

BRIEF REPORT

Talk This Way: The Effect of Prosodically Conveyed Semantic Information on Memory for Novel Words

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Speakers modulate their prosody to express not only emotional information but also semantic information (e.g., raising pitch for upward motion). Moreover, this information can help listeners infer meaning. Work investigating the communicative role of prosodically conveyed meaning has focused on reference resolution, and potential mnemonic benefits remain unexplored. We investigated the effect of prosody on memory for the meaning of novel words, even when it conveys superfluous information. Participants heard novel words, produced with congruent or incongruent prosody, and viewed image pairs representing the intended meaning and its antonym (e.g., a small and a large dog). Importantly, an arrow indicated the image representing the intended meaning, resolving the ambiguity. Participants then completed 2 memory tests, either immediately after learning or after a 24-hr delay, on which they chose an image (out of a new image pair) and a definition that best represented the word. On the image test, memory was similar on the immediate test, but incongruent prosody led to greater loss over time. On the definition test, memory was better for congruent prosody at both times. Results suggest that listeners extract semantic information from prosody even when it is redundant and that prosody can enhance memory, beyond its role in comprehension.

Keywords: prosody, spoken language processing, word learning, memory

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The arbitrary relation between form and meaning is considered an essential characteristic of linguistic signs (cf. De Saussure, 1959; Hockett, 1960). For most words, the relation between phonological form and meaning is simply a matter of convention (though see Perniss, Thompson, & Vigliocco, 2010, on iconicity in non-Indo-European languages). The same meaning can be represented by different sound patterns, for example “small” in English and “petit” in French. Because meaning cannot be predicted from form, in learning new words, listeners need to rely on extralinguistic cues to uncover form-meaning mappings.

One source of information readily available in spoken language is prosody. Prosody has traditionally been viewed mainly as a vehicle for conveying information about the speaker’s affective state and attitude, or about the syntactic and discourse structure of the message. For example, pitch accents (e.g., the *BLUE* square) evoke a contrast set containing alternative referents (e.g., a blue and a green square, but not a blue circle). Pitch accents have been

shown to affect online comprehension (e.g., Ito & Speer, 2008) as well as memory representation (Fraundorf, Watson, & Benjamin, 2010). Here, prosody’s role in conveying referential information about object shape is mediated via its role in conveying discourse structure. Until recently, the role of prosody in directly conveying semantic-referential information about properties of objects and events was left unacknowledged and not explored empirically. However, recent research has shown that speakers can capitalize on existing audiovisual cross-modal correspondences (e.g., pitch height and verticality, Melara & O’Brien, 1987; pitch and size and brightness, Marks, 1987) and convey semantic-referential information by modulating acoustic properties of their speech. For example, speakers spontaneously raised their pitch to describe upward motion, and spoke faster to describe fast-moving objects, even when the propositional content did not refer to motion. Moreover, this information is communicatively functional and recognized by listeners (Shintel, Nusbaum, & Okrent, 2006). Nygaard, Herold, and Namy (2009) found that speakers consistently modulate prosody to differentiate the meanings of antonym pairs (e.g., speaking with a lower pitch, slower rate, and higher amplitude to refer to big objects and higher pitch, faster rate, and lower amplitude to refer to small objects) and that listeners used this information to infer the intended meaning. Such “spoken gesture” can set up an iconic nonarbitrary mapping between form and meaning and facilitate comprehension.

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Thus, listeners can rely on prosodic information and infer meaning. Previous research (Nygaard et al., 2009; Shintel et al., 2006) has focused mostly on immediate benefits of prosody for comprehension, and little is known about the memory consequences of this “spoken gesture.” However, as with other kinds of prosody, the advantage conferred by prosody may go beyond a transient effect on reference resolution and affect the memory representation of the referent. Research on intersensory redundant information (see Bahrick & Lickliter, 2012) suggests that coordinated presentation of the same information across different senses promotes memory. Similarly, integration of meaning conveyed in prosody with meaning conveyed in speech may lead to a more enduring representation in memory. Consequently, this integration may benefit listeners even when they can infer the intended meaning without prosody. Indeed, research on manual gestures has shown that representational gestures facilitate memory for sentences in one’s native language (Feyereisen, 2006) and for words in a new language, even when these were learned along with their translation (e.g., “*Nomu* means drinking”), and thus gesture was not required for disambiguation (Kelly, McDevitt, & Esch, 2009). Kelly and colleagues suggest that representational gestures may facilitate word learning because they exhibit meaning imagistically and nonarbitrarily, and thus can deepen the imagistic trace for the word’s meaning. “Spoken gesture” may similarly enable a grounded, nonarbitrary, representation.

Furthermore, although listeners can use “spoken gesture” to infer meaning, it remains unresolved whether listeners attend to prosodic cues to meaning even when other sources of information are available. Previous research has primarily focused on situations in which listeners were forced to choose between alternatives and, in the absence of other cues, had to attend to prosody and use it for reference resolution (though see Shintel & Nusbaum, 2007, for the case of speech rate). However, in everyday language use, there is an abundance of contextual information that listeners can exploit for (successful or unsuccessful) disambiguation of meaning. Therefore, it is seldom the case that listeners must resort to using prosodic cues for disambiguation. Evidence that listeners attend to prosody, and extract semantic information from it, even when this level of analysis is unnecessary for disambiguation, would suggest a role for semantic-referential prosody as a cue to meaning. Relating these two issues, if listeners indeed attend to prosodic cues to meaning even when these are redundant (in the sense that they convey information available through other contextual sources), and if redundant information conveyed in “spoken gestures” results in a more enduring memory representation, we should see a facilitative effect on memory that goes beyond the effect of prosody on initial comprehension.

In the present study, we aimed to disentangle the mnemonic consequences of prosodically conveyed semantic information from its role in reference resolution. To examine these issues, participants completed a novel word-learning task in which we presented listeners with novel pseudowords, expressing the meanings of different antonym pairs, (e.g., *big–small*; *high–low*), spoken in congruent or incongruent prosody. Each word was presented with different sets of image pairs, representing the relevant contrast (e.g., a big and a small dog). Importantly, an arrow indicated the intended image. Thus, listeners could draw on the visual contrast to infer the contrastive semantic dimension and use the arrow to infer the mapping between word and meaning. To examine

whether prosody affected the memory representation of novel words, we tested memory for word meaning at two different time frames: either following learning or after a 24-hr delay.

Method

Participants

One hundred thirty-five Michigan State University students participated in the study for course credit. All were right-handed, native English speakers, with no history of memory disorders. Seven participants were excluded from all analyses because they did not complete the experiment ($n = 6$) or because of experimenter error ($n = 1$). The remaining 128 participants (98 women) had a mean age of 19.1 years ($SD = 1.2$).

Materials

Twenty antonym pairs (see the Appendix) whose meaning was previously found to correlate with specific acoustic features (in music, Eitan & Timmers, 2010; or in speech, Nygaard et al., 2009) were selected as stimuli. Twenty pseudowords (e.g., *wug*) were used as the novel words, each randomly assigned to one antonym pair. Word-meaning mappings were fully counterbalanced such that each pseudoword was paired with one pole of the antonym pair (e.g., *old*) for half the participants and with the opposite pole (*young*) for the other half. For each pair, we selected four sets of images representing the given contrast. Each set contained two images (image location randomly determined) that contrasted primarily along the relevant dimension (e.g., cotton balls and stones for soft vs. hard; see Figure 1). Although images differed along additional dimensions, the relevant contrast was salient and common to all sets exemplifying that contrast (e.g., soft fabric slippers and hard wooden clogs).

Acoustic stimuli. Each word was embedded in the carrier phrase “This one is [pseudoword].” Two versions of each sentence were produced by a native English female speaker, each prosodically congruent with the meaning of one pole of the antonym pair. The speaker was given one set of images that represented the contrast and was instructed to try and modulate her prosody to convey the meaning of the relevant pole. She was informed regarding the acoustic properties found to distinguish the two poles of the antonym pair (cf. Eitan & Timmers, 2010; Nygaard et al., 2009); however, because we wanted utterances to sound natural, she was not required to adhere to these acoustic criteria. Utterances were recorded onto the computer using an Audio-Technica ATR2100-USB microphone at a 44.1 kHz sampling rate. The speaker produced several versions of each sentence; two of these, each representing one pole (total of 40 utterances), were chosen as stimuli. Acoustic analysis of example stimuli can be found in the supplemental material. Five additional filler sentences were recorded with neutral prosody; the speaker was not aware of their assigned meaning.

To confirm that utterances conveyed the intended meaning, 40 additional participants listened to the utterances and rated the prosody with respect to the relevant contrast on a 7-point Likert scale. For example, they were asked to rate the utterance for “Wug” on a scale ranging from *Young* (1, the low side of the scale) to *Old* (7, the high side); the midpoint (4) was always labeled as



Figure 1. Example images for the antonym pairs big–small (top) and hard–soft (bottom). Copyrighted images are from Wikimedia Commons and are published under the Creative Commons Attribution-Share Alike 3.0 license. Top left: Rytis Mikelskas; top right: OppidumNissenae; bottom left: കടകനര. See the online article for the color version of this figure.

neutral. Participants could play the sentence as many times as they wanted. Each participant heard only one version of each sentence (counterbalanced across participants). On average, utterances intended to convey the meaning of the high side of the scale were rated significantly higher ($M = 5.15$, $SD = 1.1$) than utterances intended to convey the low side ($M = 2.65$, $SD = 0.85$), $t(19) = 7.17$, $p < .0001$.

Design and Procedure

Each session began with an exposure phase in which pseudowords were visually presented individually on the computer screen for 2,000 ms ($ISI = 500$). Pilot testing revealed that participants had difficulty identifying the orthography of the words; the exposure phase was designed to familiarize participants with the pseudowords and reduce the cognitive load of remembering them.

After the exposure phase, participants learned 25 novel words, presented in random order: 10 with congruent prosody, 10 with incongruent prosody, and five neutral filler items. Each trial began with two images on the screen. Participants were instructed to try to determine the property that distinguished the images. After 1,500 ms, the utterance (e.g., “This one is [wug]”) was presented through Sennheiser HD555 headphones. Two seconds after utterance onset, an arrow indicated the referent image. This sequence (images, sentence, arrow) was repeated two more times for each adjective, with different image sets (set order was random). For the first set of images, the written word appeared on the screen following the arrow.

In the test phase, participants performed two memory tests. Half the participants completed both tests immediately after learning,

and half completed the tests 24 hr after learning. The first test was a four-alternative forced-choice definition test. The 20 novel words appeared individually on the screen, in random order (filler items did not appear on either test). For each word, participants were given four adjectives and asked to choose the one that best defined the word. The four choices were composed as follows: (a) the correct adjective (e.g., *young*); (b) another adjective that the participant studied (e.g., *thin*); (c) the antonym of a different adjective that the participant studied (e.g., *cold*, if the participant studied *hot*); (d) a new, unstudied, adjective (e.g., *round*). Participants were given unlimited time to select the correct definition. Definition order was randomized for each pseudoword. After the definition test, participants completed an image selection test. Words were randomly presented, and for each word, an image set representing the contrast appeared on the screen. Participants had to choose the image that best represented the meaning they learned. The testing image set was not presented during learning, so participants had to generalize the learned meaning to new exemplars.

The two tests differed in several respects. The definition test required an explicit formulation of the meaning, whereas the image test could, in principle, be based on implicit category learning; participants could have an implicit sense of the properties of the relevant images, even if they were not able to explicate the relevant semantic dimension. Second, the image test required participants to remember the relevant pole (e.g., *young* vs. *old*), although not necessarily to link it to the correct word (remembering that the arrow pointed at young things, without remembering these were referred to as *wug* rather than *pilk*). In contrast, the definition test required participants to extract a common abstract semantic meaning and to link the meaning to a specific word (on different trials, the arrow pointed at young and thin things, but *wug* was used only for young).

Results and Discussion

Results from both memory tests were analyzed using mixed-effects logistic regression, with congruency (congruent, incongruent), delay interval (immediate, delayed), and a Congruency $\times$ Delay interaction as fixed factors. Models were fit using the *glmer* function in the lme4 package (Bates, Maechler, Bolker, & Walker, 2013) of the R software package (R Core Team, 2013). Random-effect structure was determined by a “best path” model selection algorithm (as recommended by Barr, Levy, Scheepers, & Tily, 2013) using likelihood ratio. For the definition test, the best fit model included just random intercepts by subjects and items (see Table 1). Unsurprisingly, there was a significant effect of delay

Table 1
Regression Model for the Definition Test

Fixed effects	Estimate	SE	Z	p
Intercept	0.212	0.12	1.771	<.08
Congruency	0.291	0.116	2.504	<.02
Time	−0.633	0.143	−4.419	<.0001
Congruency $\times$ Time	−0.078	0.164	−0.474	>.6
Random effects	Variance			
Participant	0.229			
Item	0.082			

interval; performance was better when tested immediately after learning than after a 24-hr delay. The odds of correctly recognizing the definition were greater on the immediate compared with the delayed test (1.88 times greater for incongruent items, 2.03 for congruent items). There was also a significant effect of congruency (see Figure 2); the odds of a correct response were greater for words presented with congruent prosody than words presented with incongruent prosody (1.34 times greater on the immediate test and 1.24 times on the delayed test). There was no significant interaction.

For the image test, the best fit model included random intercepts by subjects and items and random slope by items for congruency (see Table 2). Performance was again better on the immediate test than the delayed test (odds of a correct response were 2.14 times greater on the immediate test for incongruent items, 1.48 for congruent items). However, the effect of congruency was not significant. Importantly, there was a significant interaction between the factors; performance was better for words presented with congruent prosody on the delayed test, but not on the immediate test (see Figure 3). Incongruency increased the odds ratio between the immediate and the delayed test by 1.44. This means that the memory loss due to a time delay was bigger for incongruent items, suggesting that congruency protected against memory loss.

These results show a clear effect of prosody on memory for novel words, even in a context of a task that did not call for the use of prosody. Prosodic cues were redundant in the sense that listeners could use the visual referential context to infer the contrastive dimension; each word was learned with different image sets, and the arrow indicated the relevant pole unequivocally. Indeed, results on the image test provide a clear indication that on the immediate memory test, listeners performed at the same accuracy level irrespective of prosody, suggesting that the visual contrast and arrow allowed listeners to learn the critical properties of the referred-to images and generalize this

Table 2
Regression Model for the Image Selection Test

Fixed effects	Estimate	SE	Z	p
Intercept	1.342	0.199	6.752	<.0001
Congruency	−0.226	0.166	−1.357	>.15
Time	−0.759	0.200	−3.793	<.001
Congruency × Time	0.368	0.185	1.994	<.05
Random effects	Variance			
Participant	0.706			
Item	0.357			
Item congruency	0.168			

learning to new visual contrasts. Thus, listeners attend to and exploit prosodic cues to meaning, even when the context disambiguates the meaning. Moreover, the effect was evident with a much larger set of meanings than used in previous studies, suggesting the effect of prosodic cues to meaning is not constrained to a few semantic dimensions.

A different pattern of performance emerged on the different memory tests. On the image selection test, there was no effect of prosody on the immediate test; recognition performance was almost identical for items presented with congruent or incongruent prosody. In contrast, congruent prosody provided a clear benefit in terms of memory retention following a 24-hr delay: The decline in memory in the incongruent condition was more than twofold of that in the congruent condition (13% vs. 6%, respectively). This may be because the arrow afforded unambiguous identification such that there was no additional immediate benefit in using prosody. However, the integration of auditory and visual information enabled a more stable memory representation and protected against memory loss. Additionally, the difference in task demands may explain the different performance on both tests. The unexpected location of the arrow on

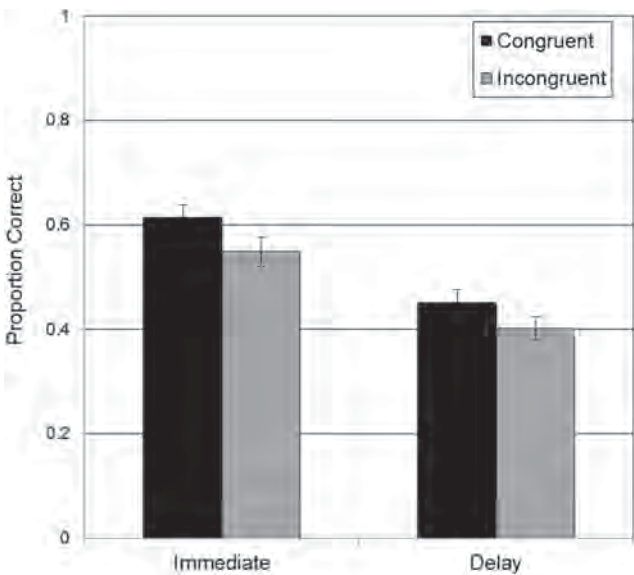


Figure 2. Memory accuracy (proportion correct) on the definition test. Error bars represent standard error.

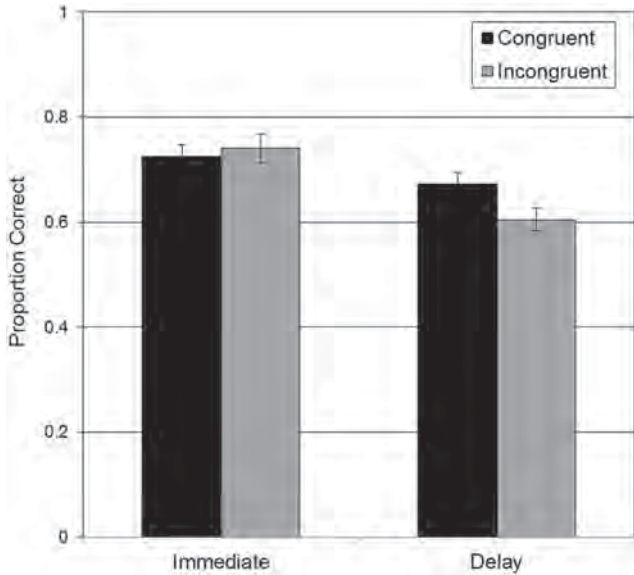


Figure 3. Memory accuracy (proportion correct) on the image selection test. Error bars represent standard error.

incongruent trials may have drawn more attention to the indicated image. This may provide an advantage, albeit a short-lived one, on the image test.

In contrast, there was an effect of prosody on the definition test at both time intervals. This test requires an explicit formulation of the word meaning. The main effect of prosody suggests that the multimodal integration of visually specified information (e.g., visually specified “bigness”) and auditorily specified information (prosodically expressed “bigness”) facilitates extraction of a common abstract semantic meaning. Bahrick and Lickliter (2012) suggested that perceiving multisensory events enhances attention to amodal redundantly specified properties of events (e.g., tempo) and promotes memory. Our results suggest that expressing semantic information in different modalities similarly facilitates memory for the common, redundantly specified, underlying property.

Previous research has shown speakers reliably use “spoken gesture,” modulating prosodic properties of their speech to express information, and that this prosodic modulation facilitates reference resolution (Shintel et al., 2006). Although in the present study, the speaker was instructed to convey specific meaning through prosody, previous research revealed that mothers spontaneously produced prosodic cues to meaning in infant-directed speech (Herold, Nygaard, & Namy, 2012) and that speakers spontaneously used prosody to convey information not expressed in the utterance, although this was irrelevant to their task (Hupp & Jungers, 2013; Shintel et al., 2006). Moreover, listeners could use prosodic properties of speech to infer the intended referents of novel words. For example, they infer that “blicket” spoken fast, with a higher pitch, refers to a small rather than to a big ball (Nygaard et al., 2009). Furthermore, the effect of prosody on reference resolution allowed listeners to infer the word’s meaning and retrieve it when they were later tested on the words with neutral prosody (Reinisch, Jesse, & Nygaard, 2013). Thus, prosodic information allows listeners to infer a persisting word-meaning mapping.

In the present study, we aimed to specifically gauge the role of prosodic information in memory, distinct from its role in reference resolution. Our results are important in two respects. First, we show that the integration of auditory-prosodic and visual cues creates a more enduring memory representation, suggesting a greater, more long-lasting, benefit of prosody than previously known. Second, we show that listeners attend to, and extract semantic information from, prosody even when this information is not necessary for reference resolution. Herold and colleagues (2011) found that 4-year-olds avoided using prosodic cues to meaning and suggested that this avoidance reflects their preference to rely on other sources of information. Because everyday reference resolution typically involves using various linguistic and extralinguistic sources of information, it is important to know whether adults attend to prosody even when they can rely on other cues. The present results show that listeners attended to redundant prosodic cues to meaning, rather than relying on visual cues alone. Thus, processing prosodic information at this level of analysis reflects a nonstrategic process, rather than a task-related effort. It further suggests a greater potential role for iconicity in spoken language processing. Instead of conveying meaning arbitrarily, prosody conveys semantic-referential information through nonarbitrary cross-

modal associations. Although some associations are reflected in language (e.g., high/low pitch), evidence suggests that they are not conventional in origin (Walker et al., 2010). The nonstrategic use of prosodic cues to meaning suggests people are sensitive to prosodic form-meaning mappings and can capitalize on these associations in comprehension and word learning.

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Appendix

Antonym Pairs Used in the Study

Experimental items		Filler items
Big–Small	Rough–Smooth	Blue–Green
Blunt–Sharp	Sleepy–Alert	Opaque–Transparent
Bright–Dark	Tall–Short	Orange–Red
Far–Near	Tense–Relaxed	Striped–Plaid
Fast–Slow	Thin–Fat (images of living objects)	Sweet–Salty
Hard–Soft	Thin–Thick (images of non-living objects)	
High–Low	Up–Down	
Hot–Cold	Weak–Strong	
Light–Heavy	Wide–Narrow	
Male–Female	Young–Old	

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