

On the derivation of Hebrew double objects – a functional imaging investigation

This paper presents an investigation of the double object construction through functional brain imaging. We begin by showing that a set of brain areas – Broca's region in left frontal cortex, and superior temporal regions on both sides of the brain – indicate a higher fMRI signal when healthy subjects analyze constructions that involve movement. This effect is not only localized, but also very robust: It generalizes across tasks (comprehension and grammaticality judgment) and across three different contrasts tested in Hebrew: (1) Object-gap relatives vs. embedded CPs (1a against 1b)(Ben-Shachar *et al.*, submitted), (2) Embedded wh-questions vs. yes/no questions (2a,b against 2c), (3) Object topicalized vs. non-topicalized main clauses (3a,b against 3c,d; see below). All contrasts activate overlapping regions. These results, obtained from normal speakers, are compatible with past PET findings (Stromswold *et al.*, 1996; Caplan *et al.*, 1999) that have documented that object extraction activates Broca's region more than subject extraction; they also agree with lesion data, demonstrating movement-specific receptive difficulties in aphasia, captured by the Trace-Deletion Hypothesis (Grodzinsky, 2000). fMRI activation can thus be used as a neural index for the existence of syntactic movement.

As a next step, we used this index as a tool for examining Hebrew double objects. The linguistic literature (e.g., Larson, 1988; Aoun and Li, 1988) raises two main questions regarding this construction:

(I) What type of movement (if any) is involved?

(II) Which complement order (dative or double object) is base generated and which is derived?

We tried to answer these questions by constructing an activation map for the functional anatomy of movement types. We conducted an fMRI experiment that compared datives and double objects (3c-d) on the one hand, and their topicalized counterparts (3a-b) on the other hand. Regarding question (I), an activation-by-region interaction between the dative-shift contrast (3c-d) and the topicalization contrast (3a-b) would imply two distinct operations, while anatomical overlap in activation would suggest that a similar process is invoked in both cases. As to question (II), following the same logic as in our wh-movement experiments, the relative intensity of the signal in (3c-d) should indicate which is the derived order. Our study thus utilized 2 types of empirical argument: the anatomical locus of the fMRI signal as reflecting uniformity or distinctness of operations (topicalization vs. dative shift), and the relative intensity of the fMRI signal within an anatomical region as reflecting more mental computation (double object vs. dative).

Constructing the test was complicated: It has been claimed that Hebrew dative complements, though superficially similar to locative and directional PPs, are markedly different from them, and actually possess certain properties of NPs (Borer and Grodzinsky, 1986; Botwinik-Rotem, unpublished). We therefore eliminated from our set of stimuli verbs that take locative or directional PPs, or are ambiguous in this respect. To this end, we used a selection procedure that was guided by three tests: A. Substitution with a pronoun is allowed only in dative *le*-phrases; B. Substitution with the preposition *'el* is allowed only in locative *le*-phrases (Landau, 1994); C. Modification by a collective modifier is allowed only in conjoined dative phrases (Landau, 1994).

Twelve healthy adult native Hebrew speakers listened to 44 sentences while fMRI acquisition took place. 14 axial functional and anatomical MRI images were obtained by a 1.5 T GE scanner. Comprehension questions were randomly interleaved in the experimental sequence, forcing the subjects to maintain continuous attention to the sentences, and monitoring their performance.

The results show topicalization-related activations in left Broca's region, as well as in bilateral superior temporal cortices. These regions overlap those activated by other instances of wh-movement (wh-questions and object relatives). The dative shift contrast yielded a different spatial pattern: it yielded significant activation in two right frontal regions, but not in any of the topicalization-related regions. The difference in activation maps between dative shift and topicalization suggests that dative-shift involves a different type of movement than the one involved in topicalization. Finally, the two right frontal regions that were sensitive to the dative-shift contrast showed significantly higher activation for double objects than for datives. These results suggest that Hebrew double objects are more demanding than datives (in the spirit of Belletti & Shlonsky, 1995), and provide an indication of their derived nature.

(1)

- a. 'azarti la-yalda Se-Rina pagSa ba-gina
I-helped to-the-girl that-Rina met in-the-garden
b. 'amarti le-Rina Se-ha-yalda yaSna ba-gina
I-told to-Rina that-the-girl slept in-the-garden

(2)

- a. ha-mit'agref Sa'al 'eize pras ha-'atlet ha-mexubad kibel ba-tekes
The-boxer asked which prize the-athlete the-distinguished received in-the-ceremony
b. ha-mit'agref Sa'al 'eize 'atlet kibel pras mexubad ba-tekes
The-boxer asked which athlete received prize distinguished in-the-ceremony
c. ha-mit'agref Sa'al 'im ha-'atlet kibel pras mexubad ba-tekes
The boxer asked if the-athlete received prize distinguished in-the-ceremony

(3)

- a. 'et ha-sefer ha-'adom Dani natan la-professor me-Oxford
Acc the-book the-red Dani gave to-the-professor from-Oxford
b. la-professor me-Oxford Dani natan 'et ha-sefer ha-'adom
To-the-professor from-Oxford Dani gave Acc the-book the-red
c. Dani natan 'et ha-sefer ha-'adom la-professor me-Oxford
Dani gave Acc the-book the-red to-the-professor from-Oxford
d. Dani natan la-professor me-Oxford 'et ha-sefer ha-'adom
Dani gave to-the-professor from-Oxford Acc the-book the-red

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