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Investigating the role of semantics and perceptual salience in the memory benefit of prosodic prominence

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Abstract

Prosodic prominence can enhance memory for the prominent words. This mnemonic benefit has been linked to listeners' allocation of attention and deeper processing, which leads to more robust semantic representations. We investigated whether, in addition to the well-established effect at the semantic level, there was a memory benefit for prominent words at the phonological level. To do so, participants (48 native speakers of Dutch), first performed an accent judgement task, where they had to discriminate accented from neutral words, and accented from neutral pseudowords. All stimuli were presented in lists. They then performed an old/new recognition task for the stimuli. Accuracy in the accent judgement task was equally high for words and pseudowords. In the recognition task, performance was, as expected, better for words than pseudowords. More importantly, there was an interaction of accent with word type, with a significant advantage for accented compared to neutral words, but not for pseudowords. The results confirm the memory benefit for accented compared to neutral words seen in earlier studies, and they are consistent with the view that prominence primarily affects the semantic encoding of words. There was no evidence for an additional memory benefit arising at the phonological level.

Index Terms: prosodic prominence, pitch accent, recognition memory, semantic mediation

1. Introduction

The prosodic structure of sentences facilitates their parsing into syntactic constituents and highlights their thematic (given/new) structure [1], thereby playing a key role in spoken language comprehension. Specifically, pitch accents can signal prosodic prominence in sentences [1, 2] and enhance listeners' verbal memory for more prominent words [3, 4]. The aim of the current study is to contribute to a better understanding of this memory benefit for accented words.

A memory effect of pitch accents has been reported in a number of studies. In these studies, participants heard sentences including target words with contrastive (L+H*) and non-contrastive (H*) accents (defined in the ToBI system) [5], and their memory for the targets was tested. A robust finding is that accented words are recognized better than matched neutral words [3, 4, 6, 7]. This memory benefit for accented words can be linked to the listeners' allocation of attention: Accented words are acoustically more salient and therefore attract attention [8, 9]. Attending to a word entails processing it with priority, which in turn strengthens its memory representations.

In the current literature, the prioritized processing of accented words and the memory benefit are allocated at the semantic level: Listeners create more fine-grained semantic representations of accented compared to neutral words [10-13]. On some accounts, the prioritized processing of focused words entails the activation of (contextually relevant) semantic alternatives to the target words [3, 4]. We call these accounts semantic mediation accounts, as they propose that the memory benefit for accented words arises from prioritized semantic processing. Strong evidence for this view comes from multiple electrophysiological studies showing that accented words elicited larger N400s than neutral words, indicating their more elaborative lexical-semantic processing [12, 13].

Though there is strong support for the semantic mediation view, pitch accents have also been shown to affect early word recognition processes [14] and might therefore also affect the generation and maintenance of phonological representations of words [15]. Such phonological mediation could arise in two ways: First, accented words are acoustically more prominent and therefore activate sharper or more detailed, and hence more durable, phonological representations. Alternatively, the phonological representations of accented words could benefit from overt or covert rehearsal or refresh processes, triggered by the listener's assumption that they are particularly important.

Despite strengthening of phonological representations through pitch accents being an obvious possible explanation for the mnemonic effect, it has, to our knowledge, not been directly studied before. The present study aims to begin to fill this gap in the literature by examining the mnemonic benefit from pitch accents when the role of semantic processing is minimized. Previous studies presented accented and neutral target words in sentence contexts, which may have invited deep semantic processing of targets. Here we used simple lists of words, half of which spoken with and half without accent. In addition to the word lists, we presented participants with lists of pseudowords, also produced with or without pitch accent. We reasoned that word lists would not invite deep semantic processing of the words to the same extent as sentence contexts do. Deep semantic processing should be even less likely for lists of pseudowords, though they may still activate phonologically similar lexical representations to some extent [16, 17]. Thus, any memory benefit for accented compared to neutral pseudowords should be primarily due to enhanced processing of the word forms. Additional memory benefit seen in words would point to the involvement of semantic representations.

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Table 1: *Acoustic properties of stressed syllables and unstressed syllables for accented and neutral words and pseudowords.*

	Words				Pseudowords			
	Accented		Neutral		Accented		Neutral	
Measure	Stressed	Unstressed	Stressed	Unstressed	Stressed	Unstressed	Stressed	Unstressed
Minimum F0	114.69	96.18	99.73	92.93	118.88	97.91	100.19	90.97
Maximum F0	193.06	125.54	120.07	108.64	196.39	127.40	122.99	109.65
F0 difference	78.36	29.37	20.32	15.68	77.49	29.56	22.86	18.61
Mean pitch	157.97	106.96	110.67	99.23	160.46	107.85	111.53	98.18
Duration	0.46	0.37	0.40	0.36	0.48	0.41	0.42	0.39
Mean intensity	58.29	50.71	54.32	47.01	58.65	50.34	54.45	47.42

During the exposure phase of the experiment, participants were asked to listen carefully to the words or pseudowords and decide for each of them whether or not it was accented. This task directed their attention to the phonological forms of the items, further reducing the likelihood of deep semantic processing. In addition, this task allowed us to examine whether participants could correctly discriminate between accented and neutral items appearing in lists. In the test phase, the participants first carried out a free recall and then a recognition task for the words and pseudowords.

2. Methods

2.1. Participants

Forty-eight native Dutch speakers participated in this experiment with financial compensation (13 male; average age 23.25 years). The sample size was defined by a power analysis based on the pilot data, conducted by *mixedpower* package [18] implemented in R (R Core Team, 2022). The power analysis indicated a requirement of 48 participants to reach 80% statistical power for the expected interaction between pitch accent and word type. All participants reported normal hearing and normal or corrected-to-normal vision. Ethical approval for this study was given by Ethics Committee of the Social Science Faculty of Radboud University.

2.2. Materials and Designs

The experiment was split into two sessions, one involving testing words, the other testing pseudowords. Whether words or pseudowords were tested first was counterbalanced across participants. In between the two sessions, participants completed two working memory tasks. Each session consisted of an exposure and a test phase (see Figure 1). In the exposure phase, participants heard a list of accented and neutral stimuli and performed an accent judgement task, indicating whether the (pseudo)words they heard were accented (Dutch instructions: *met klemtoon*, “emphasized”) or neutral. In the test phase, they heard the same stimuli, mixed with an equal number of new items, and performed an old/new recognition task. In the test phase, all items were neutral. The exposure phase was divided in three blocks, the test phase into four blocks, with short, self-timed breaks in between.

To create the materials, we selected 98 disyllabic nouns and used the software package *Wuggy* [19] to construct matched pseudowords with the same number of letters. The pseudowords shared 2/3 of the letters in variable word positions with the base (e.g., *antwoord* - *alktoord*). Since the Dutch module of *Wuggy* is based on orthography, the second author, a native Dutch speaker, inspected the pseudowords to exclude pseudo-homophones of existing Dutch words and assign stress to the pseudowords. This male speaker also recorded the items in contrastively accented (an L+H* accent in the ToBI system) and non-contrastively accented (an H* accent) intonation. In the present study, we used *accented* and *neutral* to discriminate words spoken with and without a pitch accent. Their acoustic properties are summarized in Table 1.

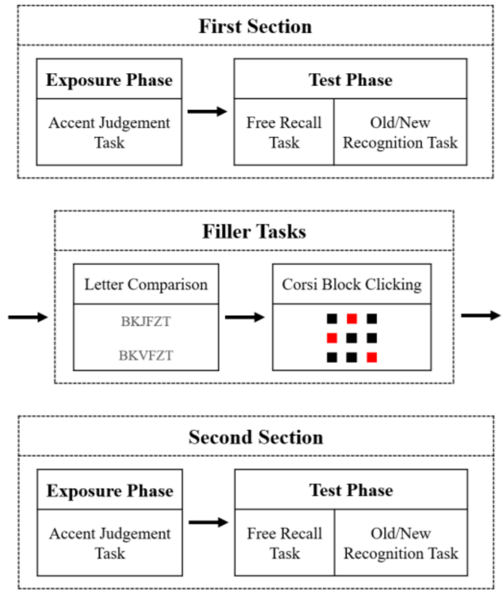

Figure 1: *Overview of the experiment. The two sections of the experiment were separated by filler tasks. Each section consisted of an exposure phase followed by a test phase with two tasks.*

Two words and two pseudowords were used on practice trials. The remaining items were split into two lists of 48 words and 48 corresponding pseudowords. The words in the two lists were matched for word frequency [20], prevalence [21], age of acquisition ratings [22], concreteness ratings [23], orthographic and phonological neighborhood frequency and size [24] (all *p*-values > 0.1). The corresponding pseudowords were matched for orthographic neighborhood frequency and size between the two lists. The items were further divided over two lists based on accentuation. In this way, the first half of the items was presented with accented prosody and the second half with neutral prosody. This was counterbalanced across participants.

During the following test phase, the words and pseudowords from the exposure phase acted as previously-heard target items, which were combined with new items in the test phase. Which half of the items functioned as previously-heard and new items was again counterbalanced across participants. Taken together, four unique stimulus lists were generated. There were 48 words and 48 pseudowords (half of which were accented and half neutral) during the exposure phase and 96 words and 96 pseudowords (half previously-heard and half new) during the test phase.

The experiment contained word type (word versus pseudoword) and pitch accent (accented versus neutral) as within-participant variables. Both the word and pseudoword sessions involved an accent judgement task during the exposure phase. In this task, trial order was pseudo-randomized, with the constraint that items with same initial letter and accent condition were not appeared in consecutively three trials. To avoid interference from the previous two trials, we also balanced transitional probabilities for both accented and neutral items across participants.

Both sessions involved a free recall task and an old/new recognition task during the test phase. In the recognition task, all items were again pseudo-randomized presented, with an additional limitation that items with same familiarity (i.e., previously-heard or new) could not appear. Pseudo-randomization was done with Mix [25]. The experiment was programmed with Presentation (Neurobehavioral systems).

2.3. Procedure

Participants were tested individually in a sound-attenuating booth. The stimuli were presented through headphones at a comfortable volume. Participants read the instructions and clicked on a button to hear two sample stimuli spoken with or without accent. They were informed that they should categorize the upcoming stimuli as accented or not accented, and also try to remember them for a memory test.

Each trial began with a fixation point (+) shown for 1500 ms. Then the screen turned blank and a word or pseudoword was played. Participants had to indicate, within 2000 ms after stimulus offset, whether the item was spoken with or without accent by pressing one of two buttons. The following trial began after a random interval between 1000 to 1500 ms, measured from response onset.

During the test phase, participants first completed a free recall task and then an old/new recognition task. In the free recall task, participants typed all items they remembered from exposure phase in any order and without time restrictions. In the recognition task, the same trial structure was used as in the exposure phase, but instead of deciding whether a stimulus was accented, participants now decided whether they had heard the item before. All stimuli were spoken without accent in this task.

Words and pseudowords were tested in separate blocks, counterbalanced across participants. In between, participants completed two working memory tasks (letter comparison test and Corsi block clicking [26]), taking approx. 15 minutes.

2.4. Statistical Analysis

Judgement and recognition accuracies were analyzed with generalized linear mixed models with *lme4* package [27] and *lmerTest* package [28]. To achieve the best-fitting model to the observed data, we first confirmed the random structure from the null model with participants and items as random intercepts. Word type, pitch accent and their interaction were added in this order as by-subject and by-item random slopes. Model comparisons (likelihood ratio tests) were performed to assess whether including a random effect inclusion improved the fitness of the model. If this was the case and the new model did not lead to converge issues, subsequent comparisons would be based on this improved model. We performed statistical inference on the fixed effects structure starting with the full model (including main effects and the interaction as fixed factors). We then assessed the significance of this term by comparing the full model to a reduced model without the term of interest. When its exclusion decreased the model fitness (as evaluated with likelihood ratio tests), this fixed effect would be considered significant. *P*-values below an alpha of .05 were considered significant. Pairwise comparisons were obtained via *emmeans* package.

3. Results

As participants on average only recalled 8.97 words and 2.54 pseudowords, the results of the free recall task were not analyzed. The remaining results are summarized in Figure 2. Data for two participants was excluded due to programming errors.

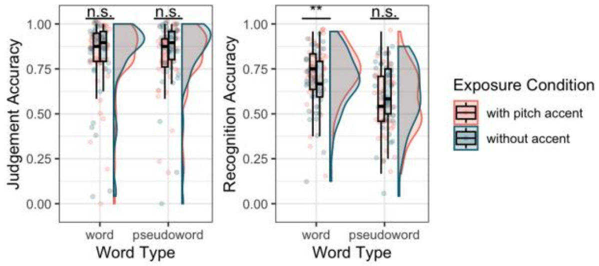

Figure 2: *Accent judgement and recognition accuracies for words and pseudowords. Box plots show the medians and 1.5 interquartile ranges. Scattered dots show aggregated data per participant. (**: $p < 0.01$; n.s.: $p > 0.05$)*

The best-fitting model for judgement accuracy in the exposure phase contained word type and pitch accent as by-participant random slopes and also by-item and by-participant random intercepts. Since none of the three potential fixed factors improved the model fit, we concluded that accuracy was not affected by the presence of pitch accent and was similar for words and pseudowords (see left panel of Figure 2).

Our first analysis of the recognition accuracy only incorporated previously-heard items. The best-fitting model for recognition accuracy in the test phase included word type as a by-participant and pitch accent as a by-item random slope. Adding the interaction between word type and pitch accent as a fixed factor significantly improved this model ($\chi^2(2)$ = 9.75, p = 0.002). Pairwise comparisons revealed that presentation of stimuli with pitch accent as compared to neutral only facilitated the recognition of words ($ß$ = 0.28, SE = 0.11, z = 2.65, p = 0.008) but not of pseudowords ($ß$ = -0.18, SE = 0.10, z = -1.77, p = 0.076; see right panel of Figure 2). Note that for pseudowords, recognition performance is, numerically, better for neutral than accented words.

To take participants' false alarm rate (i.e., incorrectly identifying new items as previously-heard) into account, we utilized the signal detection theory measurements to explore their ability to discriminate the signal (i.e., previously-heard items) from the noise (i.e., new items). We calculated participants' recognition sensitivity and bias across word types and pitch accents (see Figure 3). Sensitivity reflects how much their performance was above or below chance level, while bias indicates how much, and in which direction their response criteria were skewed. Because all stimuli were presented without accent in the recognition phase, false alarm probabilities for accented and neutral items were computed based on the same set of new items used as foils. Repeated measures ANOVAs were conducted for sensitivity and bias, with word type and pitch accent as within-subject variables. There was a main effect of word type for sensitivity ($F(1,45) = 29.10$, $p < 0.001$, $\eta_p^2 = 0.39$), reflecting higher accuracy for words than pseudowords. Both sensitivity ($F(1,45) = 7.61$, $p = 0.008$, $\eta_p^2 = 0.14$) and bias ($F(1,45) = 7.61$, $p = 0.008$, $\eta_p^2 = 0.14$) revealed interactions between these two variables. Follow-up pairwise comparisons showed increased sensitivity ($ß = 0.16$, $SE = 0.05$, $t(45) = 2.96$, $p = 0.005$) and decreased bias ($ß = -0.08$, $SE = 0.03$, $t(45) = -2.96$, $p = 0.005$) for accented words compared to neutral ones, but not for accented versus neutral pseudowords (sensitivity: $ß = -0.08$, $SE = 0.07$, $t(45) = -1.28$, $p = 0.208$; bias: $ß = 0.04$, SE = 0.03, $t(45) = 1.28$, $p = 0.208$).

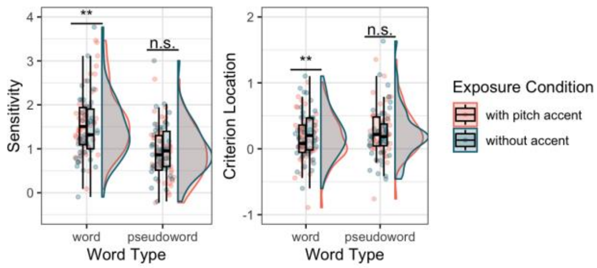

Figure 3: *Signal detection theory measurements (sensitivity and bias) for real words and pseudowords. Box plots show the medians and 1.5 interquartile range. Scattered dots represent aggregated data per participant. (**: p < 0.01; n.s.: p > 0.05)*

4. Discussion

The present study explored whether prosodic prominence facilitated listeners' memory for words and pseudowords in lists. We first used an accent judgement task to examine how well participants could discriminate accented from neutral words, and accented from neutral pseudowords. All stimuli were presented in lists. We then used a free recall and a recognition task to assess whether there was a memory benefit for the accented, compared to the neutral, stimuli.

We observed that accuracy in the accent judgement task was high for both words (81.7 %) and pseudowords (82.7 %). Apparently, the participants could use the acoustic properties indicating pitch accent equally well in providing judgements for words and pseudowords. In other words, general perceptual mechanisms were at play that did not rely on the lexicality of the stimuli. Importantly, the observation that accuracy in the accent judgement task did not differ between words and pseudowords means that any differences in memory for accented words versus pseudowords did not result from differences in the participants' ability to perceive pitch accent in the two types of stimuli.

In the free recall task, the participants' performance was, at 12.0 %, so poor that analyses of effect word type or accent were not warranted. In the recognition task, we obtained two main findings: First, performance was much better for words than pseudowords. This finding is in line with numerous earlier studies on verbal memory showing better memory for meaningful than meaningless materials [29-31].

Second, and more importantly, we found an interaction of accent with word type: For words, there was a significant advantage for accented compared to neutral stimuli, whereas for pseudowords there was a trend towards better recognition of neutral stimuli. The results obtained for words confirm the memory benefit for accented compared to neutral words seen in earlier studies [3, 4]. Our findings extend this benefit to word lists. The signal detection analysis showed that the participants' enhanced recognition accuracy for accented words was associated with increased sensitivity and decreased bias. This pattern suggests that participants could better identify previously-heard accented words from new words, even though all words were spoken in neutral prosody during the test phase. Though there was an overall tendency towards judging the items as new, the bias was reduced for accented words.

In the literature, the memory benefit for accented words has typically been allocated at the semantic level [12, 13]. On such an account, our results imply that listener generate stronger semantic representations of accented than neutral words even when the words are presented lists, where pitch does not have its regular discourse functions. Why and how participants generated these stronger semantic representations needs to be further studied. We suggest that they perceived the accented words as more important or task-relevant, as accented words are typically important in natural speech. Participants therefore strategically prioritized their processing, which led to better recognition [32-35].

As explained in the Introduction, we hypothesized that in addition to a semantic effect there might be a benefit arising from the generation of stronger phonological representations for accented stimuli. Such an effect should be visible in the memory performance for pseudowords, for which strong semantic representations are not available. Our results do not confirm this prediction. Instead there was trend towards better recognition of neutral rather than accented pseudowords. Recall that in the test phase, all stimuli were presented in the neutral form. As memory for pseudowords could not be systematically supported by existing semantic representations, participants had to rely on phonological representations [30, 31, 36]. Apparently, these representations encoded sufficient detail to lead to a small benefit for items presented in the matching, neutral form during the exposure phase. Such a benefit may also have existed for neutral words, but it was overridden by the stronger effect of pitch accent favoring the accented words.

To conclude, participants could reliably identify pitch accent in lists of words and pseudowords, but a memory benefit of pitch accent was only seen for words, but not for pseudowords. This is consistent with the view that pitch accent primarily affects the semantic encoding of words. There was no evidence for an additional memory benefit arising at the phonological level.

5. References

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