to be a pilot loved spending all of his free time reading books about . . .	*planes*	*cats*	jet (d) flat (s)
Dominant	The chemistry whiz who wanted to be a pilot loved spending all of his free time reading books about . . .	*planes*	*cats*	jet (d) flat (s)
Subordinate	The geometry whiz who wanted to be a professor loved spending all of his free time reading books about . . .	*planes*	*cats*	jet (d) flat (s)
Neutral	The physics whiz who wanted to be a professor loved spending all of his free time reading books about . . .	*planes*		jet (d) flat (s)

Note: (d) = dominant, (s) = subordinate

We have two sets of predictions for this study. The first are predictions as to the time-course of processing the dominant, subordinate, and neutral contexts. The second are our novel predictions for the processing of puns. These predictions of this are based on the reordered access model (Duffy et al., 1988) and to some extent Simpson and Krueger's (1991) cross modal priming study (though that study provided support for a selective access model and is thus incompatible with the reordered access model).

Previous studies have investigated the time-course of activation of dominant, subordinate, and neutral context sentences. Based on these findings, as well as the reordered access model, we have an idea of what we expect to find in these three contexts. Most cross-modal priming studies investigating lexical ambiguity resolution use an SOA of 0 ms, and thus we have the most concrete predictions for the patterns of activation at that point. However, our current study drew on multiple past cross-modal priming experiments using a myriad of different homograph presentations, types, sentential contexts (dominant, subordinate, neutral, or completely absent), and SOAs. Thus, we do not have any concrete data that we are attempting to replicate beyond an SOA of 0 ms. From these studies, though, in conjunction with the reordered access model, we can piece together a picture of what has been found in the past and thus what we expect to find in the current study.

We expect that a lexical decision on a dominant probe following a dominant sentence will occur at a low latency, while the lexical decision on the subordinate probe shown in conjunction with the same sentence will take longer to perform. The converse will be true for the subordinate context sentences— the subordinate probes will elicit a smaller reaction time than the dominant probe. The model also says that meaning frequency plays a similar role in the access process. This too is reflected in the predictions. There will be a greater difference between the dominant and subordinate probes in the dominant than in the subordinate context. In the dominant context, the dominant probe is facilitated above the subordinate by both factors. In the subordinate context, on the other hand, the dominant probe is still facilitated by meaning frequency while the subordinate is facilitated by the context. The contextual effect is stronger, according to prior data, allowing the subordinate meaning to be facilitated over the dominant overall. Predictions can also be made about the neutral context. Because neither meaning of the homograph is actively supported by the context, the only information present to help disambiguate the homograph is meaning frequency. Thus, the dominant meaning should experience facilitation over the subordinate.

In addition, previous results obtained by Simpson and Krueger (1991) show an increase in facilitation of both meanings between 0 and 300 ms, followed by a decrease by 700 ms. This is because at an SOA of 0 ms, when the homograph and probe are presented simultaneously, high-level processing has not occurred yet. However, by 300 ms, the sentence has been processed. By 700 ms, activation decays, causing an increase in the latency to make a lexical decision for both probes, though the probe related to the context remains facilitated over its counterpart. We expect to see such a pattern of activation in our results. Furthermore, we predict based on the exhaustive access model that the time-courses of activation for the two meanings will not differ significantly between 0 and 300 ms, only diverging by 700 ms. This will reflect the multiple access of the meanings. Based on the reordered access model, however, meanings that would be ushered to the top of the list through frequency or contextual facilitation might experience slight processing boosts in this time slice. Our predictions that are reflective of these findings can be found in Figure 1a-c.

Because no previous experiments have investigated the nature of pun processing in quite the same way we are proposing, we do not have as much data informing our predictions for processing behavior in the puns sentence. Our novel predictions expect distinct time courses of activation between the neutral and dual-context sentences. Furthermore, we predict the simultaneous contextual support for both the dominant and a subordinate meaning will cause both meanings to be activated. It is possible that the dominant probe will experience facilitation akin to that of being in the purely dominant context, and the subordinate probe will experience facilitation as if it were paired with the subordinate context and the activations will act independently of each other. On the other hand, it is possible that having both meanings present

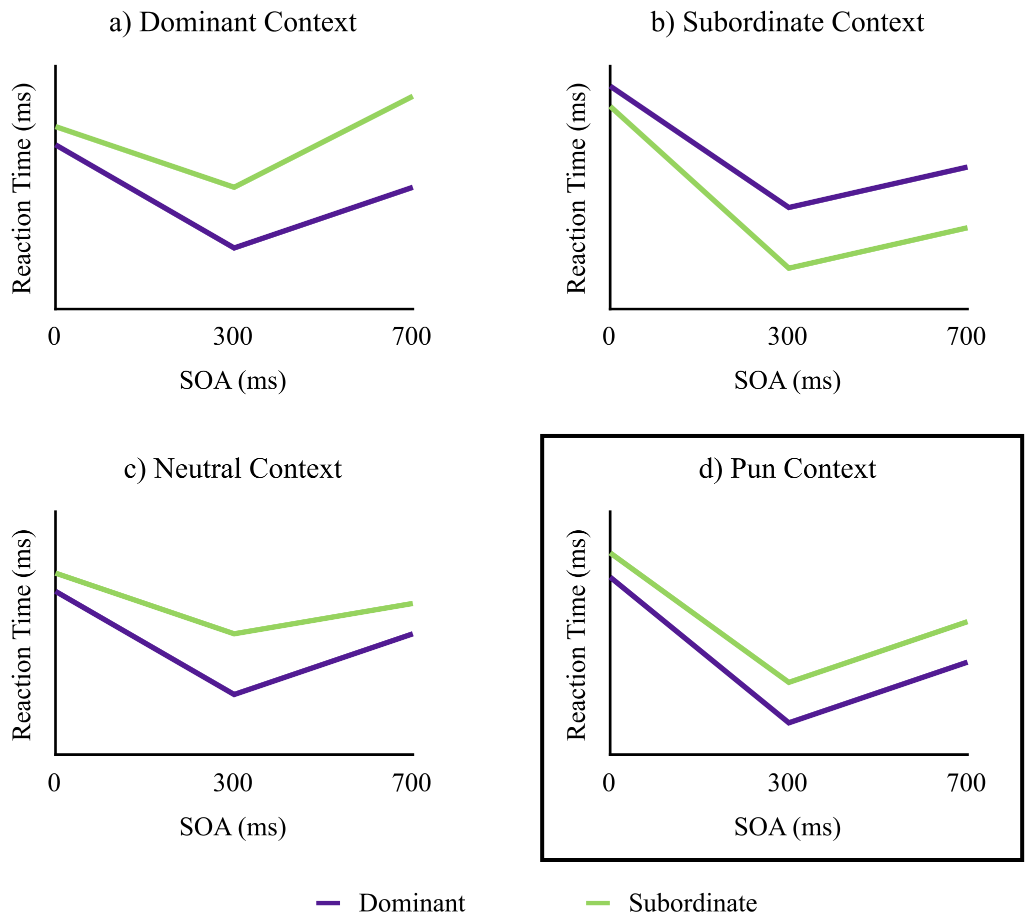

Fig. 1. Predictions for the time course of meaning activation across four sentence types in Experiment 1. Hypothesized data are based on the reordered access model as well as data from previous cross-modal priming experiments. Our novel predictions are enclosed in the box, in graph d.

Note that the reactions times are relative to only data within the same graph, not to data presented in adjacent graphs.

and supported within the discourse would cause the meanings to actively compete, lessening activation. Considering the “normal” course of exhaustive access in which all meanings are activated regardless of contextual support, the reordered access model would predict that the dominant meaning would simply be put in the accessed list before the subordinate, and processing delays will not occur. Thus, we predict that both meanings will be simply facilitated by their respective support from the discourse. Furthermore, any differences between the access of the meanings both within the pun context and across contexts would be seen only at 700 ms.

The evidence that supports the subordinate bias effect suggests that support for multiple meanings causes a delay in processing. Pun sentences provide a different set of circumstances that those that cause this effect. The dominant meaning gets two activation boosts, from both the context and frequency, while the subordinate gets a boost solely from the context. This is slightly similar to the contextual support seen in neutral sentences: the only clue toward resolution is an activation boost from the dominant meaning’s frequency while the subordinate meaning receives no facilitation. Based on this parallel, it could be argued that the patterns of activation experienced in processing pun sentences would parallel those resulting from the processing of neutral sentences. The levels of activation experienced when processing puns might simply experience a global boost above the levels seen when processing neutral context sentences.

We predict that that the time-course of activation of the two meanings in the pun sentences will be distinct from that of the neutral sentences. Both meanings of the pun are appreciated, providing humor to the pun, and thus processes distinct from those involved in parsing neutral sentence must be at work. While the reordered access model posits exhaustive access and this activation process might be similar between neutral and pun sentences, the selection and integration processes must differ between those two types of sentence. The reordered access model suggests that, because the dominant meaning of the ambiguous word will be accessed first, before the subordinate, at 0 ms, the dominant will be significantly facilitated over the subordinate. However, as the processor successfully integrates the subordinate meaning into the discourse as well, this meaning will become further activated; this will be evident at 300 ms. This prediction echoes the intuition of understanding a pun’s layers of meaning in waves, the dominant meaning being more readily apparent than the subordinate. Furthermore, this mimics the activation patterns of the two meanings found by Simpson and Krueger (1991). They found that the dominant meaning experiences facilitation across the time course while the activation of the subordinate meaning rises at a slower pace, becoming comparable with the dominant at 300 ms. Then, both meanings will experience parallel decay by 700 ms. These novel predictions are depicted in Figure 1d.

If results are as predicted and the dual context condition does not mimic the neutral context condition, it will be further support for the reordered access model (Duffy et al. 1988), because it would be clear that both context and meaning frequency affect access. In addition, these results will provide insight into the nature of the simultaneous access of meanings. This experiment will also pave the way for future experiments that will further compare the processing of puns to other discourse containing lexical ambiguity and investigate whether these differences contribute to the humorousness of puns.

3. Experiments

The current study was composed of a pair of experiments that both used a cross-modal lexical decision task. Experiment 1 investigated the nature of lexical access in processing of puns. To this end, it compared the time-course of activation of dominant and subordinate meanings of ambiguous words situated in a pun context to that of those meanings situated in three other contexts: dominant, subordinate, and neutral. Experiment 2 was a norming experiment to ensure that any results found in Experiment 1 were the result of lexical priming effects from processing of the selected meaning of the lexical ambiguities, and not from the preceding context leading to the selection of that meaning. In addition, it was performed in order to discover any item effects within the stimuli set. We based our design off Simpson and Krueger's (1991) two experiment paradigm in their study.

3.1 Experiment 1

3.1.1 Methods

3.1.1.1 Design. Each stimulus set was comprised of four contexts: pun, dominant, subordinate, and neutral. In addition, two visual probes types were used: associates of the dominant and subordinate meanings of the homograph. These two factors— context and probe type— varied within subjects. SOA varied between subjects; subjects saw the visual probe at an SOA of either 0, 300, or 700 ms. Each subject saw a total of 104 stimuli: eight practice trials and 96 experimental trials.

3.1.1.2 Subjects. Forty-eight subjects participated in this study. All participants were Brown University undergraduates who either participated for course credit or were paid $8. All subjects reported normal or corrected vision and hearing and were native, monolingual speakers of English, having not had significant exposure to any language besides English before middle school or age 12.

3.1.1.3 Stimuli and Materials. The suite of stimuli consists of sets of four sentences created surrounding 16 distinct biased lexically ambiguous nouns selected from the University of Alberta homograph norms (Twilley et al., 1994). These words were selected to be both homographs and homophones so as to eliminate any possible noise from different processing styles, as well as to make the stimuli more flexible for use in potential future experiments that utilize different presentation paradigms. The sentences were constructed such that the ambiguous word was the last word in the sentences; all context supporting the homograph preceded it. Some of the stimuli sentences were adapted from Sheridan et al. (2009).

There were four possible contexts that the sentence could provide for the ambiguous word: pun, dominant, subordinate, and neutral. The pun sentences contained context that explicitly supported both the dominant and subordinate homograph meanings. The order of context presentation in these sentences was balanced among the sixteen sentences so that in half of the sentences, the dominant context information was presented before the subordinate, and in the other half the reverse was true. We took this measure in an effort to balance any effects that would be created by one piece of contextual information being closer to the ambiguous target than the other. It should be noted that because this experiment is more an investigation of lexical ambiguity than of humor, per se, the pun sentences are more simulations of puns than discourse that would be regarded as puns in the wild. Though many puns capitalize on idioms, figurative meanings of words, and mere phonological similarity rather than identical word forms, the stimuli in the current experiment use lexically ambiguous words with multiple explicit and distinct meanings. The neutral sentences were constructed to provide no support for any meaning. This was accomplished by providing the least amount of context possible for a plausible and substantial sentence.

Furthermore, in the pun, dominant, and subordinate sentence types, we took care to put as much neutral sentential information as possible between the biasing context and the ambiguous word. This was done to reduce confounding semantic effects on the lexical decision task originating from the preceding sentential context rather than from the ambiguous word. This effort was taken for the same reason warranting Experiment 2 — we are measuring the activation of the meanings of homograph and ascribing their source to the homographs themselves rather than to the preceding context and therefore must take all precautions to ensure that this is indeed the truth.

Two unambiguous words were selected to be visual probes, one related to the dominant and one to the subordinate meaning of the homograph. If possible, they were the primary associate of the meaning as listed in the University of Alberta homograph norms (Twilley et al., 1994). These probes were matched for frequency, word length, and baseline lexical decision reaction time. All three of these data points for each word were obtained from the online database of the English Lexicon Project (Balota et al., 2007); these data can be found in Appendix B. Frequency data were log-transformed frequency norms from Lund and Burgess's Hyperspace Analogue to Language (HAL) corpus, which consists of 131 million words scraped from 3,000 Usenet groups in 1995 (Balota et al., 2007). See Table 1 for an example stimuli group or Appendix A for the full set of stimuli used in this and following experiment.

In addition, there were 80 filler sentences in this experiment, the set of which was comprised of three different types, varying by probe type. This filler sentence cohort was comprised of 48 nonword, 16 unrelated unambiguous word, and 16 related unambiguous word filler stimuli. This provided for an overall balance of word and nonword stimuli presented to a subject across the ambiguous word and filler stimuli. Thus, there were a total of 96 stimuli seen by each subject. All auditory stimuli were spoken by a 21-year-old female Brown University student with a regionally neutral accent.

The experiment was performed using a ViewSonic GraphicsSeries G90fB CRT monitor, Panasonic RP-HTX7 headphones with a RadioShack brand headphone cord extender, Dell keyboard, and a PC desktop computer running Windows XP with an ASIO audio card set to have a buffer latency of 10 ms. The experiment was prepared and presented using SR Experiment Builder, taking advantage of the software's real-time capabilities to ensure that all timing was as accurate as possible, both in stimulus presentation and reaction time recording. All instruction text was Times New Roman, size 20 and all stimulus text was size 40. All text was colored black on a white background.

3.1.1.4 Procedure. Subjects sat approximately 18 inches from the screen and instructed to put on the headphones. Participants completed eight practice trials followed by 96 test trials consisting of the 16 experimental and 80 filler sentences in pseudorandom order with no breaks. The experiment implemented the cross modal lexical decision paradigm. Subjects heard a sentence ending in the control target. While the sentence was being delivered, subjects were to attend to a fixation cross in the middle of the screen. If a subject was in the 0 ms SOA condition, then the visual probe was presented coincidental to the onset of the homograph probe. If a subject was in the 300 ms SOA condition, then the visual probe was presented 300 ms after the onset of the homograph, and likewise for 700 ms. The subjects performed a lexical decision on the probe, pressing "L" if the probe were a word, and "A" if it were a nonword. The reaction time to perform the lexical decision as well as the accuracy of the response was recorded. Following this task, a yes/no comprehension question was presented to ensure subjects were processing the sentences, and the accuracy and reaction times were recorded. To answer the question, subjects pressed "L" for "yes" and "A" for "no."

3.1.1.5 Dependent Measures. This experiment collected reaction time and accuracy data for the lexical decision task and accuracy data for the comprehension question. The reaction time data will be the basis of comparison for the analysis of the time-course of processing, and the accuracy data was collected to ensure that the data were accurate and obtained from quality trials.

While Simpson and Burgess (1985) and Simpson and Krueger (1991), the main experiments upon which this was based, reported and compared “facilitation scores,” we saw fault in this and decided to use the pure lexical decision scores instead. Their facilitation scores were determined by subtracting the reaction time for the related probe from that for a frequency- and length-matched unrelated control probe. However, through examination of queries sent to the English Lexicon Project database (Balota et al., 2007), we found that words that had similar frequencies and lengths did not necessarily have similar baseline lexical decision reaction times. Thus, we decided that comparison of reaction times for related probes to a neutral probe was undesirable, and recognize that because of this the data upon which we make our predictions might be slightly erroneous. However, the qualitative predictions to be made fit with the general pattern of data from similar experiments and thus we believe that it is suitable to make such predictions. Though baseline reaction time cannot conclusively be extrapolated as a function of frequency and word length, we did however make an effort to select dominant and subordinate probes that matched as best as possible on these dimensions, as well as the reported baseline lexical decision reaction times. See Appendix B for a complete list of homograph/homophone-probe pairs, including these three data for each of the probe words.

3.1.2 Results. Separate analyses were conducted for accuracy on the lexical decision task, accuracy on the comprehension question, and reaction time on the lexical decision task.

Accuracy on the lexical decision task was at 99.1%, as only seven out of 768 lexical decision trials were answered incorrectly. No further analyses were performed on this data. Overall accuracy on the comprehension question was lower, at 89.19%, with 83 trials answered incorrectly. Average accuracy on the comprehension questions between the four context types were all comparable to the overall mean (Dominant: 88.02%; Neutral: 93.22%; Pun: 85.41%; Subordinate: 90.10%).

The bulk of the analysis was performed on the lexical decision reaction time data. Only trials for which subjects gave a correct answer to both the lexical decision and the comprehension question were included in the analysis. We subsequently trimmed outliers from the data. Measurements exceeding 3000 ms were excluded, as determined by visual inspection of the data distribution. No data were below a threshold that we considered appropriate for removal through this method. Furthermore, experimental error warranted the removal of 6 data points.[1] Following that, z-scores were computed based on the log-normal distribution and data falling outside of 2.5 standard deviations were trimmed. These removal procedures resulted in a loss of 3.08% of the analyzable data. Means for each context-probe pairing at each SOA were computed. These results can be found in Table 2 and Figure 2.

Statistical analysis was computed for log-transformed reaction times using a mixed effects model for which fixed effects were fully crossed. Fixed effects were context type, probe type, and SOA, fully crossed. Random intercepts for participants and items and subjects, and random slopes for participants were included. We found a main effect of SOA ($F = 4.8915$; $df = 2$;

[1] An experimental error that caused a duplicate item to be presented in place of another item was discovered in the data sets of six participants. Data from the second instance of the item were omitted from analysis.

DFDef = 44.9; p = 0.0120). The interaction between probe type and SOA was also significant (F = 3.7277; df = 2, DFDen = 34.77; p = 0.0341). No other effects approached significance.

With our specific hypothesis in mind, analyses of the lexical decision reaction time were also performed for the subset of the data including only the neutral and pun sentences. The same model structure was used on this data as was used for the full lexical decision data set. Similar results were found. There was a main effect of SOA (F = 5.6064; df = 2; DFDen = 45.6; p = 0.0067). There was also a marginal interaction effect of probe type by SOA (F = 2.9580; df = 2; DFDen = 33.85; p = 0.0655). There were no other significant effects.

The data show that the activation of the meanings of the data rise and fall over time, as corroborated by the main effect of SOA. This time-course is different depending on the meaning being activated, as supported by the probe by SOA interaction. While the dominant and subordinate probes have generally the same time course form 0 to 300 ms, the patterns of

Table 2

Mean raw lexical decision reaction times and standard errors (in ms) across three stimulus onset asynchronies (SOAs) from Experiment 1.

		SOA (ms)		
Context	Probe	0	300	700
Pun	Dominant	877 (56)	755 (44)	818 (53)
	Subordinate	916 (46)	832 (65)	787 (63)
Dominant	Dominant	926 (65)	791 (60)	759 (58)
	Subordinate	907 (46)	779 (48)	675 (26)
Subordinate	Dominant	922 (53)	784 (57)	854 (82)
	Subordinate	925 (73)	804 (54)	727 (54)
Neutral	Dominant	868 (61)	777 (53)	789 (61)
	Subordinate	945 (48)	803 (57)	734 (50)

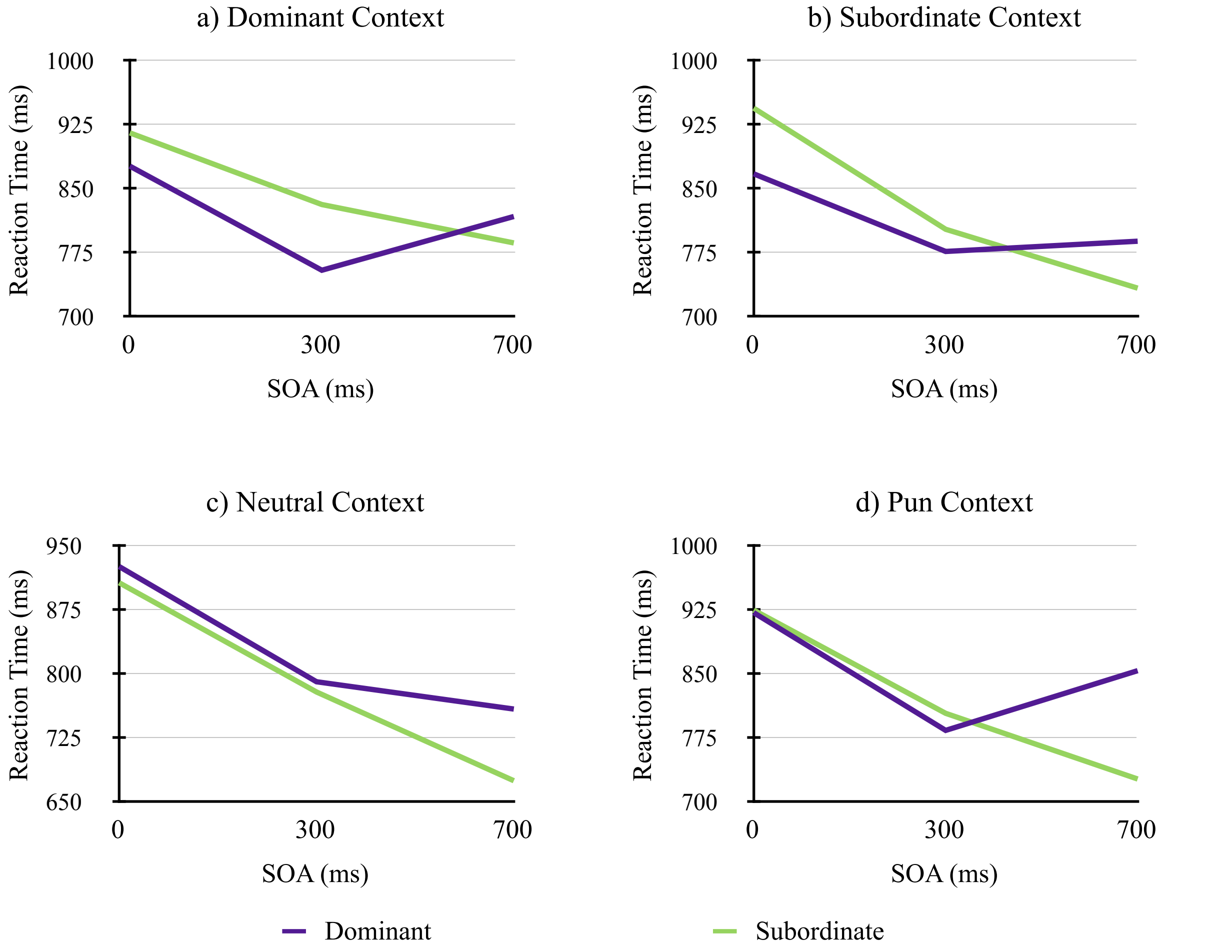

Fig 2. Mean raw lexical decision reaction times (in ms) for two probe types across three SOAs for four context types in Experiment 1

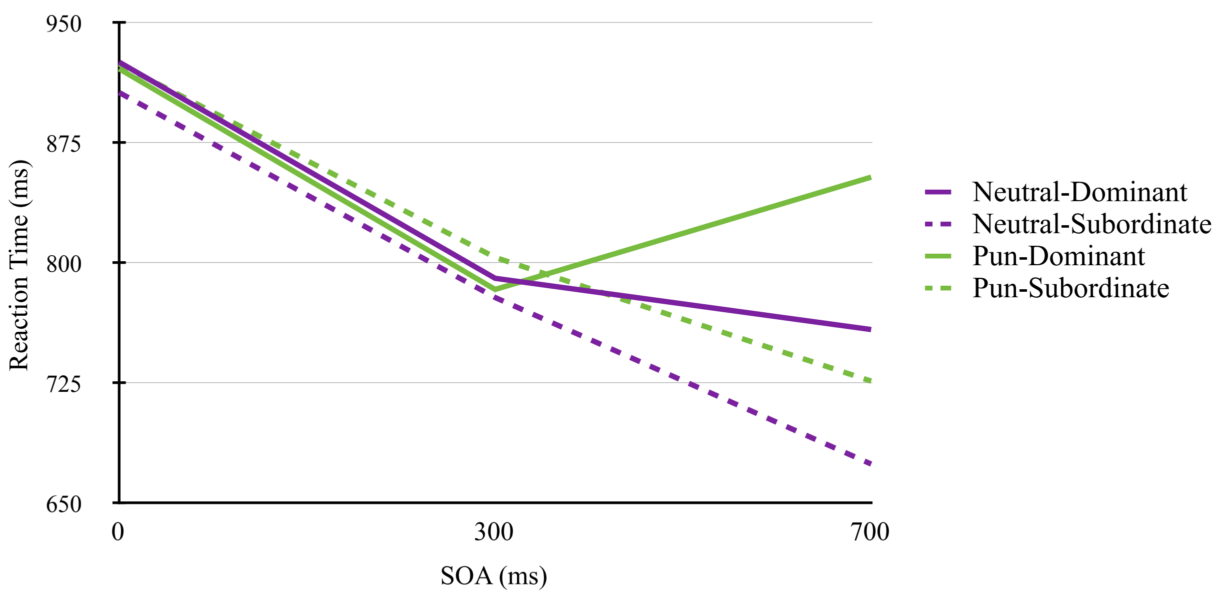

Fig. 3. Mean lexical decision reaction times (in ms) for the neutral and pun sentences across all SOAs in Experiment 1.

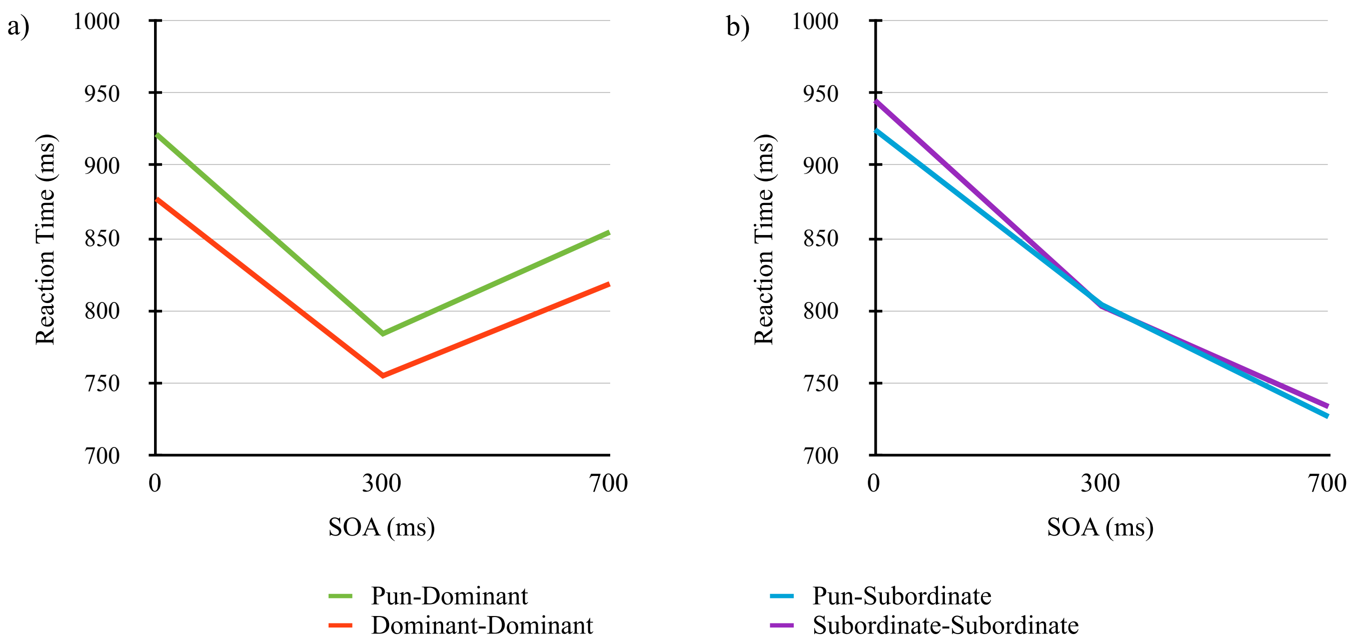

Fig. 4. Mean raw reaction times (in ms) from Experiment 1 for trials in which the meaning of the probe was supported by the context of the sentence.

processing have diverged by 700 ms. This is best demonstrated in the pun and neutral contexts. Visual analysis of the graphs in Figure 3 show that dominant meaning takes on a more v-shaped time-course of activation, gaining activation by 300 ms, and then decaying by 700 ms. On the other hand, the subordinate meanings all experience rising activation throughout the time-course, experiencing facilitation over the dominant meaning at 700 ms across all four contexts. The subordinate time course is linear for all four conditions.

Figure 3 shows the time-course of activation of the neutral and pun sentences for both the dominant and subordinate meanings. This superimposition demonstrates that the activation of both probes across both time-courses for both the contexts is relatively similar at the 0 and 300 ms time slices. However, by 700 ms, each pairing's time-course becomes distinct. Again, this is reflected in the significant probe-SOA interaction. The subordinate meaning continues to experience facilitation while the activation of the dominant meaning flattens out or decays.

Figure 4a shows the time-course of the dominant meaning in puns and in dominant context sentence. The time-courses remain parallel to each other throughout the entire time window. The meaning in the pun context gave results that were about 50 ms slower than that in the dominant. This was approximately the standard deviation of the data, suggesting that these time-courses are identical or at least quite similar. Figure 4b tells a similar story about the subordinate meaning in the pun and subordinate context sentences. Graphing the time courses of these pairings shows that these lines overlap throughout the time-courses, strongly suggesting that the meaning is processed identically in these two conditions.

3.2 Experiment 2

Experiment 2 was designed to ensure that the nature of the experimental stimuli in Experiment 1 did not confound the data. It was modeled after Simpson and Krueger's (1991) experiment that they performed to ensure the validity of their results. On one level, this experiment was meant to ensure that any effects being seen between the different types of sentences arise from the relationship between the homographs ending the sentences and the probe word on which the lexical decision is made, rather than the effect coming from the context created to constrain the meaning of the homograph. To this end, the stimuli sentences were constructed so that any biasing information is presented as far from the homograph as possible, but without sacrificing the readability of the sentences. The experiment was also performed to ensure that there were no item effects from any of the stimuli. The nature of the stimuli made it such that is was possible that subjects might find some of the sentences awkward or difficult to comprehend, and such difficulty in comprehension might cloud warranted effects or create effects not derivative of the processing of the ambiguity.

In this experiment, the stimuli sentences used ended not in the homographs used in Experiment 1, but rather in words unrelated to the homograph that fit into the sentential context. This is in an attempt to isolate any effects that would arise from the context used to constrain the homograph's meaning. If the dominant probe is significantly facilitated over the subordinate after following the dominant context sentence, the facilitation must have been caused by the context, thus confounding results found in the previous experiment. Since those results are attributed to the access of the homograph meanings, we would like to make sure that those results do indeed derive from lexical of the homograph. It is expected, however, that there will be some effect derived from the context, as was found by Simpson and Krueger (1991) in their analogous experiment.

3.2.1 Methods

3.2.1.1 Design. The design of this experiment was derivative of Experiment 1. The stimuli set for this experiment consisted of 16 sentences sets consisting each of three unique sentences differing based on contextual support for an ambiguous lexical item: dominant, subordinate, and neutral contexts. Each sentence set was then paired with two visual probe words related to the two selected meanings of the homograph. Both context and probe type varied within subjects.

3.2.1.2 Subjects. Eighteen subjects participated in this study. All subjects were Brown University undergraduates recruited through a subject pool for course credit. All subjects reported normal or corrected vision and hearing and were native, monolingual speakers of English, having not learned another language prior to middle school or age 12.

3.2.1.3 Stimuli and Materials. The dominant, subordinate, and neutral context sentences from the sixteen sentences sets used in Experiment 1 were used, except that the sentence final homograph was replaced with an unrelated but contextually appropriate non-ambiguous filler word that remained consistent across the three sentences. The neutral context sentence was not included in this experiment because it was constructed explicitly to not have any biasing context. The visual probes used for each sentence in Experiment 1 were again used in this experiment. See Table 1 for a sample stimuli set, or Appendix A for a complete list of stimuli used in this and the previous experiment. Sixteen filler sentences with pseudoword probes were also prepared. Furthermore, a short yes/no comprehension question was also provided for each sentence in the experiment. Half of the questions warranted "yes" responses and the other half warranted "no" responses.

3.2.1.4. Procedure. The procedure was largely similar to that of Experiment 1. There were two major differences that reflected the differences in design between the two experiments. Participants completed eight practice trials followed by 32 test trials consisting of the 16 experimental and 16 filler sentences in pseudorandom order with no breaks. Furthermore, the SOA in this experiment remained at 0 ms for all subjects. In addition, no headphone extender was utilized in this experiment.

3.2.1.5 Dependent Measures. As in Experiment 1, we recorded lexical decision reaction time and accuracy, as well as comprehension question accuracy. Again, lexical decision reaction time was the basis of most of our analyses.

3.2.2 Results. Separate analyses were performed for accuracy on the lexical decision task and the comprehension question, and reaction time on the lexical decision task.

Accuracy of the lexical decision task was at 98.96%, with only 3/288 incorrect responses. No further analyses were deemed necessary. Overall accuracy on the comprehension was slightly lower, as expected, at 93.75%, with 18/288 questions answered incorrectly. Accuracies on the comprehension questions between the three context types were all comparable to the overall accuracy (Dominant: 94.79%; Pun: 90.625%; Subordinate: 95.83%).

A more in-depth analysis was performed for the lexical decision reaction times. First, we trimmed the data for accuracy. Trials were eliminated if either the lexical decision or the following comprehension question were answered incorrectly, resulting in the elimination of 21 trials, or 7.3% of the data. We then trimmed the data for statistical outliers. From the remaining 267 analyzable data points, condition-wise z-scores were computed for the lexical decision reaction times based on the context-probe pairing, and outliers with a z-score greater than 3 were removed, assuming that these were guesses or premature button presses. This resulted in the removal of six trials, or 2.2% of the remaining correct data, resulting in 261 remaining trials. Means for each context-probe pair were computed. These results can be found in Table 3 and Figure 5.

Statistical analyses were computed using a mixed effects model for which fixed effects of context type and probe type were fully crossed. Random effects were also included: random intercepts for participants and items, plus random slopes for participants. No effects were significant or approached significance.

Table 3

Pairwise means and standard error (in ms) for lexical decision reaction times for Experiment 2.

Context	Probe	Mean (Std. Error)
Pun	Dominant	869 (42)
	Subordinate	825 (54)
Dominant	Dominant	858 (36)
	Subordinate	865 (40)
Subordinate	Dominant	929 (46)
	Subordinate	863 (43)

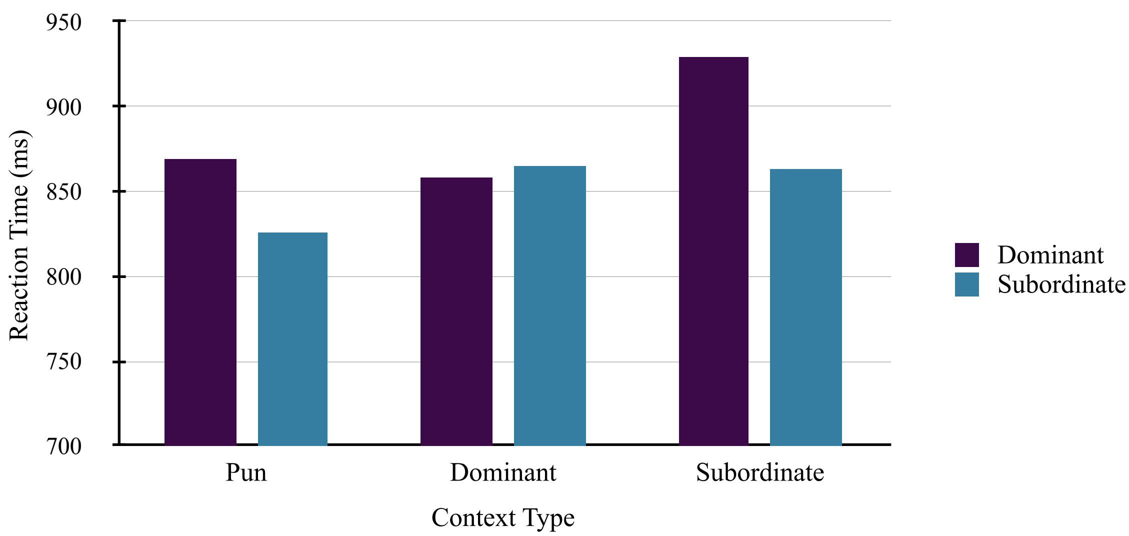

Fig. 5. Mean lexical decision reaction times (in ms) for dominant and subordinate probes across three context types in Experiment 2.

We entertained the possibility that the null results were derivative of a lack of power. Though we only had 18 subjects, three subjects saw each of the six permutation of the conditions (two probes in each of the three contexts). In Experiment 1, however, only 2 subjects saw each permutation. Since we obtained results in that experiment, we do not believe low power to be an issue.

3.2.3 Discussion. There were no significant effects throughout Experiment 2. Neither main effects nor reliable interactions were observed. Thus, it appears that the preceding context of the sentences does not prime the activation of the probe word. This was important to test because any facilitation of the probe word was attributed to the homograph in Experiment 1, and we wanted to make sure that this would be done validly.

Another purpose of this experiment was to make sure that none of the stimuli caused outlying data points. Because no main effects or interactions between the fixed effects and item type were observed, we can conclude that there were no item effects. Therefore, none of the stimuli sentences are particularly problematic, bolstering the effects we found in Experiment 1.

4. General Discussion

Overall, we found that puns are processed differently from neutral sentences holistically; when the individual meanings supported in the pun are evaluated independently, we find that they are both processed as if they were the only meaning supported in the discourse. This shows not only how puns are processed but also has implications for the definition of lexical ambiguity resolution as well as the models that seek to describe the phenomenon. Furthermore, out data provide insight into what might be making puns humorous and witty, in contrast to other language that contains ambiguities which is not considered to be notably enjoyable.

4.1 Processing Puns

We found that the time-course of puns is such that the dominant and subordinate meanings are processed similarly until 300 ms. By 700 ms, the subordinate meaning has continued to experience facilitation while activation of the dominant meaning has decayed. This trend is generally reflected across all four contexts but is best demonstrated in the pun sentences, as shown in Figure 3d. We theorize that this time-course of activation is what allows the subordinate meaning to be appreciated in puns. The fact that the dominant meaning experiences rising activation along with the subordinate and then drops off allows for the subordinate meaning to have a chance at integration. Though it appears that the dominant meaning never receives facilitation above the subordinate meaning, it is possible that this advantage occurs somewhere between 300 and 700 ms time window, and this peak of activation is obscured by the experimental methods. To gain a more comprehensive picture of the full time course and see at which point the dominant probe reaches its peak activation, data should be gathered at more frequent SOA intervals, perhaps at 500 ms, which is the time point by which Coulson and Severens (2007) found activation of both meanings to have spread from just the left hemisphere to both hemispheres. Furthermore, since the most exciting interactions between contexts, probes, and SOAs occurred in later processing, it might also be illuminating to continue investigating the time-course beyond 700 ms. Earlier cross-modal priming experiments (i.e. Onifer & Swinney, 1981) used an SOA of 1500 ms. Doing this, or even getting slices at a finer temporal resolution (i.e., at 900 ms and 1200 ms as well) would provide further insight into the time course.

Neutral and pun context sentences are theoretically similar in that in each, the subordinate and dominant receive equal amounts of contextual support. In the neutral sentences, there is an absence of support for either, and in the pun sentences there is active support for both meanings. In both sentences, the dominant receives a supposed processing boost from being the more frequent meaning. Despite this similarity, we hypothesized that the time-courses of lexical access for these two context types would be distinct. This was found to be the case, as seen in Figure 4. It is apparent that the time-course of the two contexts take on a different pattern than one another, especially considered in the light of the other comparisons that that have been performed. Even further, despite a lack of main effect by context type, we can infer that puns are slightly harder to process than neutral sentences.

Figure 4 suggests that, as was hypothesized, the activation of meanings in puns sentences is such that each meaning experiences activation such that it were the sole meaning supported by the sentential context. So, the subordinate probe experiences the same pattern of activation in the pun context as in the subordinate context. The dominant probe experiences the same pattern of activation in the pun context as in the dominant context, except with slightly less facilitation. This suggests that activation of meanings occurs independent of the activation of other meanings.

4.2 Implications for Models of Access

Lexical ambiguity resolution is usually defined as the ability of the language processor to select the appropriate *meaning* for an ambiguous word. However, this excludes the comprehension of punning because more than one meaning is settled on the course of processing. Because it is apparent that the processes of lexical access and meaning activation are identical in the case of classic lexical ambiguity resolution and puns, we argue that the processor's ability to settle on the appropriate meanings in a pun is also a form of resolution. Thus, the concept of resolution must be expanded to incorporate and support the mind's ability to pun and comprehend puns.

The overall pattern of data supports an exhaustive access model, as both of the meanings are accessed and appear to receive activation. Though Figure 3 only shows data for two of the four context types, it is apparent that both dominant and subordinate meanings in both of the presented context types experience quite similar activation patterns at the first two SOAs (0 and 300 ms) but then differ dramatically at the third (700 ms). This is evidenced in the probe by SOA interaction. The fact that the patterns of activation are the same starting at 0 ms and remain so at 300 ms is probably the source of the lack of a main effect of probe type, as there are apparent dramatic differences at 700 ms. Furthermore, this similarity between the two probes at 0 ms replicates the data found in previous cross-modal priming studies supporting the exhaustive access model. Overall, this pattern of access suggests that all meanings are accessed and thus receive facilitation, and by 700 ms, the selection process is underway and meanings are being processed differently based on their probe type and the context.

While the data clearly support the exhaustive access model, our predictions were made based on the reordered access model. The data, however, do not provide as explicit support for this model as for the more generic exhaustive access model. This is possibly due to the fact that a cross-modal priming task is unable to capture the nuances in processing that are necessary to back up the reordered access model over the integration model. After all, the differentiation of these two models from a generic exhaustive access model only arose from the use of eye-tracking methodology.

The reordered access model would predict different time courses of activation between the three contexts we were expecting to replicate (dominant, subordinate, and neutral). However, we did not witness a main effect of context type, and thus cannot say conclusively that our data reflect the model. More specifically, the model would predict that in the dominant context, the dominant meaning would begin slightly facilitated over the subordinate and would gain facilitation as it was able to be integrated into the context. Upon looking at the graphs in Figure 2, it is apparent that this is not the case; the subordinate meaning surpasses the dominant meaning in all four contexts. The model would go on to predict that in the subordinate context, the subordinate meaning would be facilitated over the dominant across the time-course. However, a similar time course occurs for the subordinate context as for the dominant. The subordinate meaning does become more facilitated over the dominant meaning, but the dominant meaning is also more facilitated in the subordinate content than in the dominant context.

Though there is no clear support of the reordered access model, the data are simultaneously inconclusive in that respect, not allowing support for either that model or the integration model. The low temporal resolution of the data make it hard to understand exactly what is occurring between 300 and 700 ms. In order to provide data that would have the power to capture the nuances necessary to lend more conclusive support to a more differentiated exhaustive access model— reordered access model or integration model— an eye-tracking while reading study should be performed. However, the main purpose of the current study was not to provide support for one model of resolution over another. Thus, we are satisfied with finding data consistent with a general exhaustive access model.

4.3 Potential Insights into Humor

Though we will not advocate here for one model of humor elicitation over another, through looking at the present data we can glimpse insight into what makes pun processing different from the processing of other language with ambiguity that is not considered funny or witty. The very nature of the two distinct types of discourse suggested processing differences, but the data show that the processing of each meaning is barely different from when it is processed individually. However, both meanings of the pun are appreciated, and this is what makes the pun enjoyable, The pun is not enjoyable until the second meaning is realized, and experience comprehending puns suggests that "getting" the pun, or the process of understanding that second meaning occurs after rather than coincidental with the comprehension of the first meaning. Previous studies in lexical ambiguity resolution and the reordered access model would suggest that the dominant meaning within the pun is probably appreciated first, followed by the subordinate meaning. This is reflected in the current data, which suggest that the mind finds a meaning that it can integrate, but then continues iterating through trying to integrate meanings in the accessed list, as evidenced by the continued activation of the subordinate meaning. The processor is not accustomed to finding a second integrable meaning because most ambiguities can be smoothly resolved to a single meaning, but it does. This violates expectations, which is theorized to be a source of humor.

5. Conclusion

This study was comprised of two experiments that investigated the time-course of lexical access in the processing of puns. Puns are a unique linguistic phenomenon in that they are comprised of multiple threads of context that converge on a single word, thus providing equal contextual support for the two meanings of the word. We conclude that the patterns of activation for the multiple meanings supported in the pun are the same as if that meaning were the only meaning supported by the discourse. This is in contrast to mimicking the patterns of activation found in sentences in which neither meaning of a multiple meaning word are explicitly highlighted in the discourse, or having a distinct pattern of activation altogether.

The results obtained support an exhaustive access model, but they do not explicitly support the widely supported reordered access model as much as we would have hoped or expected. Regardless, the consistency throughout the trials that allows for the results to shine through allows us insight into the nature of pun processing as well as lexical ambiguity resolution in general. From these results, we advocate that the notion of lexical ambiguity resolution be expanded to encompass and support pun processing.

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Appendix A: Experimental Stimuli for Both Experiments

Homograph	Condition	Sentence	Probes
stock	Pun	The broth company was experiencing success in testing their new recipe and was preparing to start selling their STOCK/product.	bond (d) soup (s)
	Dominant	The newly-formed corporation was finalizing their financial plans and was preparing to start selling their STOCK/product	
	Subordinate	The French restaurant had finally perfected their new recipe and was ready to start selling their STOCK/product	
	Neutral	The company was experiencing success in testing their new formula and was preparing to start selling their STOCK.	
pen	Pun	The journalist started composing the introduction to an article about the special pig while she looked for her PEN/friend	ink (d) cage (s)
	Dominant	The journalist started composing the introduction to an article about the special boy while she looked for her PEN/friend.	
	Subordinate	The farmer started telling the schoolchildren a story about the special pigs while he looked for their PEN/friend.	
	Neutral	The professor looked for her PEN.	
suit	Pun	The attorney and the tailor discussed the specifics of the SUIT/game.	tie (d) law (s)
	Dominant	The tailor and his client discussed the specifics of the SUIT/game.	
	Subordinate	The attorney and the client discussed the specifics of the SUIT/game.	
	Neutral	The doctor and the businessman discussed the specifics of the SUIT.	
plant	Pun	The botanist rushed to the factory upon receiving a message that there might be a problem with the PLANT/experiment.	green (d) power (s)
	Dominant	The botanist rushed to the laboratory upon receiving a message that there might be a problem with the PLANT/experiment.	
	Subordinate	The scientist rushed to the reactor upon receiving a message that there might be a problem with the PLANT/experiment.	
	Neutral	The scientist rushed to the PLANT.	
story	Pun	On Tuesday, the newspaper moved to a new building, and subsequently, the journalist started working on the second STORY/project.	piece (d) floor (s)
	Dominant	On Tuesday, the newspaper started a new column, and subsequently, the journalist started working on the second STORY/project.	

Homograph	Condition	Sentence	Probes
	Subordinate	On Tuesday, the law office moved to a new building, and subsequently, the lawyer started working on the second STORY/project.	
	Neutral	On Tuesday, the woman started working on the second STORY.	
plane	Pun	The geometry whiz who wanted to be a pilot loved spending all of his free time reading books about PLANES/cats.	jet (d) flat (s)
	Dominant	The chemistry whiz who wanted to be a pilot loved spending all of his free time reading books about PLANES/cats.	
	Subordinate	The geometry whiz who wanted to be a professor loved spending all of his free time reading books about PLANES/cats.	
	Neutral	The chess whiz who wanted to be a professor loved spending all of his free time reading books about PLANES.	
coat	Pun	Although he was anxious to finish the job, the cold painter decided to take a minute and put on another COAT/song.	jacket (d) paint (s)
	Dominant	Although he was anxious to get out of the cold, the worker decided to take a minute and put on another COAT/song.	
	Subordinate	Although he was anxious to finish the job, the tired painter decided to take a minute and put on another COAT/song.	
	Neutral	Although he was anxious to finish the job, the tired worker decided to take a minute and put on another COAT.	
stage	Pun	When she arrived at the playwriting workshop, Susan found the coordinator, who informed her about her project's STAGE/location.	platform (d) process (s)
	Dominant	When she arrived at the theatre festival, Susan found the coordinator, who directed her to her project's STAGE/location.	
	Subordinate	When she arrived at the product development workshop, Susan found the coordinator, who informed her about her project's STAGE/location.	
	Neutral	When she arrived at the workshop, Susan found the coordinator, who informed her about her project's STAGE.	
key	Pun	The businessman was whistling while trying to get into his apartment, but he just couldn't find the right KEY/door.	lock (d) tune (s)
	Dominant	The businessman was talking while trying to get into his apartment, but he just couldn't find the right KEY/door.	
	Subordinate	The tone-deaf man was whistling while walking down the street, but he just couldn't find the right KEY/door.	
	Neutral	The businessman couldn't find the right KEY.	
leaf	Pun	For my birthday, my aunt gave me an antique floral plate, and my favorite part of it is the gold LEAF/swan.	stem (d) foil (s)

Homograph	Condition	Sentence	Probes
	Dominant	For my birthday, my aunt gave me a beautiful quilt, and my favorite part of it is the gold LEAF/swan.	
	Subordinate	For my birthday, my aunt gave me an ornate plate, and my favorite part of it is the gold LEAF/swan.	
	Neutral	For my birthday, my aunt gave me a plate, and my favorite part of it is the gold LEAF.	
yarn	Pun	My grandmother used to tell me about her childhood while knitting, but she would always lose track of her YARN/place.	string (d) story (s)
	Dominant	My grandmother used to watch her favorite TV show while knitting, but she would always lose track of her YARN/place.	
	Subordinate	My grandfather used to tell me about his childhood while cooking, but he would always lose track of his YARN/place.	
	Neutral	My grandmother used to always lose track of her YARN.	
bar	Pun	The gymnast, who had just turned twenty-one, was nervous as she approached the BAR/President.	drink (d) beam (s)
	Dominant	The girl, who had just turned twenty-one, was nervous as she approached the BAR/President.	
	Subordinate	The gymnast, who had just learned a new routine, was nervous as she approached the BAR/President.	
	Neutral	The girl was nervous as she approached the BAR.	
shower	Pun	The plumber's bride-to-be and her friend discussed the colors she envisioned for the SHOWER/room.	water (d) party (s)
	Dominant	The plumber and his wife discussed the new tiles they wanted in their SHOWER/room	
	Subordinate	Sub: The teacher's bride-to-be and her friend discussed the colors she envisioned for her SHOWER/room	
	Neutral	The teacher and her friend discussed the colors she envisioned for her SHOWER.	
diamond	Pun	The dealer's fiancée almost had a flush, and all of the players were stunned when he gave her a DIAMOND/kiss	ring (d) card (s)
	Dominant	While dining in the fancy restaurant, the man gave his wife a DIAMOND/kiss.	
	Subordinate	The poker player almost had a flush, and everyone was stunned when the dealer gave her a DIAMOND/kiss.	
	Neutral	The man handed his partner a DIAMOND.	
bug	Pun	The programmer who was afraid of insects was unhappy to find that his project was full of BUGS/holes.	spider (d) mistake (s)

Homograph	Condition	Sentence	Probes
	Dominant	The woman who was afraid of insects was unhappy to find that the bag was full of BUGS/holes.	
	Subordinate	The programmer who was afraid of failure was unhappy to find that his project was full of BUGS/holes.	
	Neutral	The researcher returned to the office to find that the project was full of BUGS.	
habit	Pun	When Anne was a nun, she was frequently scorned for having dirty HABITS/shoes.	routine (d) dress (s)
	Dominant	When Anne was in etiquette school, she was frequently scorned for having dirty HABITS/shoes.	
	Subordinate	When Anne was a nun, she was frequently scorned for wearing dirty HABITS/shoes.	
	Neutral	Anne was frequently scorned for having dirty HABITS.	

Appendix B: Probe Word Data

Homograph	Probes (Dominant, Subordinate)	Word Length (letters)	Log Frequency	Lexical Decision RT (ms)
stock	bond	4	9.469	587.424
	soup	4	8.707	539.559
pen	ink	3	8.630	575.061
	cage	4	9.048	588.032
suit	tie	3	9.608	589.118
	law	3	11.739	540.323
plant	green	5	11.416	623.471
	power	5	12.142	604.412
story	piece	5	10.739	620.091
	floor	5	10.481	562.788
plane	jet	3	9.417	548.970
	flat	4	10.176	571.471
coat	jacket	6	9.231	580.029
	paint	5	9.678	555.719
stage	platform	8	10.106	658.969
	process	7	11.503	681.161
key	lock	4	9.810	583.419
	tune	4	9.414	590.031
leaf	stem	4	8.183	565.818
	foil	4	8.595	634.250
yarn	string	6	10.410	619.647
	story	5	11.482	601.968
bar	drink	5	9.897	560.182
	beam	4	8.972	633.364
shower	water	5	11.571	564.879
	party	5	11.138	539.710

Homograph	Probes (Dominant, Subordinate)	Word Length (letters)	Log Frequency	Lexical Decision RT (ms)
diamond	ring	4	10.696	545.333
	card	4	12.314	605.091
bug	spider	6	8.8472	625.121
	mistake	7	10.143	606.438
habit	routine	7	9.625	652.030
	dress	5	9.424	550.441