Comparing Semantic and Syntactic Expectation between Verbs and Thematic Roles: Evidence from Eyetracking

Introduction

It has been shown with priming paradigms at the single word level (e.g., Edmonds & Mizrahi, 2011; Ferretti, McRae, & Hatherell, 2001) and eyetracking methods at the sentence level (e.g., Altmann & Kamide, 1999; Kamide, Scheepers, & Altmann, 2003) that a verb generates semantic expectations about an upcoming noun (McRae, Ferretti, & Amyote, 1997). In addition to semantic relationships, syntactic constraint is also involved in the expectation process (e.g., Friederici, Steinhauer, & Frisch, 1999; Gunter, Friederici, & Schriefers, 2000). Therefore, both semantic and syntactic constraints are important for fast and accurate language comprehension. However, previous studies have investigated the importance of each constraint independently and have not compared the two constraint effects. Therefore, the purpose of this study is to investigate the effects of semantic and syntactic constraint to evaluate whether one constraint plays a more important role in expectancy generation.

We presented pictures of objects representing the thematic roles of patient (a receiver of the action) and instrument (an object used to do the action) with simultaneous auditory presentation of verbs. With respect to syntax, the patient (*bathtub*) would be required after a 2-place verb (*scrubbing*), but the related instrument (*sponge*) would be optional and not syntactically required. To evaluate semantic expectation, we manipulated the degree of the semantic relationship (see Materials) of the patients and instruments as they related to the presented verb. Using eyetracking, we hypothesized that if participants looked at the patient picture regardless of how strongly the patient was semantically related to the verb, it would indicate that syntactic expectation overrides semantic expectation. Alternatively, if participants looked at the highly-related picture regardless of whether it was a patient or instrument, it would indicate that semantic expectation overrides syntactic expectation.

Materials

Sixteen 2-place verbs were included, and each verb was paired with a patient and instrument, which were semantically manipulated (highly-related/less-related), and three foil objects, which were unrelated to the verb. Semantic relationships were determined with a commonness ratings questionnaire that asked *How common is it for a(n) (patient) to be (verbed)?* or *How common is it for a(n) (instrument) to be used to (verb)?*. Highly-related patients/instruments were defined as very commonly used patients/instruments in relation to the verb (average ratings over 5.5 from commonness ratings) and less-related patients/instruments were defined as infrequently used but plausible in relation to the verb (average ratings between 2.5 and 5). The foil objects were implausible patients/instruments and not semantically related to the verb.

Each verb (e.g., *scrubbing*) was presented in three conditions: (1) with a highly-related patient, a highly-related instrument, and two unrelated objects (*bathtub-sponge-feather-flower*), (2) with a highly-related patient, an less-related instrument, and two unrelated objects (*bathtub-towel-feather-ice cream*), and (3) with a less-related patient, a highly-related instrument, and two unrelated objects (*mirror-sponge-flower-ice cream*). In total, forty-eight experimental trials and ninety-six foil trials were included.

The verb stimuli in present progressive form were recorded by a female native English

speaker. Line-drawings for objects were chosen and matched size for visual complexity. Four pictures were displayed in a 2 by 2 table in each trial (each box was approximately 11x14 inches). The distribution of pictures in each quarter of the table was counter-balanced across trials.

Participants and Procedures

Forty-three healthy young adults participated in the study. The participant was seated in front of a 46" computer monitor. The SMI RED eyetracker was located between the monitor and participants. After a calibration process, participants were instructed to sit relatively still and read the instructions, which informed them that they would hear a verb and see pictures on the screen and that they were allowed to look at anything. They were also told that after the pictures disappeared they would be randomly given a yes/no question about the verb they just heard. During each trial, an auditory verb stimulus was simultaneously presented with four pictures which remained for 3 seconds. The random questions were foils to keep participants paying attention to the experiment, and the questions only appeared after foil trials.

Statistical Analysis and Results

Each box of four pictures was designated as an area of interest (AOI). The first fixation after verb presentation and the total fixation time during picture presentation were calculated to compare each AOI across conditions. For the first fixation analysis, we calculated a verb presentation time using the Goldwave sound wave program. Then we calculated how many participants initially looked at each AOI after the verb presentation and calculated the percentage by item. For the total time analysis, we calculated the percentage of the total fixation time during picture presentation in each AOI by item. A Repeated-measure ANOVA with Bonferroni post-hoc tests was conducted for both analyses.

For the first fixation analysis, we found no main effect of condition [$F(2, 14)=.789$, $p>.05$], but we did find a main effect of object type [$F(3, 13)=9.211$, $p<.01$] and a significant interaction [$F(6, 10)=4.350$, $p<.05$]. The significant differences between patients and instruments were found in condition 2 (verbs with highly-related patients and less-related instruments) (see Figure 1).

From the total time analysis, we did not find a main effect of condition [$F(2,14)=.961$, $p>.05$], but we did find a main effect of object type [$F(3,13)=57.39$, $p<.001$] and a significant interaction [$F(6,10)=33.017$, $p<.001$]. Bonferroni post-hoc tests showed that in condition 1 (verbs with highly-related patients and highly-related instruments), the patient and instrument pictures were statistically the same. In condition 2 (verbs with highly-related patients and less-related instruments), the patient pictures were looked at significantly longer than the instrument pictures. In condition 3 (verbs with less-related patients and highly-related instruments), the instruments were looked at significantly longer than the patient pictures (see Figure 2).

Discussion

The current study investigated whether semantic or syntactic constraint plays a more important role in the expectancy generation process. Using eyetracking we found that participants looked at the highly-related objects earlier and/or longer regardless of syntactic constraint (conditions 2 and 3), which suggests that semantic expectation may override syntactic expectation at a single word level. Interestingly, in condition 1 with highly-related patients and instruments, participants looked at instruments earlier and longer than patients (though this trend was not significant). A priori we hypothesized that patients would be looked at more than

instruments in this condition, because patients fulfilled both semantic and syntactic constraints. This preliminary finding may imply that a verb is semantically closer with a highly-related instrument than with a highly-related patient, because a critical semantic feature (function) of an instrument (*sponge*) is described with a verb (*scrubbing*) whereas a verb (*scrubbing*) is not a critical semantic feature of a patient (*bathtub*), and a patient is easily substituted by other related patients. Findings from Park & Edmonds (2012) support this possibility. In a primed noun naming paradigm they reported an interference trend from a verb prime to patient naming but a facilitation trend from a verb to instrument naming. They explained these trends with the lexical competition theory, where a verb generates fewer competitors during instrument naming.

Our next goal is to implement this experiment to persons with Wernicke's and Broca's aphasia, who have shown semantic (e.g., Jefferies & Lambon Ralph, 2006) and syntactic (e.g., Caramazza, et al., 1981) difficulties respectively, to investigate how semantic and syntactic constraint may differently affect each type of aphasia.

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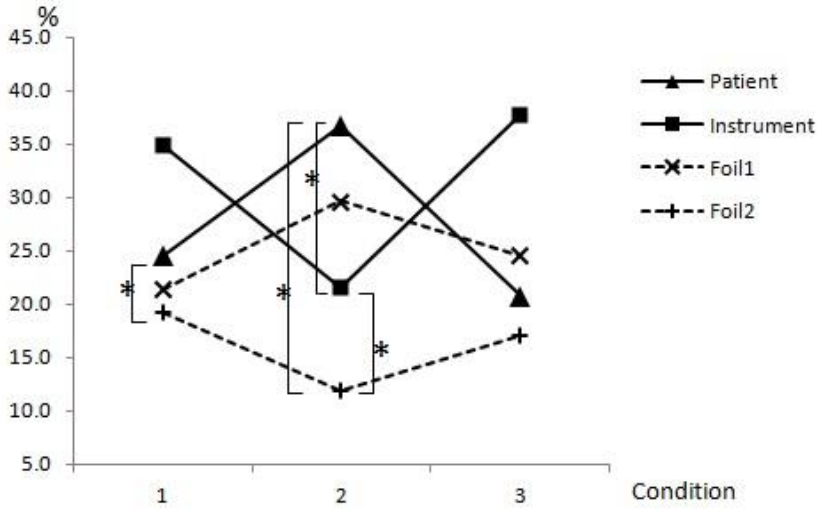

Figure 1. The percentage of the number of the first fixation in each object in each condition. Condition 1 includes a verb with a common patient and common instrument; Condition 2 includes a verb with a common patient and uncommon instrument; Condition 3 includes a verb with an uncommon patient and common instrument.

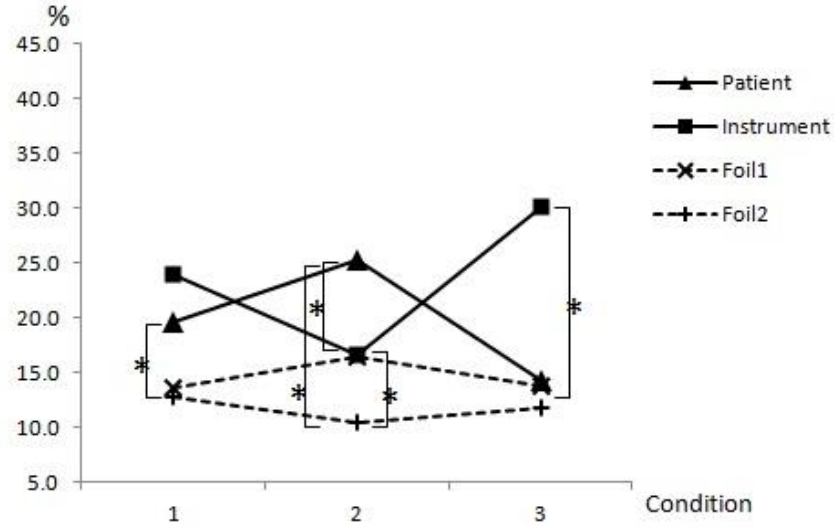

Figure 2. The percentage of the total fixation time in each object in each condition. Condition 1 includes a verb with a common patient and common instrument; Condition 2 includes a verb with a common patient and uncommon instrument; Condition 3 includes a verb with an uncommon patient and common instrument.