Review Article

Mental Imagery of Representation beyond the Equivalence of Perception by Emphasizing Methods FMRI

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Abstract

Introduction: Knowledge representation includes different methods through which our mind creates mental structures, the representation of what we know about the world out of our mind. In mental imagery, we create similar mental structures which represent the things which our sensory organs haven't sensed. Some studies relating to the blind subjects and some applied studies on rehabilitation have highlighted the importance of mental imagery for the cognitive psychologists. Aim of this study is to investigate the mental imagery with FMRI studies on neural structures in common tasks with the normal consciousness range for comparison of neural functional equivalence beyond the neural perception level.

Methods and Material: The research was conducted with key words of mental imagery, representation, FMRI in pubmed, google Scholar and Science direct databases and SID database, without time limitation and in both Persian and English languages.

Results: 70 original research papers were obtained among which 5 papers were reviewed finally after the evaluation of scientific validity for responding to the research questions. Analysis of the final papers showed that knowledge representation through mental imagery was beyond the perceptional neural functional equivalent.

Discussion and conclusion: Common neural bases can be searched by designing specific tests in different consciousness levels such as hypnotism, mental imagery, and normal awareness and with FMRI expanding functions.

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Introduction

Mental imagery is the mental representation of the objects which are not sensed at that time with sensory organs (1,2). Based on the dual-code theory, we used visual and verbal codes to present information. Paivio used the experimental evidence about difference in verbal information processing and imaginary information in speed of reminder and speed of sequence of reminding photos shown to the subjects and with this argument, mental imagery representation can be called with two visual and verbal dual-called codes (3,4). Analogue codes are one of the major characteristics of physical stimuli observed in the environment and symbol of codes is a type of representation which has been selected to represent a thing which is used in mental imagery.

Mental imagery is not saved based on propositional theory of mental representation as images and word but it is regarded as abstract forms of a proposition and images are the epiphenomenon resulted from other cognitive processes (5-8). In Gestalt imagination experience, semantic titles are effective on mental imagery. In this attitude, neural foundations of sense and perception have been underestimated.

Based on attitude of the neural foundations of sense and perception in physical perception based on functional equivalence hypothesis, mental imagery is functionally equivalent to visual perception (9). Mental imagery similar to movements, spatial relations (10), construction of image in scale (11,12) and image scanning (13,14), adapts among the objects and physical perceptions. So, there is direct a relationship between rotation angle and the time of reaction in the mental rotation of three-dimensional shapes (15-17). Similar areas of brain are activated for mental interference in an image and physical interference in an object. With Functional magnetic resonance imaging FMRI, the areas of brain interfering in perception are also involved in mental rotation task (18,19). Studies on the monkeys are the same (20). Perceptional experience doesn't always respond to mental imagery because tasks of the map scanning with location characteristics were performed in people who were born blind and didn't have any experience in visual perception. Although they responded more slowly than the normal subjects, they used similar pattern (21,22). In audio imagery, the pattern was similar but it was slower than the normal subject (23,24). Perhaps, the use of mental patterns cannot explain the cases which cannot be explained completely as visual imagery.

In mental pattern theory, mental representation includes three propositions the word, the expressible language, image, the physical perception, and mental patterns, the structure of knowledge that people make to understand and explain the experiences (25, 26).

In mental patterns model, no attention has been paid to mental imagery in future, learning and activity though the previous beliefs and knowledge can be explained in this model. In dual model of mental imageries, one cannot explain that person is creative or adds to his beliefs or perceptional images have been underestimated in the propositional model. In functional equivalent model, sense and perception have been considered as a visual recognition but less attention has been paid to representation, creative image, memory, and learning because human is able to imagine what he has not perceived.

According to perceptional theory of Kosslyn, there are many similarities between perception and visual imagery. The important point is that the Birdman's primary visual cortex (areas 17-18) is active during visual imagery. Intracranial magnetic stimulation of visual cortex disrupts the first visual imagery but the presence of discontinuities between perception and imagery is one of the problems raised from theory of Kosslyn. Although the primary visual cortex has a neural equivalent functional role in mental imagery (27) but we think that neural active equivalent brain areas are beyond perception. In our proposed model, neural functional equivalence of consciousness level is raised and mental imagery as one of the consciousness level includes activity of the similar areas of brain which occurs in sense, perception and coding, storage and representation of reaction occuring in normal consciousness level which can be common with neural activity. But a systematic review was done on mental imagery beyond the perception confirmed with FMRI to compare engagement range of brain activity with common task, given that mental imagery is beyond perception with emphasis on Functional magnetic resonance imaging FMRI method.

FMRI is an indirect neuroimaging method. In this study, radio waves are used to move the atoms in the brain. Magnetic changes produced by a magnet around patients are registered with the use of computers and accurate interpretation of the three - dimensional images become when an area of the brain has active blood flow and oxygen increases to the area. A change in the oxygen level changes magnetic properties of blood flow. Of the benefits of FMRI is to study both the structure and the performance of brain (28).

Methods

This study was conducted to explain representation mental imagery beyond the equivalence of perception by emphasizing FMRI method. We used the research framework of University of York for Reviewers and Dissemination Guidance approach (2008) (29).

At the first time, we searched to find a possible systematic review carried out with the aim of question similar research study, a search in the database which contains articles Cochran database of systemic review of the most recent systematic reviews were conducted systematic review aimed question similar study in 2015 to study abroad as well as the database's SID. We did not find systematic review with this question and aim. For implementation of the review of the literature after that defining the question, review was done on four general phases, the first stage of: Seeking to identify all relevant articles with keywords in related databases. Literature search using main keywords such as "representation"," mental imagery","FMRI"and Related keywords in multiple databases included Science direct, Pubmed, Google Scholar, and manual search in related Journals.Given the degree of access to different databases cover articles in this field, search the database in three main proprietary data base of scientific articles was made. Study inclusion criteria were published articles up to 2015 written in English language. Methodology was not a concern and every article that contained a rich description of representation mental imagery. At this stage, for better management of literature, retrieval of articles was simultaneously performed with transfer to EndNote software. Search by title, abstract in English key word without limit of time was unit 2015.The second stage of: careful study of all the articles and determine its relevance to the research question and retrieval of articles related to the purpose of this. Third stage of retrieved articles were undergone the quality assessment. Quality assessment criteria were based on study objective and relevancy, and on the basis of the

scientific credibility. Articles that met quality assessment criteria qualified for entry into next stage. Step four final extraction articles into integrative review of the literature.
Two people from research team independently performed search in resources and retrieval of articles. Agreement or otherwise on the results and relevant reasons were investigated by the team, and disagreements were reviewed and decisions were made. Extraction of textual data and categorization were also performed independently by two team members, and examined in a team meeting. The search was yielded 70 relevant and reliable published articles, Ultimately, 5 articles underwent final review, 5 articles that completely explain representation mental imagery beyond the equivalence of perception by emphasizing FMRI methods.(figure 1, table 1). It is noteworthy that we try to much more access to articles but maybe many articles were not accessible for us.

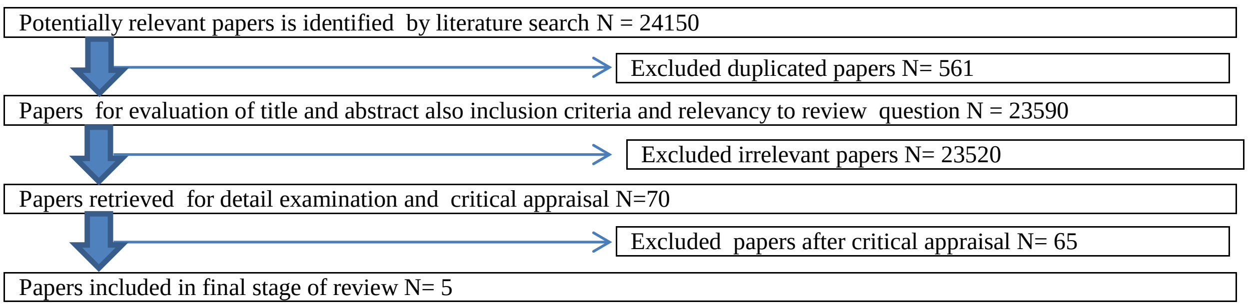

Figure 1. Search process and outcome.

Table 1. Summary of the results

Results from using functional MRI	Aim	Methods	Author
enhanced activation in the left primary somatosensory cortex, attenuated activation intensity in the right primary motor cortex, and enhanced right cerebellar activation observed during the motor imagery task using the affected right hand after mental practice training	Changes in brain activation in stroke patients after mental imagery and physical exercise	15 patients who suffered stroke with neurological deficit impairment were recruited. 10 patients underwent mental practice combined with physical practice training, and 5 patients only underwent physical practice training	Hua Liu, et al .2014
The parietal activations reported here for executed, imagined, and observed reaching are also consistent with previous functional imaging studies on planned reaching and delayed pointing movements, and extend the proposed localization of human reach-related brain areas to observation as well as imagery of reaching.	Human cortical representations for reaching: mirror neurons for execution, observation, and imagery	Hand actions of 15 healthy volunteers were examined, related to grasping, observation, and imagery hand-grasping interactions	F. Filimon ,et al.2007
Results showed may have implications for the development of novel virtual reality interactions for neurorehabilitation interventions and other applications involving training of motor tasks. Sm1and primary motor cortex observed during the motor task, and enhance dinsula and parital activation observed during the motor imagery and observation task using the affected right hand after mental practice training	Enhanced activation of motor execution networks using action observation combined with imagination of lower limb movements	The activation resulted from observation, coupled with online imagination and online imitation of a goal-directed lower limb movement using functional MRI (fMRI) in a mixed block/event-related design with 14 Healthy volunteers	Michael Villiger, et al,2013
Showed that simultaneous visual mental imagery and auditory stimulation led to an illusory translocation of auditory stimuli and was associated with increased activity in the left superior temporal sulcus (L. STS), a key site for the integration of real audiovisual stimuli.	The investigation of the neural basis of mental imagery induced by multisensory perception in humans	Mental imagery visual and auditory induced by multisensory perception were examined in 20 Healthy volunteers	Christopher C,et al 2014
During non-haptic shape recognition, blind subjects activated large portions of the ventral visual stream, including the cuneus, precuneus,	That blind subjects recruit the ventral visual stream during	Congenitally 8 volunteers blindness and10 volunteers blindfolded sighted control subjects were scanned after they had been trained during four	Maurice Ptito,et al . 2012

inferotemporal (IT), cortex, lateral occipital tactile vision area (LOtv), and fusiform gyrus.	non-haptic tactile-form recognition.	consecutive days to perform a tactile-form recognition task with the tongue display unit

Results

In study by Hua Liu, et al. (30) on effect of rehabilitation whit brain activation regions after 4 weeks of training, and explored the correlation of activation changes with functional recovery of the affected hands. The results showed that, after 4 weeks of mental practice combined with physical training, the Fugl-Meyer assessment score for the affected right hand was significantly increased than that after 4 weeks of practice training alone .Functional MRI showed enhanced activation in the left primary somatosensory cortex, attenuated activation intensity in the right primary motor cortex, and enhanced right cerebellar activation observed during the motor imagery task using the affected right hand after mental practice training

In a study by Filimon, et al. (31) on brain's mirror cells with FMRI, assuming that the brain's mirror cells play common role in observation, imitation and mental imagery, 16 right-handed people were included, in which a person was excluded due to high head movement, thus 15 people were examined. The results suggested that the mirror neuron cell is kind of hand activation performed, and that these fronto-parietal activations are a putative human homologue of the neural circuits underlying reaching in macaques.

In a study performed by Michael Villiger et al., executive motor network was activated with the methods of observation, mental imagery and lower-limb activity (32). In this research, the scenario had been designed such that the person acted online from computer through observation, mental imagery and imitation. 14 healthy volunteers among students of University of Zurich participated. The results using FMRI method showed that premotor cortex bilateral ventral parts, left intero parietal and left insula are active in the state of observation and the observation with mental imagery. The executive parts of motor in the state of observation with mental imagery and foot activity included S1, M1, left premotor part played role in awareness and attention showed activity pattern.

In an experimental research by Maurice Ptito et al., (33) the brain activity of mental imagery involved in lingual touching task was studied on born-blind people in Canada compared with the non-blind people. The test was included 10 people in control group with closed eyes and 8 born-blind people due to retinopathy with no memory of image as inclusion criteria. The studies with FMRI showed that the occipital cortex in the blind people is activated in these areas in a touching task such as Braille, and the observed activity patterns in the visual cortex were considerably higher than the non-blind people. Magnetic stimulation disrupts mental imagery in the blind people, same as the non-blind people. The active brain areas relating to dorsal visual pathway involved in visual movement and ventral temporal areas were equal in touching objects in both non-blind and blind people. This study is aimed to investigate the brain activity pathway during mental imagery in two groups. The obtained results with FMRI showed larger touch recognition in brain's parts in both born-blind people and non-blind people with closed eyes.

In a study by Christopher et al., (34) it was shown that the neural basis of mental imagery induces multisensory perception in humans. 22 healthy people were participated from students in Stockholm, without a history of mental illness or specific nervous disorder and no problem in the ear and eye. A moral consent was obtained and two sleepy people were excluded. The subjects were asked to speak on behalf of a puppet or beast with mental imagery and delusional thought to review the brain's activity with FMRI. The results showed that left lobe temporal has important role in the integration of audio-visual stimuli, so that visual mental imagery and auditory stimulation led to anillusory translocation of auditory stimuli and was associated with increased activity in the left superior temporal sulcus (L. STS), a key site for the real audiovisual stimuli.

Results are in line with our proposed model as neural functional equivalence which is beyond neural basis of perception considering the same brain activity in common tasks but in different extent of consciousness levels such as consciousness level of mental imagery, normal awareness and hypnosis.

Discussion

Mental imagery is mental representation of the objects which are not sensed with sensory organs (1,2).

Our results were obtained from comparison of the involvement extent of the equivalent neural areas performed in two levels of ordinary conscious awareness and mental imagery including systematic review on the mental imagery beyond the perception which were confirmed with FMRI. Results of previously investigated papers are in line with our proposed model as neural functional equivalence of consciousness level which is beyond neural basis of perception

considering the same brain activity in common tasks but in different extent of consciousness levels such as consciousness level of mental imagery which is below hypnosis consciousness level that is below normal consciousness level. In a clinical and applied study conducted by Hua Liu, et al., (30), the effect of rehabilitation with physical exercise and motor mental imagery was studied in the patients with brain stroke using FMRI. The mental exercise of motor imagery is a new rehabilitation method for improvement and rehabilitation. Particularly in months following brain stroke, the improvement of performance and acceleration of improvement are of the concerns. What has active role in rehabilitation is neurogenesis and reorganization of brain. In this research, new and economical intervention of motor mental imagery training had been used. In this study 15 right-handed people with brain stroke were included, 10 people were under physical education with mental exercise of motor imagery and 5 people were only under physical education for 4 weeks. The physical education intervention was performed by physiotherapist and the interventions relating to the motor mental imagery included the same movements as prerecorded instructions which a person imagines with closed eyes. Physical movements were first performed and after 5 minutes of rest, imagery was done during which the brain activity was studied with FMRI. The results of physical exercise with motor mental imagery compared to the group which only had physical exercise for the right hand after 4 weeks showed an increase in the activity in FMRI images in the SM1 left motor sensor and right cerebellum during the mental exercise and it generally led to an improvement in the performance of right hand. (see Figure2).
Results of this research showed that the mental imagery exercise is important for rehabilitation in people with brain stroke after neurological damage of right hand as a nonaggressive strategy and the rehabilitation shows brain activity beyond perception level i.e. in memory level, coding (learning), retrieval (recall and recognition), language and rehabilitation motor activity which are processed in high brain levels. Cohen hypothesizes that memory is practical, and motor activity is nonstrategic and verbal memory is strategic. In learning, practical memory provides optimal form of encoding which doesn't improve with strategies (35) while Nilsson mentions that encoding of practical memory is both strategic and nonstrategic and automatic and several sensory canals are involved (36).

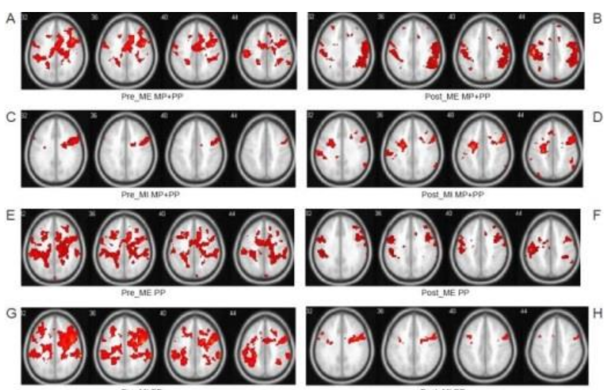

Figure ۲ brain FMRI. Hua Liu, et al. 2014

Engel Kamp predicts a separate motor program plus verbal and visual program in encoding (37). kormi-nouri has suggested that there is a episodic memory in practical memory with which person records the information in brain considering his goals and the time and space of occurrence. All of the cases which indicate the brain activity beyond the perception in the mental imagery show a better encoding considering the effect on the memory. In other studies, the effect of mental imagery on rehabilitation and better performance of the brain has been specified with studies relating to FMRI (39-43). This indicates that the brain performance in the mental imagery is beyond the equivalent only in the perception level which is in line with our suggestion and hypothesis.
The space perception through visual and motor measurements is regarded as a key part in space perception. Brain's mirror cells are a scale for the visual and the motor representation. Researchers trained the monkeys to move physically a cluster toward bright by immobilizing a unit of cells in the motor cortex of monkeys. Then in the absence of the cluster, with the observation of the bright target, the cells of cortex tended to respond as if the monkeys predict the rotation along with special sites of the bright target. In the study by Filimon, et al., (31) on the brain's mirror cells with FMRI, given that the brain's mirror cells play a common role in observation, imitation of activity and mental imagery, 16 right-handed people with a healthy vision were participated in the study after receiving informed consent and one of them was excluded from the study due to frequent head movements. These people received a video clip which showed 5 different forms and only showed a forearm which grasped the objects. 4-second display was considered for each object. The brain images were taken from participants in a state of real action for reaching a charade object and passive observation of objects with video clip and mental image of reaching object with FMRI. The results showed

that the brain's activity in dorsal premotor , superioparietal , sulcus interoparietal and special mirror cells were active in frontoparietal and broca and pulmonary areas in all three states (see Figure3). Overlapping of the active areas in the brain and the activation of brain's mirror cells in three states of activity, observation and mental imagery with a common task indicate the equivalence of neural functional beyond perception in all levels of the brain which occurs in conscious state, in the different involvement extent of the active areas in the brain depending on normal consciousness level or mental imagery. In this study, overlapping of the active areas in the brain is comparable with larger extent in the state of practical imitation and then passive observation and mental imagery. In other studies, the performance of mental imagery and representation and mirror neural system with neural basis has been specified in frontoparietal with FMRI method (44,45,46,47,48).

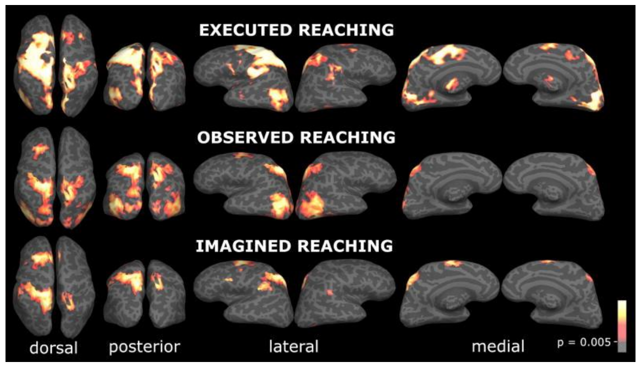

Figure 3 . brain FMRI Filimon ,et al.2007.

Perhaps, this is one of the reasons for better effects due to the activity along with observation which indicates the brain's activity in a level beyond perception in mental imagery which is in line with our study.
A study by Michael Villiger, et al., (32) et al., was performed with the aim of activating the executive motor network with the methods of observation, mental imagery and the activity of lower limb. In this research, scenario had been designed such that the person acted observation, mental imagery and imitation online through computer. 14 healthy volunteers among students of University of Zurich were asked to watch a video clip in which a person was in his feet on the floor and then kicked at a ball with his right foot. The persons were asked to be in three positions of only observation - observation and mental imagery - and start to move the feet as how they saw in the film. FMRI images were taken from the participants before and during the meeting. A sand bag had been used to limit foot at the time of imagination, and EMG had been used to check the absence of activity of the foot muscles. Results of this research showed that premotor cortex bilateral ventral parts, left interoparietal left insula were activated in state of observation and observation with mental imagery. In state of observation with mental imagery and performance of activity and foot movement, executive parts of motor including S1, M1, left premotor part played role in awareness and attention. Results of this research show positive consequences of mental imagery, observation and physical activity for the interventions of neural rehabilitation and its applications (see Figure4). In learning process, mirror neural cells are activated in brain through observation so that the person doesn’t perform activity when neural centers are activated in brain, like a person who is performing the same activity. The mirror neural cells have been located in insula. In this research, the insula has been activated in learning through observation and mental imagery. In all three conditions of observation, imagination and imitation, executive motor centers have been activated. These results show that encoding and learning, storage, retrieval and remembering have been done in memory levels. This shows that mental imagery acts beyond perception in the brain by activating mirror cells and motor centers. In other studies, the role of motor mental imagery has been specified with neural bases (49,50). All of the mentioned activities are processed in high brain levels and are beyond perception level.

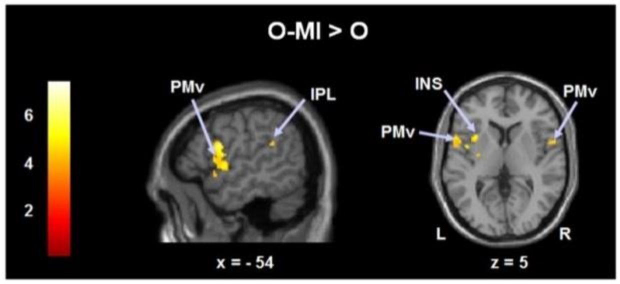

Figure 4. brain FMRI Michael Villiger, et al, 2013

In the experimental study conducted by Maurice Ptito et al,. (33) to study the brain activity of the mental imagery involved in lingual touching task in the born-blind people in Canada compared with the non-blind people, 10 persons were included in the control group with closed eyes and 8 born-blind people were included in the study due to retinopathy who had no memory of image as inclusion criteria. The people were trained during 10 sessions for 15 min with four rectangular, square, triangular and letter E shapes with language touch electrode and with laptop matrix. The people were asked to have mental imagery of the images which they had learnt though language touches while brain activity of two groups was studied with FMRI. Results of this study showed that larger parts of the brain's activity were involved in the people who were born blind in language touch form pathway compared with the people with closed eyes. Representation of the mental imagery of the people with closed eyes with neural functional equivalent basis in visual cortex areas was less dispersed than the people who were born blind in terms of the extent of brain's activity. Hearing and touching senses were more developed in the blind people than the non-blind people. Studies with FMRI show that occipital cortex in the blind people is activated in the non-blind people when the touching tasks such as Braille or the work are performed by the tester and the observed activity patterns in the visual cortex were considerably higher than the non-blind people (see Figure5). Like the non-blind people, the blind people with TMS had disrupted mental imagery. Active brain areas relating to visual pathway involved in visual movement and ventral temporal areas were equal in touching the objects in non-blind people and blind people. It was shown in this study that there was neural functional equivalent in mental imagery considering consciousness level in the people who were born blind but the brain's activity in common task of the blind people was higher than that of the non-blind people in terms of dispersion though hearting and touching senses which are more developed in blind people, it is important to note that the people who were born blind didn’t experience perception like the blind people but they had common brain's activity areas with little difference in the extent of the neural activity compared with the non-blind people. Therefore, based on Kosslyn’s theory in which the neural functional equivalent of perception is defined as equal to the recognition in the born blind people without perceptional experience shows that the mental imagery is beyond the perception. In this study, it is shown that coding, storage, retrieval and language touching learning have been obtained following which blind people and people with closed eyes could represent what they have learnt and imagined mentally. In other studies, similar brain activities have been reported in the blind people without the previous perception and non-blind people with FMRI (51, 52). In study by kormi-nouri (53) which compared the non-blind and the blind subjects and non-blind subjects with closed eyes, it was shown that practical memory with all types of real or unreal objects or real or imaginary movement is preferred over verbal memory and there is no significant difference between the types of practical memory. In this study, there was no considerable difference in memory of the blind and non-blind subjects. It shows a type of neural functional equivalence in higher levels of perception which is in line with our suggestion and hypothesis

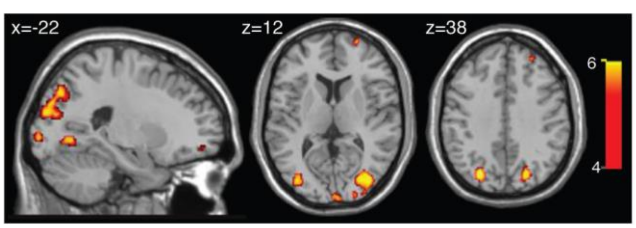

Figure 5. brain FMRI Maurice Ptito,et al . 2012

In an experimental research by Christopher C et al., (34) there are several senses for establishing communication with the surrounding world and integrated understanding of the world with FMRI to study brain activity in concurrent integration of information. 2 out of 22 healthy participants were excluded from the research due to sleepiness and the people were asked to see an image in vitro condition and imagine after a specified time and audio stimulation was done under synchronous and asynchronous conditions. The people were asked to talk instead of doll or animal at time of mental imagery with imaginative thought and brain activity was studied with FMRI during this term. Results of this research showed that left temporal lobe played an important role in the combination and the integration of audiovisual stimuli so that visual imagery and audio stimulation and creation of an audiovisual imagination showed an increase in temporal cortex. The temporal cortex had important and moderating role in the combination of audiovisual imagery for integrating our understanding of the world (see Figure6). This research shows that some audio-visual perception senses are integrated with each other to understand the world consistently. When the people are asked to talk or hear instead of doll or animal with an imaginary thought, it indicates that memory process, information coding, information storage, information retrieval, information representation, learning and activity are activated as language movement and language understanding in the brain. In other studies, integration of some senses and role of insula is shown (54,55,56).

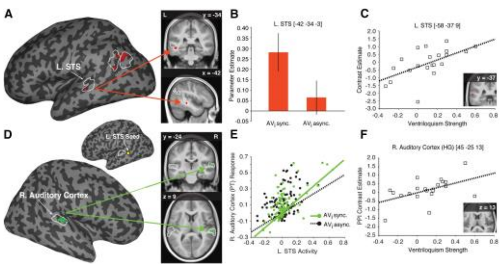

Figure 6. brain FMRI Christopher C,et al 2014

Conclusion

Functions of a mapping in the first phase in the brain include sampling from the external world through motion and attention messages and in the next phase, they include categorization of these messages withy help of reentry pathways continuously and synchronization of neuron group. In our proposed model, neural functional equivalence of the consciousness level which is beyond neural basis of perception considering the same brain activity in common tasks but in different extent of consciousness levels such as consciousness level of mental imagery, awareness and hypnosis. Study limitation: in this study, these papers were accessible to us. It is likely that there are other findings in other papers which don't confirm our results which are not accessible to us. Another case is that we have investigated the studies conducted with FMRI method. Considering that the use of other instruments may lead to different results, other studies which have used different instruments on one sample should be done and their results should be compared with each other.

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