Implied motion because of instability in Hokusai Manga activates the human motion-sensitive extrastriate visual cortex: an fMRI study of the impact of visual art

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The recent development of cognitive neuroscience has invited inference about the neurosensory events underlying the experience of visual arts involving implied motion. We report functional magnetic resonance imaging study demonstrating activation of the human extrastriate motion-sensitive cortex by static images showing implied motion because of instability. We used static line-drawing cartoons of humans by Hokusai Katsushika (called 'Hokusai Manga'), an outstanding Japanese cartoonist as well as famous Ukiyoe artist. We found 'Hokusai Manga' with implied motion by depicting human bodies that are engaged in challenging tonic posture significantly activated the motion-sensitive visual cortex including MT+ in the human extrastriate cortex, while an illustration that does not imply motion, for either humans or objects, did not activate these areas under the same tasks. We conclude that motion-sensitive extrastriate cortex would be a critical region for perception of implied motion in instability. ***NeuroReport*** **21:264–267 © 2010 Wolters Kluwer Health | Lippincott Williams & Wilkins.**

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Introduction

Visual artists developed various visual cues for representing implied motion (IM) in two-dimensional art. Photographic blur, action lines, affine shear, instability, superimposition, and stroboscopic images are possible technical solutions for representing IM [1]. In a realistic painting, artists have tried to represent motion using superimposed or blurred images, while in abstract painting, like Marcel Duchamp artists have tried to portray a moving object on a static canvas by superimposing successive portrayals of the object in action [2].

One of the critical issues in the cognitive neuroscience of visual art is how our visual brain creates the impression of motion using IM clues. Several investigators have employed paintings [2], photographic actions balanced for body part [3], static photograph [4,5], glass patterns [6], and body perspective pictures [7] for the study of IM. A single strip of static line cartoons suggesting dynamic motion could even create an impression of motion. However, there has been limited study using line cartoons like Hokaisai Manga ('Manga' indicates comic cartoons in Japanese and an IM is likely helpful to enrich the cartoon image) in which motion is implied by instability.

As one of a leading artist of the 'Ukiyo-e' school in the 18th century, Hokusai made great progress in representing IM using unstable bodily action without introducing action lines or even blur because of affine shear. Hokusai Katsushika (1760–1849) was a famous Japanese painter and wood engraver who depicted humans in purposeful motion in his volume entitled Hokusai Manga (1814) [8]. He depicted aspects of everyday Japanese life in his woodcuts and strongly influenced European Impressionist artists. Figure 1 shows an example of an image from Hokusai Manga. He sketched nearly 4000 illustrations, 15 volumes showing motion in people, animals and objects. We investigated this particular novel aspect of conveying motion impression via simple art drawings that do not involve additional traits of reduplication to give the impression of motion. Hokusai Manga portrays dynamic human action using rich unstable lines without action lines or blur for representation of IM. This study used functional magnetic resonance imaging (fMRI) to investigate whether the observation of static line cartoons that imply motion because of dynamic bodily actions using instability as a visual cue could activate the motion sensitive V5/MT+ region in the human brain. For this purpose, we first used Hokasai Manga as unstable stimuli in an IM experiment.

Recent studies have indicated that even when the stimulus does not explicitly show motion, observation of a static photograph of human actions with IM produces an increase in cortical brain activation including V5/MT+, left extrastriate body area, left superior temporal sulcus (STS) (BA38) and related motion-related areas [3].

Furthermore, IM could even be generated by presenting a word either of an action verb [9] or a mimic word. Using fMRI, Osaka (2009) [10] observed activation of the human extrastriate visual cortex and STS on presentation of mimic words that implied 'walking' heard by the ears while both eyes were closed.

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Recent findings from fMRI studies on IM generated from static images suggest that the major cortical area involved in IM is the middle temporal gyrus (MT +) and its neighboring areas involving the MST, STS, and premotor areas.

Methods

Participants

Fourteen healthy college students or graduates served as participants. They were recruited as paid volunteers from the Psychology Department of Kyoto University. They all had normal or corrected-to-normal visual acuity and normal color vision. All participants received information on fMRI and reported that they did not have any history of psychiatric or neurological disorders. In accordance with the protocol approved by the ATR Institute Review Board, informed consent was obtained from each individual before participation in these fMRI experiments.

Materials

We obtained behavioral indices of implied motion and control conditions: Four illustrations from Hokusai Manga were selected from the top four cartoons depicting humans in positions that highly IM. All stimuli were selected from Hokusai Manga based on a 10-point scale of evaluation (10 for highest IM and one for lowest IM) as shown in Fig. 2. Average evaluation value for evoking an image of IM was 8.5 on the scale for generating a subjective sense of motion as shown in Fig. 2 (left column). We also used four static (no-implicit motion: no-IM) illustrations of humans (middle column) showing no or significantly less motion (mean value of 2.5) along with static object (object: mean value of 0) illustrations (right column) to obtain control values.

Procedure

Visual stimuli were presented through an LCD projector onto a translucent screen. Observers viewed the display screen binocularly through a mirror attached to the head coil. The experiment was controlled by a PC with Presentation software (Neurobehavioral Systems Inc., Albany, California, USA).

We used a block design and introduced three conditions: (i) an illustration of a human with IM, (ii) an illustration of a human without IM (no-IM), and (iii) an illustration of a static object (object) as a reference.

These stimuli subtended from a minimum of $7.0^\circ \times 7.0^\circ$ to a maximum of $17.2^\circ \times 11.8^\circ$. All stimuli were black and presented on a white background. We selected a total of 12 stimuli from each class (Fig. 2).

Each block contained successive presentation of 12 illustrations taken from a single stimulus condition. Each illustration was presented for 2000-ms, and then a 500-ms blank interval followed. Individuals were required to push a button to indicate whether each illustration has an impression of motion (either strong or weak). Inter-block interval was 15-s. There were six blocks per experimental condition and the order of blocks was counterbalanced across sessions and participants in order to avoid possible habituation. During the tasks, participants were instructed to focusing attention on the stimulus.

Functional magnetic resonance imaging data acquisition

Whole brain imaging data were obtained with a 1.5 Tesla MR scanner (Shimadzu-Marconi Magnex Eclipse; Shimadzu Corp., Kyoto, Japan) using a head coil. Head motion was minimized with a forehead strap.

For functional imaging, we used a gradient-echo echo-planar imaging sequence with the following parameters: repetition time 3 s, echo time 49 ms, flip angle 90°, field of view 192 by 192. Thirty contiguous, 6-mm thick slices (32-mm × 3-mm in plane) were obtained for 294 volumes on the axial plane for each participant. Preceding the acquisition of functional images, T2-weighted images (fast-spin echo sequence, 1 mm × 1 mm in-plane, 30 axial slices) were collected.

Functional magnetic resonance imaging data analysis

Image data were analyzed with SPM 2 (Wellcome Department of Cognitive Neurology, London, UK) implemented in MATLAB 6.5.1 (Mathworks, Sherbon, Massachusetts, USA). Five initial images were discarded from the analysis to eliminate the nonequilibrium effects of magnetization. All of the functional images were realigned to correct for head movement, and then the first volume of

Fig. 1

An example of cartoon images from Hokusai Manga, which involves implied motion because of instability.

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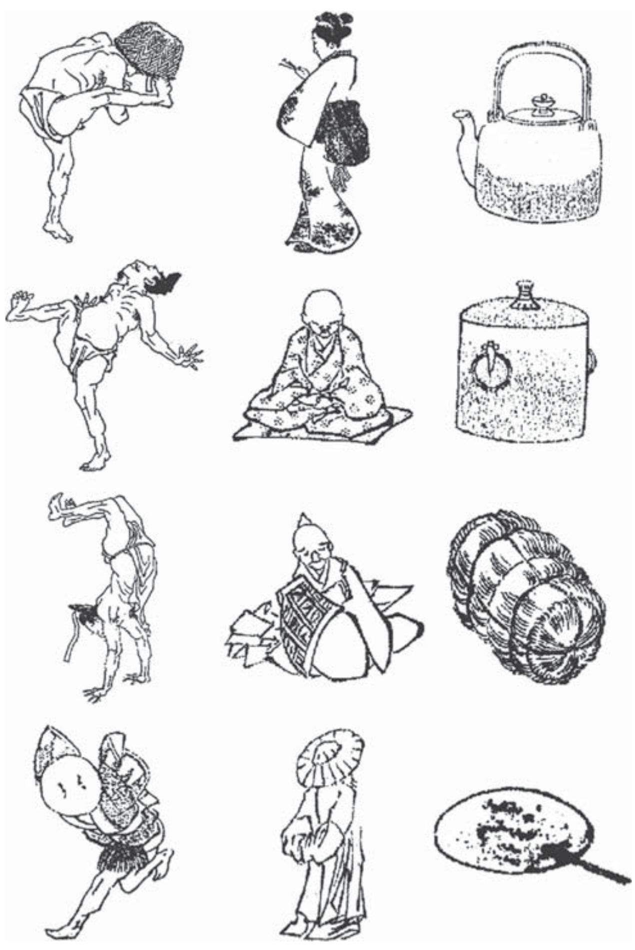
the functional images was coregistered to the anatomical image. Following coregistration, the functional images were normalized using a Montreal Neurological Institute template brain, and then spatially smoothed with a three-dimensional Gaussian kernel (FWHM=8 mm). After the preprocessing described above, the functional images were high-pass filtered and then data were modeled using a box-car function. Single participant data were analyzed with a fixed-effects model while group data were analyzed using a random-effects model.

Results

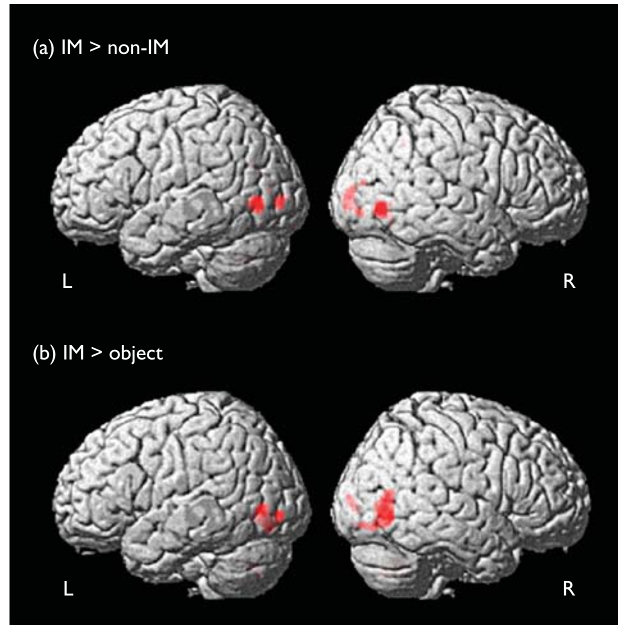
Figure 3 shows activated brain areas (IM > non-IM: control activation subtracted from IM activation) (corrected, $P < 0.005$). As Fig. 3 shows, the major activated cortical areas were the bilateral inferior temporal gyrus close to MT + (BA19: $x=-50$, $y=-72$, $z=-2$ and $x=54$, $y=-72$, $z=-4$ in Talairach coordinates (Montreal Neurological Institute converted) with peak scores of $Z=4.93$ and 4.39, respectively), right inferior occipital gyrus (BA18: $x=32$, $y=-94$, $z=6$ with a peak score of 4.03) and left inferior occipital gyrus (BA19: $x=-40$, $y=-88$, $z=0$ with a peal score of 3.99) under the IM > no-IM condition. While the major activated cortical areas (IM > object: reference activation subtracted from implicit motion activation) were the right middle temporal gyrus (BA37 close to B A19: $x=54$, $y=-72$, $z=0$ with a peak score of 4.46), extrastriate visual cortex (BA19: $x=52$, $y=-76$, $z=0$ with a peak score of 3.98) and cerebellum ($x=0$, $y=-64$, $z=-36$ with a peak score of 4.37) under IM > object condition.

Fig. 2



Illustrations from Hokusai Manga. Cartoons depicting humans in positions that highly implied motion (IM), humans showing no or less motion (static), and objects showing no motion (object).

Fig. 3



Major activated brain areas (right and left brain) under implied motion (IM) > non-IM and IM > object condition.

Discussion

As shown in Fig. 3, we obtained significant activation (IM > non-IM) in bilateral inferior temporal gyrus in the extrastriate cortex (BA19) and bilateral inferior occipital gyrus (BA18 and BA19), which involves MT +, while there were no significant activations seen in the reverse contrast (IM activation subtracted from non-IM activation). The most interesting finding obtained here was a unique activation in the bilateral extrastriate visual cortices when the participant observed an implicit motion cartoon because of instability.

Using static photograph of athletes in motion contrasted with photographs of athletes at rest and photographs of houses, Kourtzi and Kanwisher (2000) [4] found greater activation in MT + when viewing IM on fMRI study of eight participants. In their fMRI study with six

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participants, David and Senior (2000) [5] showed activation of the extrastriate cortices (MT +) under an IM condition using video clips of the items in motion (e.g. man jumping from ledge).

Using event-related potential, Proverbio *et al.* (2009) [3] indicated that the photograph of human actions with differing degrees of dynamism to portray implicit motion produced increased cortical activations in the right V5/MT, left extrastriate body area, left STS (BA38), left premotor (BA6), and motor (BA4) areas.

These fMRI studies confirmed that extrastriate visual cortex (MT +) activation occurred while viewing photographs showing implicit motion. Our findings here further confirmed their results using more abstracted line drawings from Hokusai Manga. Thus, we are the first to report that the visual art represented in Hokusai's cartoons and Ukiyoe, as well, introduced a rich IM by its unique motion instability structure.

Furthermore, some investigations have suggested that IM perception may be correlated with mirror neurons that respond more strongly to implied dynamic than to less or no dynamic actions or the absence of action. Observation of static photographs of dynamic actions enhanced the activation of movement related brain areas like the left STS, premotor, and motor areas along with the right V5/MT [3]. Specifically, observation of action activated not only the ventral premotor (BA6/44) and inferior parietal areas where mirror neurons have been found in the monkey, but also the dorsal premotor area and cerebellum [11]. It has been suggested that a possible role for mirror neurons may be in understanding the intentions of observed actions, feeling empathy and formation of theory of mind. However, we could not find any mirror-related activation areas involving premotor and related areas, since only the right cerebellum has been activated under IM > object condition. Further investigations will be necessary to clarify the mirror neuron correlates with IM. Right cerebellum may be activated because of perception of challenging tonic posture, since the cerebellum plays an important role in the coordination and motor control.

One question is that as to what extent those effects are truly specific to Hokusai Manga. The particular way those cartoons represent IM is by depicting human bodies that are engaged in either challenging tonic posture (e.g. head down, feet up) or static postures that defy gravitational equilibrium. As such, the effect of brain activation may be generally because of perceiving motion in difficult posture that, however, would not only be restricted to this particular kind of artwork. Further studies will also be necessary to clarify the issue.

Finally, we consider here the neural correlates of visual memory and IM. Using PET, there has been evidence that human MT + , during the retrieval of motion because of earlier episode, could even be reactivated in the right V5/MT + [12]. Moreover, activation of the extrastriate visual cortex can be activated by presenting mimic words implying 'walking' (IM) [10]. These findings that the extrastriate motion-sensitive area MT + could be attentionally modulated by top-down processing because of an IM memory system.

Conclusion

We found that Hokusai Manga cartoons, possibly because they richly portray IM using postural instability as a visual cue, stimulate the extrastriate visual cortex. Thus, an IM evoked by human bodies that are engaged in challenging tonic posture could effectively contribute to an appreciation of motion in visual art.

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