ABSTRACT: The aim of the present study was to compare the processing of lexical stress across modalities in native speakers of English. We utilised the same disyllabic stimuli in both visual and auditory grammatical classification. Participants were asked to classify each individually presented word as being either a noun or a verb as quickly and accurately as possible. In line with previous findings (Arciuli & Cupples, 2002; Kelly & Bock, 1988; Kelly, 1988)), the results of our visual task showed that typically stressed words (trochaic nouns and iambic verbs) elicited advantaged processing over atypically stressed words (iambic nouns and trochaic verbs). In contrast, the results of our auditory task showed no overall effect of stress typicality. This finding is also in line with previous research (Davis & Kelly, 1997, Cutler & Clifton, 1984). Interestingly, however, a median split analysis showed that participants with high error rates did exhibit a significant effect of stress typicality during auditory grammatical classification.

INTRODUCTION

In English, the majority of disyllabic nouns exhibit trochaic stress e.g., “apple”), whereas most disyllabic verbs exhibit iambic stress (e.g., “accept”). This pattern has been investigated by both Sereno (1986) and Kelly and Bock (1988). Sereno sampled 1425 disyllabic nouns and 523 disyllabic verbs and found that 93% of nouns exhibited trochaic stress while 76% of verbs exhibited iambic stress. Kelly and Bock (1988) examined 3,000 disyllabic nouns and 1,000 disyllabic verbs and found a similar pattern. Their analysis showed that 94% of nouns exhibited trochaic stress while 69% of verbs exhibited iambic stress. Thus, trochaic nouns and iambic verbs could be considered to be typically stressed while iambic nouns and trochaic verbs could be considered to be atypically stressed.

With regard to visual word recognition, numerous studies carried out by Kelly and colleagues suggest that effects of stress typicality emerge when certain types of ‘off-line’ (unspeeded) tasks are used (e.g., Kelly & Bock, 1988; Kelly, 1988). Recently, we obtained stress typicality effects using ‘on-line’ naming and lexical decision (Arciuli & Cupples, 2002). Our results showed that, in both tasks, typically stressed words (trochaic nouns and iambic verbs) elicited significantly fewer errors than atypically stressed words (iambic nouns and trochaic verbs).

Interestingly, we noted orthographic differences between our typically and atypically stressed words that were not associated with length, neighbourhood or spelling-sound consistency. We carried out a corpus analysis of 340 word-endings and found support for our hypothesis that there are orthographic correlates of both grammatical class and lexical stress in word-endings. In additional experiments we showed that readers are sensitive to these correlates in their processing of nonwords.

Our findings led us to wonder whether stress typicality effects could be obtained during spoken word recognition. To our knowledge, there has been no direct comparison of the effects of lexical stress (where stress typicality is defined on the basis of grammatical category) across visual and spoken word recognition using the same stimuli and the same task. There has, however, been some previous research that has specifically addressed the processing of lexical stress in spoken word recognition. Cutler and Clifton (1984) employed an auditory grammatical judgement task where participants heard experimental items in the context of “to…” or “the…” and were asked to decide
whether what they heard was a grammatical phrase. The results did not indicate advantaged processing for typically stressed words.

Davis and Kelly (1997) used an auditory grammatical classification task with native and non-native speakers of English. Their task was different to the one used by Cutler and Clifton in that participants were presented with individual words and asked to classify each one as being either a noun or a verb. The results indicated an effect of stress typicality in non-native speakers. In contrast, there was no significant effect of stress typicality found in the native speaker group. Davis and Kelly went on to suggest that non-native speakers showed an effect where native speakers did not because of task difficulty (an average error rate of 15% for non-native speakers vs. 5% for native speakers).

Some of the above mentioned studies provide support for the hypothesis that stress typicality is an orthographic effect in that native speakers have not shown advantaged processing for typically stressed words in the auditory modality. However, Davis and Kelly did find an effect of stress typicality using auditorily presented stimuli with a group of non-native speakers. This finding raises interesting questions about the nature of the stress typicality effect as an orthographic effect and about the possibility of individual differences in the processing of lexical stress (even, perhaps, in native speakers).

Our main aim here was to examine the processing of lexical stress in native speakers of English using the same stimuli across both auditory and visual modes of presentation. In addition, we extended the work of Davis and Kelly (1997) by investigating the possibility of individual differences in the processing of lexical stress within a group of native speakers. Specifically, we wondered whether some individuals who find the task particularly difficult might process lexical stress differently from other individuals. These issues were investigated using a grammatical classification task in the following two experiments.

EXPERIMENT ONE

The aim of this experiment was to investigate the processing of lexical stress during visual word recognition. Based on previous research (Arciuli & Cupplees, 2002; Kelly & Bock, 1988; Kelly, 1988) we expected to find a significant difference in the processing of typically and atypically stressed words.

Method

Participants. A total of 29 undergraduate Linguistics students gained course credit for their participation. All were native speakers of English with normal or corrected to normal vision.

Materials. A set of 120 unambiguous disyllabic words was selected for the experiment. Equal numbers of words represented each of four categories, which were obtained by crossing the factors of grammatical category (noun vs. verb) and stress typicality (typical vs. atypical). Of the 60 nouns included, 30 had typical trochaic stress (e.g., ‘wizard’) and 30 had atypical iambic stress (e.g., ‘terrain’). Of the 60 verbs included, 30 had typical iambic stress (e.g., ‘invent’) and 30 had atypical trochaic stress (e.g., ‘punish’). The base frequency of each item was obtained from Francis and Kucera (1982). Typically and atypically stressed words were closely matched in terms of frequency (67.5 vs. 67), length (both around 6.3 letters), neighbourhood size (1.17 vs. 1.42) and the average frequency of neighbours (26 vs. 24). There were no significant differences between typically and atypically stressed words on any of these variables (all Fs < 1).

Procedure. The experiment was run using DMASTR software developed at Monash University and the University of Arizona by K.I. Forster and J.C. Forster (1990, 1996). Participants sat in front of a computer and were presented with individual words on the screen. Approximately half (15) of the participants were instructed to press the right shift key if the word was a noun and the left shift key if the word was a verb. The other 14 participants pressed the left shift key for a noun and the right shift key for a verb.

There was a practice set of 20 items followed by the experimental set, which was presented in a uniquely randomised order for each participant. Each target word was preceded by a set of empty
brackets that appeared on the screen for 750 milliseconds to assist fixation. Target words were presented individually for 750 milliseconds. Inter-stimulus delay was response contingent with a time-out period of 6000 milliseconds. Participants received feedback for incorrect responses (where the word “WRONG” appeared on the screen immediately after the response).

Results
We carried out 2 x 2 ANOVAs in our subject analyses where stress typicality (typical vs. atypical) and grammatical category (noun vs. verb) were included as repeated measures. We also carried out 2 x 2 ANOVAs in our item analyses but here stress typicality and grammatical category were entered as between items measures.

Response Times. Participants’ mean reaction times for each category of word are presented in Table 1. The results showed that native speakers responded more quickly to typically stressed words than to atypically stressed words ($F_1 (1,28) = 13.7, p < .005; F_2 (1,116) = 7.35, p < .005, minF' (1,124) = 4.78, p < .05$). There was no significant main effect of grammatical category and no interaction between stress typicality and grammatical category.

Table 1.
<table>
<thead>
<tr>
<th></th>
<th>Typical Stress</th>
<th>Atypical Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nouns</td>
<td>839 (5.4)</td>
<td>877 (10.1)</td>
</tr>
<tr>
<td>Verbs</td>
<td>833 (5.2)</td>
<td>861 (13.2)</td>
</tr>
<tr>
<td>Overall</td>
<td>836 (5.3)</td>
<td>869 (11.7)</td>
</tr>
</tbody>
</table>

Error Rates. Participants’ mean error rates are also presented in Table 1. These data showed a similar pattern to response times in that typically stressed words elicited fewer errors than atypically stressed words ($F_1 (1,28) = 35.59, p < .001; F_2 (1,116) = 13.61, p < .001; minF' (1,138) = 9.85, p < .005$). There were no other significant effects.

Discussion
The results of this experiment are in line with previous studies (Arciuli & Cupples, 2002, Kelly & Bock, 1988, Kelly, 1988). Specifically, the results of Experiment 1 have demonstrated advantaged responding for typically stressed words (trochaic nouns and iambic verbs) over atypically stressed words (iambic nouns and trochaic verbs) during visual word recognition by native speakers of English. Advantaged responding was present in both reaction time data and error rates.

EXPERIMENT TWO
The aim of this experiment was to investigate the processing of lexical stress during spoken word recognition. We predicted that if stress typicality effects are purely orthographic in nature then typically stressed words (trochaic nouns and iambic verbs) should show no advantage over atypically stressed words (iambic nouns and trochaic verbs) during spoken word recognition. However, we were open to the possibility that stress typicality might have some influence in the auditory modality and that this influence might be restricted to a subset of participants who find the task particularly difficult.

Method
Participants. A total of 23 undergraduate Linguistics students gained course credit for their participation. All were native speakers of English with normal or corrected to normal vision and normal hearing.
Materials. The same set of 120 unambiguous disyllabic words was used for this experiment. Stimuli were professionally recorded using a female speaker. Equipment included an AKG-C414B microphone and tokens were mixed on a Mackie mixer and edited using Goldwave. The resulting files were in 44.1KHz 16bit DAT format. Tokens were edited and trimmed where sound levels were below 40dB below average SPL, with a linear fade from t=0 to t=50 milliseconds before and after the utterance. We measured the duration of each wav file and found that the average duration of typically stressed items was 787 milliseconds and the average duration of atypically stressed items was 802 milliseconds. As expected, a one-way ANOVA showed that there was no significant difference in wav duration (F < 1) across these items.

Procedure. The experiment was run in a sound-proof room using the DMDX software developed at Monash University and the University of Arizona by K.I. Forster and J.C. Forster (1990, 1996). Participants sat at a comfortable distance from the monitor and were instructed that they would hear individual words through headphones and would be prompted for a response to each word by a message on the computer screen. They were informed that at this point they would have to decide as quickly and accurately as possible whether each word was a noun or a verb.

Approximately half (13) of the participants were instructed to press the left mouse button if the word was a noun and the right mouse button if the word was a verb. The other 10 participants were instructed to press the right mouse button if the word was a noun and the left mouse button if the word was a verb.

There was a practice set of 16 items followed by the experimental set, which was presented in a uniquely randomised order for each participant. At the beginning of the experimental set there were 6 warm-up items that were not included in the analysis of the 120 test items. Presentation of each wav was immediately followed by the phrase “Noun or Verb?” (for the first 13 subjects) or “Verb or Noun?” (for the last 10 subjects). This phrase disappeared after a response was made (time-out period of 4000 milliseconds). Inter-stimulus delay was 1000 milliseconds (after a response) or 5000 milliseconds (if no response was provided).

Results
As in Experiment 1, we used repeated measures in our subject analyses and between items measures in our item analyses.

Response Times. Participants’ mean reaction times for each type of word are presented in Table 2. The reaction time data provided no evidence to indicate an overall advantage in the processing of typically stressed words (trochaic nouns and iambic verbs) over atypically stressed words (iambic nouns and trochaic verbs). The results showed that there was no significant difference in these means (both Fs < 1). There was no main effect of grammatical class and no interaction between stress typicality and grammatical class (all Fs < 1).

<table>
<thead>
<tr>
<th>Typical Stress</th>
<th>Atypical Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nouns</td>
<td>758 (9.0)</td>
</tr>
<tr>
<td>Verbs</td>
<td>740 (8.1)</td>
</tr>
<tr>
<td>Overall</td>
<td>749 (8.6)</td>
</tr>
</tbody>
</table>

Error Rates. Participants’ mean error rates for each category of word are also shown in Table 2. These data differed from response times in providing some evidence for an overall difference between words with typical versus atypical stress patterns. Participants were more accurate in
classifying typically stressed words than atypically stressed words, a difference that was significant in the subject analysis ($F_1(1,22) = 9.13$, $p < .01$), but did not generalise to items ($F_2(1,116) = 1.92$, $p > .10$). There were no other significant effects (all Fs < 1).

Interestingly, a correlational analysis indicated a strong relationship ($r(23) = .50$, $p < .05$) between overall error rate and the size of the stress typicality effect (computed by subtracting the mean error rate for typically stressed words from that for atypically stressed words). As error rates increased, so did the size of the stress typicality effect. We carried out a median split analysis to investigate further the possibility that task difficulty might be related to stress typicality effects in spoken word recognition. The median overall error rate was 10%. First we analysed the error rates of the 12 participants who achieved an overall error rate between 0 and 10%. We found no significant main effect of stress typicality ($F$s < 1). In contrast, when we looked at the remaining 11 participants who had exhibited overall error rates above 10% we did find a significant main effect of stress typicality in the subject analysis ($F(1,10) = 16.38$, $p < .005$) and a marginal effect in the item analysis ($F(1,116) = 3.19$, $p = .08$). For this group, typically stressed words elicited fewer errors than atypically stressed words.  

Discussion

The results of this experiment indicate that, overall, stress typicality effects do not emerge during spoken word recognition. The results are in line with those presented by Cutler and Clifton (1984) who failed to find any effect of stress typicality during an auditory grammatical judgement task. The results are also in line with those obtained by Davis and Kelly (1997) who noted a trend but actually found no significant difference in the processing of typically and atypically stressed words in native speakers. However, while the sample sizes are small, our median split analysis showed that a subset of native speakers with high error rates (presumably, these participants found the task to be quite difficult) did exhibit a stress typicality effect. This pattern was found in both auditory grammatical classification and auditory lexical decision. These findings suggest that stress typicality does exert some influence during spoken word recognition in some native speakers.

GENERAL DISCUSSION

The main aim of this study was to examine the processing of lexical stress in native speakers of English using the same stimuli across both auditory and visual modes of presentation. Based on Davis and Kelly’s hypothesis about task difficulty (which came about through a comparison of native and non-native speakers of English), we also set out to investigate the possibility of individual differences in the processing of lexical stress. Specifically, we extended the work of Davis and Kelly by investigating whether some native speakers might process lexical stress differently from others.

In line with previous research, our results showed that, overall, stress typicality affects visual word recognition but not spoken word recognition in native speakers of English. Our results were obtained using the same stimuli in both auditory and visual grammatical classification. Initially, we felt these results might also provide some support for the notion that stress typicality effects are orthographic in nature in that effects emerge during visual word recognition but not auditory word recognition. Importantly, however, we did find evidence to support the hypothesis that some native speakers (who find certain tasks particularly difficult) do exhibit effects of stress typicality during the processing of spoken words. In future research we intend to investigate further the possibility of qualitative differences between the effects of lexical stress found in visual word recognition and those found in spoken word recognition. As part of this investigation we intend to explore the reasons why some individuals find spoken word recognition difficult by looking at the influence of factors such as vocabulary.

1 Interestingly, we carried out an auditory lexical decision task using the same stimuli and found a very similar pattern of results. After the removal of two items that elicited unusually high error rates, we found no main effect of stress typicality for the group as a whole (in either response times or error rates). However, a median split analysis again showed that participants with higher error rates (over the median of 3.5%) showed a significant effect of stress typicality ($F_1(1,10) = 5.17$, $p < .05$; $F_2(1,114) = 4.86$, $p < .05$).

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