Introduction

Spoken words unfold over time. Consequently, the initial sounds in any given word are usually compatible with several words. A long-standing issue in language comprehension has been how listeners resolve these ambiguities. While continuous integration models describe lexical access as a joint venture between top-down and bottom-up information processing, delayed context integration models argue that top-down information comes into play only after bottom-up processing has made available the lexical alternatives. Early research using ambiguous words such as ‘bank’ and ‘rose’ suggested that recognition of a word was only affected by context after all of the possible meanings were considered, supporting delayed integration models. (Swinney, 1979; Tanenhaus, Leiman & Seidenberg, 1979). However, more recent studies utilizing eye-tracking and natural language stimuli to study the time course of spoken word recognition suggest that contextual information is immediately integrated with bottom-up information (Allopenna, Magnuson, & Tanenhaus, 1998; Dahan, Magnuson, & Tanenhaus,, 2001; Dahan & Tanenhaus, 2004).

One limitation of examining spoken word recognition with natural language materials is that it is difficult to control the nature of the constraints provided by the context. Artificial lexicons provide a logical way to overcome this issue since experimenters have control over word frequency, word length, and phonetic similarity (Magnuson et al., 2003). Several studies have demonstrated continuous integration of contextual information in lexical processing with the use of artificial lexicons and eye-tracking. Specifically, studies which trained participants to associate novel modifiers and nouns demonstrated that this learned contextual information immediately becomes available to listeners during word recognition tasks (Magnuson, Tanenhaus, & Aslin, 2008; Revill, Tanenhaus, & Aslin, 2008). Though these findings provide a solid start, it is important to see whether they generalize to probabilistic contexts more similar to those found in natural language (Magnuson et al., 2008). The present study, therefore, employed eye-tracking and an artificial lexicon in order to investigate the effects of specific contextual constraints—probabilistic contingencies—on the processing of temporarily ambiguous lexical items.

Methods

Stimuli

A 9-item artificial lexicon was created. The lexicon consisted of 6 nouns referring to specific shapes and 3 modifiers describing actions that could be applied to each shape (Table 1). Visual materials included 6 unfamiliar shapes (Figure 1), 3 modifications (or actions) that could be applied to each shape (shapes could rotate, display a face, or turn blue), and 3 icons that corresponded to these modifiers (Figure 2).

Procedure

13 neurologically healthy participants received training on two consecutive days. On day 1, participants heard a speaker produce one of 6 nouns and selected the corresponding shape in a visual display. Participants first completed a 2-shape alternative forced choice task followed by a 4-shape alternative forced choice task. Also on day 1, participants heard a speaker produce one of 3 modifiers and observed a hexagon rotating, displaying a face, or changing color. At the top

of the screen, 3 icons corresponding to the modifiers appeared. Upon clicking on an icon, the incorrect icons disappeared, and the correct icon along with the hexagon undergoing the appropriate modification remained on the screen. In all tasks, the name corresponding to the correct lexical item was repeated to provide feedback.

In the final phase of day 1, each noun was assigned a probabilistic contingency that determined how often a specific modification could be applied to a given noun (Table 2). The auditory stimulus consisted of a modifier-noun phrase, while the visual stimuli consisted of 4 shapes centered on the screen and 3 modifier icons arranged in a row above the shapes (Figure 3). The shapes corresponded to a correct item, or target (ie, /pibuka/), a cohort competitor (differing only in the last syllable) (ie, pibuta), and two unrelated cohorts, or distracters (ie, /kugati/ and /kugapi/). Participants first clicked on the shape and then on the modifier icon which corresponded to the phrase they heard, leaving the correct shape and icon on the screen. Participants then heard the speaker repeat the correct phrase. This final phase was repeated in day 2 and followed by an eye-tracked testing phase. The test was very similar to the final test phase; however, feedback was not provided. The test consisted of four conditions based on the probabilities learned in the training phases: target-biased, competitor-biased, distractor-biased, and control (Table 3).

Results

The proportion of fixations to each of the four objects on the screen (target, competitor, distracter 1, and distracter 2) was performed for each condition. To analyze anticipatory effects, analyses were confined to the intervals of -1000ms-0ms and 0ms-600ms (relative to noun onset). These intervals were chosen because the modifier onset occurred about 978ms before noun onset and noun disambiguation onset (the onset of the final syllable) occurred at about 483ms.

Paired samples t-tests comparing proportion of fixations of each of the four items to each other yielded no significant effects in either of the intervals of interests in any of the four conditions (target-biased, competitor-biased, distracter-biased, and control) (see Figures 4-7).

Fixations to the target after noun disambiguation across conditions were compared to assess whether any delayed effects of condition were observed (see Figure 8). Fixations in the 1000ms-2000ms time interval were analyzed with paired-samples t-tests that compared target fixations across all possible pairs of conditions. A comparison of target fixations of the target-biased and distractor-biased conditions yielded a significant result, $t(1, 12)=2.749$, $p<.05$, with a higher fixation proportion in the target-biased condition.

Discussion/limitations

The lack of anticipatory looks does not negate the possibility that people were using probabilistic information when completing the eye-tracking portion of the experiment. The high proportions of fixations to items other than the shapes in each of the four conditions (indicated by the black line in Figures 4-7) are evidence that a methodological issue prevented these effects. It is very likely that participants were fixating on the modifier icons at the top of the screen while the modifier word was presented and only began to look at the shapes at the onset of the noun. Had the modifier icons disappeared as the first word (the modifier) was presented and reappeared only after the auditory stimuli were presented, it is reasonable to predict that participants would make anticipatory looks based on the probabilistic information which they learned during the training phases.

A comparison of target fixation proportions in the target-biased and distracter biased conditions immediately after noun offset demonstrated a significant result which could be interpreted as delayed effects of the integration of probabilistic information that would have been immediate had the methodological issue been fixed. Because the difference in target probability relative to the modifier was strongest between these two conditions, we would expect the effect of probabilistic learning to be the strongest, meaning that the difference in fixations between targets should be the greatest. Because a significant difference is still observed between these two conditions a second after the offset of the noun, it is reasonable to conclude that we can expect to observe anticipatory looks if the set-up of the experimental display is altered.

After methodological issues regarding timing have been resolved, future research can be directed toward understanding effects of probabilistic contingencies on lexical processing mechanisms in persons with aphasia.

References

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Table 1

The Lexicon

Object Words	Modifier Words
/pibʊka/ /pibʊta/ /tadʊki/ /tadʊpi/ /kʊgati/ /kʊgapi/	/ʃʊbat/ /babʊt/ /tigat/

Table 2

Modifier	Associative Probability
Babut	'pibʊka' (18.75%)/'pibʊta,'(75%); 'kʊgati'(3.125%)/'kʊgapi'(3.125%)
Babut	'taduki' (18.75%)/'tadupi,'(75%); 'kʊgati'(3.125%)/'kʊgapi'(3.125%)
Shubat	'pibʊta' (18.75%)/'pibʊka,'(75%); 'kʊgati'(3.125%)/'kʊgapi'(3.125%)
Shubat	'tadupi' (18.75%)/'taduki,'(75%); 'kʊgati'(3.125%)/'kʊgapi'(3.125%)
Tigat	'pibʊka' (25%)/'pibʊta,'(25%); 'kʊgati'(25%)/)/'kʊgapi'(25%)
Tigat	'taduki' (25%)/'tadupi,'(25%); 'kʊgati'(25%)/)/'kʊgapi'(25%)

Table 3

Example of Each Condition Type in the Test Phase

	Auditory Stimuli	Display
Control	/tigat/ /pibʊka/	Pibʊka (25%) Pibʊta (25%) Kʊgati (25%) Kʊgapi (25%)
Target-biased	/ʃʊbat/ /pibʊka/	Pibʊka (75%) Pibʊta (18.75%) Kʊgati (3.125%) Kʊgapi (3.125%)
Competitor-biased	/babʊt/ /pibʊka/	Pibʊka (18.75%) Pibʊta (75%) Kʊgati (3.125%) Kʊgapi (3.125%)
Distractor-biased	/ʃʊbat/ /kʊgati/	Pibʊka (75%) Pibʊta (18.75%) Kʊgati (3.125%) Kʊgapi (3.125%)

Figure 1

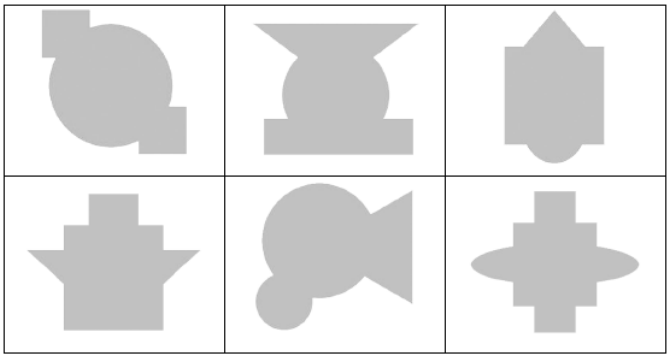


Figure 2

Figure 3

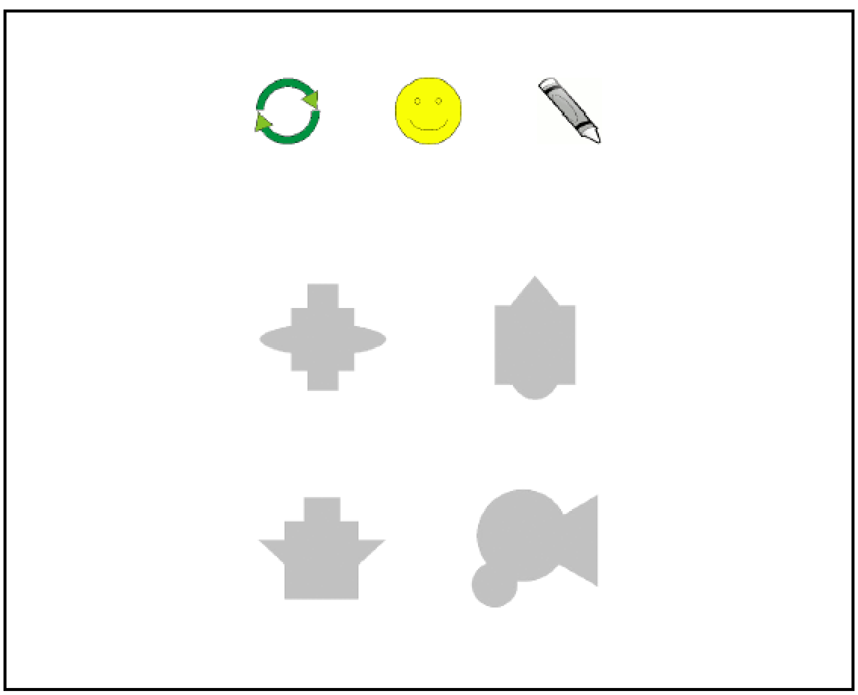
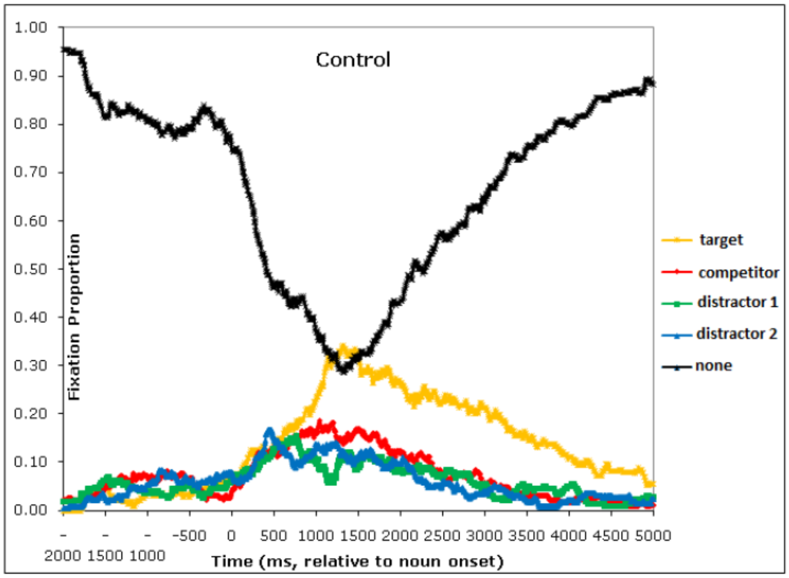


Figure 4



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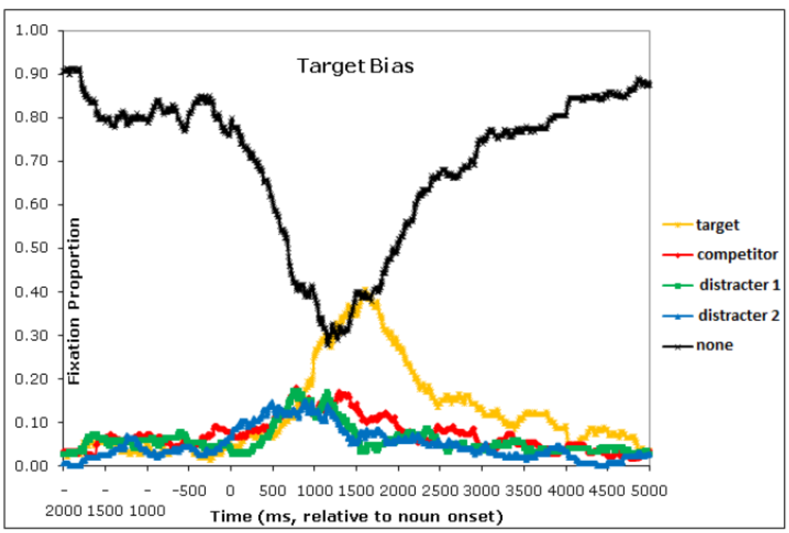

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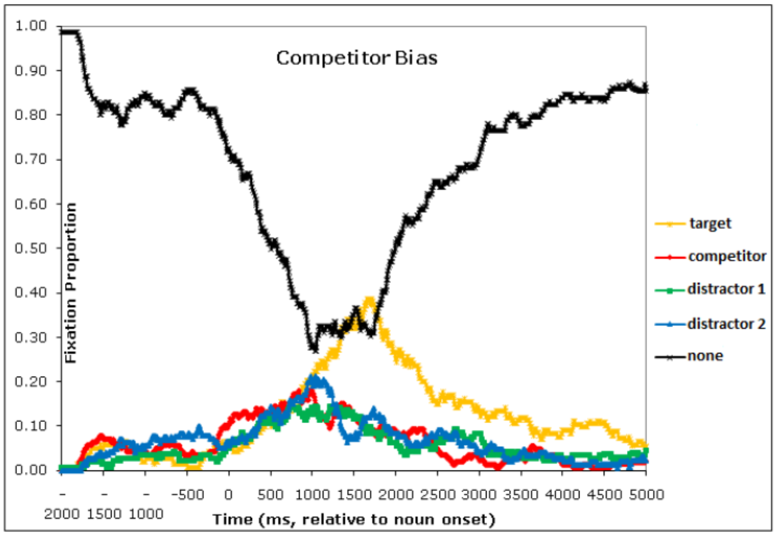


Figure 7

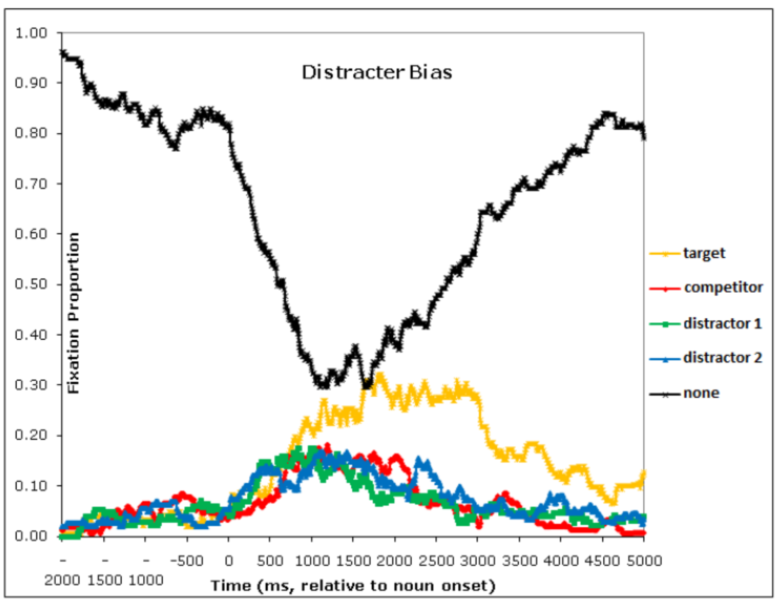
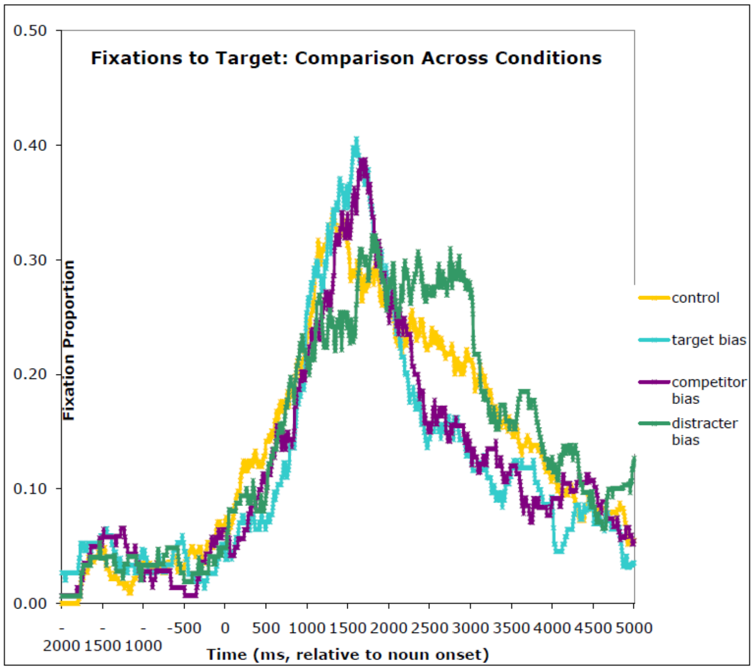


Figure 8


Fixations to Target: Comparison Across Conditions
0.50
0.40
0.30
0.20
0.10
0.00
Fixation Proportion
-2000
-1500
-1000
-500
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Time (ms, relative to noun onset)
control
target bias
competitor bias
distracter bias