Implicit and Explicit Knowledge in Artificial Grammar Learning: An fMRI Study

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Implicit learning encompasses a variety of heterogeneous tasks involving learning of complex relational information without the use of conscious hypothesis testing strategies and without accompanying verbalizable knowledge sufficient to account for test performance (Seger, 1994). In the artificial grammar learning task, participants first study a set of letter strings formed according to an artificial grammar, then are shown novel strings and decide for ach one whether it is grammatical or not. The first questic we asked was whether retrieval of implicit and explicit knowledge are reliant on different neural substrates. Knowlton and Squire (1996) found that artificial grammar learning is preserved in patients with amnesia, who have damage to the hippocampal and diencephalic brain systems and who are impaired on explicit memory tasks. The second question we asked was how does changing the surface features of stimuli affect the neural systems recruited for grammatical judgment making. Several experiments have shown that participants, including amnesic patients, can transfer grammar knowledge to strings in which the underlying grammar is the same but the letters used to instantiate them have been changed, though it is unclear what knowledge underlies transfer (Knowlton & Squire, 1996; Redington & Chater, 1996; Seger, 1994).

Ten right-handed volunteers participated. 6 in the implicit group, and 4 in the explicit group. Imaging was performed with a 1.5T whole-body MRI scanner. A small head coil was used for signal reception; head movement was minimized using a bite bar. A T2* sensitive gradient 3D echo spiral sequence, was used for functional imaging with parameters of TR = 1080 msec, TE = 40 msec, and flip angle = 22 degrees. Four interleaves were obtained for each image with an acquisition time (sampling interval) of 4.32 sec per image. Sixteen 4-mm thick slices were acquired in the horizontal plane of the Talairach and Tournoux atlas (1988) starting from 12 mm below the anterior-commisure (AC) posterior commisure (PC) line, with a 0 mm inter-slice interval.

Participants performed the learning task (observation of grammatical strings) while structural images were being taken. The implicit group then performed two functional scans In both, they viewed novel strings and alternated the judgment made about each string: either grammaticality (does the string followed the same rules as the strings studied in the learning phase?) or perceptual judgment, (Is there a TT in the string?). In the first scan (same letters), the strings were formed using the same letter set as the strings in the learning task. In the second scan (transfer) the strings were formed using a different letter set, and the perceptual baseline task was to decide whether there was a DD in the string. The explicit group performed one scan in which they alternated recognition judgments with perceptual judgment Half of the strings were repeated from the learning phase, and half were novel grammatical strings.

In all three scans, activation was seen in bilateral posterior parietal areas and bilateral fusiform gyri. Two main differences were found between implicit scans and the explicit scan. First, the right middle frontal gyrus was only active in the explicit condition. Second, overall activation in the implicit condition was left lateralized, whereas activation in the explicit condition was right lateralized. Right lateralized activations in the explicit condition are consistent with other brain imaging studies of recognition, and implicit left-lateralization is consistent with the role of the left hemisphere in processing categorical relationships.

Similar areas were active in both same letter and transfer implicit scans: posterior parietal, supramarginal gyrus, bilateral premotor, left inferior frontal, left middle frontal, and fusiform gyri Letter set transfer affected the relative amounts of activation in these areas: higher order visual areas such as the fusiform gyri were relatively less active after letter set transfer, whereas frontal and parietal areas were relatively more active after letter set transfer. This is consistent with subjects devoting less attention to visual aspects of the strings in the transfer condition.

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