# Functional MRI study of visual processing of affirmative and negative sentences

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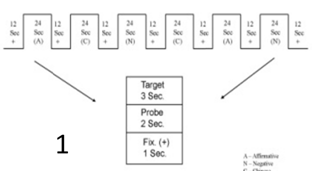
**Abstract:**
Functional Magnetic Resonance Imaging technique has been employed to study the expression and interpretation of negation in Hindi language. Hindi is subject-object-verb (SOV) language and has a long tradition of grammar and literature. To account the effect of semantic and syntactic features on neural network the study was undertaken where native Hindi reader performed the sentence judgment task (target-Probe) in affirmative and negative sentences. The result shows involvement of common as well as distinct regions for affirmative and negative sentences.

**Introduction:**
Sentential negation is universal in all human language and behavioral studies indicate that negative sentences are more difficult to process than affirmative, resulting in increased reading time and errors **[1, 2]**. Different explanations have been reported in the literature regarding the processing of negation; they include aspects of sentence length, as well grammatical form of negation. Using fMRI tools processing of affirmative and negative sentence were explored by few studies **[3]**; reported higher activity in the left posterior temporal and bilateral parietal brain regions for the negative compared to affirmative sentences. Hasegawa *et. al.* **[4]** used target and probe matching task in Japanese (first language, L1) and English (second language, L2). A significant effect for negative sentences was noticed in the left temporal and left precentral gyrus but only for the more demanding L2 condition. In the present study we aim to investigate the processing of negation in Hindi language. The native Hindi reader performs the sentence judgment task (Target and Probe) in Hindi. Language topologists classify Hindi as an SOV language. English uses position to code crucial information of the relation between the words in a sentence. So when one says English is an SVO language, one is asserting a fact about the encoding of grammatical relations, viz. subject and object, in English. The position immediately preceding a verb marks the subject and the one immediately following marks an object. On the other hand, Hindi is a relatively free word order language.

**Materials and Method:** Fourteen native Hindi speaking subjects (5 female, mean age = 28.3 years, SD=3.2) participated in the study. All participants had normal vision acuity with no history of neurological disease. Informed consent was taken from each participant approved by the Center of Biomedical Magnetic Resonance Institutional Human Ethics Committee. The entire stimulus set consisted of 48 target- probe pairs with 24 negative and 24 positive targets and probes. All the target sentences were bi-clausal and had similar structure, namely main clause followed by subordinate clause. The probes were kept related to it in order to ensure that participant is fully competent to comprehend the sentences. The experimental task **(fig: 1)** was a probe-to-target matching task previously used by Hasegawaet al. (2002). Each session lasted for 236 seconds and consisted of two task blocks (Affirmative, Negative and Chinese) with a fixation crosshair (12 seconds) followed. Chinese was used as a control condition; none of the participants had been exposed to the Chinese language/character. Data were collected on a 3 T Siemens Magnetom Skyra scanner at the Center of Biomedical Magnetic Resonance. T2*-weighted functional images were acquired using a gradient-echo EPI sequence (TR=2000 ms, TE=30 ms, flip angle=77°, 33 oblique plane slices, FOV = 224x224, image matrix = 64x64). A three-dimensional $T_1$-weighted image using the magnetization-prepared rapid gradient-echo (MPRAGE) sequence was also collected (TR=1690 ms, TE=2.56 ms, flip angle=12°, matrix=224×256, 1 mm isotropic voxels, sagittal partitions). Data were analyzed with Statistical Parametric Mapping software (SPM 5; Wellcome Department of Cognitive Neurology, London, UK). The contrast maps from each participant were taken into second-level group analyses. For second-level group analyses, we employed one-sample t-test to identify brain regions significantly activated by affirmative and negative sentences. ($p < 0.001$ uncorrected, k = 10). A Conjunction analysis was performed to find common areas involved in affirmative and negative sentences.

**Results and Discussion:** Response Time were faster in the Affirmative condition than in the Negative condition and there was no significant difference in accuracy between two condition **(fig: 2)**. Neuro-imaging revel the common region **(fig: 3 (A))** involved in processing of both conditions such as LIFG, left SMA, bilateral mid temporal, left parietal and left occipital. It is noteworthy that particularly within LIFG, it is pars opercularis which is primarily considered for syntactic operation as well as interpretation of thematic role, where as pars trinagularis and pars orbitalis have more involvement towards comprehension of semantic relationship between syntactically complex sentences and also for the processing of lexico-semantic information. One of the crucial findings in this study is the activation of bilateral temporal pole for negative sentence **(fig: 3 (B))**; whereas no separate region is found specifically for affirmative sentence. **[5]** argued for a specific role of the temporal pole, based on their investigation on aphasics and they reported that this region may be involved in morpho-syntactic comprehension. Anterior temporal pole could be a possible region that is involved in semantic integration at the sentence and lexical levels.

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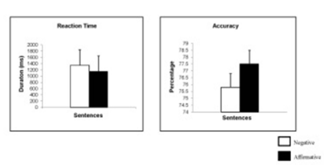


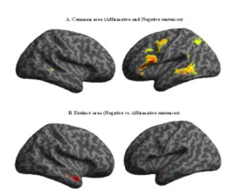

***Figure 1***. Schematic of the paradigm design. ***Figure 2.*** (A) Reaction time for reading English and Hindi words. Panel shows reaction time for the target-probe judgment task for Affirmative and Negative sentence .The mean Reaction time for Negative (mean=1345.57, SD=490.60) was higher than Affirmative (mean= 1149.60, SD=428.61).***Figure 3:*** fMRI activation pattern rendered on a standard brain conforming to stereotactic space showing a semantic effect in Affirmative and Negative sentences thresholded at uncorrected $P < 0.001$ with spatial extent k = 20 voxels. (A) Result of conjunction analysis showing common area for Affirmative and Negative sentences indexed to baseline condition (Chinese). (B) Brain activation map of direct comparison between Negative Vs Positive sentences.

**Reference:** **[1]** Carpenter *et al.*, Psychological Review, (1975), 82(1):45-73. **[2]** Clark HH *et.al*, Cognitive Psychology, (1972) 3(3): 472-517. **[3]** Carpenter *et.al*, Neuroimage (1999), 10(2):216-224. **[4]** Hasegawa M *et al*. Neuroimage (2002) 15(3):647-660. **[5]** Dronkers NF *et al.* Brain and Language (1994) 47(3):461–462.