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Focus projection and prenuclear accents: evidence from lexical processing

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ABSTRACT
Theories of Focus Projection claim that a single pitch accent on a verb's argument is sufficient to prosodically mark that verb as part of the focus, negating the need for a prenuclear accent on the verb itself. The present study employed online lexical processing to test this claim empirically. In three cross-modal associative priming experiments, listeners heard English SVO sentences with/without prenuclear accenting on the verb in both broad (VP) and narrow (object) focus contexts. Results showed that the absence of a prenuclear accent in broad focus contexts did not disrupt priming, but the presence of one in narrow focus contexts did. This disruption was found to be somewhat modulated by individual differences in "autistic traits". Overall, the findings are interpreted as supporting a model that includes both (a) a Focus Projection mechanism and (b) an information structural function for prenuclear accents, with the latter possibly subject to cross-listener variation.

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Introduction

One of the most basic observations about the relation between prosody and information structure in English is that focus (an utterance's new, informative, or contrastive content) shares a close relationship to the sentence's nuclear pitch accent (the last pitch accent in an intermediate phrase; Beckman & Pierrehumbert, 1986; Pierrehumbert, 1980). However, it is also known that this correspondence is not one-to-one. This can be seen in examples like (1), where the focus of the sentence is regarded as the information required to provide a full answer to a WH-Question (e.g. "FOC interpretation" in Selkirk, 1995; see also Büring, 2007, among others):

(1) a. Q: Who borrowed the salt?
A: $[\text{ROBERT}]_{\text{Foc}}$ borrowed the salt.
b. Q: What did Robert borrow?
A: Robert borrowed $[\text{the SALT}]_{\text{Foc}}$
c. Q: What did Robert do?
A: Robert $[\text{borrowed the SALT}]_{\text{Foc}}$

In the context of the question in (1a), which asks for the subject of a borrowing event, the focus of the sentence is "Robert"; in the context of the question in (1b), which asks for the object of a borrowing event, the focus of the answer is "the salt"; in the context of the question in (1c), which asks about an activity carried out by "Robert", the entire verb phrase (VP) "borrowed the salt" is focused. In addition to the discourse salience of focus, the presence of focus is standardly assumed to add to the semantic interpretation of the utterance (Beaver & Clark, 2008; Rooth, 1992; Schwarzschild, 1999). Notably, while the utterances in (1b) and (1c) are information structurally distinct, it is less clear that they are prosodically distinct; in both (1b) (which will be referred to as a case of "narrow focus") and (1c) (which will be referred to as a case of "broad focus"), the nuclear pitch accent, most likely a H*, falls on the object.[1]

The present study concerns itself with this contrast in the size of a focus constituent in English SVO constructions, which, given the observation about nuclear accent placement, is often regarded as a prosodic ambiguity (e.g. Ladd, 1996). Making use of the cross-modal associative priming paradigm, this study asks two basic questions:

(1) *Is the broad/narrow focus contrast a genuine prosodic ambiguity?*
(2) *Does the answer to the first question depend on individual differences in cognitive processing styles?*

The first question is the one of primary interest to this investigation, and it is one that has been asked previously using off-line methodology. As discussed further below, there are a number of reasons to re-examine the issue using additional tools, particularly online measures of sentence and lexical processing. Like some previous psycholinguistic work, however, the present investigation will be guided primarily by two theories of Focus Projection (Gussenhoven, 1984, 1999;

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Selkirk, 1984, 1995), and of central concern will be their divergent treatment of a particular aspect of the prosodic representation: prenuclear accentuation.

The second question is motivated by recent work suggesting that variation in "autistic traits" across neurotypical individuals may predict variation in the use of prosodic and pragmatic contexts in sentence processing. Since each of these kinds of information is crucial to the linguistic contrast of interest, the present study explored whether such traits, thought to represent an aspect of "cognitive processing style" (Ausburn & Ausburn, 1978; Yu, 2010), might account for some variability related to its processing.

The rest of the paper is organised as follows. The next section introduces Focus Projection Theory's basic relevance to the broad/narrow focus contrast, and then reviews some of the existing psycholinguistic and phonetic evidence bearing on the two prominent versions of the theory, as well as some additional predictions by Bishop (2013) based on this evidence. Then, the motivation for using the cross-modal priming paradigm to probe listeners' expectations, and for considering individual differences in autistic traits, is motivated. The following section then presents three cross-modal lexical decision experiments intended to address the two questions above, followed by a discussion and conclusion based on the findings.

Focus projection and prenuclear accentuation in English

Theories of focus projection

A starting point for the present investigation into the prosody of the broad/narrow focus contrast is Focus Projection Theory, which has guided research on the issue previously. In the most basic sense, theories of Focus Projection model focus as an interpretational feature that is licensed by the presence of an accent on a word. However, that feature is able to percolate (via a set of explicit Focus Projection rules) from the accented word to larger constituents, thus allowing, for example, a single (nuclear) pitch accent on an object to either mark focus on that object, or on the larger VP containing it. That is, an additional (prenuclear) pitch accent on the verb is unnecessary to license a VP focus interpretation. Two prominent models of Focus Projection exist in the literature: the model proposed by Selkirk (1984) and the model proposed by Gussenhoven (1984). Despite the difference in the level of representation these two theories emphasise (syntactic for Selkirk, semantic for Gussenhoven), they make a number of overlapping predictions about how prosody relates to focus in various constructions. What is of primary interest here is the differing role played by prenuclear accents in revised versions of these two models (Gussenhoven, 1999; Selkirk, 1995).[2]

In Gussenhoven's (1999) model, a nuclear accent marking an internal argument of a verb (e.g. an object), is able to project focus up to the larger predicate, thus allowing a nuclear accent on an object to be acceptable for either broad VP or narrow object focus. Prenuclear accents, on the other hand, are added optionally (via phonological rule), subsequent to the nuclear accent in the derivation. Thus, prenuclear accents (which may be present for various reasons, such as rhythm) bear no grammatical relation to information structural meaning in the simple SVO constructions under consideration here.

In the model proposed by Selkirk (1995), a nuclear accent on an object is also able to project up the (syntactic) tree, and thus mark the larger VP containing. However, a separate stipulation holds that prenuclear accents are interpreted as marking information as "new" in the discourse.[3] Therefore, although they are not required to mark the verb as part of a VP focus (due to Focus Projection from the object), they are in fact unexpected when focus is narrowly on the object, because in such a case, the verb is *not* new. Unlike in Gussenhoven's (1999) model, then, Selkirk's (1995) theory allows for prenuclear accents to bear semantic/pragmatic significance, and they are predicted to be completely optional only under broad focus.

Empirical evidence for focus projection

Psycholinguistic evidence

The first psycholinguistic studies testing Focus Projection theories' predictions about prenuclear accent placement are among the most widely cited in the experimental literature on prosody and focus. These investigations utilised a common basic paradigm: off-line and explicit judgments of appropriateness in context. The two variants of this paradigm are referred to here as "context matching" and "appropriateness rating". "Context matching" attempts to elicit listeners' knowledge of how prosody and focus relate by presenting a sentence with a certain prosodic structure (e.g. an SVO sentence with a nuclear accented object, with or without a prenuclear accent on the verb) in a context that sets up a certain information structural interpretation for that sentence (e.g. the sentence follows a WH-question, as in the above examples). The listener is then required to decide whether a different pairing of prosody and context would be more appropriate or natural. "Appropriateness rating" is perhaps more explicit (or more

metalinguistic) yet, and, as the name suggests, requires the listener to take the sort of pairings just described, and assign a numerical appropriateness value to the answer sentence.

The earliest of these studies was Gussenhoven's (1983) experiment (see also Gussenhoven, 1984) using context matching, the results of which showed speakers of British English to lack any significant preference regarding prenuclear accents when comparing sentences in broad and narrow focus contexts (although, crucially, the listeners were shown to perceive the accents). However, Gussenhoven did find that listeners matched sentences without a prenuclear accent to narrow object focus contexts more consistently than they matched sentences *with* prenuclear accents to broad VP focus contexts. That is, although listeners were largely ambivalent about the presence of a prenuclear accent in both broad and narrow focus contexts, there seemed to be something "more ambiguous" about broad focus sentences. A trend in this direction would seem to be predicted by Selkirk's theory, since, as described above, optionality in prenuclear accent placement is expected in broad focus contexts only. Given the statistical non-significance of this observation, however, the ambiguity of broad and narrow focus prosody in Gussenhoven's study would seem to be supported, and was in fact replicated by Welby (2003) using the appropriateness rating version of the task.

Two additional studies, however, suggest that off-line tasks of this sort may not always reflect listeners' knowledge about how prosody relates to information structure. First, Birch and Clifton (1995) report two experiments using appropriateness ratings and find inconsistent ambiguity, at least for broad VP focus (narrow object focus preferences were not tested by the authors). In one version of the experiment (Experiments 2 and 4 in their study), listeners heard sentences with or without an accent on the verb, and were asked to rate whether the answer sentence "made sense".[4] In a second version (Experiments 1 and 3), listeners were instructed to attend specifically to the answer sentence's prosody, given the context. Birch and Clifton found that listeners in the first type of experiment gave the ambivalent judgements reported in the Gussenhoven and Welby studies cited above. In the second version of the experiment, however, which directed them to prosody, listeners showed a small but statistically significant preference for broad focus sentences to have a prenuclear accent on the verb. This finding seems to indicate that it cannot be taken for granted that listeners in appropriateness judgement tasks will relate context and prosody if they are not directed to do so (or if they are not aware of the potential for ambiguity).

This point, which has been made previously with respect to prosodic disambiguation in production studies (e.g. Jun, 2010; Snedeker & Trueswell, 2003), is echoed in a second, more recent investigation by Breen, Fedorenko, Wagner, and Gibson (2010). In a cooperative/communicative version of the context matching task, both speakers (trying to produce unambiguous sentences) and listeners (trying to use the cues provided to identify information structure) were explicitly aware of the ambiguity. Under these conditions, speakers tended to produce broad focus sentences with acoustic correlates of greater (relative) prenuclear prominence, and, crucially, listeners showed an ability to use these cues to retrieve the intended focus context well above chance level. This result thus demonstrates a potential for prosodic disambiguation that is apparently latent in some appropriateness judgement experiments.

Although Breen and colleagues showed some ability of prosody to disambiguate both broad and narrow focus sentences, there were some asymmetries in their data that are worth noting in the context of the present discussion. First, apparent in the authors' results is the same trend reported in the early Gussenhoven's (1983) study: prenuclear prosody was not equally used for the identification of broad and narrow focus; across their Experiments 2 and 3, 69–80% of Breen and colleagues' listeners accurately matched narrow focus productions with narrow focus contexts above chance level, while only 46–80% of listeners were able to correctly match broad focus productions with broad focus contexts above chance level. Although the statistical relevance of this difference across their two separate experiments is not known, again we see an asymmetry in the direction predicted by Selkirk's model of Focus Projection: prenuclear prominence seems to be less relevant to identifying broad focus than to identifying narrow focus. An additional and interesting observation to be made from Breen *et al.*'s study is that not all listeners could perform their task above chance level at all (note that the accuracy statistics just cited were in terms of proportion of listeners), and so the ability to retrieve intended information structure based on prosodic prominence patterns must be subject to some individual differences. This matter is returned to further below.

Phonetic evidence

While psycholinguistic evidence has been somewhat mixed, results of phonetic production studies have generally provided less support for the notion that broad and narrow focus are ambiguous, and in this sense, less support for Focus Projection Theory. In brief, this work has explored a number of acoustic cues to prominence, and the patterns seem to be broadly consistent

with the idea that speakers produce greater prenuclear prominence on verbs under broad focus, and less under narrow focus (Breen et al., 2010; Sityaev & House, 2003; Xu & Xu, 2005; see also Baumann, Becker, Grice, & Mücke, 2007; Baumann, Grice, & Steindamm, 2006; Féry & Kügler, 2008 for closely-related German). Here, too, however, there is much variation in the details within and across studies, and there are two important generalisations one can make based on this variation. First, speakers seem to vary with respect to which cues dominate their disambiguation, with f0, intensity/loudness, and duration being the most studied (e.g. Breen et al., 2010).[5] Second, speakers may vary with respect to how they implement this prominence: either "directly" by manipulating prenuclear prominence itself (Xu & Xu, 2005), or instead "indirectly" by either manipulating adjacent nuclear prominence (Eady & Cooper, 1986; Eady, Cooper, Klouda, Mueller, & Lotts, 1986; see also Hanssen, Peters, & Gussenhoven, 2008 for Dutch), or manipulating the acoustic cues to both prenuclear and nuclear prominence in tandem (Baumann et al., 2006, 2007; Breen et al., 2010).

An important point to make about these production patterns is that they appear to be to some extent internalised by listeners, as listeners exhibit expectations for them in perception experiments that do not rely on appropriateness judgements. For example, Bishop (2012) found that when presenting the same production of an answer sentence, spliced into broad or narrow focus contexts, the focus context predicted perceived prominence judgements of both the verb and the object (see also Bishop, 2016, as well as a study with Dutch speakers in Rump & Collier, 1996). Top-down effects of this sort suggest that the broad versus narrow focus contrast is not entirely ambiguous in the minds of listeners, and may somehow be marked by a relative prenuclear–nuclear prominence relation.

Phonetic studies therefore pose two problems for theories of Focus Projection: (1) neither broad nor narrow focus appear to be as ambiguous as predicted, and (2) the crucial prosodic feature, if it is a prenuclear–nuclear relation, is not easily characterised as the presence versus the absence of a prenuclear pitch accent. Attempting to provide a workable phonological treatment of this situation, Bishop (2013) proposed a model based on a syntagmatic "tonal metrical structure" (Ladd, 1990, 1993, 1996). To capture the production data, the model emphasises the relative prominence between the verb and the object, and allows for ambiguity; when the verb is unaccented and the object is nuclear accented, the relation is tipped in the direction of the object, and is the optimal realisation for narrow object focus. However, when the verb is prenuclear accented (e.g. bears a H*) and the object's nuclear accent is subordinate (i.e. a phonetically lower !H*), this is an optimal broad focus realisation. Between these two realisations, there are a number of phonetically intermediate values of relative prenuclear–nuclear prominence that should be more or less ambiguous as a consequence. For example, a realisation of the sentence with a phonetically low H* on the verb and a higher H* on the object will be highly ambiguous, but may weakly favor narrow object focus; a realisation with two roughly equal H*s on the verb and object (i.e. a "hat pattern") will be highly ambiguous but may slightly favor a broad focus interpretation.

Bishop's tonal metrical proposal thus stands as an alternative to Focus Projection, one that is essentially a formalisation of the results from phonetic studies. The model predicts unambiguous pronunciations to be possible – the extreme ends of a spectrum where either the prenuclear (verb) or nuclear (object) is maximally prominent. It also allows for ambiguity, but this ambiguity is due to phonetic gradience in the realisation of a prenuclear–nuclear prominence relation, not to a spreadable focus feature (i.e. not to Focus Projection).

Present study

Use of cross-modal associative priming

What should be clear from the discussion thus far is the existence of considerable uncertainty regarding whether broad and narrow focus, a contrast in information structure, are genuinely ambiguous prosodically in English SVO sentences. The motivation for carrying out an online investigation of the processing of this contrast should also be clear; off-line measures using explicit appropriateness judgements have produced rather conflicting results, and may not be sufficiently sensitive to listeners' knowledge about prosodic well-formedness. Additionally, it has been difficult to relate previous psycholinguistic studies to more recent phonetic work. The goal of the three experiments below was to determine whether some insight might be gained from considering a more online measure of processing, namely the cross-modal associative priming paradigm.

In the cross-modal priming paradigm, a listener is auditorily presented with a word, either in isolation or embedded in a sentence, and must then make a lexical decision about a related target word, presented visually following the prime. Priming occurs when the target word (e.g. PEPPER) is recognised more quickly following a related prime (e.g. *salt*) than following an unrelated control prime (e.g. *tape*).[6] However, lexical priming effects are not automatic (i.e. not entirely predictable

based on word–word associations alone), but are sensitive to at least two basic factors. First, priming tends to fail when details of a prime's realisation do not conform to the listener's context-sensitive expectations (e.g. Blutner & Sommer, 1988; Locasto & Connine, 2011; Sumner, 2013; Swinney, 1979). In the present case, theories of Focus Projection make different predictions about whether or not a sentence such as "He borrowed the SALT" (where capitals represent a nuclear accent and underlining represents a prenuclear accent) is appropriate in the context of a narrow focus question like "What did he borrow?". If this realisation is felicitous to the listener – i.e. the focus structure and the prosodic structure are perceived to "match" – we have no reason to expect words in the sentence to serve as poor primes. For example, there is no reason for a word like *salt* in the sentence to not prime a semantic associate word like PEPPER. This set-up served as the basic design for Experiments 1–3, with priming effects used as an indirect measure for whether the listeners perceived prosodic realisations to be appropriate.

The second factor priming is known to be sensitive to are the details of the semantic relationship between prime and target (e.g. Whitney, McKay, Kellas, & Emerson, 1985), but this relationship is itself dependent on the word's sentence-level context (Foss & Ross, 1983; Norris, Cutler, McQueen, & Butterfield, 2006; Tabossi, 1988; Williams, 1988). Given that the contexts in which prime words will occur in this study are focused contexts – and that focus may introduce a contrastive meaning (Rooth, 1992) – the most effective types of prime words in the present study would be those bearing a contrastive relationship with their corresponding target. In fact, compelling evidence for this has been reported by Braun and Tagliapietra (2010; see also Braun & Tagliapietra, 2011). In their study (with Dutch listeners), the authors showed that when prime words like *flamingo* were interpreted contrastively (induced in their study using prosody only, not context), priming was stronger for contrastively related targets (e.g. PELICAN) than for non-contrastively related targets (e.g. PINK).[7] Contrastive prime-target pairs like the *salt*-PEPPER example were therefore used in the experiments in the present study.

To summarise, the present study aimed to use cross-modal associative priming to test whether English-speaking listeners show preferences for the presence/absence of prenuclear accent in SVO constructions with different focus interpretations. The basic assumption was that primes embedded in prosodic structures that are unexpected/infelicitous/dispreferred given their information structure are difficult to process, and so will fail to produce robust priming. For explicitness, a preview of the design and predictions for Experiments 1–3 are described here.

Using context to manipulate focus size, Experiment 1 tested whether sentences without a prenuclear accent on the verb (henceforth [–Prenuclear Accent] prosody) were preferred in narrow object focus contexts rather than broad VP focus contexts. That is, SVO sentences with [–Prenuclear Accent] verb prosody were presented as answers to either narrow object or broad VP questions:

VP Focus Context:	What did Robert do when he came by? Did he snoop around?
Object Focus Context:	What did Robert borrow when he came by? Did he borrow the broom?
Test Sentences:	[–Prenuclear Accent] He borrowed the SALT.

Here, both Gussenhoven's and Selkirk's theory make the same prediction; as long as the sentence contains a nuclear accent on the object, a VP focus interpretation is licensed, negating any need for explicit accentual marking of the verb's in-focus status. Priming from auditorily presented *salt* to a related visual target word like PEPPER should obtain equally in both conditions according to their theories. According to Bishop (2013), however, sentences without a prenuclear accent on the verb (and thus higher relative prominence on the object) are preferred narrow focus pronunciations, and so priming is expected to be more robust in the narrow object focus context than the broad VP focus context.

Experiment 2, an extension of Experiment 1, probed for a preference that sentences in VP focus contexts contain a prenuclear-accented verb (henceforth [+ Prenuclear Accent] prosody) rather than an unaccented verb. Here the question was asked by presenting both [+ Prenuclear Accent] and [–Prenuclear Accent] sentences as answers to broad VP focus questions:

VP Focus Context:	What did Robert do when he came by? Did he snoop around?
Test Sentences:	[+ Prenuclear Accent] He borrowed the SALT. [–Prenuclear Accent] He borrowed the SALT.

As with the comparison in Experiment 1, Gussenhoven and Selkirk agree. Both assume there should be no difference between the two prosodic conditions; in both conditions, focus can project from the objects' nuclear accent, making prenuclear pitch accents optional. Priming from *salt* to visual target word PEPPER

should obtain equally in both conditions. On the other hand, Bishop's (2013) proposal, based primarily on production evidence, predicts no ambiguity. Rather, since focus is broad on the VP, more prominent verb prosody should be preferred, and so more robust priming from *salt* to PEPPER is expected in the [+Prenuclear Accent] condition than in the [–Prenuclear Accent] condition.

Finally, Experiment 3 was designed to test the more contentious issue, the one that crucially distinguishes Gussenhoven's theory from Selkirk's: whether sentences with [+Prenuclear Accent] verb prosody and sentences with [–Prenuclear Accent] verb prosody are equally appropriate under narrow focus conditions:

Object Focus Context:	What did Robert borrow when he came by? Did he borrow the broom?
Test Sentences:	[+Prenuclear Accent] He borrowed the SALT. [–Prenuclear Accent] He borrowed the SALT.

Gussenhoven's theory predicts that, as for the other pairings, sentences with and sentences without prenuclear-accented verbs should be equally felicitous in an object focus context. Selkirk, however, predicts an asymmetry; since prenuclear accents have a [+new] interpretation, they are unexpected in narrow object focus contexts, since in such contexts, the verb is old/given information. Again, Bishop (2013) predicts [+Prenuclear Accent] sentences to be dispreferred, since the narrowly focused object would be of fairly low prominence relative to the verb. Selkirk and Bishop therefore both predict listeners' processing to be disrupted in this case, and so more robust priming effects should be observed in the [–Prenuclear Accent] condition than in the [+Prenuclear Accent] condition. The predictions about the presence of priming for different focus/prosody pairings are summarised in Table 1.

Table 1. Summary of predictions made by two theories of Focus Projection, and Bishop's (2013) proposal, applied to priming effects in Experiments 1–3.

	Gussenhoven (1999)		Selkirk (1995)		Bishop (2013)	
	VP-Foc	Obj-Foc	VP-Foc	Obj-Foc	VP-Foc	Obj-Foc
[+Prenuclear Accent]	✓	✓	✓	×	✓	×
[–Prenuclear Accent]	✓	✓	✓	✓	×	✓

Notes: A "✓" indicates the prediction of priming effects, "×" the predicted failure of priming effects. [+/–Prenuclear Accent] refers to the verb's prosodic status in the SVO sentences presented to listeners.

Individual differences

Implicit in most of the discussion thus far is the assumption that, when interpreting an utterance, all listeners attend to, and incorporate, information from previous discourse equivalently. Similarly, the discussion up to now has assumed that all listeners who share a language utilise patterns of prosodic prominence in the same way. However, there is growing evidence that calls into question the validity of both assumptions, and a basic treatment of this situation must be described before moving on to the three cross-modal priming experiments.

To give a brief summary of our still-very-incomplete knowledge at this point, it has been argued that the extent to which pragmatic information is used in sentence comprehension and speech processing varies measurably across individuals, and that at least part of this variation is correlated with "autistic traits". Autistic traits are personality traits that resemble the communication and information processing tendencies associated with individuals with Autism Spectrum Conditions, and can be measured in neurotypical populations using instruments such as the Autism Spectrum Quotient (the "AQ"; Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). A number of recent studies have shown that at least one subscale of the AQ, namely the subscale measuring "communications skills" (henceforth "AQ-Comm") predicts performance on a number of language processing tasks.[8]

First, it has been shown that individuals with higher AQ-Comm scores (indicating poorer, more autistic-like communication skills) are less likely to utilise pragmatic knowledge when interpreting sentences, and thus come to unexpected conclusions about their felicitousness or grammaticality. This tendency has been detected using both off-line (Xiang, Grove, & Giannakidou, 2013) and ERP measures (Nieuwland, Ditman, & Kuperberg, 2010; Xiang et al., 2013). To the extent that attending to (and constructing a model of) discourse is crucial to assigning information structure to a sentence, such variation across individuals is of obvious relevance to the present study.

Of no less importance is the fact that AQ-Comm has, separately, been argued to correlate with differences in the use of prosodic prominence in sentence comprehension, with evidence coming from two recent studies exploring the use of prosody in the resolution of relative clause (RC) attachment ambiguity. In particular, Jun and Bishop (2015a) show that individuals with higher AQ-Comm scores are more sensitive to the presence of prosodic boundaries (see also Jun & Bishop, 2015b). Using a prosodic adaptation of the structural priming paradigm (Bock, 1986), they tested whether auditory primes such

as (2a) were more likely than ones such as (2b) to prime high attachment (i.e. to NP1, "the servant") of a relative clause in an analogous target sentence (where "//" indicates a large prosodic phrase boundary):

(2) a. Someone shot the servant of the ACTRESS//who was on the balcony.

b. Someone shot the SERVANT//of the actress who was on the balcony.

Notably, this is the pattern of attachment preference predicted by the Implicit Prosody Hypothesis (Fodor, 1998, 2002), although only individuals with very high AQ-Comm scores exhibited it. Jun and Bishop argued that this is because placing a boundary after NP2 ("the actress") caused it (i.e. NP2) to be nuclear accented, and thus highly prominent. Because accentuation is independently known to attract attachment – what Schafer, Carter, Clifton, and Frazier (1996) called "Focus Attraction" (see also Lee & Watson, 2011), Jun and Bishop reasoned that the high AQ-Comm listeners showed Fodor's expected boundary effects more robustly because they were less distracted by the conflicting cue presented by the prominence patterns. Some additional evidence for the relation between AQ-Comm and the perception of prominence comes from Bishop (2016). In an experiment replicating Bishop's (2012) finding, cited above, Bishop found that listeners had expectations for verbs to be relatively more prominent when they occur in broad focus contexts. However, the size of this effect was strongly dependent on AQ-Comm, as listeners with higher scores (again, indicating more robust autistic traits) showed weaker expectations for verb prominence based on focus size.

While the issue of individual differences is secondary in the present study, autistic traits were taken into account, given both the discourse-sensitive nature of the semantic contrast to be investigated, and especially its relation to prosodic prominence. The basic prediction was that, if listeners with more autistic traits (as measured by AQ-Comm) are less sensitive to either discourse context or prosodic prominence (or both), the predictions in Table 1 should generally apply less well to them. In particular, preferences for particular focus-to-prosody mappings may be weaker, and so priming patterns should not depend as strongly on them.

Experiments

Methods

Materials

Materials were designed for a set of cross-modal lexical decision experiments, intended to probe for effects of prenuclear accents in different focus contexts. The basic design of the primes, targets, and sentences, used for all three experiments, was similar to that used by Braun and Tagliapietra (2010). The materials consisted of target words (e.g. PEPPER), and primes that were either related to the target (e.g. *salt*) or were unrelated control primes (e.g. *tape*). Since it has been shown that contrastive associative relationships are most likely to facilitate priming in contrastive/focused sentences (Braun & Tagliapietra, 2010), all related primes were contrastive with their targets, and these prime-target pairs were selected as follows. First, 32 English nouns, mostly monosyllables, or disyllabic words with a strong-weak stress pattern, were chosen to serve as the primes. These primes were then used in a web experiment to elicit contrastively related associates from 80 native English-speakers. Participants in this web experiment were presented with the 32 primes in frames such as "He didn't say "X", he said ___", to which they responded with the first word that came to mind. For each of the primes, the most frequent response was selected and used as the target for that prime (the mean association rate was 47.7% of responses; range 26.2% – 87.7%). Thirty-two simple SVO sentences were then constructed, in which the primes just selected were to serve as the sentence-final objects. Care was taken so that, for each sentence, the object prime was the only word semantically related to the target. Thus 64 SVO sentences (one version of all 32 sentences containing the related prime, a second version containing the unrelated control prime), were produced by a male speaker of American English trained in phonetics and intonational phonology.

In order to create the two prosodic conditions, the two sets of 32 sentences were produced with two different prosodic structures, contrasting the presence versus absence of a prenuclear pitch accent on the verb (henceforth "verb prosody"). All sentences bore a nuclear pitch accent on the object. This was carried out as follows.

First, a production was recorded in which the verb bore a prenuclear H* pitch accent with a following nuclear accent on the object that was intended to be ambiguous between a H* and a !H*. This production was used as the [+ Prenuclear Accent] condition (see Figure 1(a)). A second version of each of the sentences was then read without a prenuclear accent on the verb (subjects, which were in most cases a pronoun, bore no accent). The object was produced with a prominent L + H* nuclear accent (see Figure 1(b)). In order to hold the acoustic information for the primes themselves (i.e. the objects) constant, while manipulating only verb prosody, the same recording of the object prime word was used in both verb prosody conditions. This was

accomplished by excising the production of the prime from the [+ Prenuclear Accent] condition and splicing it into the corresponding unaccented recording, replacing the original (natural) production of the L + H* object. Thus, the final stimuli for the [+ Prenuclear Accent] condition were original, unedited productions, and the sentences in the [–Prenuclear Accent] condition were manipulated versions. Although the phonological structure of the edited [–Prenuclear Accent] condition contained a L + H* on the object, this accent was generally phonetically less prominent than the one it replaced (Figure 1(c)). All experimental sentences (i.e. those containing related primes, and those containing unrelated control primes) were created in this way and saved as wav files.

To help confirm that the prosodic manipulation resulted in the intended accentuation contrast, acoustic measurements (following the recommended criteria in Turk, Nakai, & Sugahara, 2006) were carried out for verbs and objects in the final stimuli. The mean values across items for the most common acoustic correlates of phonetic prominence are shown in Table 2. As can be seen, f0 values for verbs in the [+ Prenuclear Accent] condition were significantly higher than those of the objects for both the test and control conditions (on average 110% the height of the object for each type of primes, consistent with a "falling hat pattern", or H* H* sequence). In addition, verbs were considerably longer and of greater intensity when they were produced with a prenuclear accent. Thus, while the primes themselves were the same productions with the same absolute acoustic properties, they followed verbs that were more or less prominent, depending on verb prosody condition.

Finally, in order to create the information structure conditions in which these sentences would appear, lead-in questions were produced. These were WH-questions such as "What did Robert do?" (in the case of VP focus) and "What did Robert borrow?" (in the case of object focus). In order to produce maximally contrastive contexts for the focused constituents, yes/no questions were additionally made to follow the WH questions. For example, the full question contexts were of the form "What did Robert do when he came by? Did he snoop around?" for VP focus, or "What did Robert borrow when he came by? Did he borrow the broom?" for object focus. Question contexts, like the test sentences, were constrained such that only words unrelated to the targets could be used, as any additional related words could serve as unintended primes. All question contexts were produced and recorded by a female speaker of American English and were made to precede the SVO sentences in the stimuli, so that the SVO test sentences appeared as corrective/contrastive answers to them.

The full list of all materials used (sentences, test primes, control primes, and targets) is shown in the Appendices. In addition to these materials, there were also 96 filler sentences with filler primes and filler targets. Sixty-four of the filler trials contained non-word targets; of the remaining 32 filler trials, half contained primes that were semantically unrelated to the target words, and half were related. In other respects, filler trials were the same as the experimental trials, with the same two prosodic versions of each. (For fillers, however, the prosodic conditions were both natural productions, with no splicing being done). An additional set of 6 filler sentences was also created to be used as items in a brief practice session to familiarise participants with the task.

Procedure

Three different cross-modal priming experiments were carried out (i.e. three different sets of participants), corresponding to the three different questions described above. In each experiment, four lists were formed by rotating the 32 test items through four conditions (crossing either the information structure or prosodic manipulation with the prime type manipulation so that there were eight 8 items in each condition). In Experiment 1, this meant four lists were formed by rotating the 32 test sentences and visual targets through the two prime type conditions (related and unrelated control prime) and the two information structural conditions (broad VP or narrow object focus contexts); all sentences contained [–Prenuclear Accent] verbs. In Experiment 2, the four lists were formed by taking the 32 test sentences and corresponding visual targets and rotating them through the two prime type conditions and the two verb prosody conditions ([+/–Prenuclear Accent]); all sentences were presented in broad VP focus contexts. Finally, Experiment 3's lists were created by rotating the same 32 sentences/visual targets through the two prime type conditions and the two verb prosody conditions, but all sentences were presented in narrow object focus question contexts.

Participants in each experiment were assigned (randomly) to one of the lists; they were seated individually in a sound-attenuated booth and were told they would hear short question–answer exchanges, and were to then make a lexical decision about a string of letters presented on a screen (in 72pt white font on a black background), after each one. Visual targets were presented immediately at prime offset. The auditory stimuli were played binaurally over Sony MDM headphones at a comfortable listening volume (held constant across

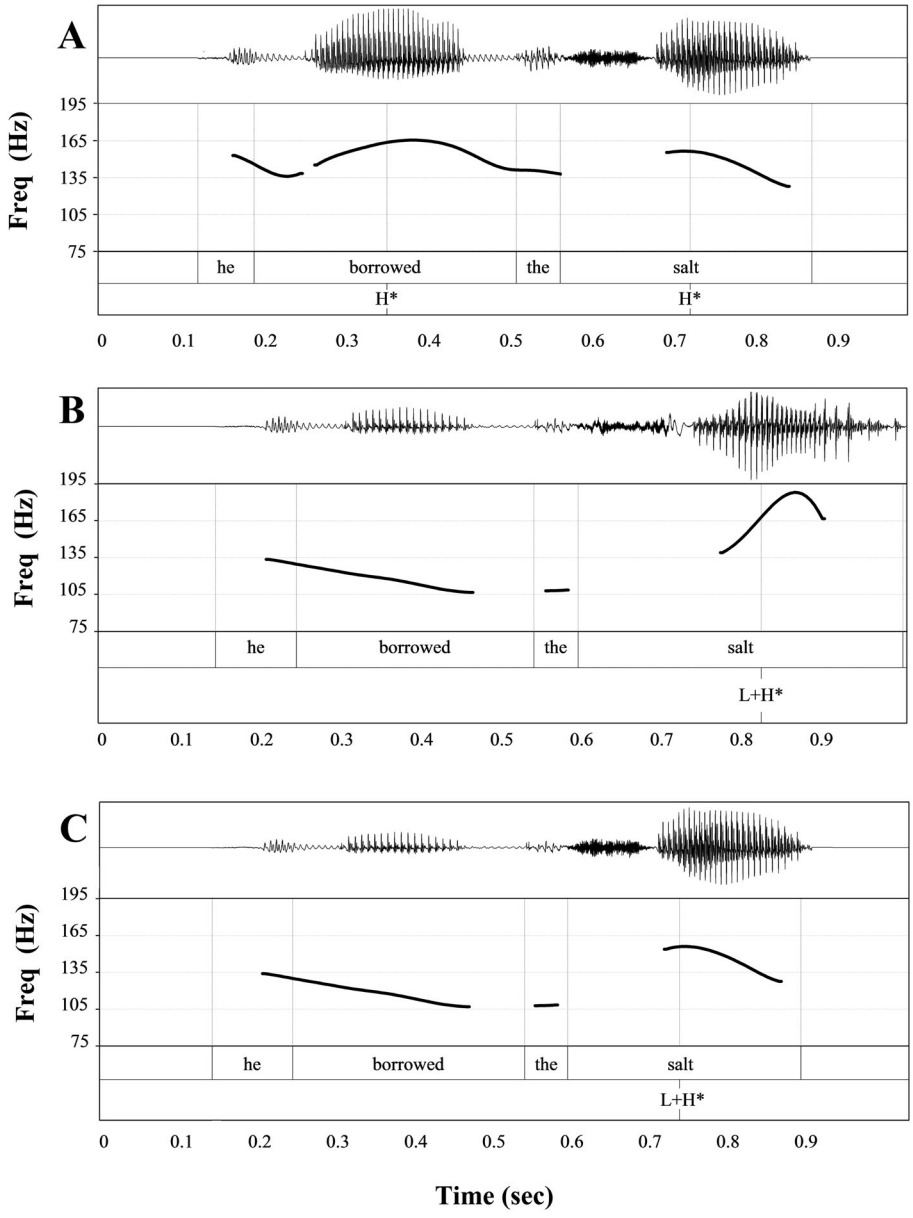

Figure 1. Example of an SVO test sentence in the two verb prosody conditions. (A) shows the sentence produced with a prenuclear H* on the verb, used in the [+ Prenuclear Accent] condition; (C) shows the sentence used for the [–Prenuclear Accent] condition, which was created by splicing the object "salt" from (A) into the production of the same sentence in (B).

participants). Participants were to push a "yes" or "no" key on a computer keyboard as quickly as possible to indicate that they recognised the word on the screen (the "yes" button was placed on the left or right, depending on which was the participant's dominant hand). Presentation of stimuli (randomised for each participant) and recording of responses and reaction times (RTs, measured from stimulus offset) were controlled by a MATLAB script.

Following the lexical decision task, participants also completed the Autism Spectrum Quotient (Baron-Cohen et al., 2001). The Autism Spectrum Quotient is a 50-item, self-report questionnaire, measuring autistic-like personality traits along five dimensions: *social skills* ("I would rather go to a library than a party."), *imagination* ("When I'm reading a story, I find it difficult to work out the characters' intentions."), *attention to detail* ("I usually notice car number plates or similar strings of information."), *attention-switching* ("I frequently get so absorbed in one thing that I lose sight of other things."), and *communication* ("I frequently find that I don't know how to keep a conversation going."), requiring one of four forced-choice responses to each of the 50 statement items: *definitely agree*, *slightly agree*, *slightly disagree*, or *definitely disagree*. Participants completed a computerised version of the complete test, although

Table 2. Acoustic properties of the verb and object in each of the two prosodic conditions for test and control sentences.

Test items	[+ Prenuclear Accent] verb	[– Prenuclear Accent] verb	Nuclear accented object
Dur (ms)	294 (87)	257 (88)	466 (99)
Intensity (dB)	76.1 (2.9)	66.2 (3.3)	73.5 (3.1)
f0 min (Hz)	138 (12)	112 (7)	106 (9)
f0 max (Hz)	175 (19)	126 (10)	158 (13)
f0 range (Hz)	35 (14)	15 (8)	52 (14)
Control items	[+ Prenuclear Accent] verb	[– Prenuclear Accent] verb	Nuclear accented object
Dur (ms)	304 (92)	260 (86)	520 (96)
Intensity (dB)	75.5 (3.4)	67 (4.9)	73.9 (3.6)
f0 min (Hz)	146 (13)	112 (9)	108 (12)
f0 max (Hz)	177 (16)	132 (14)	160 (12)
f0 range (Hz)	31 (15)	19 (9)	52 (15)

Notes: The same object was used in both conditions, and so only one object is shown for each item type. Values shown are means with standard deviations in parentheses.

for reasons described earlier, only scores on the communication subscale (again, referred to here as "AQ-Comm") were used for the analysis. Scoring was done using a 4-point Likert scale as in Yu (2010) and elsewhere rather than the binary *agree/disagree* scoring used in Baron-Cohen et al. (2001). For each of the three experiments, participants' AQ-Comm scores were roughly normally distributed and were similar to those reported by Yu (2010): Experiment 1 (mean = 22.2, range = 10–40, sd = 6.8), Experiment 2 (mean = 18.8, range = 10–28, sd = 3.7), Experiment 3 (mean = 19.0, range = 10–30, sd = 3.6). Additionally, participants also completed a measure of verbal working memory (the RSPAN task; Daneman & Carpenter, 1980), although this measure is not of interest to the present investigation, and will not be included in the analyses. Participation took place in a sound-attenuating booth or quiet testing room and lasted approximately 40 minutes in total.

Participants

Approximately 90 participants (all native speakers of American English, most native to California) took part in each of three cross-modal lexical decision experiments (92 in Experiment 1, 84 in Experiment 2, and 88 in Experiment 3). None participated in more than one of the experiments, and none had participated in the web-based association experiment used for stimulus design. All participants confirmed that they lacked any history of a hearing, speech or communication disorder.

Results

Experiment 1

Reponses to experimental targets were considered errors if the participant failed to hit the "yes" key, or their response was slower than 1800ms (Norris et al., 2006). For the 92 subjects, this resulted in 63 errors (approximately 2.1% of experimental trials), which were evenly distributed across the conditions and of no further interest. RTs for all correct responses falling within 2 standard deviations of the mean RT were analysed, resulting in a total of 2,819 observations that were modelled using mixed-effects linear regression using the *lmer* function in the *lme4* package (ver. 1.1–12; Bates, Maechler, Bolker, & Walker, 2015) for R Statistics (ver. 3.3.1; R Development Core Team, 2016).

Recall that the primary question being tested in Experiment 1 was whether the effectiveness of primes embedded in [–Prenuclear Accent] sentences depended on focus interpretation. The predictors that were of primary interest were therefore (a) the linguistic predictor, the size of the focus constituent (broad VP vs. narrow object focus), (b) the prime type (related prime versus unrelated control prime), and, particularly, (c) their interaction. Also included were a number of stimulus-level variables known to be relevant to the lexical decision task: the duration of the prime word, the length of the target word (in characters), the CELEX log frequency of the target word, and the RT to the preceding trial. Finally, AQ-Comm scores and listener sex – participant-level predictors – were also included in the initial models, as was their interaction with each other. Interaction terms were also tested between each of the primary predictors and each of the stimulus- and participant-level variables (i.e. a set of maximally three-way interactions). The initial model included all predictors just described as fixed-effect terms (with continuous predictors centered on their means, and contrast coding used for categorical predictors), as well as random intercepts for participant and item, and by-participant slopes for each of the primary- and stimulus-level predictors (Barr, Levy, Scheepers, & Tily, 2013). From this initial model, terms with a large *p*-value ($p > .1$) were then removed if it did not result in a significant decrease in model fit as assessed by a log-likelihood ratio test using the *ANOVA* function in *R*. After removing non-contributing predictors (whose non-significance is implied) in this way, the simper model was refitted.

Table 3. Results for fixed-effects factors for the model of reaction times in Experiment 1.

	B	SE	df	*t*-Value	*p*-Value
(Intercept)	12.360	7.053	118	1.75	<.1
Trial	−.289	.059	88	−4.93	<.001
Previous RT	.047	.009	2,795	5.41	<.001
Log frequency of target	−19.770	3.917	29	−5.05	<.001
Target length	3.809	1.827	29	2.09	<.05
Prime type (*Related*)	−9.991	3.044	2,666	−3.28	<.01
Focus (*Narrow*)	−7.794	3.047	2,674	−2.56	<.05

Note: Default level for the categorical factors is shown in italics.

The output of the final model is shown in Table 3.[9] As expected, some stimulus-based predictors had a significant effect on RTs. In particular, RTs to targets were slower when the RT in the preceding trial was slower, when the target contained more characters, when the target was of low lexical frequency, and when the trial occurred earlier in the experiment. However, there was also a simple effect of prime type, such that RTs were faster for targets following related primes than following unrelated control primes. That is, priming had occurred. There was also a significant simple effect for focus, such that RTs were significantly faster when the prime occurred in a narrow object focus context relative to VP focus contexts. Note that this does not indicate priming; rather, this indicates that participants were simply faster to make lexical decisions when the prime – regardless of its relatedness to the target – was narrowly focused (Figure 2).

Conspicuously absent from the model (because it did not contribute to model fit) was the presence of an interaction between focus and prime type, indicating the non-relevance of focus to predicting priming patterns.[10] The lack of this interaction is predicted by both Gussenhoven's and Selkirk's theory; it is inconsistent with Bishop's, which predicts an interaction such that robust priming is observed in the narrow focus condition only. Interestingly, however, there was a numerical trend in this direction (average priming of 11.3 ms for narrow focus sentences versus 7.8 ms for broad focus sentences), although this trend was just that. In summary, then, Experiment 1 found that, at the level of on-line lexical processing, sentences with a single pitch accent on an object and no prenuclear accent on the verb were equally acceptable in broad and narrow focus contexts, with perhaps some weak, non-significant tendency favouring such prosody in narrow focus contexts.

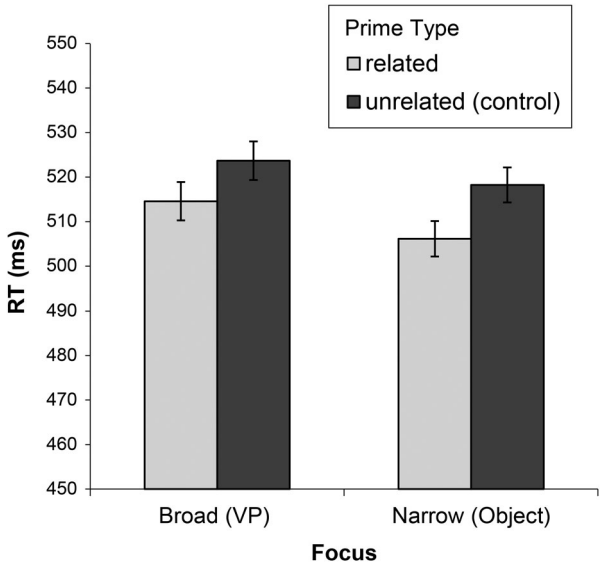

Figure 2. Mean reaction times for each of the information structural and prime-type conditions in Experiment 1 (all sentences had [–Prenuclear Accent] prosody. Error bars show standard error.

Experiment 2

Errors were identified as in Experiment 1; for the 84 subjects in Experiment 2, this resulted in 93 exclusions (approximately 3.5% of experimental trials), not considered further. A total of 2,529 remaining observations (those within 2 standard deviations of the mean) were analysed using the same methods as Experiment 1. Recall that the primary question being tested in Experiment 2, however, was whether the effectiveness of primes in broad VP focus sentences depended on the accent status of the verb. Focus was therefore held constant (as broad VP focus), and what varied was verb prosody ([+/–Prenuclear Accent]).

The resulting model for Experiment 2 is shown in Table 4. As in Experiment 1, RTs to targets were significantly slower when the RT in the preceding trial was slower, when the target was longer, of lower lexical frequency, and for trials that occurred earlier in the experiment. However, there was also a simple effect of prime type (RTs were faster following related primes relative to control primes) indicating that, overall, priming had occurred in the experiment. There was also a simple effect for verb prosody, indicating that, regardless of whether the prime was related to the target or not, RTs to targets were faster following primes in [–Prenuclear Accent] sentences than primes in [+ Prenuclear Accent] sentences. Again, note that this effect does not indicate priming, as it applied to primes both related and unrelated to the target. Finally, again, the primary interaction of interest, here between verb prosody and prime type, did not contribute to the model, and thus was not significant to predicting RTs.[11] Again, this is the pattern predicted by both Gussenhoven (1999) and Selkirk (1995), since broad focus should be appropriate with or without a prenuclear accent. However, there was again

Table 4. Results for fixed-effects factors for the model of reaction times in Experiment 2.

	B	SE (*β*)	*t*-Value	*p*-Value
(Intercept)	20.876	15.183	1.37	>.1
Trial	−.551	.143	−3.85	<.001
Previous RT	.078	.01	7.83	<.001
Log frequency of target	−31.666	7.87	−4.02	<.001
Target length	5.384	3.679	1.46	>.1
Prime type (*Related*)	−12.192	5.037	−2.42	<.05
Verb prosody (*[–PA]*)	−12.656	5.022	−2.52	<.05

Note: Default level for the categorical factors is shown in italics.

a numerical trend in the direction predicted by Bishop (2013), as [+ Prenuclear Accent] sentences resulted in an average of 19.7 ms of priming and [–Prenuclear Accent] sentences 10.9 ms of priming. In summary, then, Experiment 2 was intended to test whether broad VP focus sentences were equally felicitous with or without a prenuclear accent on the verb. The results suggest that they were, again supporting the predictions of both Gussenhoven (1999) and Selkirk (1995). Again, however, there was a numerical trend in the direction of broad VP focus sentences producing more priming when they contained a prenuclear-accented verb (Figure 3).

Experiment 3

Data from one participant were excluded due to very slow overall RTs (fewer than 20% of responses were below 1800 ms). For the remaining subjects, error rate was determined as above, and was similar (2.5%, resulting in 2,601 usable observations for the model). Modelling

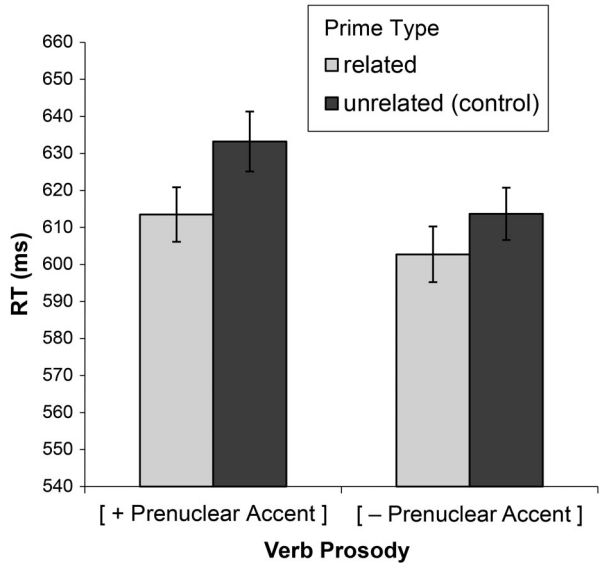

Figure 3. Mean reaction times for each of the verb prosody conditions in Experiment 2 (all sentences had broad VP focus). Error bars show standard error.

Table 5. Results for fixed-effects factors for the model of reaction times in Experiment 3.

	B	SE	df	*t*-Value	*p*-Value
(Intercept)	11.543	14.242	110	.81	>.1
Trial	−.328	.098	82	−3.34	<.01
Previous RT	.014	.006	2,523	2.22	<.05
Log frequency of target	−29.218	7.241	29	−4.04	<.001
Target length	4.128	3.383	29	1.22	>.1
AQ-Comm	−1.096	3.841	96	−.29	>.1
Prime type (*Related*)	3.539	6.014	2,432	.59	>.1
Verb prosody (*[–PA]*)	−1.106	6.020	2,440	−.18	>.1
Prime type (*Related*)*AQ-Comm	−3.832	1.722	2,473	−2.23	<.05
Verb prosody (*[–PA]*)*AQ-Comm	−2.591	1.71	2,474	−1.52	>.1
Prime type (*Related*)*Verb prosody (*[–PA]*)	−15.801	8.508	2,442	−1.86	<.1
Prime type (*Related*)*Verb prosody (*[–PA]*)*AQ-Comm	6.376	2.452	2,488	2.6	<.01

Note: Default level for the categorical factors is shown in italics.

was also done as above, with the linguistic predictor of interest again being the manipulation of prenuclear accentuation. However, the primary question in Experiment 3 was whether the effectiveness of primes in narrow focus sentences depended on the accent status of the verb. Focus was therefore held constant (this time as narrow object focus), and verb prosody again varied ([+/–Prenuclear Accent]).).

The resulting model is given in Table 5. The stimulus-based predictors all had the same effect on RTs as in Experiments 1 and 2 (significantly, with the exception of target length). Unlike in Experiments 1 and 2, however, there was not a significant simple effect for prime type, indicating that, overall, related primes were not more effective primes than control primes. Verb prosody was also not a significant predictor overall; unlike in Experiment 2, the lack of a simple effect for verb prosody indicated that RTs to targets were not, overall, faster following primes embedded in [–Prenuclear Accent] sentences. The lack of significant simple effects for these two predictors, however, is likely due to the fact that an interaction between them entered into the model. In particular, the two-way prime type × verb prosody interaction indicated that RTs were shorter following related primes when they occurred in [–Prenuclear Accent] sentences rather than [+ Prenuclear Accent] sentences. This pattern, indicating priming in primarily [–Prenuclear Accent] sentences, is the one predicted if prenuclear-accented verbs are dispreferred in narrow focus sentences, as assumed by Selkirk (1995) and Bishop (2013). However, this interaction, which can be seen in Figure 4, was only marginally significant.

The reason for the marginal significance in this case appears to be related to an additional interaction in the model, namely a significant three-way interaction

Table 6. Results for fixed-effects factors for the model of reaction times in Experiment 3, excluding listeners with AQ-Comm scores more than 1 sd above the mean.

	B	SE	df	*t*-Value	*p*-Value
(Intercept)	8.808	15.760	85	.56	>.1
Trial	−.418	.110	66	−3.82	<.001
Previous RT	.012	.007	2,010	1.84	<.1
Log frequency of target	−27.990	7.004	29	−4.00	<.001
Target length	3.029	3.277	29	.92	>.1
Prime type (*Related*)	6.978	6.742	1,937	1.04	>.1
Verb prosody (*[–PA]*)	4.365	6.750	1,940	.65	>.1
Prime Type (related)*Verb prosody (*[–PA]*)	−22.220	9.524	1,940	−2.33	<.05

Note: Default level for the categorical factors is shown in italics.

between prime type, verb prosody, and AQ-Comm scores, indicating that the two-way interaction just described applied less reliably to listeners with higher AQ-Comm scores. That is, for listeners with higher AQ-Comm scores (indicating poorer, more autistic-like communication skills), priming of targets by object primes was less sensitive to the presence or the absence of a prenuclear accent on the verb. This is consistent with the significant two-way interaction between prime type and AQ-Comm in the model, indicating that priming was overall (i.e. regardless of verb prosody) more reliable as AQ-Comm scores increased.

It thus appears that the consequence of the prosodic manipulation on priming was considerably dependent on AQ-Comm scores, with higher AQ-Comm listeners being less sensitive to it. To test this further, an additional mixed-effects regression model was tested on a subset of the data that excluded listeners whose AQ-Comm score was greater than one standard deviation from the mean score (which resulted in the exclusion of 18 participants). What is assumed is that a two-way interaction between prime type and verb prosody should now emerge as significant, since it was higher AQ-Comm listeners who seemed to be exempt from the effect. The output of this model is given in Table 6, and confirms this.

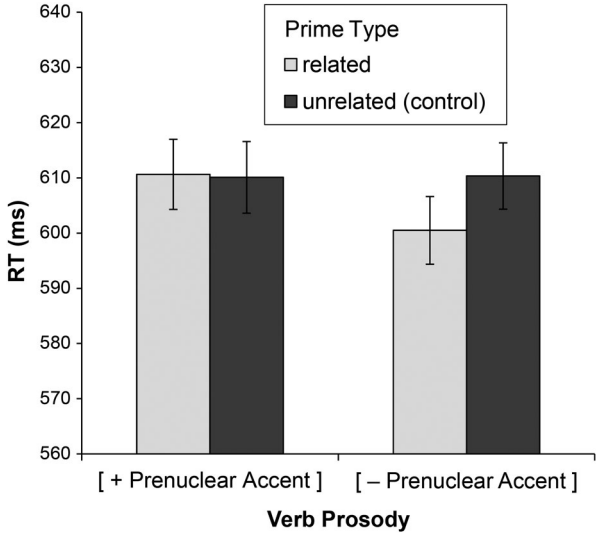

Figure 4. Mean reaction times for the prosodic conditions in Experiment 3 (all sentences had narrow object focus). Error bars show standard error.

To summarise, the goal of Experiment 3 was to use priming patterns to explore whether sentences with narrow object focus were equally easy to process with or without prenuclear-accented verbs. Unlike in Experiments 1 and 2, listeners, at least a systematic subset of them, did not seem to be ambivalent with respect to the presence of prenuclear accents, since priming did not occur for most listeners if the sentence contained a prenuclear accent.[12] This is most consistent with Selkirk's (1995) and Bishop's (2013) proposals, and least consistent with Gussenhoven's (1999) proposal. However, the fact that sensitivity to prenuclear accents in Experiment 3 was somewhat dependent on individual differences is also important to note, and is consistent with the idea that some listeners fail to attend to context, although additional sources of this finding are discussed below.

General discussion

The role of prenuclear accents in English focus marking

The primary goal of this study was to explore whether English-speaking listeners had expectations, detectable in online lexical processing, about the relation between the size of a focus constituent and the presence of a prenuclear accent in simple SVO constructions. The investigation was guided by explicit proposals predicting varying levels of ambiguity: the Focus Projection theories of Gussenhoven (1999) and Selkirk (1995), and the relative prominence marking proposal of Bishop (2013). The results of the cross-modal priming study presented above suggest that prenuclear accents were unexpected under narrow focus, and were apparently optional under broad focus only. Thus, while the presence of a prenuclear accent is not as important to marking broad focus (Experiments 1 and 2) as its absence is to marking narrow focus (Experiment 3), prenuclear accents do seem to play some role in listeners' expectations about the contrast.

This pattern of results lines up best with Selkirk's (1995) model. Instead of the random semantic distribution assumed by Gussenhoven (1999), Selkirk's theory assigns discourse meaning to prenuclear accents, namely a [+new] interpretation. Explicitly

marking a verb as [+ new] in this way is optional, due to the ability of a nuclear accented object to project focus to it, but it would infelicitously mark a verb as [+ new] in narrow object focus contexts. By assuming that prenuclear accents do not contribute to discourse semantic/information structural interpretation, Gussenhoven's theory predicts too much ambivalence. The disruption to processing listeners exhibited in Experiment 3, where sentences with narrow object foci contained prenuclear-accented verbs, is thus unexpected under this account.

Bishop's (2013) proposal, however, would seem to predict too little ambivalence, since Experiments 1 and 2 found only insignificant trends in the direction he would predict. The results of the first two experiments in this study are thus somewhat surprising given the phonetic studies on which his relative prominence model was based. Although in production speakers seem to prefer marking the left edge of a broad focus constituent with higher relative prominence (e.g. Breen et al., 2010), and although listeners seem to have measurable perceptual expectations for this (Bishop, 2012, 2016; Rump & Collier, 1996), this correspondence may represent only a preference or tendency, not a strong constraint on interpretation. In a recent paper, Gussenhoven (2015) argues this to be true in general, claiming that the results of perceptual studies like Bishop (2012) (and presumably appropriateness rating experiments like those in Birch & Clifton's, 1995 study) do not indicate that prenuclear accents have a grammatical relation to information structure, but rather that listeners have the expectation that in-focus material will be paralinguistically emphasised or hyperarticulated (i.e. produced as more prominent, but outside of the phonological system).

Gussenhoven's claims are interesting, and worth considering further in the context of the present experiments. While teasing apart the paralinguistic from the linguistic is perhaps the most difficult challenge in studying the prosody of human languages (Ladd, 1996), Gussenhoven's assertion about the linguistic status of prenuclear prominence in English may find some support in the details of the results above. First, the fact that evidence for a preference for prenuclear accents in broad focus sentences was apparent only as a non-significant trend (Experiments 1 and 2) is what might be expected if such tendencies reflect mere paralinguistic associations. Second, in Experiment 3, although priming patterns indicated that prenuclear accents were dispreferred in narrow object focus contexts, in line with Selkirk, this result was subject to cross-listener variation in autistic traits. This variation was anticipated in the design of the present study, as it was the justification for the inclusion of AQ-Comm to begin with. However, the reason was because it was predicted that listeners with higher levels of autistic traits may attend less to discourse context (necessary to assigning information structure to the test sentences). Another possibility, however, is that the three-way interaction in Experiment 3 was instead the result of high AQ-Comm listeners' being less sensitive to prenuclear accents in general, and thus less sensitive to any paralinguistic use they may have to interpreting the verb as part of the focus constituent. While this question is not well-addressed in a cross-modal priming experiment like the present one (in which the intended information structure was induced explicitly by a question context), it could be answered in an experiment in which listeners were presented with context-less sentences either with or without a prenuclear accent, and their interpretation of its information structure tested.

While this possibility is left open to future research (but see Hurley & Bishop, 2016 for some preliminary investigation), it should be noted that if Gussenhoven is correct and the expectations revealed in Experiment 3 reflect paralinguistic associations, not linguistic knowledge per se, these preferences clearly play a systematic and very early role in processing (much earlier than could be assumed from previous off-line investigations). Additionally, if prenuclear accents are completely optional in relation to the size of a focus constituent, what is still left a mystery is the clear asymmetry between the processing of prenuclear-accentless broad foci (Experiments 1 and 2) and the processing of prenuclear-accented narrow foci (Experiment 3). Given this asymmetry, the conclusion drawn here is that modelling the expectations of native English-speaking listeners requires assuming both (a) a Focus Projection mechanism, and (b) some interpretational function for prenuclear accents. However, further research is needed to better understand the nature of their interpretational effects, in particular whether they are best characterised as genuinely linguistic (as in Selkirk's, 1995 model) or perhaps more paralinguistic (as Gussenhoven, 2015 claims).

Conclusion

The role of prenuclear accents in marking information structure in English is quite understudied. The first to use an online measure of processing to explore their possible function, the present investigation tested listeners' expectations about the relation between the size of a focus constituent and the presence of prenuclear accents in SVO sentences. While phonetic production and perception studies (and some previous off-line

psycholinguistic studies) have suggested that prenuclear accents are useful for disambiguating broad from narrow foci, theoretical models differ in their predictions about this. Findings from three cross-modal priming experiments presented here suggest that prenuclear accents are optional under broad focus only, and are dispreferred in narrow focus contexts by most listeners. This was understood as justification for both a Focus Projection mechanism in the grammar, as well as an interpretational function for prenuclear accents in English. Notably, Selkirk's (1995) theory of Focus Projection has both of these elements, and so was better able to predict the pattern of results than either Gussenhoven's (1999) theory of Focus Projection, or Bishop's (2013) relative prominence marking theory. Taken together, the experiments presented here add to previous work indicating that the tools used to study online lexical processing can be fruitfully applied to the study of prosody's role in sentence processing, and to the evaluation of theories about the relation between prosody and information structure.

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Disclosure statement

No potential conflict of interest was reported by the authors.

Notes

1. Throughout this paper, unless otherwise noted, pitch accent annotations correspond to the categories used in the ToBI conventions (Beckman & Hirschberg, 1994).
2. It should be emphasized here that the target constructions in the present study – English SVO sentences – represent only one of a wide range of structures for which Focus Projection theories aim to model focus-to-prosody mappings. Despite the remarkable empirical coverage that each of these theories enjoys, however (see Büring, 2006 and Gussenhoven, 1999 for overviews), it is this simple construction that continues to pose some of the most interesting challenges. Most pertinent to the present interests in prenuclear accent placement, SVO constructions are also an area where the two prominent models of Focus Projection do not agree.
3. For a recent and similar characterization of the function of pitch accents, based on predictability, see Beaver and Velleman (2011), as well as relevant discussion in Pan, McKeown, and Hirschberg (2002), Watson, Arnold, and Tanenhaus (2008), Calhoun (2006), and Turnbull (2016).
4. In connecting Birch and Clifton's study to the present discussion, one note of caution is necessary. According to the authors, verbs in their test sentences were not prenuclear accented, since an intermediate phrase boundary separated the accented verbs and their accented objects, and so both were nuclear accented in their stimuli. However, to the extent that they tested Focus Projection from nuclear accented arguments to relatively prominent versus relatively less prominent verbs, their results are relevant here. It is also unclear how salient the intervening phrase boundaries were in their stimuli, and thus whether listeners did not actually perceive the accented verbs in their experiments as prenuclear.
5. See also Peters, Hanssen, and Gussenhoven (2014) for dialects of Dutch and German, though the effects they report are small for focus size, possibly due in part to their conflating of focus type (contrastive/non-contrastive) and focus size (broad/narrow) in the structures they investigate. Additionally, they exclude some prosodic structures from their analysis, namely those with downstepped nuclear accents, though the authors report this to be a small number of exclusions overall.
6. Throughout the rest of this paper, examples of auditory primes will be shown in italics, visual targets in small caps.
7. For a recent and intriguing investigation into the mechanisms underlying priming of contrastive associates, see Husband and Ferreira (2016).
8. See Yu (2010) and Turnbull (2015) for discussion of a number of findings not discussed here.
9. All *p*-values shown in this study were generated using lmerTest (ver. 2.0–32; Kuznetsova, Brockhoff, & Christensen, 2016), and also checked against the method described in Baayen (2008, Chapter 7), which did not produce different results.
10. Although the focus × prime-type interaction term was not found to contribute to model fit (and was therefore discarded), a model was also constructed that included this interaction, as an additional test for its significance. Even in this model (which otherwise contained the same factors as the best-fitting model), the focus × prime-type interaction was not significant ($B = -8.391$, SE = 6.087, $t = -1.38$, $p > .1$)
11. As for Experiment 1, a model was also tested that included the interactions of the two linguistically interesting variables (here, prosody × prime type), even though it did not contribute to the fit of the model. This interaction was not found to be significant ($B = -3.730$, SE = 10.080, $t = 0.37$, $p > .1$).
12. A reviewer asks whether one of the prosodic conditions might have suffered an unnaturalness penalty, since only one was created through editing (i.e. cross-splicing was not used). However, this is clearly ruled out, since a priming difference between the two prosodic conditions was found in only one context (namely in narrow focus contexts, Experiment 3), and in this case it was not primes embedded in the edited sentences that failed to prime, but rather those embedded in the *unedited* (i.e. [+ Prenuclear Accent] sentences.

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