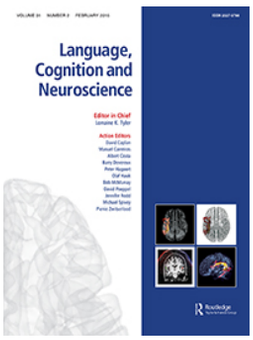

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The role of selection in the comprehension of focus alternatives

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ABSTRACT

Successful language comprehension often requires comprehenders to infer contrastive focus alternatives, but the mechanisms used to establish contrastive alternatives are still poorly understood. We propose that comprehenders establish contrastive alternatives by using selection mechanisms that distinguish contrastive from non-contrastive candidates. To examine this proposal, we investigated the time course of contrastive alternatives in two cross-modal priming experiments, manipulating contrastive focus on prime words and the contrastiveness of visual targets. Experiment 1 examined early processing where comprehenders are entertaining candidates for contrastive alternatives. Experiment 2 examined later processing where comprehenders have selected contrastive alternatives from the candidate set. Results demonstrated that when primes were contrastively focused, initially both contrastive and non-contrastive associates were facilitated, but, in subsequent processing, non-contrastive associates became deactivated while contrastive associates maintained facilitation. We argue that selection mechanisms distinguish contrastive from non-contrastive candidates by deactivating non-contrastive candidates, enabling comprehenders to draw proper inferences about speakers' implicit meanings.

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Cross-modal priming; contrastive focus alternatives; pitch accent; selection mechanisms; semantic processing

Carrying on a conversation is usually effortless, in part because conversations are highly structured and much of their content can be implicitly conveyed. One of the core linguistic devices that structures the flow of conversation is sentential *focus*, the marking of new or emphasised information in a sentence (Chomsky, 1972; Jackendoff, 1972). Often, this information is provided in implicit contrast to other possible alternatives (Rooth, 1985). In English, one way a speaker marks *contrastive focus* is by placing a prominent accent on a word, indicating that a statement stands in contrast to other alternatives (Pierrehumbert & Hirschberg, 1990; Selkirk, 1984). Saying *The museum thrilled the SCULPTOR* (with a pitch accent on *sculptor*) indicates both that the sculptor was thrilled and that other alternatives such as a painter or a potter were not. Successful comprehension requires comprehenders to infer this set of contrastive alternatives as intended by the speaker.

Questions about how comprehenders infer the intended set of contrastive alternatives rest on at least two issues. The first, which has been investigated more widely in the recent literature, concerns what sources of information comprehenders draw upon to correctly infer the contrastive set of alternatives (Byram Washburn, Kaiser, & Zubizarreta, 2011; Fraundorf, Benjamin, & Watson, 2013; Fraundorf, Watson, & Benjamin, 2010). The second concerns what mechanisms act on these information sources to establish the proper set of contrastive alternatives. This paper investigates this second issue, the mechanisms comprehenders use to establish the set of contrastive focus alternatives during online sentence processing. It proposes that a process of *selection* from a set of active candidates plays a key role in establishing the set of contrastive alternatives. Cued by contrastive focus marking, this process of selection evolves over time as comprehenders reject non-contrastive candidates, ultimately resolving the proper set of contrastive focus alternatives.

Focus and its processing

The focus of a sentence is information that is new, unrecoverable, or emphasised from preceding discourse and may be marked prosodically by a pitch accent, syntactically by a cleft or focus particle, or by a preceding discourse context, including a wh-question (Chomsky, 1972; Jackendoff, 1972; Kiss, 1998; Rooth, 1985; Selkirk, 1984). These focusing tools may also be used in combination; for example, clefted constituents are typically also prosodically prominent. During sentence

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processing, the identification of focus has been argued to influence attention and memory for a focused word (Birch, Albrecht, & Myers, 2000; Birch & Garnsey, 1995; Cutler, 1976; Cutler & Fodor, 1979; Hornby, 1974; Osaka, Nishizaki, Komori, & Osaka, 2002; Sanford, Price, & Sanford, 2009; Sturt, Sanford, Stewart, & Dawydiak, 2004; Ward & Sturt, 2007), to affect lexical access (Blutner & Sommer, 1988), and to guide parsing and interpretative decisions under ambiguity (Filik, Paterson, & Liversedge, 2005; Liversedge, Paterson, & Clayes, 2002; Ni, Crain, & Shankweiler, 1996; Paterson, Liversedge, & Underwood, 1999; Schafer, Carlson, Clifton, & Frazier, 2000; Schafer, Carter, Clifton, & Frazier, 1996; Sedivy, 2002; Sedivy, Tanenhaus, Eberhard, Spivey-Knowlton, & Carlson, 1995). Focus marked by a cleft, focus particle, or preceding discourse context affects fixation durations and regressive movements of the eyes during silent reading (Birch & Rayner, 1997, 2010; Morris & Folk, 1998; Ward & Sturt, 2007). In addition, focus affects downstream processing of ellipsis (Carlson, Dickey, Frazier, & Clifton, 2009; Frazier, Clifton, & Carlson, 2007) and the resolution of noun phrase anaphora and pronouns (Almor, 1999; Almor & Eimas, 2008; Arnold, 1998; Colonna, Schimke, & Hemforth, 2012; Cowles, Kluender, Kutas, & Polinsky, 2007; Foraker & McElree, 2007; Kaiser, 2011; Klin, Weingartner, Guzman, & Levine, 2004; Sanford et al., 2009), demonstrating its role in structuring broader discourse.

One way that focus can structure discourse is by evoking a set of alternatives to the focused element (Jackendoff, 1972; Rooth, 1985, 1992). Often, these alternatives are contrastive to the focused element. Offline evidence for the use of contrastive alternatives finds that focus marking of a contrastive alternative makes comprehenders more accurate at identifying the veracity of a statement about contrastive alternatives that were previously paired in a discourse (Byram-Washburn, Kaiser, & Zubizarreta, 2011; Fraundorf et al., 2010, 2013). Comprehenders also use alternatives to rapidly guide their behaviour online, making more fixations to an unmentioned visual object when the object's referent is focused than when it is not focused (Dahan, Tanenhaus, & Chambers, 2002, but note Arnold, 2008), and also making more fixations to a contrastive visual object when the referent noun or preceding modifier is contrastively focused than when it is not contrastively focused (Ito & Speer, 2008; Watson, Tanenhaus, & Gunlogson, 2008; Weber, Braun, & Crocker, 2006).

These studies provide evidence that comprehenders rapidly make use of focus alternatives. They each examine how prior discourse, visual context, and semantic/phonological association act as information sources for focus, addressing questions concerned with the information sources that are available to focus and how quickly those information sources are accessed. Very few studies, however, have investigated the mechanisms that comprehenders use to establish the proper set of focus alternatives from these information sources, leaving open questions concerned with how comprehenders arrive at the correct set of alternatives.

Examining this mechanism, Kim, Gunlogson, Tanenhaus, and Runner (2008, 2015) proposed that comprehenders rely on semantic context to establish contrastive alternatives elicited by the focus particle *only*. In one visual world study, they presented participants with a target sentence such as *Jane only has some apples* and they also showed participants four visual referents, including a target (*apples*) and a cohort competitor (*anchors*). Prior to hearing the target sentence, participants heard a context sentence that either mentioned the target (*Mark has some apples and some oranges*), mentioned items from the same semantic category (*Mark has some pears and some oranges*), or mentioned items from a different semantic category (*Mark has some boots and some sandals*). They found that participants fixated targets more rapidly not only when the focused target had been previously mentioned in the linguistic context, but also when the focused target was from the same semantic category of the linguistic context, compared to when it was from a different semantic category of the linguistic context. This finding suggests that semantic context is used to establish contrastive alternatives. Kim et al. (2008, 2015) propose that comprehenders generate hypotheses about the set of focus alternatives by priming semantic and contextual associates which enable them to more rapidly converge on an appropriate visual target.

Often, however, the set of focus alternatives does not include all of the semantic and contextual associates that are activated by the linguistic context. Returning to our initial example, when a comprehender hears *The museum thrilled the SCULPTOR*, the word *sculptor* primes its semantic associates, which include contrastive associates such as *painter* and *potter*, but also non-contrastive associates such as *statue* and *chisel*. However, contrary to a prediction of Kim et al.'s (2008, 2015) contextual priming mechanism, while comprehenders can infer that the museum did not thrill a painter, they do not also infer that the museum did not thrill a chisel. Therefore, the sentence comprehension system must have access to a mechanism that can exclude non-contrastive semantic associates from the alternative set.

One possibility is that semantic priming distinguishes between contrastive and non-contrastive semantic associates. Braun and Tagliapietra (2010) investigated this possibility in two cross-modal priming studies.

Participants listened to sentences such as *He photographed a flamingo/FLAMINGO*, where the final prime word either did or did not have a contrastive pitch accent. At the offset of the prime word, they presented participants with visual target words that were either contrastive (*pelican*) or unrelated (*celebrity*) to the prime word (Experiment 1), or non-contrastive (*pink*) or unrelated (*celebrity*) to the prime word (Experiment 2). In the first cross-modal priming experiment, contrastive pitch accents facilitated the priming of contrastive associates when compared to unrelated targets. The second cross-modal priming experiment found weak priming of non-contrastive associates given either contrastive focus or neutral prosody when compared to unrelated targets. These two studies suggest that comprehenders distinguish between the contrastive and non-contrastive semantic associates of a contrastively focused word by increasing the amount of activation that contrastive associates receive. Contrastive focus facilitates contrastive associates and leaves non-contrastive associates unaffected.

There are some potential experimental and theoretical issues concerning this interpretation. First, because the studies in Braun and Tagliapietra (2010) did not directly compare the priming of contrastive and non-contrastive associates, it is difficult to draw conclusions about the relative priming between contrastive and non-contrastive associates from their separate studies. Second, in the neutral prosody baseline, contrastive associates were not facilitated while non-contrastive associates were, and yet both were semantic associates and therefore both should have been semantically primed in the neutral prosody condition. This suggests that other factors, perhaps length, frequency, or association strength differences between the contrastive and non-contrastive targets, significantly affected target reaction times. The additional priming found for contrastive associates in the focused condition may have resulted from either the additional time comprehenders had before the probe in the focused condition as contrastive focus on a word tends to increase duration in addition to pitch (Breen, Fedorenko, Wagner, & Gibson, 2010; Katz & Selkirk, 2011; for Dutch specifically see Hanssen, Peters, & Gussenhoven, 2008), or the stronger sentential context association with contrastive associates compared to non-contrastive ones which may have benefited the activation of contrastive associates, but not non-contrastive ones which were activated only by the prime. Finally, it is theoretically unclear how additional facilitation of contrastive associates establishes a true distinction between contrastive and non-contrastive associates given that both display priming in the focused condition. Even if contrastive associates are more facilitated than non-contrastive associates, both remain active and it seems that comprehenders could potentially be confused as to which active associates are part of the set of alternatives. Any viable mechanism for comprehending focus alternatives must be able to address this problem when distinguishing between contrastive and non-contrastive associates.

The alternative mechanism explored in this paper is that the set of contrastive focus alternatives is established over time as part of a continuous process of activation and selection, suggesting that Braun and Tagliapietra's (2010) findings are only part of the story. The hypothesis we investigate is that comprehenders establish the set of contrastive alternatives through a process of selection over currently active potential candidates. These candidates may come from a variety of sources, including not only semantic associates of a focused element, but also other active contextual and discourse representations. Following Braun and Tagliapietra (2010) and concentrating only on the semantic associates activated by a focused element, in a case like *The museum thrilled the SCULPTOR*, semantic associates of the word *sculptor*, such as *painter* and *statue*, are activated by *sculptor* and form an initial set of candidates to be considered for the set of contrastive alternatives. Resolving which of these initial candidates should be included in the contrastive set requires selection from these initial candidates. This selection process is driven by the semantic representation of an alternative focus set. As argued by Rooth (1985) and others, a contrastive pitch accent on *sculptor* cues comprehenders to enrich the semantic representation of *The museum thrilled the SCULPTOR* by adding the contrastively focused proposition "there is a set *x* such that the museum did not thrill *x*" to the asserted proposition "the museum thrilled the sculptor" that is established by normal comprehension processes. Currently active candidates that can be members of this set are those that are contrastive. Currently active candidates that cannot be members of this set are those that are non-contrastive. In the case of *The museum thrilled the SCULPTOR*, where initially both *painter* and *statue* are activated as candidates for the set of contrastive focus alternatives, *painter* is selected and *statue* is rejected because the former can be a member of the set defined by the contrastively focused proposition whereas the latter cannot.

Selection in language processing

Previous research has demonstrated that the mechanism of selection plays an important role in language comprehension (Gernsbacher & Robertson, 1995). For instance, in research on the role of context in determining the

meaning of an ambiguous word, Swinney (1979) demonstrated that when listeners encounter an ambiguous word (*bug*), initially all of the word's meanings are activated as candidate meanings. He found that even given a biasing sentence context (*The man was not surprised when he found several spiders, roaches, and other bugs* …), reaction time on lexical decision or naming tasks was faster for words that were semantically associated with both the contextually appropriate meaning (*ant*) and contextually inappropriate meaning (*spy*) compared to semantically unrelated words (*sew*) (Conrad, 1974; Lucas, 1987; Onifer & Swinney, 1981; Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982; Swinney, 1979; Tanenhaus, Leiman, & Seidenberg, 1979). The facilitation of contextually inappropriate candidate meanings is, however, short lived. Within as little as 200 ms (Tanenhaus et al., 1979), rejection of a contextually inappropriate meaning by a selection mechanism leads to deactivation of its associates while maintaining facilitation of a contextually appropriate meaning and its associates, regardless of whether the context was semantically or syntactically constraining.

Previous research has also suggested that selection mechanisms are involved in the comprehension of focus. Using an offline change detection paradigm, Sanford et al. (2009) observed that detection of an alteration of a target word to a close semantic associate compared to a distant one was enhanced when the target word had been focused by a pseudocleft construction compared to when the target word was in an unfocused or neutral construction. This suggested that participants had a stronger memory representation distinguishing between semantically close associates vs. semantically distant ones in the focused condition, perhaps resulting from a selection mechanism which maintains activation of semantically close alternatives and deactivates semantically distant ones as part of the representation of a focused proposition (see also Sturt et al., 2004).

The particular processes that underlie the selection mechanism are still under debate and different models have incorporated different processes to handle these kinds of effects. Focusing again on ambiguous words, a topic on which much more research has been done, passive models assume that contextually inappropriate meanings either decay or compete for activation with contextually appropriate meanings (Duffy, Morris, & Rayner, 1988; Duffy, Kambe, & Rayner, 2001; Perfetti & Hart, in press). Active models assume that selection of contextually appropriate meanings involves active suppression of contextually inappropriate meanings (Binder & Morris, 1995; Gernsbacher, 1990, 1993; Gernsbacher & Faust, 1991a, 1991b, 1995; Gernsbacher, Robertson, & Werner, 2001; Gunter, Wagner, & Friederici, 2003; McNamara & McDaniel, 2004; Morris & Binder, 2001; Pylkkanen et al., 2006; Simpson & Kang, 1994; Simpson & Adamopoulos, 2001).

Regardless of whether selection is a passive or active process, we can draw an analogy between the resolution of the set of contrastive focus alternatives and the resolution of the meaning of an ambiguous word: Contrastive associates of contrastively focused words are contextually appropriate meanings for the contrastively focused proposition and non-contrastive associates of contrastively focused words are contextually inappropriate meanings for the contrastively focused proposition. If comprehenders distinguish between contrastive and non-contrastive associates by using selection mechanisms similar to those that distinguish between contextually appropriate and inappropriate meanings, we expect to find that contrastive and non-contrastive associates are both initially activated, but subsequently, contrastive associates are selected and maintained as appropriate meanings for the contrastively focused proposition, while non-contrastive associates are rejected and deactivated as inappropriate meanings for the contrastively focused proposition.

The current study examines the role of selection mechanisms during the comprehension of contrastive focus by examining the time course of selection as the comprehension system resolves the proper set of focus alternatives. Following Braun & Tagliapietra (2010), we restricted ourselves to examining contrastive and non-contrastive associates of a contrastively focused word in out-of-the-blue utterances, setting aside for now issues concerning what possible information sources aside from generic semantic knowledge contribute to the contrastive set. Based on previous literature, we investigated priming at two stimulus onset asynchronies (SOA) over two experiments: a 0 ms SOA to examine the activation of contrastive and non-contrastive associates as initial alternative candidates in Experiment 1, and a 750 ms SOA to examine the subsequent selection of contrastive associates and rejection of non-contrastive associates for the contrastive set in Experiment 2. Our critical prediction was that contrastive and non-contrastive semantic associates would initially be facilitated even when the prime word was contrastively focused, but that non-contrastive semantic associates would subsequently lose their facilitation as comprehenders resolved the contrastive set. To preview our findings, both contrastive and non-contrastive associates of a contrastively focused word were facilitated at our early SOA, but at our later SOA, non-contrastive associates had lost facilitation while contrastive associates maintained facilitation.

Experiment 1

The first experiment was designed to assess the initial activation of alternative candidates regardless of whether they were contrastive or non-contrastive semantic associates. This study also helps determine whether contrastive focus cued by a pitch accent influences the very early activation of semantic associates. We hypothesised that if contrastive focus affects even the earliest stages of processing, then we should find facilitation for contrastive associates over and above any facilitation for non-contrastive associates when the prime word is contrastively focused (Braun & Tagliapietra, 2010). However, if the early stage of activation is unaffected by contrastive focus, then both contrastive and non-contrastive associates should be primed when the prime word is contrastively focused.

Participants performed a cross-modal lexical decision task in which they were presented at the offset of the prime word with contrastively focused or neutral sentence primes and target words that were contrastive, non-contrastive, or unrelated. Behavioral responses to target words were collected and analysed to test the hypotheses.

Method

Participants. Sixty native English speakers from the University of South Carolina participant pool participated in this study in exchange for course credit.

Materials. Seventy-two quadruples of English words were selected for the experimental items. Each quadruple contained a prime word (*sculptor*), a contrastive associate related to the prime (*painter*), a non-contrastive associate related to the prime (*statue*), and a control word that was not related to the prime (*register*). Latent semantic analysis, which approximates the relationship between words and phrases and provides similarity scores by measuring corpus co-occurrences in a high-dimensional space (see Latent Semantic Analysis @ CU Boulder; Landauer & Dumais, 1997 for more details), was used to determine the association strength of the contrastive associate, non-contrastive associate, and unrelated control word to the prime word and to balance the association strength of contrastive and non-contrastive associates on an item by item basis (prime-contrastive, 0.4325; prime-non-contrastive, 0.4347; prime-unrelated, 0.0569; $F(1,2) = 395.660$, $p < .001$; contrastive vs. non-contrastive, $t(71) = 0.2003$, $p = .8418$; contrastive vs. unrelated, $t(71) = 21.6885$, $p < .001$; non-contrastive vs. unrelated, $t(71) = 22.0313$, $p < .001$). In addition to latent semantic analysis, the length and frequency of each target word were closely matched, as these variables are known to affect lexical decision reaction times (length: contrastive, 5.89; non-contrastive, 5.58; unrelated, 5.58; $F(1,2) = 0.8582$, $p = .4254$; CELEX database frequency: contrastive, 502.06; non-contrastive, 665.90; unrelated, 537.08; $F(1,2) = 0.428$, $p = .6524$).

Sentences were constructed using standard subject–verb–object word order such that the prime word appeared after the verb (typically as a direct object) but before the end of the sentence. For each item, the contrastive associate word and the prime word could be substituted for one another and still form a grammatical and plausible sentence, while substitution of the prime word with the non-contrastive associate would form an ungrammatical or implausible sentence (ungrammatical: 32 items; implausible: 40 items). Latent semantic analysis was used to determine the association strength of the sentence context to the targets (contrastive, .2481; non-contrastive, .2081; unrelated, .1524; $F(1,2) = 20.843$, $p < .001$; contrastive vs. non-contrastive, $t(71) = 2.509$, $p = .014$; contrastive vs. unrelated, $t(71) = -4.565$, $p < .001$; non-contrastive vs. unrelated, $t(71) = 2.555$, $p = .013$). Note that these asymmetries in contextual support for target words could affect the priming of contrastive vs. non-contrastive semantic associates. If strong contextual support can pre-activate semantic features of the target (Kutas & Federmeier, 2000; Van Petten & Luka, 2012), we could see robust facilitation of contrastive semantic associates while facilitation of the non-contrastive semantic associates remains more sluggish. These sentences were recorded twice: once using neutral prosody and once using focus prosody (i.e. a contrastive pitch accent) on the prime word. To elicit a natural contrastive pitch accent on the prime word, focused prosody sentences were recorded using an initial carrier phrase such as "No they didn't." followed by an experimental sentence like "The museum thrilled the SCULPTOR when they called about his work". This carrier phrase was then digitally excised from the recordings. The resulting stimuli had H* or !H* pitch accents on target words in the neutral prosody condition and L + H* pitch accents on target words in the focus prosody condition (Beckman & Hirschberg, 1994). The duration and intensity of the prime word was measured in each condition (Duration: focused, 619.81 ms; neutral, 366.10 ms; $t(71) = 19.359$, $p < .001$; Intensity: focused, 78.39 dB; neutral, 75.35 dB; $t(71) = 7.510$, $p < .001$; Pitch: focused, 213.247 Hz; neutral, 168.626 Hz; $t(71) = 6.505$, $p < .001$). An example of the prosody manipulation is given in Figure 1. See Appendix 1 for experimental items.

Filler sentences were constructed with a prime word also appearing after the verb and before the end of the sentence. All filler sentences were recorded with neutral prosody. The study included six practice trials

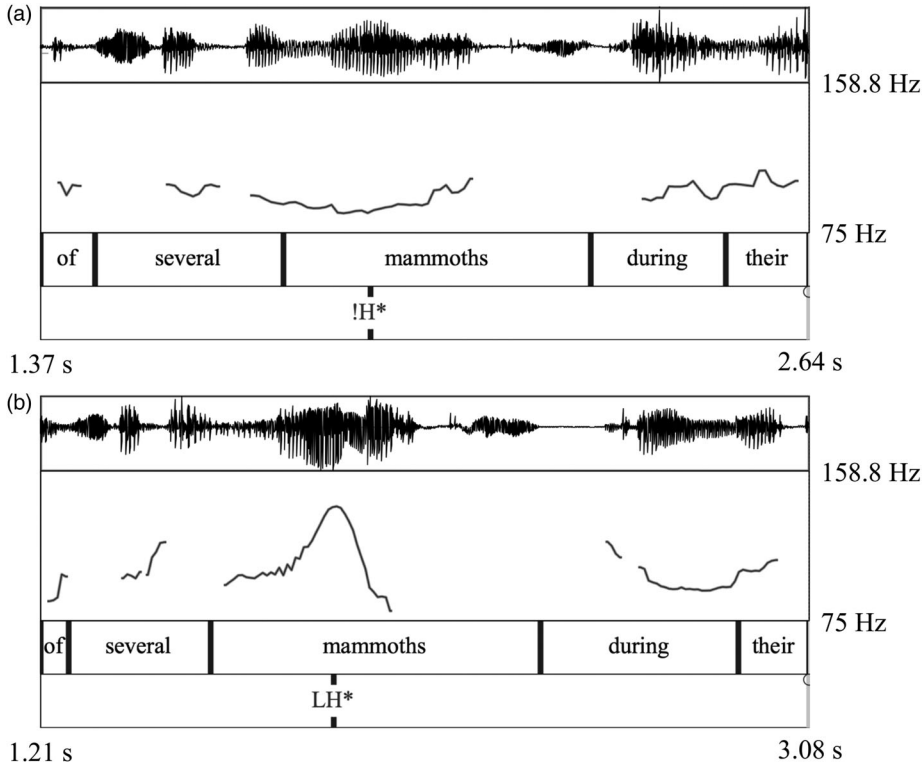

Figure 1. Examples of the prosody manipulation in the neutral condition (a) and the focus condition (b). The intonational annotation for these examples follow ToBI.

and 144 filler trials. In brief, 108 filler trials had nonword targets that were drawn from the ARC Nonword Database (Rastle, Harrington, & Coltheart, 2002), 18 filler trials had targets that were phonologically related to their prime drawn from the Speech & Hearing Lab Neighborhood Database at Washington University (2009), and 18 filler trials had targets that were unrelated to their prime (filler prime-unrelated, 0.047). Six lists of 72 experimental trials were constructed in a Latin square design crossing target type (contrastive, non-contrastive, unrelated) and sentence prosody (neutral, focused), giving 12 observations per experimental mean per participant. All filler sentences were added to each list, resulting in 216 total trials. Each participant saw only one list.

Procedure. Each sentence was played in stereo at a normal volume through headphones while the participant was presented with a fixation cross in the middle of a screen. The visual target appeared on the screen while the sentence was being played and the participant indicated by button press whether the letter string was an English word. The SOA between the offset of the prime word and the onset of the target word was 0 ms. The full experiment lasted approximately 25 min.

Analyses. Accuracy and reaction time data collected in each experiment were analysed using mixed effects models with participants and items as crossed random factors with the maximal random effect structure justified by the data (Baayen, Davidson, & Bates, 2008; Barr, Levy, Scheepers, & Tily, 2013; Jaeger, 2008). Convergence errors were dealt with incrementally, starting with the maximal model, followed by a model dropping only by item slopes, followed by a model dropping only by subject slopes, following by a model dropping both by item and by subject slopes. Random intercepts were included in all models. Key predictors included sentence prosody (neutral and focused) and target type (contrastive, non-contrastive, and unrelated). Accuracy was analysed using mixed effects logistic regression modelling, and included all participants. Contrasts in the accuracy analysis were sum coded to examine main effects and interactions and target type was Helmert coded to examine associativity (contrastive and non-contrastive associates vs. unrelated targets) and contrastiveness (contrastive vs. non-contrastive). Participants were required to reach 75% accuracy on both nonword and control word fillers and all experimental conditions to be included in the reaction time analyses. Inaccurate trials and trials with reaction times exceeding 6000 ms were excluded from further analysis. The reaction times of remaining trials were log transformed and analysed using linear mixed effects modelling, including the maximal random effect structure justified by the data

as above. Given the basic definition of priming as facilitation over baseline and given our interest in the priming of our key conditions crossing prosody and contrastiveness, the contrasts in the reaction time analysis were treatment coded with the neutral prosody unrelated target condition as the intercept, allowing us to model estimates of the difference from this condition for each of the remaining condition combinations, with significant negative estimate differences indicating facilitation. The resulting *p*-values of linear mixed effects models were calculated based on the *t*-values of the model by treating *t*-values as *z*-values (Dale Barr and Roger Levy, p.c.).

Results

Accuracy. As seen in Table 1, overall accuracy on the experimental trials was high at over 98% in each condition. The results of the logit mixed effects model are summarised in Table 2. While participants made more accurate lexical decisions on semantically associated targets compared to unrelated targets ($z = 4.180$, $p < .001$), there was no interaction between prosody and target types.

Reaction time. One participant's data were removed from reaction time analyses for failure to meet the accuracy criterion (> 75% accuracy). The reaction times for the 59 remaining subjects were analysed using linear mixed effects models. Inaccurate trials and trials with reaction times greater than 6000 ms were also excluded, resulting in a loss of 2.3% of the data. The results of the linear mixed effects model are summarised in Table 3 and the mean reaction time for each condition, calculated on the basis of the model, is given in Figure 2. The neutral prosody unrelated target condition and the focused prosody unrelated target condition did not differ significantly ($t = -0.25$; $p = .802$), with only a slight numerical trend for the focused prosody unrelated target condition to be faster. Contrastive targets were facilitated compared to the neutral prosody unrelated target baseline regardless of whether the prime word received focused or neutral prosody (neutral contrastive: $t = -2.08$, $p = .038$; focused contrastive: $t = -2.73$, $p = .006$). Non-contrastive targets were also facilitated compared to the neutral prosody unrelated target baseline, though only when the prime word received focused prosody ($t = -2.51$, $p = .012$).[1]

To confirm the basic findings of our models, we also conducted planned comparisons between contrastive and non-contrastive targets and unrelated targets. Neutral contrastive targets showed facilitation over neutral unrelated targets ($t1(58) = -2.806$, $p = .007$; $t2(71) = -2.008$, $p = .048$) while neutral non-contrastive targets did not ($t1(58) = -0.931$, $p = .356$; $t2(71) = -0.633$, $p = .529$). Focused contrastive and non-contrastive targets both showed facilitation over focused unrelated targets, though the focused non-contrastive vs. focused unrelated target comparison was only significant by subjects (contrastive: $t1(58) = -4.100$, $p < .001$; $t2(71) = -2.303$, $p = .024$; non-contrastive: $t1(58) = -2.389$, $p = .020$, $t2(71) = -1.638$, $p = .106$).

We also conducted planned comparisons between the neutral and focused prosody conditions for all three target types. No significant differences were found between neutral and focused prosody conditions for any target types (contrastive: $t1(58) = 0.396$, $p = .693$, $t2(71) = 0.277$, $p = .783$; non-contrastive: $t1(58) = 1.147$, $p = .256$, $t2(71) = 1.282$, $p = .204$; unrelated: $t1(58) = -0.293$, $p = .771$, $t2(71) = -0.388$, $p = .699$).

Because the neutral and focused prosody conditions differed in prime word duration and targets differed in their associative strength to sentential contexts, we ran an additional analysis to determine whether prime word durational differences or sentential context differences affected the priming of targets. We refit our overall model with prime duration and sentential context as additional predictors. Model comparison revealed some improvement in model fit ($\chi^2(18) = 27.501$, $p = .070$; see Baayen, 2008, chap. 7 for discussion on model comparison). There was a significant interaction between neutral prosody non-contrastive targets and sentential context strength ($t = 1.91$, $p = .056$) not found for other targets (neutral contrastive: $t = 0.74$, $p = .457$; focused contrastive: $t = 0.93$, $p = .354$; focused non-contrastive: $t = 0.96$, $p = .336$). Duration did not interact significantly with any target reaction times (all $t < 0.68$, $p > .499$). This additional analysis suggests that the initial priming of neutral prosody non-contrastive targets was significantly affected by sentence context, while prime word duration did not affect target priming in general.

Table 1. Mean accuracy scores for Experiment 1.

		Target type		
		Contrastive (%)	Non-contrastive (%)	Unrelated (%)
Prosody	Neutral	99.57	98.99	98.85
	Focused	99.87	99.67	99.90

Table 2. Estimates, standard errors, *z* values and *p* values of the final logit mixed effects model for accuracy in Experiment 1. Model: Accuracy ~ Prosody * TargetType + (1 + Prosody * Target Type | Subject) + (1 | Item).

Fixed effect		Estimate	Std. Err.	*z* value	Pr(> |*z*|)
Intercept (neutral prosody, unrelated target)		5.047	.251	20.103	< .001***
Prosody (neutral, contrastive)		0.015	.123	0.120	.904
Associativity (unrelated, associated)		0.709	.170	4.180	< .001***
Contrastiveness (contrastive, non-contrastive)		0.249	.167	1.495	.135
Prosody × associativity		0.088	.153	0.575	.565
Prosody × contrastiveness		0.116	.186	0.623	.533
Random Effects		s^2	Std. Dev.	Corr	
Subject	Intercept	1.118	1.057		
	Prosody	0.009	0.096	−1.000	
	Associativity	0.192	0.439	0.605	−.605
	Contrastiveness	0.017	0.130	−0.385	0.385
	Prosody × associativity	0.011	0.106	−0.919	0.919
	Prosody × contrastiveness	0.278	0.527	−0.110	0.110
Item	Intercept	1.359	1.166		

*p < .05.
**p < .01.
***p < .001.

Table 3. Estimates, standard errors, *t* values, and *p* values of the final linear-mixed effects model for reaction time in Experiment 1. Model: log(RT) ~ Condition + (1 | Subject) + (1 + Condition | Item).

Fixed effect		Estimate	Std. Err.	*t* value	Pr(> |*t*|)
Intercept (neutral prosody, unrelated target)		6.494	.023	284.19	< .001***
Neutral prosody, contrastive target		−0.038	.018	−2.08	.038*
Neutral prosody, non-contrastive target		−0.015	.018	−0.82	.410
Focused prosody, unrelated target		−.004	.014	−0.27	.789
Focused prosody, contrastive target		−0.055	.020	−2.73	.006**
Focused prosody, non-contrastive target		−0.049	.019	−2.51	.012*
Random effects		s^2	Std. Dev.	Corr.	
Subject	Intercept	.019	.139		
Item	Intercept (neutral, unrelated)	.008	.090		
	Neutral, contrastive	.018	.132	−.774	
	Neutral, non-contrastive	.012	.110	−.562	.902
	Focused, unrelated	.002	.043	.005	.234
	Focused, contrastive	.015	.124	−.751	.474
	Focused, non-contrastive	.013	.113	−.722	.339

*p < .05.
**p < .01.
***p < .001.

Discussion

The goal of Experiment 1 was to establish whether contrastive focus cued by a pitch accent can affect early automatic priming of semantic associates by distinguishing between contrastive and non-contrastive associates and only priming those which are contrastive. The results of Experiment 1, shown in Figure 1, suggest that both types of associates are initially primed. This initial priming seems to be insensitive to the contrastiveness of an associate. In particular, focused words prime their semantic associates regardless of the contrastiveness of the associates themselves. This result is in contrast to Braun and Tagliapietra (2010), who reported somewhat different effects of contrastive focus on the initial activation of contrastive and non-contrastive associates. However, as noted above, the stimuli in their study were less well balanced compared to this study: contrastive associates were less semantically associated with the prime word compared to non-contrastive associates, and contrastive associates were also significantly longer and less frequent than non-contrastive associates. The stimuli in this study were more carefully balanced on these characteristics, which may account for the difference between our findings and theirs.

Although not crucial to our main predictions, priming was not observed for non-contrastive targets with neutral prosody. This lack of priming appears to be due to the semantic relatedness differences of the sentence context to contrastive and non-contrastive associates. Contrastive semantic associates were more strongly related to the semantic context and could potentially have benefited from early activation by the semantic context. Non-contrastive associates were not as strongly related to the semantic context, so they may have only been activated by the prime word itself. Since the neutral prosody condition was fairly short, the initial

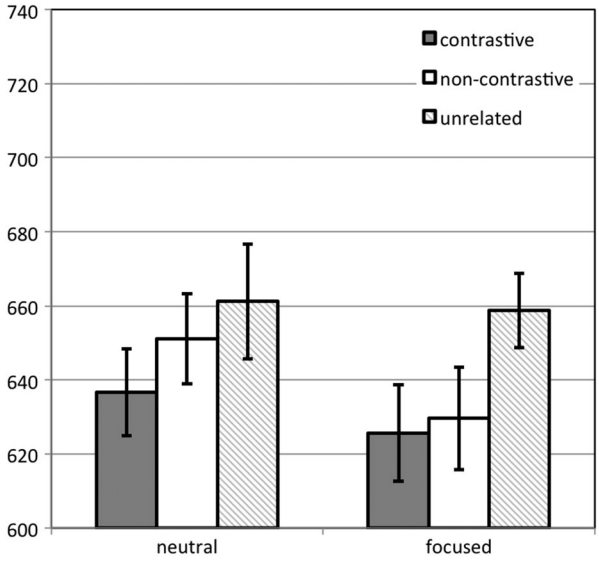

Figure 2. Mean reaction time to contrastive, non-contrastive, and unrelated targets given neutral or focused prosody at 0 ms SOA in Experiment 1. Error bars depict standard error of the means.

activation of the non-contrastive associates had less time to be further activated by associate relationships associated with the prime word, whereas contrastive associates had the additional benefit of receiving some activation from the sentential context. Interestingly, the overall time increase of the focused prosody condition appears to have neutralised any contextual advantage contrastive associates had over non-contrastive associates, as both contrastive and non-contrastive associates showed equivalent facilitation in the focused prosody condition. Based on this reasoning, we expect to find facilitation for both contrastive and non-contrastive targets in the neutral prosody condition in our second experiment, which uses a longer SOA.

Experiment 1, then, sets the stage for Experiment 2. In Experiment 1, we observed that both contrastive and non-contrastive associates were initially primed by a contrastively focused word, indicating that both were entertained as part of the initial set of alternative candidates. Experiment 2 addresses whether selection mechanisms are used to distinguish contrastive associates from non-contrastive associates as comprehenders continue processing and attempt to resolve the proper set of contrastive focus alternatives from the initial set of alternative candidates.

Experiment 2

The second experiment was designed to assess the subsequent processes used to distinguish between contrastive and non-contrastive semantic associates after their initial activation. As discussed in the Introduction, the process of selection could operate in at least two different ways. One possibility is that selection distinguishes between contrastive and non-contrastive associates by further facilitating contrastive associates, along the lines of the proposal offered by Braun and Tagliapietra (2010). This first possibility predicts continued facilitation for both contrastive and non-contrastive associates, with contrastive associates being facilitated more than non-contrastive associates in later processing. Alternatively, selection could distinguish between contrastive and non-contrastive associates by passive decay/competition or active suppression of non-contrastive associates similar to the way semantic associates of the inappropriate meaning of an ambiguous word become deactivated over time (Swinney, 1979; Tanenhaus et al., 1979; and many others). This second possibility predicts continued facilitation for contrastive associates while non-contrastive associates become deactivated in later processing.

To assess these possibilities, participants performed a cross-modal lexical decision task in which they were presented with contrastively focused or neutral sentence primes and target words that were contrastive, non-contrastive, or unrelated at 750 ms post-offset of the prime word. Behavioral responses to target words were collected and analysed to test the hypotheses. The materials were the same as in Experiment 1, except that the SOA between the offset of the prime and the onset of the target word was 750 ms rather than 0. Sixty native English speakers from the University of South Carolina participant pool who had not participated in Experiment 1 participated in this study in exchange for course credit. All other aspects of the methods were the same.

Results

Accuracy. As can be seen in Table 4, overall accuracy on the experimental trials was again high at over 98% in each condition. The results of the logit mixed effects model are summarised in Table 5. Participants were slightly more accurate for contrastive associates

Table 4. Mean accuracy scores for Experiment 2.

		Target Type		
Fixed effect		Contrastive (%)	Non-contrastive (%)	Unrelated (%)
Prosody	Neutral	98.86	98.50	98.09
	Focused	98.89	98.82	98.60

Table 5. Estimates, standard errors, *z* values and *p* values of the final logit mixed effects model for accuracy in Experiment 2. Model: Accuracy ~ Prosody * TargetType + (1 + Prosody * Target Type | Subject) + (1 + Prosody * TargetType | Item).

Fixed Effect		Estimate	Std. Err.	*z* value	Pr(> |*z*|)
Intercept		5.679	.265	21.418	< .001***
Prosody (neutral, focused)		−0.040	.129	−0.310	.757
Associativity (unrelated, associated)		−0.512	.340	−1.422	.155
Contrastiveness (contrastive, non-contrastive)		0.611	.228	2.682	.007**
Prosody × associativity		0.799	.207	3.863	< .001***
Prosody × contrastiveness		0.157	.167	0.940	.347

Random effects		s^2	Std. Dev.	Corr				
Subject	Intercept	1.589	1.261					
	Prosody	0.017	0.129	1.000				
	Associativity	0.406	0.637	0.287	0.287			
	Contrastiveness	0.250	0.500	0.864	0.864	0.730		
	Prosody × Associativity	0.331	0.576	0.523	0.523	−0.489	0.116	
	Prosody × Contrastiveness	0.163	0.404	0.270	0.270	−0.472	−0.056	0.114
Item	Intercept	0.529	0.727					
	Prosody	0.101	0.318	−1.000				
	Associativity	3.916	1.979	−0.784	0.784			
	Contrastiveness	1.398	1.182	0.007	−0.007	0.114		
	Prosody × associativity	0.233	0.482	0.293	−0.293	−0.817	−0.046	
	Prosody × contrastiveness	0.091	0.301	0.453	−0.453	0.146	0.526	−0.582

*p < .05.
**p < .01.
***p < .001.

compared to non-contrastive associates ($z = 2.682$, $p = .007$), though there was no interaction between prosody and contrastiveness ($z = 0.940$, $p = .347$). There was an interaction between prosody and associativity in which participants were more accurate on associated targets in the focused condition ($z = 3.863$, $p < .001$), but again, overall, participants were highly accurate.

Reaction time. Data from five participants were removed from reaction time analyses for failure to meet the accuracy criterion (> 75% accuracy). The reaction times for the remaining 55 subjects were analysed using linear mixed effects models. Inaccurate trials and trials with reaction times greater than 6000 ms were also excluded, resulting in a loss of 2.5% of the data. The results of the linear mixed effects model are summarised in Table 6 and the mean reaction time for each condition, calculated on the basis of the model, is given in Figure 3.

Again, the neutral prosody unrelated target and focused prosody unrelated target conditions were not significantly different ($t = 0.83$, $p = .385$), although the focused prosody unrelated target condition was numerically slower. Based on previous research by Sanford et al. (2009) (see also Gernsbacher & Jescheniak,1995) in which inhibitory effects of contrastive focus on unrelated lexical items were observed, we suspect that contrastive focus has some influence on unrelated targets, preventing them from providing an unbiased baseline for lexical access. Contrastive targets were facilitated compared to the neutral prosody unrelated target baseline regardless

Table 6. Estimates, standard errors, *t* values and *p* values of the final linear mixed effects model for reaction time in Experiment 2. Model: log(RT) ~ Condition + (1 + Condition | Subject) + (1 | Item).

Fixed effect	Estimate	Std. Err.	*t* Value	Pr(> |*t*|)
Intercept (neutral prosody, unrelated target)	6.554	.024	270.06	< .001***
Neutral prosody, contrastive target	−0.041	.015	−2.67	.008**
Neutral prosody, non-contrastive target	−0.038	.016	−2.42	.015*
Focused prosody, unrelated target	0.014	.017	0.83	.405
Focused prosody, contrastive target	−0.049	.019	−2.57	.010*
Focused prosody, non-contrastive target	−0.015	.018	−0.87	.385

Random effect		s^2	Std. Dev.	Corr.				
Subject	Intercept (neutral, unrelated)	.023	.151					
	Neutral, contrastive	.008	.087	.324				
	Neutral, non-contrastive	.0004	.214	−.769	−.854			
	Focused, unrelated	.003	.054	.726	.886	−.998		
	Focused, contrastive	.005	.071	.577	.557	−.694	.688	
	Focused, non-contrastive	.001	.033	−.301	.023	.150	−.131	−.802
Item	Intercept	.004	.067					

*p < .05.
**p < .01.
***p < .001.

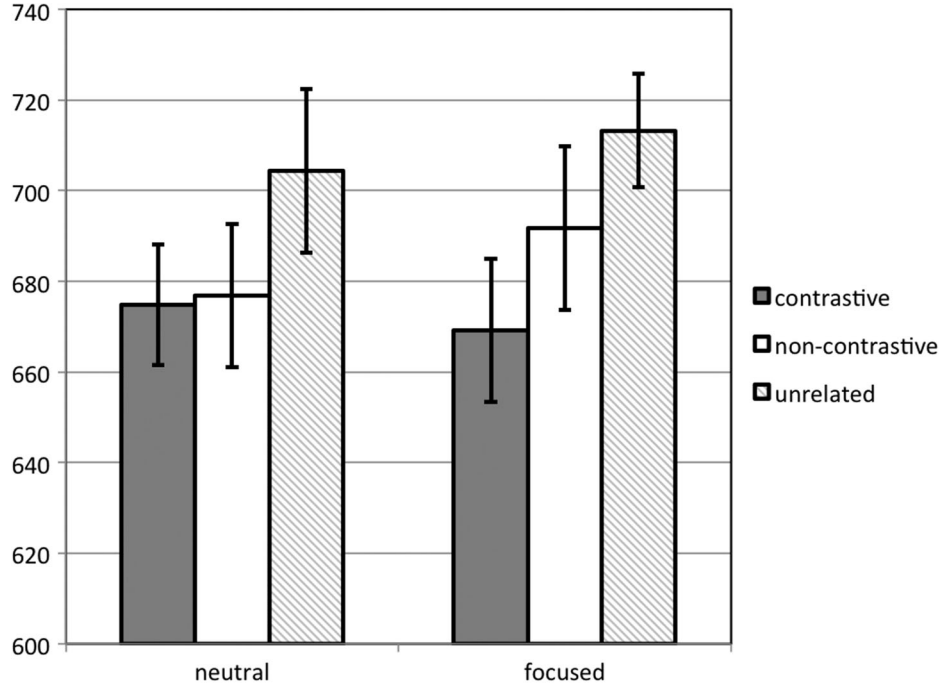

Figure 3. Mean reaction time to contrastive, non-contrastive, and unrelated targets given neutral or focused prosody at 750 ms SOA in Experiment 2. Error bars depict standard error of the means.

of whether the prime word received focused or neutral prosody (neutral contrastive: $t = -2.67$, $p = .008$; focused contrastive: $t = -2.57$, $p = .010$). Non-contrastive targets were also facilitated compared to the neutral prosody unrelated target baseline, though only when the prime word had neutral prosody ($t = -2.42$, $p = .015$). Non-contrastive targets of focused prime words were not facilitated relative to the neutral prosody unrelated target baseline ($t = -0.87$, $p = .385$).[2]

To confirm the basic findings of our models, we also conducted planned comparisons between contrastive and non-contrastive targets and unrelated targets. Neutral prosody contrastive and non-contrastive targets both showed facilitation over neutral prosody unrelated targets, though the comparison between non-contrastive vs. unrelated targets was not significant by items (contrastive: $t1(54) = -2.327$, $p = .024$; $t2(71) = -2.123$, $p = .037$; non-contrastive: $t1(54) = -1.951$, $p = .056$; $t2(71) = -1.524$, $p = .132$). Focused prosody contrastive targets showed facilitation over focused prosody unrelated targets ($t1(54) = -3.570$, $p < .001$; $t2(71) = -2.723$, $p = .008$) while focused prosody non-contrastive targets did not ($t1(54) = -1.543$, $p = .129$, $t2(71) = -1.173$, $p = .245$). A comparison of focused prosody contrastive targets to focused prosody non-contrastive targets showed only marginally significant facilitation by subjects ($t1(54) = -1.828$, $p = .073$; $t2(71) = -1.526$, $p = .131$).

We also conducted planned comparisons between the neutral and focused prosody conditions for all three target types. Non-contrastive targets were significantly slower in the focused prosody condition compared to the neutral prosody condition, though this comparison was only marginally significant by subjects ($t1(54) = -1.681$, $p = .098$, $t2(71) = -2.015$, $p = .048$). All other comparisons between neutral and focused prosody conditions for target type were non-significant (contrastive: $t1(54) = -0.330$, $p = .743$, $t2(71) = -0.397$, $p = .692$; unrelated: $t1(54) = -0.985$, $p = .329$, $t2(71) = -1.102$, $p = .274$).

As in Experiment 1, we ran an additional analysis to determine whether durational or sentential context differences affected the priming of targets. We refit our overall model with prime duration and sentential context as additional predictors. Model comparison revealed significant improvement in model fit ($\chi^2(12) = 39.482$, $p < .001$); however, significant interactions in this model occurred between sentential context and focused prosody contrastive targets ($t = 2.30$, $p = .022$) and neutral prosody non-contrastive targets ($t = 2.12$, $p = .034$) only, along with trending significant interactions between prime duration and neutral prosody contrastive targets ($t = 1.75$, $p = .080$) and neutral prosody non-contrastive targets ($t = 1.75$, $p = .080$). Unlike Experiment 1, none of these effects provide an alternative explanation to the lack of facilitation in focused prosody non-contrastive targets, suggesting that this effect in our initial model is due to prosody and contrastiveness alone.

Discussion

As in Experiment 1, contrastive associates were facilitated regardless of whether their prime was contrastively focused or not. Non-contrastive associates of contrastively focused primes, which showed facilitation at 0 ms in Experiment 1, showed no facilitation at 750 ms in Experiment 2. Only those semantic associates that were contrastive continued to be facilitated, suggesting that they continued to be considered as part of the set of alternatives as comprehenders resolved the proper set of contrastive focus alternatives.

Interestingly, both contrastive and non-contrastive associates showed facilitation in the neutral condition, strengthening the idea that the lack of facilitation for non-contrastive associates in Experiment 1 was due to the relatively slow activation of non-contrastive associates which did not benefit from sentential context. By 750 ms, comprehenders had enough time to prime all the semantic associates of the prime word, and both contrastive and non-contrastive associates appear to be maintained given neutral prosody which did not cue a selection process.

General discussion

In two cross-modal priming experiments that manipulated the prosody of prime words (focused vs. neutral) with the contrastiveness of visual targets (contrastive, non-contrastive, and unrelated) across two different SOAs (0 ms and 750 ms), we found evidence that selection mechanisms play a role in the comprehension of contrastive focus. The results demonstrated that contrastive and non-contrastive associates, which are both initially activated when their prime word is contrastively focused, are distinguished from one another by selection and continued facilitation of contrastive associates and rejection and deactivation of non-contrastive associates. Importantly, we found that only the non-contrastive associates of contrastively focused primes became deactivated over the time course of processing; all other semantically associated targets became or maintained their facilitation across the two experiments. Taken together, these studies find that comprehenders take an initial set of active candidates and select from them just those that are appropriate as alternatives to the contrastive utterance. They do this by deactivating those candidates that are non-contrastive, thus resolving the proper set of contrastive focus alternatives.

We proposed that the selection of alternatives in contrastively focused sentences is similar to the selection of appropriate meanings for ambiguous words in sentence contexts. As this literature has been extremely fruitful in discussing core architectural features of language processing, including what stages of processing there are and the extent to which such stages are encapsulated or interactive, we expect studies on focus alternatives to also highlight such issues. However, there are several caveats concerning the interpretation of our studies with respect to these architectural questions, as the experimental conditions we have employed, while necessary given our hypotheses, limit what can be inferred. Although our study design appears to suggest a two-stage model for contrastive focus comprehension, with an initial stage of activation encapsulated from the effects of the contrastively focused proposition, the activation and selection of candidates may in fact represent a continuous process that works to refine the semantic representation of the incoming linguistic signal incrementally through an on-going collection of overlapping processes. As a result, a high level of experimental control was required to isolate any particular process at play. Our studies were designed so that cues to both the activation of semantic associates and the focus manipulation both occurred on the prime word, allowing us to better isolate cues to processes that activated semantic associates and processes that selected the contrastive alternatives from active candidates through their compatibility with the contrastively focused proposition. Although activation of semantic associates of the prime word is fairly automatic, it is likely that the comprehension system takes time to map a pitch accent cue to a contrastively focused proposition that can then be used to select alternatives from the set of currently active representations. It is also possible that the selection process cued by the contrastively focused proposition is a controlled process, engaging attentional and memory resources which unfold over time. Thus, the appearance of two stages of processing may be a consequence of our particular experimental design. We manipulated the timing of the cues that triggered activation and selection processes, and then tapped into the processing stream that unfolded at two particular time points with targets designed to detect the time course of contrastive selection. This design allowed us to separate out and detect a process of selection, and it also enables us to make several proposals about the nature of this selection process, to which we now turn.

As noted above, this process of selection may proceed by allowing non-contrastive associates to rapidly decay or compete (Duffy, Morris, & Rayner, 1988; Duffy, Kambe, & Rayner, 2001; Perfetti & Hart, 2001), or by a more active process of suppression (Binder & Morris, 1995; Gernsbacher, 1990, 1993; Gernsbacher & Faust, 1991a, 1991b, 1995; Gernsbacher et al., 2001; McNamara & McDaniel, 2004; Morris & Binder, 2001; Neill, 1989; Neill

& Valdes, 1996; Pylkkanen et al., 2006; Simpson & Kang, 1994; Simpson & Adamopoulos, 2001). There is some indirect evidence from our studies for a more active process of suppression of non-contrastive associates of focused primes. If non-contrastive associates merely decayed over time because the semantic context failed to support their meaning, we would expect non-contrastive associates to decay regardless of whether the prime received focused or neutral prosody; however, non-contrastive associates of neutral primes showed facilitation at 750 ms. Consistent with this interpretation, other work has shown that recall of non-focused words in a sentence with a contrastively focused word tends to be slower and less accurate, possibly reflecting suppression of non-focused meanings (Gernsbacher & Jescheniak, 1995; Jescheniak, 2000; Sanford et al., 2009; but cf. Fraundorf et al., 2010). However, it could be that the general process of decay is speeded by contrastive focus, perhaps due to a shift in attention to only those associates that are contrastive. Further research is needed to determine precisely how selection handles non-contrastive alternatives and whether such processes are passive or active.

This research also provides evidence that establishing the proper set of contrastive alternatives is a process that unfolds over time. Initially, both contrastive and non-contrastive associates of the focused word were facilitated, and it was only at a later time that comprehenders distinguished between contrastive and non-contrastive associates. An interesting question is whether this time course is specific to focus manipulations involving contrastive pitch accents. The contrastive pitch accent used in this study cued comprehenders to the presence of contrastive focus on the prime word, however, other markers of focus, including focus particles, clefts, and wh-questions, cue comprehenders to the presence of focus well before the focused element, and comprehenders could engage in different strategies to select focus alternatives depending on the way focus is marked. Strategies such as prediction, for instance, could affect the time course of selecting focus alternatives, allowing comprehenders to anticipate potential contrastive alternatives before speakers utter the focused element. For example, because the focus particle *only* in a sentence like *The museum only thrilled the SCULPTOR* comes before the focused word, comprehenders could began anticipating the likely shape of the contrastively focused proposition before encountering the focused word and use this to begin early selection of potential contrastive alternatives that are already active candidates due to the semantic or discourse context.

In proposing selection as the key mechanism comprehenders use to establish the set of focus alternatives, our study raises several important but unanswered questions about the interaction of selection with different information sources. Because we chose to minimise any direct effect of discourse or background knowledge in favour of better control over the semantic relationship of our target words to the prime for these particular studies, we are unable to speak directly to questions concerning how both discourse and background knowledge can activate candidates for the set of focus alternatives beyond those activated by association with the focused word itself. Discourse in particular appears to play a strong role in determining the alternative set. Fraundorf et al. (2010), for instance, found no evidence for the inclusion of unmentioned alternatives in the alternative set in an offline verification task, suggesting that unmentioned contrastive alternatives may not actually be entertained as part of the alternative set. Their result initially appears to be at odds with our finding that unmentioned contrastive associates are primed and remain primed in focus constructions, which suggests that they are being entertained as part of the alternative set. From our point of view it seems likely that Fraundorf et al.'s (2010) use of prior mention in the discourse played a strong role in shaping the initial candidate set and the selection of contrastive alternatives from this candidate set.[3] In their study, discourse-established candidates could have out-competed candidates that were semantically introduced because of their stronger representation in memory. In general, however, it is important that comprehenders be able to consider unmentioned but semantically associated concepts given that speakers do not always explicitly provide all the relevant alternatives. Without this ability, we would be unable to explain how comprehenders can successfully infer speakers' implicit meanings. We also suspect that comprehenders may sometimes engage in more strategic reasoning about what to include in the set of focus alternatives. For instance, comprehenders may select or reject previously mentioned discourse candidates or other unmentioned candidates because of their fit with the discourse's situation model (Fraundorf et al., 2013). How comprehenders prioritise semantic and discourse information and engage in strategic decisions online during the selection of focus alternatives will be a fruitful line of future research. Certainly, a complete theory will need to address these issues, though we suspect that any such theory will assume that selection plays an important role in establishing focus alternatives.

Additional questions about the set of contrastive focus alternatives itself also remain. One question concerns how fine-grained the set of focus alternatives is. For instance, while it is possible that comprehenders

specifically represent *painter* in the alternative set alongside other alternatives given the case of *The museum thrilled the SCULPTOR*, it is also possible that comprehenders represent the alternative set as an ad hoc category of persons whom museums thrill, a category that is likely to have high overlap with the category of artists, of which *painter* is but one member. Although our study used specific words for contrastive and non-contrastive targets, suggesting a very fine-grained representation, these items were designed to act only as semantically balanced probes to detect the time course of establishing the proper set of contrastive alternatives. Since priming of these targets could be driven by direct selection/rejection of these words or by indirect selection/rejection through these words' associations with (possibly ad hoc) categories, the question of how fine-grained the representation of the alternative set is remains unsettled.

Along with Braun and Tagliapietra (2010), our results suggest that contrastive focus marks contrastive associates as salient to comprehenders. To this, we add that selection mechanisms enable comprehenders to distinguish between contrastive and non-contrastive associates by deactivating non-contrastive associates. Our experiments indicate that, while rapid, the resolution of the set of contrastive focus alternatives cued by a pitch accent takes time as initially activated candidates are selected or rejected, leaving active only those which form the proper set of contrastive focus alternatives. This process enables comprehenders to use this alternative set to draw inferences about a speaker's implicit meaning, allowing conversation to be rapid and efficient.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes

1. A reviewer suggested that the failure to find significant priming in the neutral prosody noncontrastive target condition could have been driven by the ungrammaticality of some of the noncontrastive alternatives given the sentence context. To address this, we fit an additional model that included grammaticality of alternatives. Grammaticality did not significantly interact with the neutral prosody noncontrastive target condition ($t = 1.62$), though its inclusion did numerically increase priming of this condition ($t = -1.14$ with grammaticality included vs. $t = -0.82$ as reported in Table 3), suggesting that grammaticality may have had a small effect on priming.
2. As in Experiment 1, the failure to find significant priming in the focused prosody noncontrastive target condition could have been driven by the ungrammaticality of some of the noncontrastive alternatives given the sentence context. An additional model that included grammaticality of alternatives did not reveal a significant interaction with the focused prosody noncontrastive target condition ($t = 1.59$), and there was very little change between estimates of the priming effect ($t = -0.91$ with grammaticality included vs. $t = -0.87$ as reported in Table 6).
3. While we find the idea that selection is sensitive to the discourse status of a candidate for an alternative set compelling, an examination of materials from Experiment 3 of Fraundorf, Watson, and Benjamin (2010) finds weaker semantic association between the true response and unmentioned alternatives compared to the true response and the mentioned alternative (true-unmentioned: .297; true-mentioned: .344; $t(63) = 1.828$, $p = .072$), thus it may be possible that the lack of an effect of unmentioned alternatives in their study could be due to this difference in semantic association and not discourse status.

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Appendix 1: Experimental materials

The prime word which is underlined received either neutral or focused prosody. The latent semantic analysis value between the prime word and the target word is given in parentheses.

Item	Sentence
	Contrastive Non-contrastive Unrelated
1	The museum thrilled the sculptor when they called about his work painter (0.58) statue (0.62) register (−0.02)
2	The murderer killed the nurse last Tuesday night doctor (0.52) clinic (0.63) plug (−0.01)
3	Scientists found the fossils of several mammoths during their excavation dinosaurs (0.44) extinct (0.50) corporate (0.00)
4	The engineer designed the bridge after winning the contract building (0.22) river (0.28) interest (−0.02)
5	The boy liked to feed the duck in the park swan (0.43) nest (0.49) chain (0.02)
6	The woman wanted to wear her favorite jeans to the party scarf (0.45) skinny (0.35) theory (0.02)
7	The baker needed to make a cake for the big day muffins (0.52) birthday (0.50) bracelet (0.02)
8	The maid found a mouse in a can under the table jug (0.24) soup (0.24) lapel (0.07)
9	The model adored the new necklace during the photo shoot tiara (0.32) posh (0.28) lecture (0.06)
10	The kennel owner was playing with a kitten when the phone rang puppy (0.43) furry (0.44) beach (0.06)
11	The farmer went out to check his garden after the storm lawn (0.41) hoe (0.56) box (0.14)
12	The tourists wanted to see the ancient buildings near their hotel modern (0.55) tombs (0.55) weak (0.05)
13	The passenger boarded the airplane and quickly found his seat train (0.23) baggage (0.23) splinter (0.03)
14	The manager drove along a straight road to reach his appointment curving (0.61) line (0.51) gear (0.15)
15	The students heard a loud noise behind the building faint (0.46) big (0.32) dry (0.08)
16	The craftsman built the table in his work shop chair (0.61) dinner (0.57) pool (−0.06)
17	Her wedding day ended up rainy so the reception was moved indoors cloudy (0.43) tropics (0.58) industry (0.05)
18	The mother was very gentle with her children kind (0.31) slope (0.35) teal (0.13)
19	The shopper found the sale prices inexpensive when she visited the other store economical (0.41) durable (0.37) organic (0.15)
20	The victim became hysterical when she heard the news emotional (0.44) mental (0.44) country (0.02)
21	Every student knew that the homework for math was due the next day physics (0.26) numbers (0.20) tooth (0.02)
22	The new purse was yellow and had lots of pockets violet (0.55) daisies (0.31) tornado (0.06)
23	The suede blazer had gotten wet from all the rain damp (0.64) rain (0.70) exile (0.00)
24	The city gets a lot of snow during the winter sleet (0.50) frozen (0.67) blocks (0.05)
25	The outfit was rather odd for such a formal occasion strange (0.58) even (0.54) potato (0.16)
26	The girl found her shoe in the kitchen under the table bathroom (0.74) stove (0.75) eagle (0.04)
27	The old mansion was pretty dusty after years of disrepair filthy (0.34) cluttered (0.20) vector (0.01)
28	They were told to write with a pencil instead of typing pen (0.42) eraser (0.43) rake (0.13)
29	The rancher herded his cows out of the field sheep (0.56) grass (0.47) plastic (0.07)
30	All of the new kittens were grey and had very small paws brown (0.64) dull (0.46) fruit (0.09)
31	Yesterday afternoon, the toddler played with a turtle in the backyard toad (0.59) pond (0.49) jail (0.03)
32	The host decided to make a drink with lemons for the party oranges (0.67) sour (0.67) useful (0.18)
33	The guest happened to notice the eel in the corner of the tank fish (0.52) slimy (0.41) kiss (0.01)
34	Our next-door neighbor was kind of scary because of her cat eerie (0.29) monster (0.40) mushroom (0.08)
35	The family visited the cathedral after speaking with a tour guide church (0.43) priest (0.39) collie (0.02)
36	The aunt hired an experienced attorney to handle the case prosecutor (0.69) lawsuit (0.67) popcorn (−0.01)
37	The boy wanted to play the cello in the youth orchestra bass (0.24) string (0.21) crutch (0.06)
38	The junior class all had green shirts on for the class trip purple (0.46) grass (0.41) tyranny (−0.01)
39	The woman's friend surprised her with roses for her birthday tulips (0.58) pink (0.48) tubas (0.09)
40	The hungry triplets wanted to have rice with their dinner noodles (0.43) fried (0.43) patrol (0.04)
41	The boy asked his father to pass the napkin to him before he ate fork (0.43) lap (0.36) ears (0.10)
42	The director brought his new umbrella with him, just in case raincoat (0.38) raining (0.40) sword (0.12)
43	The customer thought that the soup was too cool, but ate it anyway warm (0.76) humid (0.62) fake (0.10)
44	The artist enjoyed a cigarette after the dinner party pipe (0.30) lungs (0.33) cobra (0.02)
45	The newest room in the house was square and painted blue circular (0.30) angles (0.37) experience (0.09)
46	They got their dog a collar and a new water bowl leash (0.42) leather (0.39) planet (0.00)
47	The renter realized that his apartment had a termite infestation cockroach (0.29) burrow (0.21) shingle (0.08)
48	The fisherman bought two pounds of lettuce from the market cabbage (0.45) salad (0.57) tournament (0.07)
49	The students wondered why such a difficult question had been asked tricky (0.25) heavy (0.30) attic (0.10)
50	The home owners wanted to get the tiny dog from the shelter miniature (0.32) particle (0.32) hoop (0.10)
51	The couple thought the appetizer tasted too spicy so they left the restaurant sweet (0.49) chili (0.53) silly (0.08)
52	The assistant let her fear get in the way of talking to her boss guilt (0.44) afraid (0.45) conceptual (0.04)
53	Although the driveway was a bit too long, the couple liked the house wide (0.54) length (0.42) cola (0.08)
54	The group of girls approached the door very carefully and quietly window (0.66) open (0.73) dip (0.12)
55	It was always incredibly windy near the top of the mountain sunny (0.57) kite (0.45) cults (−0.05)
56	The grandmother purchased some *fabric* for her new project ribbon (0.22) cotton (0.44) holy (0.01)
57	They had always been interested in the wild aspects of nature untamed (0.31) jungle (0.38) tweet (0.01)
58	The children could see the sun reflected on the surface of the lake moon (0.28) bright (0.39) mop (0.05)
59	The manager cleaned his cup out before getting a refill mug (0.48) coffee (0.68) mole (0.10)
60	The officer's actions were quite heroic on that fateful day brave (0.30) ballad (0.44) couch (0.09)
61	The nanny made sure that the baby went to sleep on time toddler (0.36) embryo (0.33) wheel (0.10)

(*Continued*)

Continued.

Item	Sentence
62	The family owned a small cabin that they used during the summer tent (0.32) woods (0.48) ash (0.11)
63	The village was hit by a hurricane and was nearly destroyed quake (0.35) clouds (0.41) zebra (0.00)
64	The farmer always found a deer by the riverbank on his property snake (0.32) antler (0.43) truth (0.06)
65	The meat needed a bit more salt to bring out the flavor pepper (0.21) ocean (0.33) trees (0.04)
66	The infection was caused by a bacteria in the lower intestines parasite (0.52) microscope (0.42) impulse (0.01)
67	The young woman always had apples to snack on at work pears (0.51) ripe (0.52) polite (0.15)
68	The path running beside the swamp was always too muddy forest (0.26) water (0.22) cowboy (0.05)
69	The archaeologist discovered a rare artifact when digging in the desert typical (0.27) chicken (0.19) pine (0.15)
70	The doctor was considered an honest man by the people corrupt (0.36) lawyer (0.35) sandpaper (0.01)
71	The restaurant featured salmon on the menu every weekend caviar (0.39) stream (0.30) roof (0.01)
72	The press was told that cameras were not allowed by the administration recorders (0.34) lenses (0.44) ice (0.04)