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The Effect of Prosody on Conceptual Combination

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Abstract

Research into people's comprehension of *novel* noun-noun phrases has long neglected the possible influences of prosody during meaning construction. At the same time, work in conceptual combination has disagreed about whether different classes of interpretation emerge from single or multiple processes; for example, whether people use distinct mechanisms when they interpret *octopus apartment* as property-based (e.g., an apartment with eight rooms) or relation-based (e.g., an apartment where an octopus lives). In two studies, we manipulate the prosodic emphasis patterns of novel noun-noun combinations (placing stress on the modifier noun, the head noun, or dual stress on both nouns) and ask participants to generate an interpretation for the novel phrase. Results show that people are faster to generate property-based interpretations when dual emphasis stresses both nouns equally, with prosody having little effect on the speed of relation-based interpretations. These findings highlight a role for prosody during meaning construction and underline important differences between relation- and property-based interpretations that are difficult to reconcile with unitary process views of conceptual combination.

Keywords: Conceptual combination; Prosody; Emphasis; Language comprehension; Concepts; Compounds

1. Introduction

Language comprehension is a complex feat of cognition whose mechanisms have long fascinated cognitive scientists interested in how people retrieve familiar conceptual representations and construct new ones. Spoken language comprehension presents a particular challenge because it is also modulated by pragmatic factors such as social roles, speaker intentions, and paralinguistic cues.

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Prosody, as one such element, refers to changes in aspects of speech such as emphasis, pitch, intonation, rhythm, and timing, and is a central feature in linguistic communication. Even within individual words, the placement of emphasis can completely alter the intended meaning (e.g., OBject vs. obJECT). At a phrasal or sentential level, prosodic emphasis can facilitate activation of relevant semantic information (Cutler, Dahan, & van Donselaar, 1997; Isel, Gunter, & Friederici, 2003; Steinhauer, Alter, & Friederici, 1999), with emphasized words also being easier to process (Cutler & Foss, 1977; Lindfield, Wingfield, & Goodglass, 1999) and more highly activated (Bock & Mazzella, 1983) than unemphasized words. Given the capacity of prosodic emphasis to influence language comprehension, it is somewhat surprising that research to date has neglected its potential role in meaning construction for novel noun compounds (i.e., conceptual combination).[1]

1.1. Unitary or distinct processes in conceptual combination

Most research into conceptual combination has focused on two types of interpretation that result from understanding novel noun-noun compounds: property-based and relation-based interpretations (e.g., Costello & Keane, 2000; Estes, 2003; Gagné, 2000; Wisniewski, 1997). A property-based meaning is one where a property of one concept is transferred to the other (e.g., a *robin snake* as a snake with a red breast), while a relation-based meaning is one where a thematic relation is used to link the two concepts (e.g., *robin snake* as a snake that eats robins). Together, these categories account for approximately 90% of all interpretations produced (Costello & Keane, 2000; Wisniewski, 1996). While there is little disagreement over the existence of these interpretation types, a primary issue is whether they can be constructed using a single process (''unitary process'' theories: e.g., Costello & Keane, 2000; Gagné, 2000) or whether two separate processes are required (''distinct process'' accounts: e.g., Estes, 2003; Wisniewski, 1997). From the unitary process point of view, Gagné's competition among relations in nominals (CARIN) theory argues that both types of interpretation are actually relation-based by positing the existence of an infrequent *resembles/like* relation that is ''followed by an elaboration process in which the properties/features of the newly formed combination are derived'' (Gagné, 2000, p. 384; see also Gagné & Shoben, 1997). Although also positing a unitary process account, Costello and Keane's (2000, 2001) constraint theory takes quite a different view in holding that both types of interpretation emerge from the application of informativeness, diagnosticity, and plausibility constraints over the set of possible meanings for the phrase. In contrast, Wisniewski's (Wisniewski, 1997; Wisniewski & Love, 1998; see also Estes, 2003) dual-process theory describes two separate paths to finding a plausible interpretation for a compound; where comparison between constituents reveals one or more differences that can be mapped across concepts, the interpretation will be property-based, and where concepts fall into roles in a particular scenario, the interpretation will be relation-based.

Evidence for unitary or distinct processes in conceptual combination has been mixed. Several studies have shown that property-based interpretations are less frequent than relation-based interpretations (e.g., Costello & Keane, 2000; Estes, 2003; Gagné, 2000; Tagalakis & Keane, 2006). However, frequency data cannot separate unitary and distinct process accounts because the higher frequency of relation-based interpretations could emerge from either the rarity of the resembles/like relation (Gagné, 2000), the differential applicability of constraints (Costello & Keane, 2000), or the faster completion of the relational process (Wisniewski, 1997). Although other offline measures, such as drawing tasks by Wisniewski and Middleton (2002), are suggestive of distinct processes for different interpretation types it is difficult to map such findings directly to online processing. However, existing investigations of the timecourse of property- and relation-based interpretations have also led to conflicting results. Some studies have found that people may be faster to process relations than properties in conceptual combination but have construed this finding differently. Gagné (2000) asked people to judge the sensibility of compounds that were usually accorded a property- or relation-based interpretation and concluded that slower property-based responses were consistent with the idea that a relatively infrequent resembles/like relation is only employed if a more frequent relation has failed to produce a plausible interpretation. Estes (2003), on the other hand, used a similar paradigm and concluded that slower property-based responses were the result of the comparison-attribution process simply taking longer than the distinct role-finding process that produces relation-based interpretations. However, other studies have failed to replicate the ''relations faster than properties'' effect, both for sensibility judgement and interpretation generation (i.e., where people detail their understanding of a compound rather than decide if it is sensible: Tagalakis & Keane, 2006; Wisniewski & Love, 1998). Despite their differences, what all these studies have in common is that compounds were read as written text rather than heard as speech. In this paper, we present compounds auditorially in order to test if prosodic emphasis can disentangle the unitary and distinct process accounts of conceptual combination.

1.2. Current study

In the following experiments, participants listen to novel compounds over headphones and are asked to provide an interpretation. Importantly, this form of presentation allows all participants to receive the same set of novel compounds, with only the prosodic stress of each compound being manipulated as modifier emphasis (e.g., *OCTOPUS apartment*[2]), head emphasis (e.g., *octopus APARTMENT*), or dual emphasis (e.g., *OCTOPUS APARTMENT*). Since none of the aforementioned theories posit a role for prosody in the conceptual combination process, it is difficult to derive theory-specific predictions; notwithstanding, our interest lies in how long people take to arrive at property- or relation-based interpretations in each emphasis condition. If prosodic emphasis produces dissociable effects for different types of interpretation, then this offers strong evidence for distinct processes in conceptual combination.

2. Experiment 1

This experiment uses an interpretation generation paradigm, where participants are asked to press the spacebar when they have actually thought of an interpretation for a compound (and then to type in the meaning just generated). We use an interpretation generation task in preference to sensibility judgement as past research suggests that sensibility judgement reflects ''a rough feel for whether or not an interpretation is likely to be found'' (Tagalakis & Keane, 2006, p. 1293) rather than a full process of conceptual combination where a meaning must be constructed rather than simply retrieved from memory. Furthermore, we use a single-button response task in order to increase the number of successful interpretations by removing the expectation of rejection inherent in a yes/no forced-choice task.

Placing prosodic emphasis on a word increases its ease of processing and activation (Bock & Mazzella, 1983; Cutler & Foss, 1977; Norris, Cutler, McQueen, & Butterfield, 2006). For example, Norris and colleagues have shown that emphasized words in sentences give rise to increased priming effects relative to neutral or de-emphasized conditions. Similarly, Lindfield et al. (1999) demonstrated that, outside sentential context, words are identified more quickly when they are stressed compared to being unstressed, which indicates increased activation and availability of these words (Marslen-Wilson, 1990). Our manipulation of emphasis was therefore aimed to facilitate the conceptual activation of the modifier concept (modifier emphasis), the head concept (head emphasis), or both concepts (dual emphasis). If property- and relation-based interpretations emerge from a unitary process, then any effects of prosodic emphasis should apply equally to both interpretation types (i.e., response times will show no interaction between emphasis and interpretation type). Alternatively, if property- and relation-based interpretations emerge from distinct processes, of which prosody affects only one, then there will be an interaction of emphasis and interpretation type. In particular, if property-based interpretations require both constituent concepts to be compared in some detail so that mappable differences can be identified, then any factor that can facilitate this comparison process will speed up property-based interpretation times. Given that the detailed comparison of two concepts requires both concepts to be highly active, dual emphasis—where both words are prosodically stressed—should facilitate processing relative to just one concept being highly active. No such facilitation would be expected for relation-based interpretations, where the process of finding situationally appropriate roles for the constituent concepts may be more reliant on how these and similar concepts have been combined in the past (e.g., Gagné & Shoben, 1997; Wisniewski & Murphy, 2005; Maguire, Devereux, Costello, & Cater, 2007).

2.1. Method

2.1.1. Participants

Thirty native English speakers were recruited from the university's e-mail lists and paid a nominal fee for their participation. Data from one participant were excluded from analysis due to technical error during the experiment.

2.1.2. Materials

The nature of the experiment meant that we felt using human readers to record stimuli would be likely to lead to unplanned cues, with readers making subjective choices as to how words should be read based on what they understood the phrase to mean. Human readers also introduce problems of consistency, with readers possibly altering their pitch, durations, and levels of emphasis from one phrase to the next. To eliminate these potential confounds, we used a high-quality speech synthesis system (rVoice, 2005) that provided us with objective and consistent auditory stimuli in a female voice (UK-English voice F015). In order to create consistent emphasis patterns, the synthetic prosody was manipulated using a speech markup language, SSML (Speech Synthesis Markup Language, similar to HTML). We constructed three templates to represent the three possible emphasis patterns (modifier, dual, or head emphasis) and created emphasis by increasing the pitch and increasing the duration of that portion of the phrase (Hayes, 1995; Sproat, 1994). Fig. 1 illustrates the pitch contour for a sample test item, while Appendix A provides the specific SSML tags used. Example audio files have also been uploaded to the Cognitive Science repository.

One hundred noun concepts used previously in the conceptual combination literature (Costello & Keane, 2001; Gagné & Shoben, 1997; Wisniewski, 1996) were selected to represent a mix of artefacts, natural kinds, abstract concepts, object, and non-object concepts (see Medin, Lynch, & Solomon, 2000). To minimise confounding of responses by familiarity (Tagalakis & Keane, 2006; Wisniewski & Murphy, 2005), we randomly generated a set of candidate two-word combinations from these concepts (see Bock & Clifton, 2000; Markman & Wisniewski, 1997; Wisniewski, 1996; for similar use of random compound construction) and ensured that all items had a frequency count of zero in the British National Corpus (BNC, 2001) before synthesizing them into audio files. Three independent judges were asked to listen to the candidate set of synthesized compounds, transcribe what they heard, and rate the quality of the synthesized speech as good, okay, or bad. All 27 compounds used in this experiment met the criteria of having been correctly transcribed and judged as good quality. Importantly, there was no difference in the lengths of the audio files for the three emphasis conditions ($F < 1$). Finally, in order to ensure that the compounds

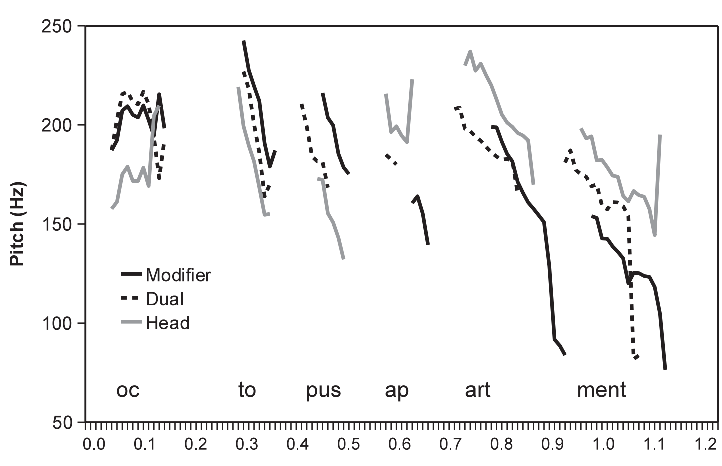

Fig. 1. Pitch contour (F0) for the compound ‘‘octopus apartment’’ with modifier, dual, and head emphasis conditions.

themselves were easily interpretable, an off-line pretest presented them in written form to 20 participants (who did not participate in any related studies): Interpretations were provided in 95.9% of cases (with a minimum of 80% for any single item). This ensures that while the compounds are novel, thus preventing straight meaning retrieval from memory, they are also highly interpretable.

The final material set thus consisted of 81 stimuli: 27 compounds by three possible emphasis patterns (modifier, dual, head; see Appendix B). Each participant received all 27 compounds but only ever heard one emphasis version of each test item (e.g., if a participant heard the compound *antelope coconut* with modifier emphasis, he or she would not hear it with dual or head emphasis). The presentation of emphasis types was counterbalanced so each participant and item received modifier, dual, and head emphasis in equal numbers. We also created a set of synthesised filler items which passed the same clarity and quality criteria as the test items. Filler items were lexicalized compounds (e.g., *hospital wing*, *guerrilla warfare*) with frequencies greater than 20 in the BNC (2001) and were presented with a mix of emphasis types.

2.1.3. Procedure

Stimuli were presented through standard closed-ear stereo headphones using a 16-bit sound card. Participants were told that they would be presented with two-word phrases through their headphones; some of these phrases would be familiar to them, while others would not. Each trial began with the word ''Ready'' onscreen for 2000 ms, followed by the auditory presentation of an item. Participants were instructed to press the spacebar when they had thought of a meaning. If there was no response within 30 s, the program moved to the next trial. If participants pressed the spacebar, a screen appeared where they then typed in the interpretation they had just generated. Trials were separated by an ISI of 1,000 ms. Prior to the main experiment, participants completed a number of practice trials containing both lexical and novel compounds. The experiment lasted approximately 20 min.

2.1.4. Coding

Participant interpretations were considered successful if they described the compound as more than just the head noun (e.g., *elephant complaint* must be interpreted as more than just ''a type of complaint''). Overall, 83.2% of test trials resulted in successful interpretations, equal across emphasis types: modifier = 85.2%, dual = 82.3%, head = 82.0%—χ^2 (2, n = 783) = 1.11, p = .573. Each successful interpretation was then classified by the first author and two independent coders (all blind to emphasis condition) as one of four interpretation categories: property-based, relation-based, hybrid (where the interpretation is an equivalent mixture of the two concepts, e.g., a *robin snake* is part snake and part robin), or other. Agreement between multiple coders for nominal categories was calculated as Fleiss's Kappa (n = 632) = 0.829, with disagreements resolved by discussion. The majority of interpretations were relation-based (56.0%) or property-based (33.1%) and the small proportion of hybrid (0.8%) and other (10.1%) interpretations meant they were not subject to further analyses. There was no difference between emphasis conditions in the distribution of interpretation types, χ^2(6, n = 632) = 5.83, p = .442.[3]

2.1.5. Design and analysis

Two factors were manipulated both within-participants and within-items: Emphasis (modifier, dual, head) and interpretation type (property-based, relation-based), with response times for target items as the dependent variable. Outliers more than 2.5 standard deviations from the condition mean were removed (3.19% of data): The mean response time of 3.600 s was comparable with other interpretation tasks in the literature (e.g., Gerrig & Bortfeld, 1999; Tagalakis & Keane, 2006). Response times on remaining trials were analyzed using linear mixed models with crossed random effects of participants and items, which offers a more complete description of systematic sources of variance in the model than separate $F_1 \times F_2$ analysis, particularly for unbalanced data (e.g., when incorrect and outlier responses are excluded from analysis: Baayen, Davidson, & Bates, 2008; Locker, Hoffman, & Bovaird, 2007). The validity of including random effects for participants and items was tested empirically by comparing restricted log likelihood values: From the baseline of an empty model, adding participants as a random factor significantly improved model fit, $\chi^2(1) = 93.68$, $p < .0001$, which was in turn improved by crossing the random effect of items, $\chi^2(1) = 27.05$, $p < .0001$. The final analysis thus included crossed random effects of participants and items and crossed fixed factors of emphasis and interpretation type.

2.2. Results

Fig. 2 shows mean response times per condition. Analysis of response times showed a significant interaction between interpretation type and emphasis type, $F(2, 505.36) = 4.11$, $p = .017$. There was no main effects of emphasis (modifier $M = 3.788$, $SE = 0.366$; dual $M = 3.552$, $SE = 0.378$; head $M = 3.888$, $SE = 0.370$; $F < 1$). Furthermore, there was no main effect of interpretation type, with relation-based interpretations ($M = 3.664$, $SE = 0.347$) not being reliably faster than property-based interpretations ($M = 3.821$, $SE = 0.372$; $F < 1$). Simple effects analysis of the interaction showed that prosodic emphasis

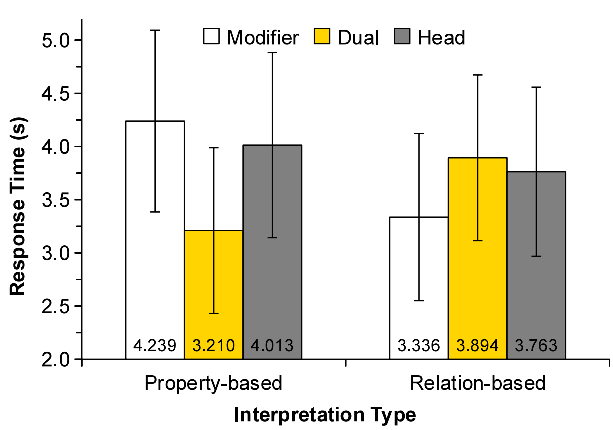

Fig. 2. Response times (estimated marginal means), with their corresponding 95% confidence intervals, for property- and relation-based interpretations produced under each emphasis type in Experiment 1.

had no reliable effect on the speed of constructing relation-based interpretations, $F(2, 495.06) = 1.65$, $p = .194$, but did affect the speed of processing property-based interpretations, $F(2, 502.91) = 2.77$, $p = .063$. Property-based interpretations for dual emphasis were significantly faster than for modifier ($p = .011$) and head emphasis ($p = .041$) in planned comparisons, while head and modifier conditions did not differ ($p = .291$). When emphasis types were separately examined, property-based interpretations were constructed more quickly than relation-based interpretations in the dual emphasis condition ($p = .060$), while in the reverse was true in modifier emphasis ($p = .010$). There was no difference between interpretation types in the head emphasis condition ($p = .265$).

2.3. Discussion

Prosodic emphasis influenced the speed of constructing property-based interpretations, but not relation-based ones. This dissociable effect of prosody supports accounts of conceptual combination that posit distinct processes for property- and relation-based interpretations. Specifically, property-based interpretations were fastest in the dual emphasis condition, suggesting that highly activating both concepts can facilitate the comparison process better than boosting the activation of just one concept. For example, interpreting *octopus apartment* as an apartment with eight rooms involves comparing the concepts until the property of an octopus having eight appendages is identified as plausibly mappable to the spatial layout of the apartment. People generated this property-based interpretation in all three emphasis conditions but were facilitated when both concepts received equal emphasis and activation (e.g., *OCTOPUS APARTMENT*) compared to when just one concept was emphasized (e.g., *OCTOPUS apartment* or *octopus APARTMENT)*. In contrast, when the same compounds gave rise to relation-based interpretations (e.g., an *octopus apartment* is an apartment where as octopus lives), prosody had no effect on processing speed. Here, the process of finding plausible situational roles for both constituent concepts is relatively insensitive to differences in conceptual activation: An octopus is a living thing and an apartment is where somebody lives, and so a *lives-in* or *located-in* relation can link the two concepts without needing the representational detail of the number of arms or rooms involved.

It is worth noting that every compound that produced a property-based interpretation also had a plausible relation-based interpretation available, indicating that property-based interpretations do not represent a last-ditch strategy to interpret the uninterpretable. Overall, 93% of items gave rise to both interpretation types with the proportion of property interpretations produced ranging from 0% to 85% per item, and relation-based interpretations from 10% to 90%. Furthermore, since both interpretation types emerged from the same set of compounds, the observed differences in processing times cannot result from differences in compound familiarity (Tagalakis & Keane, 2006), similarity of the constituent concepts (Wisniewski & Love, 1998), salience of modifier properties (Bock & Clifton, 2000; Estes & Glucksberg, 2000), variations in modifier relation frequencies (Gagné & Shoben, 1997), or any other psycholinguistic factors such as token frequency or length. We return to the impact of these findings on theoretical accounts of conceptual combination in the general discussion.

3. Experiment 2

The previous experiment showed that prosodic emphasis affected only property-based interpretations, with faster interpretation times in the dual emphasis condition than in head and modifier emphasis. We interpret this effect as facilitation; the comparison process that is specific to property-based interpretation is facilitated by having both concepts highly available (in dual emphasis) compared to having one concept more available than the other (in head or modifier emphasis). However, it could be argued that dual emphasis does not necessarily act to facilitate processing of property-based interpretations, and, instead, that interference or inhibition in the head and modifier conditions is responsible for the critical effect.

The present experiment therefore extends Experiment 1 by including a no-emphasis baseline condition, where neither modifier nor head noun receives prosodic stress. Given that the detailed comparison of two concepts requires both concepts to be highly active, we expected dual emphasis (where both words are prosodically stressed, e.g., *OCTOPUS APARTMENT*) to facilitate processing relative to no-emphasis (where both words are unstressed, e.g., *octopus apartment*).

3.1. Method

Identical to Experiment 1 with the following exceptions.

3.1.1. Participants

Sixty-three native speakers of English, who had not taken part in previous experiments, participated for course credit.

3.1.2. Materials

For each compound in Experiment 1, a no-emphasis version was created by splicing the unstressed modifier noun from the head emphasis condition with the unstressed head noun from the modifier emphasis condition, and aligning the waveforms to render the splice inaudible. This method of creating two equally unstressed nouns was necessary in order to prevent the untagged prosodic contour of a compound phrase stressing the first word by default. One additional compound (cloth organ), which was not featured in Experiment 1 but had passed the same pretest criteria, was included in order to allow counterbalanced presentation of all four emphasis types in equal numbers per participant and item. The final materials set thus consisted of 112 stimuli: 28 compounds by four emphasis types (no emphasis, modifier emphasis, dual emphasis, and head emphasis). As before, each participant received all 28 compounds but only ever heard one emphasis version of each test item. The same filler items were included as per Experiment 1.

3.1.3. Procedure

Participants were instructed to press the spacebar when they had thought of a meaning; if there was no response within 10 s, the program asked the participant to try to respond more quickly.

3.1.4. Coding

The overall rate of successful interpretations was high at 94.5%, again equal across emphasis types: no emphasis = 93.0%, modifier = 95.9%, dual = 95.2%, head = 93.9%—$\chi^2(3, n = 1{,}667) = 0.25$, $p = .970$. Interpretations were coded independently by the two authors as per Experiment 1, blind to emphasis condition. Agreement between raters was calculated as Cohen's Kappa ($n = 1{,}667$) = 0.863, with disagreements resolved by discussion. Once again, most interpretations were relation-based (50.0%) and property-based (43.5%), while the small proportion of hybrid (0.7%) and other (5.8%) interpretations were not subject to further analyses. There was no difference between emphasis conditions in the distribution of interpretation types, $\chi^2(6, n = 1{,}655) = 7.46$, $p = .280$.[4]

3.1.5. Design and analysis

Outliers more than 2.5 standard deviations from the condition mean were removed (2.18% of data). From the baseline of an empty model, adding participants as a random factor significantly improved model fit, $\chi^2(1) = 501.94$, $p < .0001$, which was in turn improved by crossing the random effect of items, $\chi^2(1) = 63.85$, $p < .0001$. The final analysis thus included crossed random effects of participants and items plus crossed fixed factors of emphasis and interpretation type.

3.2. Results

Mean response times are shown in Fig. 3. Replicating Experiment 1, we again observe a critical interaction between emphasis and interpretation type, $F(3, 1428.85) = 2.92$, $p = .033$, with no main effects of either emphasis—no emphasis $M = 2.897$, $SE = 0.115$; modifier $M = 2.852$, $SE = 0.115$; dual $M = 2.758$, $SE = 0.115$; head $M = 2.886$, $SE = 0.115$; $F(3, 1430.36) = 1.74$, $p = .156$—or interpretation type (property-based $M = 2.854$, $SE = 0.112$; relation-based $M = 2.842$, $SE = 0.111$; $F < 1$). Analysis of the

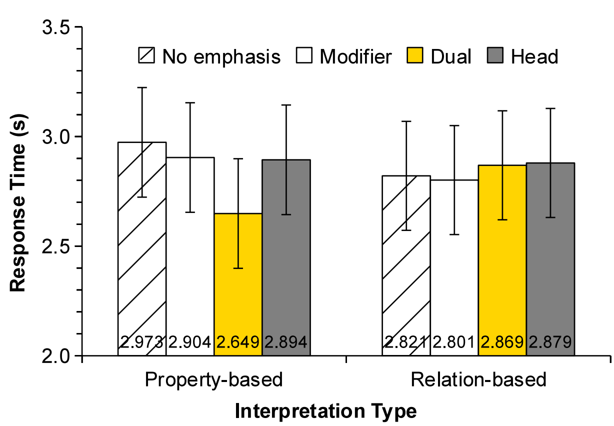

Fig. 3. Response times (estimated marginal means), with their corresponding 95% confidence intervals, for property- and relation-based interpretations produced under each emphasis type in Experiment 2.

interaction showed a significant emphasis effect for property-based interpretations, $F(3, 1434.70) = 3.97$, $p = .008$, but not for relation-based interpretations ($F < 1$). In planned comparisons, property-based interpretations for dual emphasis were again faster than those for modifier ($p = .011$) and head emphasis ($p = .041$), and, importantly, were also faster than those for no emphasis ($p = .001$). Relation-based interpretation times did not differ between head, modifier, and no-emphasis (all ps > .2). Lastly, when each emphasis type was examined separately, property-based interpretations were faster than relation-based interpretations in the dual emphasis condition ($p = .016$), while this effect was marginally reversed for no emphasis ($p = .069$), and nonsignificant for head ($p = .443$) and modifier emphasis ($p = .156$). As before, all items that gave rise to a property-based interpretation also had a relation-based interpretation available, with 96% of items giving rise to both interpretation types.

3.3. Discussion

As hoped, the results of this experiment replicated the critical interaction between emphasis and interpretation type and provided additional evidence of facilitation effects in the dual emphasis condition. Prosodic emphasis made no difference to relation-based interpretation times, but facilitated property-based interpretations in the dual emphasis condition. These results underscore the differences between property- and relation-based interpretations and, as with Experiment 1, support distinct-process views of conceptual combination over unitary-process accounts.

4. General discussion

In this paper, we investigated the influence of prosody on the comprehension of novel noun-noun compounds. The key finding from two studies is that prosodic emphasis differentially affects the speed of interpretation of novel compounds, with emphasis shown to affect property-based but not relation-based interpretations. This dissociable effect should not arise if both interpretation types emerged from a unitary process, and instead suggests distinct processes for property- and relation-based conceptual combination. So, given that none of them currently posits a role for prosody, what do these findings mean for existing theories of conceptual combination?

Our findings are consistent with the idea that property-based interpretations require a relatively detailed comparison process that benefits from both constituent concepts being highly activated by equal prosodic stress. This general process description is compatible with both Wisniewski's (1996, 1997) dual-process theory and Estes and Glucksberg's (2000) interactive property attribution model. For example, a *celebrity spear* may be interpreted as a famous spear from legend. According to dual-process theory, people arrive at this interpretation by comparing the conceptual structure of *celebrity* and *spear* so an important difference is revealed (celebrities are famous while spears are not) which allows a new compound meaning to be constructed: Here, having two highly active concepts could facilitate this comparison process. According to the interactive property attribution model, people identify a salient property of *celebrity* (being famous) that is relevant to some dimension of *spear* (its familiarity) and so the property is mapped across and elaborated; here, having two highly active concepts could facilitate the interaction of modifier properties and head dimensions. Of course, there are important differences between these theories, not least that the interactive property attribution model concentrates on property-based interpretations while dual-process theory describes a separate scenario creation process for relation-based interpretations. Our finding that relation-based interpretations were not influenced by prosody is also consistent with the dual-process view of concepts playing roles in newly created scenarios. For example, some participants interpreted *celebrity spear* as a spear for attacking celebrities: Here, *spear* occupies its role as a weapon while *celebrity* takes the role of a victim in a crime scenario (or prey in a hunting scenario). The process of generating these appropriate situational roles does not require extensive representational detail of the individual concepts, and so is relatively insensitive to the different levels of concept activation brought about by prosodic emphasis.

Dual-process theory holds the additional assumption that the property- and relation-based processes operate in parallel, with the ''winner''—or first process to arrive at a plausible interpretation—determining the type of interpretation produced (Wisniewski, 1997). This parallel race might lead one to expect that the fastest interpretation type should also be the most frequent interpretation type, given its processing was completed first. However, with no differences between emphasis conditions in the proportions of interpretation types produced, despite response time differences, our data suggest otherwise. An alternative account of distinct processes in conceptual combination is that these processes do not operate concurrently and in competition within an individual's mind; rather, depending on an individual's experience of the constituent concepts he or she will engage in constructing either a property- or relation-based interpretation. In the current studies, every participant produced both property- (from 5% to 64% of responses) and relation-based interpretations (20–80%), demonstrating that any participant is capable of producing both types of interpretation from one compound to the next.

Although the above findings demonstrate support for a class of theories that postulate distinct processes for different interpretation types, one should always be cautious in postulating the complexity of two processes over the parsimony of one. Is it possible for extensions of unitary theories to accommodate the current findings? A reinterpretation of Costello and Keane's (2000) constraint theory may be able to do so. Recall that three pragmatic constraints (diagnosticity, informativeness, plausibility) guide both property- and relation-based interpretations of novel compounds. Certainly, the interpretations given by participants in our experiments appear to satisfy the necessary constraints. For example, if a *celebrity spear* refers to a famous spear from legend, then this satisfies the diagnosticity constraint by using a highly diagnostic feature of celebrities (being famous), the informativeness constraint by offering new information (spears are not normally famous), and the plausibility constraint by applying it in a way that fits with prior knowledge (objects, as well as people, can be famous: see also Connell & Keane, 2004, 2006). In other words, property- and relation-based interpretations could arise from distinct processes that are both guided by Costello and Keane's constraints. One possibility would be for prosody to be treated as another pragmatic factor that influences the availability of knowledge necessary for the application of these constraints. Currently, however, constraint theory (and its accompanying C3 model) ''makes no attempt to parallel people's actual response-time performance'' (p. 327). Instead, C3 focusses on the types of interpretations people produce. If constraint theory were extended to specify the time-course of interpretation, it is unclear whether prosody could be treated as a constraint of equal influence in such a reorienting of the theory or whether it could only be incorporated by having a two-stage approach to processing (e.g., where prosody exerts some influence initially, and then the three original constraints behave as in the original model).

On the other hand, the current findings are not easily accommodated by the CARIN theory (Gagné, 2000; Gagné & Shoben, 1997). In this theory, property-based interpretations emerge from the use of an infrequent resembles/like relation that is employed when other more frequent relations fail to produce a plausible interpretation. Although we found that relation-based interpretations were overall more common than property-based interpretations, the lack of a consistent speed advantage for relation-based interpretations makes this account unlikely. Regarding the resembles/like relation, Gagné (2000, p. 384) states that ''because this relation is used so infrequently, it should longer [sic] to interpret combinations using this relation than to interpret combinations using other relations.'' This timecourse prediction was not borne out: Property-based interpretations were actually *faster* than relation-based interpretations in the dual emphasis condition, and of equal speed in head emphasis. Alternatively, since CARIN claims that properties are derived during an elaboration process after the selection of a relation, one could argue that this process involves comparison and thus could be influenced by prosody. For example, in *celebrity spear*, prosody would not influence the selection of the relation that a spear resembles a celebrity, but would influence the subsequent derivation of the property of being famous. Again, however, this account would predict that property-based interpretations should always be slower than relation-based interpretations because ''it takes longer to derive a property than to state the relation on which that property is based'' (Gagné, 2000, p. 384); as previously noted, this prediction not borne out by the results. In short, while modifier relation frequency may indeed be a useful cue in identifying suitable situational roles in relation-based interpretation, it is difficult to reconcile the present findings with the CARIN theory's account of property-based conceptual combination.

From the perspective of prosody research, the current findings highlight the importance of semantics and meaning construction in relation to stress assignment. This issue has historically plagued the development of speech synthesis systems, where compound stress assignment has been shown to be notoriously difficult to predict (Sproat, 1994). For example, Plag, Kunter, Lappe, and Braun (2008) demonstrated that rule-based stress assignment cannot accurately predict the stress pattern of lexicalized compounds, and that assignment based on the semantic relationship between compound constituents was more successful.

However, semantic relationships were restricted in this study to a small set of relations (e.g., causes, makes, has), similar to those used by Gagné and colleagues, which cannot deal with the relatively high frequency of property-based meanings (e.g., 33–44% in our studies). Thus, it seems likely that the incorporation of property-based meanings in the semantic approach to stress assignment could further improve success rates.

Furthermore, although prosodic influences are ubiquitous in the act of speech comprehension, they may also extend into text comprehension. Fodor (2002) suggested that people impose a silent prosodic contour during reading, and that this contour could affect online processing. In support, Ashby and Clifton (2005) found that, when people read words that contain two stressed syllables (e.g., *radiation*), their gaze durations were longer than when they read single stress words of equal length and syllable number (e.g., *intensity*). Such work suggests that people may impose a similar prosodic contour when they read noun-noun compounds, and that future work on conceptual combination needs to take prosody into account when positing process models of the online comprehension of property- and relation-based interpretations.

While there is much evidence that changes in emphasis affect how meaning is retrieved for familiar words and phrases (e.g., Cutler et al., 1997; Isel et al., 2003), these findings are the first to highlight that emphasis changes also affect the timecourse of how meanings are *constructed* for novel noun combinations. Additionally, our results provide support for distinct-process accounts of conceptual combination over unitary-process accounts. Nevertheless, we see this work only as a starting point; future research will not only have to consider the precise nature of the processes necessary for conceptual combination but will also require greater focus on the timecourse of conceptual activation due to prosodic emphasis, on the potential impact of a silent prosodic contour during text reading, and on the modulating effects of sentential embedding on both conceptual activation and prosody. Thus, studies of prosody and meaning construction must not be carried out in isolation, as an integrative view is crucial for a full understanding of spoken and written conceptual combination and language comprehension more generally.

Notes

1. Although some work has examined the effect of prosodic emphasis in processing *lexicalized* noun compounds (e.g., Isel et al., 2003; Koester, Gunter, Wagner, & Friederici, 2004), such compounds are understood via straight retrieval rather than undergoing a process of conceptual combination (Tagalakis & Keane, 2006).
2. Throughout this paper, we use the convention of using block capitals to indicate the emphasised (stressed) word in a compound.
3. Although observed values for some cells were less than 5, all conditions were included as none of the expected values were less than 5.
4. Hybrid interpretations appeared very infrequently (2–4 occurrences per emphasis type) and had to be omitted from the chi-squared analysis in order to keep expected cell counts above 5.

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Appendix A

SSML Templates used to control emphasis placement. The values were arrived at in order to ensure that each emphasis pattern sounded as natural as possible. Audio files were generated from the templates at high-quality, 32 kHz sampling frequency at 16-bit resolution, with the volume normalized for all files.

Modifier Emphasis:

<prosody rate=‘‘85%’’><prosody pitch = ‘‘125%’’> *modifier* </prosody>
</prosody> *head*

Dual Emphasis:

<prosody rate=‘‘85%’’><prosody pitch = ‘‘125%’’> *modifier-head* </prosody>
</prosody>

Head Emphasis:
modifier <prosody rate=‘‘85%’’><prosody pitch = ‘‘125%’’> *head* </prosody> </prosody>

Appendix B

Test items used in Experiments 1 and 2

Airplane chemical	Piano cow
Antelope coconut	Pig restaurant
Army decision	Rhinoceros cactus
Bed helicopter	Scarf coconut
Cabbage cup	Seal viper
Celebrity spear	Skunk tent
Chocolate clay	Slug tree
Cloth organ*	Snail shark
Drill tile	Spider moth
Elephant complaint	Steam saxophone
Lobster college	Tent shirt
Monkey chisel	Termite frog
Octopus apartment	Whale knife
Onion bus	Whiskey giraffe

*Item only used in Experiment 2.

Supporting information

Additional Supporting Information may be found in the online version of this article on Wiley InterScience:

Audio S1. Octopus Apartment—Dual emphasis.
Audio S2. Octopus Apartment—Head emphasis.
Audio S3. Octopus Apartment—Modifier emphasis.
Audio S4. Octopus Apartment—Neutral.

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