An fMRI-study of Illusory Movement Perception and V5

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22-05-2017

Abstract

Area V5, located in the occipital lobe, is the brain area critical for motion perception. In this study, it was investigated whether V5 takes part in the processing of illusory movement, in similar ways as it does with actual movement. The analysis revealed that the illusory movement did evoke activation in V5, but that it was not as great as that evoked by actual movement.

Introduction

The human perception of different scenes and actions seem well unified and whole, but there is not always coherence between what is actually in the visual scene and what we perceive. This is the case when looking at optical illusions, where movement, that is not actually there, is perceived.

Studies of human and primate perception suggest a subdivision of the visual system into different parts, each with distinct functions such as colour, depth, form, texture, or movement perception (Livingstone & Hubel, 1988).

This study focus on the perception of illusory movement, i.e. movement that objectively is not there. It is hypothesised that when an optical illusion is observed, brain activation in V5, similar to that of actual movement, will be evoked. This hypothesis is investigated by presenting different versions of a peripheral drift illusion (see figure 1) while in a functional Magnetic Resonance Imaging scanner (fMRI).

The visual cortex and V5

The visual cortex is located in the occipital lobe and can, as mentioned, be divided into different areas with different processing functions (Gazzaniga, Ivry, & Mangun, 2014).

What is of interest in this paper is the brain areas critical for movement processing. Through studies of the human and primate visual cortex they have been possible to identify. This area is called V5 or in humans, human area MT. The name MT refers to the position in the Middle Temporal lobe in macaque monkeys (Maunsell & Van Essen, 1983; Zeki, Watson, & Frackowiak, 1993).

The Talairach coordinates for V5 in the human brain has been estimated through several fMRI studies, but can vary between individuals. The average Talairach coordinates used in this study are from Dumoulin et al.'s fMRI study (2000).

Anatomically, the V5 is located in the extrastriate visual cortex, near or in at the junction between the parietal, temporal, and occipital lobes – most often within a sulcus in that area (Dumoulin et al., 2000).

Several PET- and fMRI-studies have found activation in V5 when participants was asked to look at illusions intended for motion perception (Goebel, Khorram-Sefat, Muckli, Hacker, & Singer, 1998; Larsen, Madsen, Ellegaard Lund, & Bundesen, 2006; Zeki et al., 1993).

Clinical data from human lesion patients have showed that lesions to this specific area result in permanent loss of movement perception, also known as akinetopsia (Zihl et al. 1983 - as cited in Zeki et al. 1993 and (Gazzaniga et al., 2014).

In a single-cell recordings study by Maunsell & Van Essen (1983) conducted on macaque monkeys, it was found that neurons in MT is highly speed and direction selective, i.e. single neurons display maximal response to movements in a specific orientation and speed. These same neurons have also been found not to be responsive to other features of the visual scene, like colour (Gazzaniga et al., 2014).

Movement illusions

In this experiment, a peripheral drift illusion was used. It consists of a repeated serrated circular pattern, with a dark-to-light luminance gradient. This means that the colours gradually are getting lighter. When this pattern is observed in the periphery of the visual field, it evokes the sensation of movement. The direction of the illusory movement is decided by the direction of the luminance gradient, i.e. if the dark-to-light go clockwise, so does the movement (Faubert & Herbert, 1999). Therefore, the illusion works best when the observer look at a point outside of the illusion.

The peripheral-spatiotemporal-integration hypothesis (Faubert & Herbert, 1999) suggests three conditions as necessary for the generation of illusory movement: First, there has to be some kind of eye- or stimulus-movement, to reset the visual processes. Second, it is theorised that luminance information is processed at different speeds, depending on how light or dark the information is. Third and lastly, they proposed that the illusion is only perceived in the outer part of the visual field, because information from a large area is integrated. This means that lighter stimuli are processed faster by the luminance sensitive neurons, which results in information arriving at the motion sensitive neurons with different latencies. The stronger the luminance contrast, the larger the difference in processing time. This difference is interpreted as motion signals by the motion sensitive neurons in V5.

These motion signals are then summed and a movement perception in the dark-to-light direction is the result. By blinking or moving the stimulus, the image is reset and the process starts over (Faubert & Herbert, 1999).

This type of illusion only works with serrated or saw-toothed patterns because the dark-to-light edges produces asymmetrical temporal differences. Had the temporal differences been symmetrical, they would have cancelled each other out (like they do in e.g. square waves), which would have caused the image to be perceived as just that; an image (Faubert & Herbert, 1999).

Methods

Design & materials (apparatus)

The study used a within-participant 2 x 2 factorial event-related design. The two dimensions in the study were blurred vs. illusion and movement vs. still (Table 1).

Table 1: *The four different conditions of the experiment.*

Condition 1	**Illusion still**
Condition 2	Blurred still
Condition 3	Illusion with movement
Condition 4	Blurred with movement

The still stimuli used was a picture of an optical illusion (peripheral drift illusion) inducing perception of movement and a blurred version of the illusion where no perception of movement was induced (Figure 1).

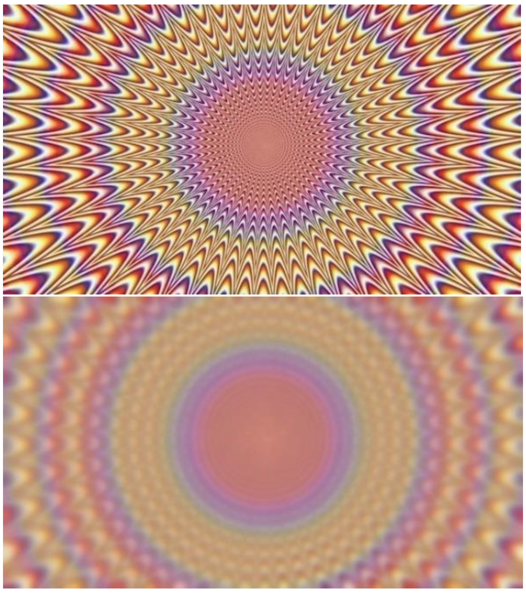

Figure 1: *The stimuli used in the experiment. Top: stimuli of condition 1, Bottom: stimuli of condition 2*

For the moving stimuli two movies were made of the pictures slowly spinning. In order to keep the resolution at a reasonable level, the pictures were enlarged by superimposing them on larger versions of themselves. The edges were smoothed by a transparency gradient for a more seamless merge.

The experimental paradigm was coded in Python and was run using Psychopy. The fMRI-scanner was a Siemens Trio scanner with an interscan interval of 2 seconds.

Participant(s)

One Finnish male, age 21, participated in the experiment. The requirements for participation were having normal or corrected vision, not being colourblind and not being prone to motion sickness. Critical for the experiment was also that the illusion induced a perception of movement in the participant. The participant participated voluntarily and was aware of his right to leave the experiment at any moment.

Procedure

Before the experiment was conducted, it was confirmed that the illusion induced a perception of movement in the participant. The participant was informed of his rights and the precautions of participating in an fMRI experiment.

The participant was first presented with instructions describing the task to be done. During the experiment the participant had to press a button with his middle finger if seeing the blurred stimuli and with his index finger if seeing the illusion, as a behavioral task. The behavioral task was in order to keep the participant aware and make sure that he was awake during the entire experiment.

During the experiment stimuli were presented for 3.4 seconds at a time. Delays between stimuli varied from 2.1 seconds to 3.5 seconds. A session lasted 12 minutes in total. The participant did two sessions of the experiment with an eight-minute session of another experimental paradigm in between.

Pre-processing and analysis

The pre-processing and analysis was done in SPM12 (*Spm12*2014) and consisted of realignment, co-registration, segmentation, normalization, smoothing and a high pass filter of 128 Hz.

The realignment has the goal of removing movement artefacts in the fMRI data. Co-registration links the structural and functional data.

Segmentation gives additional structural information by dividing the brain into areas of grey and white matter. It also gives the deformation field used to normalize the brain.
Normalization spatially transforms the brain into a standard brain in order for the results to be generalizable.

Smoothing merges the signal of neighbouring voxels in order to reveal patterns of activation. Also, this makes the effect less vulnerable to movement.

The high pass filter removes noise from the data (Ashburner et al., 2014).

For the analysis of the movement vs. still main effect we used the average coordinates of the V5 (left hemisphere: (-47, -76,2), right hemisphere (44, -67, 0)) (Dumoulin et al., 2000). These are Talairach coordinates that were converted into MNI-coordinates (left hemisphere: (-52.5, -74.9,7.0), right hemisphere (50.9, -65.6, -3.2)) prior to being put into SPM (**The MNI brain and the talairach atlas**.2017).

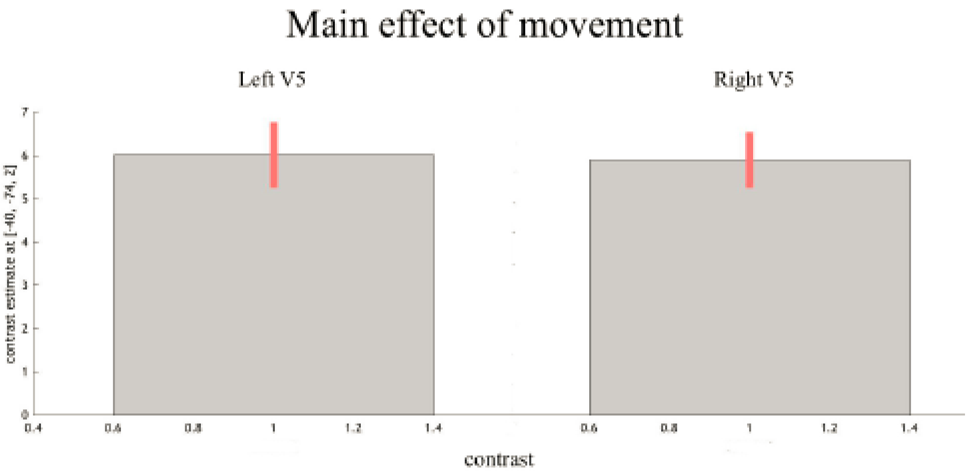

Figure 2: *Main effect of movement in left V5, MNI coordinates (-40, -74, 2) and right V5, MNI coordinates (-44 , -62, 0)*

Then we found the nearest local maximum in order to make sure that we found our participant's V5 (See figure 2 and 3 for local coordinates). This approach could be used because we only had one participant.

For the analysis of the non-blurred versus blurred main effect we found the global maximum, which was in the visual cortex, and analysed the effect there.

For the plots, we used an F-contrast, so that we could look at the effect of each condition in the areas of interest. For the comparisons of the contrasts, a familywise error corrected t-test was used. The significance level used was $p<.05$.

Results

In the movement versus still main effect, V5 was significantly more active in both hemispheres in the movement condition, $t(676)=13.03$, $p<.05$ for left and $t(676) = 14.96$, $p<.05$ for right (Figure 2; Figure 4).

In the non-blurred versus blurred main effect, there was significantly more activation in the whole visual cortex in the non-blurred condition, $t(676)=24.18$, $p<.05$ (Figure 3).

The pattern of activation was consistent for both main effects in both sessions (Figure 5).

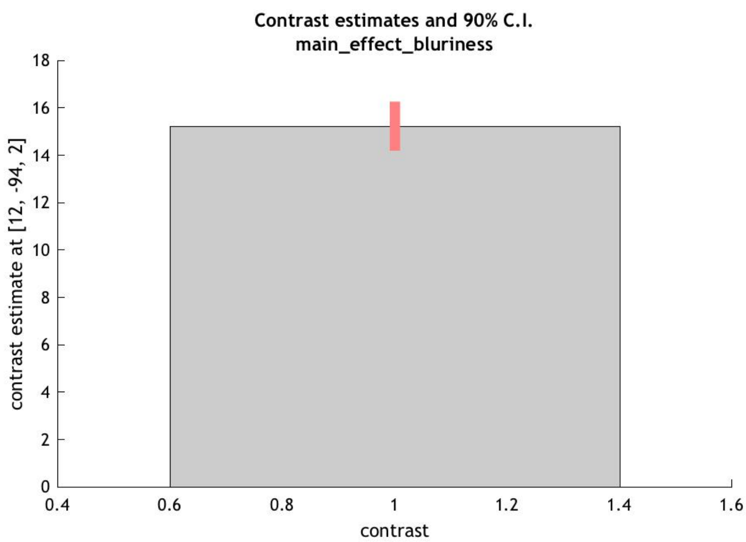

Figure 3: *Main effect of blurriness, MNI coordinates (12, -94, 2)*

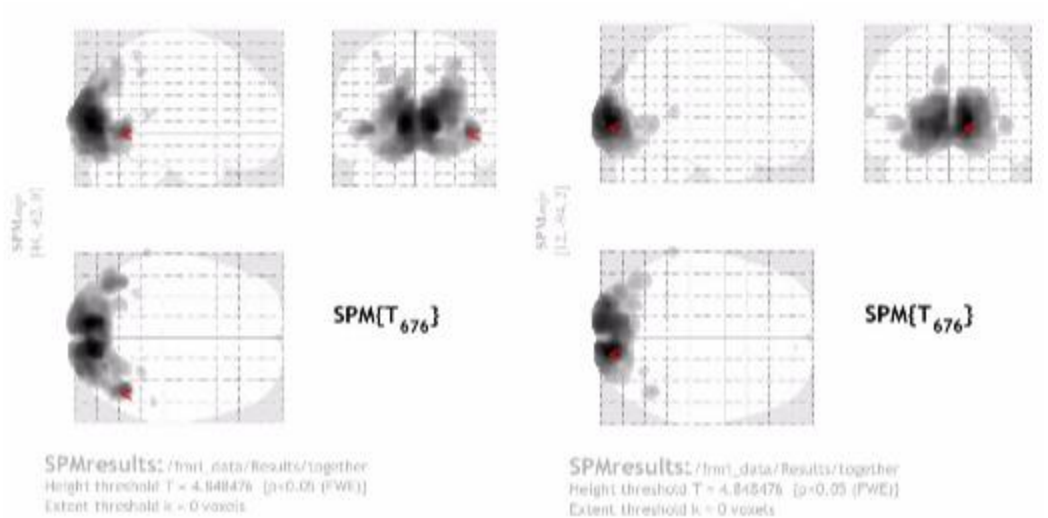

Figure 4: *Left: glass brain of the movement main effect. The arrow is pointing at the right V5 Right: glass brain of the blurriness main effect. The arrow is pointing at the global maximum.*

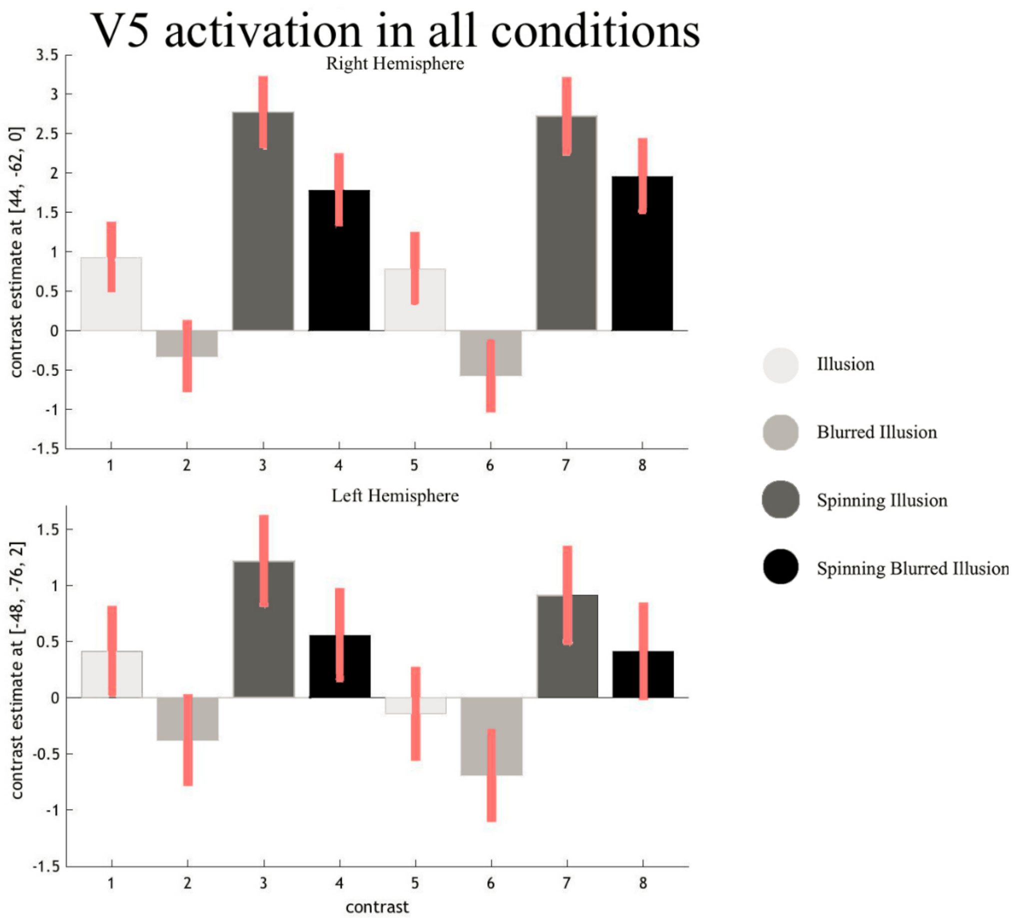

Figure 5: *Activation in the left V5, MNI coordinates (-40, -74, 2) and in the right V5, MNI coordinates (-44, -62, 0).*

Discussion:

The voxels used in the analysis was, as mentioned, chosen by finding the local maximum nearest the average MNI-coordinates for V5. That of course ensures that supporting evidence for the hypothesis is bound to be found.

To make sure that the local maximum could be accepted as V5, it was investigated whether the activation was located within an acceptable distance from the averaged V5. The difference between the local maximum's and the averaged coordinates were (-11.00, -0.90, 4.38) and (6.08, -3.54, 3.54) for the left and right hemisphere respectively. This means that the new coordinates, except the left x-coordinate, fall within 2 standard deviation from the mean, as reported by Dumoulin et al. (2000)[1], which is considered to be acceptable.

The decision of using this method grounds in the fact that only one participant was used in the experiment. Therefore, the risk of missing activation was great, as the coordinates for V5 varies across individuals.

Looking at the main effect of blurriness (figure 3), there was significantly more activation in the whole visual cortex in the non-blurred conditions, compared to the blurred conditions. This could be due to the brighter colours and sharper edges. However, images of this type might also demand more attention than the blurred images, which might increase the activation in the visual cortex too.

As expected the main effect of movement in both hemispheres (figure 2) show that there was a greater activation of V5 when the participant was watching the actual moving stimuli, than when the stimuli was still. This finding follows the theory, suggesting the neurons in V5 as being sensitive to movement.

As seen from figure 5, the activation in V5 was consistent throughout both sessions for all conditions. By comparison the conditions with actual movement evoked stronger activation than that of watching the still illusion. This is in line with the findings of Axel Larsen et al. (2006), who also found stronger activation for apparent movement than for the illusory movement alone. This finding can be explained by the fact that the two types of movement that the conditions induce are very different; the illusion induces a sensation of jitter in the image, like the pattern is jumping back and forth. Whereas the spinning of the actual moving stimuli is a stronger and much more evident

[1] (3.8, 4.9, 2.79) and (3.3, 3.1, 5.1) for left and right hemisphere respectively

movement, which probably should be expected to evoke a stronger reaction in V5.

The activation for the spinning illusion was stronger in V5 than for the spinning blurred illusion, which might be caused by the effect of the illusion, which might induce extra motion perception. Though it cannot be caused by the brighter colours, as the neurons in V5 does not respond to this, it can be caused by the sharper lines and edges in the non-blurred image.

Overall, it can be said that the results from this study support the hypothesis stating that illusory movement induces the same kind of activation in V5 as actual movement does, though it was weaker.

Limitations

Only having one participant is the obvious limitation of this experimental design, as it causes the statistical power of the analysis to be very limited. This means that to be able to conclude anything in general from this, more participants are needed.

During the experiment, the experimental script crashed. This meant that the experiment kept running beyond the 12 minutes that was planned. This may have caused some confusion for the participant. Besides that, data points recorded after the experiment should have ended was removed. This have been judged to not have affected the results.

To improve this experimental design, it should be considered how to get the stimuli as similar as possible. In this experiment, the solution of blurring the image can be said to probably not be the optimal solution as it changed the colours and edges. This resulted in a completely different kind of stimulus. Therefore, the difference in activation is difficult to interpret, because it is hard to know whether it is due to the differences in stimuli or due to the illusion having an effect.

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