A Survey of Brain Mechanisms of Visual Motion Perception

Xiaoya Yu , Jinglong Wu, Shengfu Lu
The International WIC Institute
Beijing University of Technology
Beijing, P.R. China
yuxiaoya@emails.bjut.edu.cn

Xiaoya Yu
Department of Computer Science
Beijing Institute of Education
Beijing, P.R. China

***Abstract*—Perception investigation is one of major subtopics in the field of Human Information Processing System (HIPS). From its systematic design of cognitive experiments in BI methodology to its results, perception study provide support evidence for thinking investigation of HIPS, and may have an impact on the construction of artificial systems. In this paper, we introduced our aims, reviewed the basic concepts and related work. At last, we suggested our future work.**

Keywords-Visual motion perception, brain mechanism, ventral pathway, dorsal pathway, MT, functional MRI, ERP

I. INTRODUCTION

According to Ning Zhong et al.[1], The aim of Brain Informatics(BI) is systematically study human information processing systems. The major subtopics in the field of BI include thinking centric investigation of HIPS; perception centric investigation of HIPS and modeling human information processing mechanism, et al.

Functions of HIPS can be classified as the lower and higher functions. Thinking oriented study in HIPS needs to understand relationship between lower and higher functions of HIPS. If we want to understand the mechanism of higher functions, such as reasoning, problem-solving and decision-making, we need to understand the mechanism of lower functions, such as attention, memory, vision, and their relationships[1].

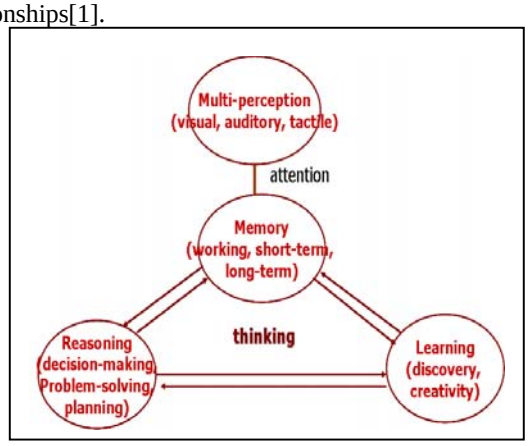

Figure 1. The relationship between perception and thinking investigation of HIPS. In BI research area, perception investigation is the basics of all high level thinking investigation.(The figure from Ning Zhong, 2007)

Figure 1 shows the relationship between perception and thinking investigation of HIPS. From the figure, we could find the perception is the basics of all high level thinking investigation. It is the inevitable pathway to high level thinking centric research area.

When we analysis the experimental data, we must think about the influence of sensory channel. We should discussion the perception factors such as attention of subjects, the motion of stimuli, et al.

The primate visual motion system performs numerous functions essential for survival in a dynamic visual world. Among all input information, 80% are the visual input information [2]. Because almost all of our experiments adopted visual stimuli, as the same time thought about the human visual system is a complex system, we focused our research interesting in visual motion perception system. We tried to investigate the judgment mechanisms of the motion or static pattern. This investigation would benefit the stimuli analysis in thinking investigation experiments.

The primate visual motion system performs numerous functions essential for survival in a dynamic visual world. Among all input information, 80% are the visual input information [2]. Because almost all of our experiments adopted visual stimuli, as the same time thought about the human visual system is a complex system, we focused our research interesting in visual motion perception system. We tried to investigate the judgment mechanisms of the motion or static pattern. This investigation would benefit the stimuli analysis in thinking investigation experiments.

II. BASIC CONCEPTS ON VISUAL MOTION PERCEPTION

As we know, human visual system has been evolving through the long history and has attained very high performance. However, artificial systems for those are often poorer in performance despite of remarkable progress in their efficiency. In order to construct artificial systems with high performance, such as human visual system, it is necessary to elucidate the mechanisms of human visual system.

A. Two pathway in human visual system

In human visual system, visual information transmits along a hierarchical pathway. The retina received outside world signals, then throw away information along the chiasm optic and optic tract into the LGN, at last get to the primary cortical areas(V1).

The studies evidence of primates and human beings show that the visual information passed striate visual areas(V1, V2), project to extrastriate visual areas, in this area, information processing were performed at two anatomical

and functional differently parallel pathway: ventral pathway and dorsal pathway. A dorsal stream is responsible for detection of location and motion, namely "where", and a ventral stream responsible for form and object perception, namely "what"[3]. The ventral stream is also called the occipitotemporal cortical pathway, as it organized hierarchically from areas V1, V2, V4, and further stations in inferior temporal areas; in contrast, the dorsal stream, the occipitoparietal pathway, as it organized hierarchically from areas V1, V2, V3, MT/V5, and further stations in posterior parietal areas.

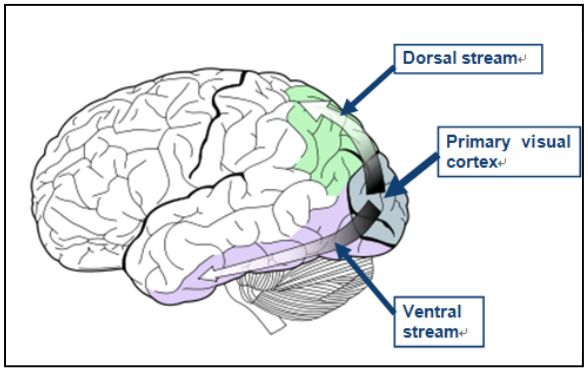

Figure 2. The dorsal stream (green) and ventral stream (purple) are shown. They originate from a common source in visual cortex. The dorsal stream is responsible for detection of location and motion. (The figure from Wikipedia, the free encyclopedia.)

The two visual processing pathways are not separate completely; there is much communication between them. These communications are the basic architectural in performing visual information integration during high level processing stage.

On the other hand, the two pathway all project to prefrontal cortical area, in reverse, prefrontal sent feedback signal to cortical processing area, play a role of up-down adjustment[4]. Some researchers suggested the adjustment mechanism has begun at extrastriate visual areas.

If all of our experiment data come from the two visual pathway and then project to brain cortical, how the two pathway cooperate and separate, this still worth studying. Furthermore, The two pathway, respond "what" and "where "respectively, our aims to investigation human high level thinking, are confirm its space-temporal relationship. Study space-temporal relationship between the two visual pathway would support the study on high level space-temporal relationship. When we considered how to focus our research, we know motion connected space and time, the other reason is almost all of our experiments used visual stimuli, we would investigate visual motion perception.

B. *What is visual motion perception?*

Visual motion perception is the process of inferring the speed and direction of objects and surfaces that move in a visual scene given some visual input. Although this process appears straightforward to most observers, it has proven to be a difficult problem from a computational perspective, and extraordinarily difficult to explain in terms of neural processing.[2]

On the basis of whether the object move truly or not, the visual motion perception was divided into the following two types:(1)Real motion,Motion perceived when an object is continuously displaced across the visual field.(2)Apparent motion,Motion perceived when the displacement of an object is discontinuous or intermittent. Apparent motion: displacement in time and space leads to impression of motion.

1) Apparent motion phenomenon:

The motion phenomena are rich and varied. Apparent motion has a long study history , generally, it has four classified phenomenon[2]:

a) Stroboscopic Movement

Movement is experienced when the object appears to undergo a change in its location. For example, motion pictures are really a series of slightly different still pictures flashed on a screen at a rate of 24 pictures, or frames, per second. From this rapid succession of still images, our brain perceives fluid motion—a phenomenon known as stroboscopic movement. The rate of presentation of the still images must be just right to produce the illusion of fluid motion. If the rate is too slow, you perceive a flicker. If the rate is too fast, you perceive a blur.[5]

Under some circumstances, people perceive movement from one location to another even though they cannot see actual movement between the two locations. For example, when two adjacent stationary lights flash in quick succession, an observer sees the light move from the first location to the second. This type of illusory motion, called the phi phenomenon, is often used by theater marquees and signs. Again, the interval between light flashes must be just right to produce the illusion of motion—about one-tenth of one second between flashes. If the interval is too long—say, two-tenths of one second—the lights appear to flash on and off independently.[5]

b) Autokinetic effect

Stationary point of light in a completely darkened area will appear to move when we fixate on it.

The apparent movement of a stationary point of light when viewed in a totally dark environment, resulting from physiological nystagmus that the visual system cannot compensate for in the absence of any visible frame of reference. Also called the autokinetic phenomenon or the autokinetic illusion (AKI).[Coined in 1887 by the German physiologist and psychologist Hermann Aubert (1826–92) from Greek autos self + kinetikos of or relating to motion, from kineein to move or kinesis movement + -ikos of, relating to, or resembling] [6].

c) Induced Movement

A stationary form will appear to move when its frame of reference moves. One of the most striking illusion caused by image motion is the feeling that it is ourselves that is moving rather than the image. Most people will have had the strange feeling when sat in a train, believing that their journey has just begun, only moments later to realize that they are still in

the station and it is the train next to them that has pulled away.

d) Motion aftereffect (the waterfall effect)

The interesting motion illusion occurs as an aftereffect of watching motion in a continuous direction for a long time. For example, if you stare at a waterfall for several minutes, when you look away, stationary objects will appear to move in a direction opposite to that of the original motion. This illusion probably arises when cells that detect motion in a particular direction become fatigued, leaving cells that detect motion in the opposite direction dominant.[5]

One of the most obvious and important functions of visual motion perception is to encode and represent the trajectories of moving real-world objects. Our perception of speed depends on three factors: the background, the size of the moving object; and velocity. Background often complexity increases the perception of movement; size , smaller objects appear to be moving faster than larger objects; and velocity- actual velocity is difficult to judge.

2) Real motion phenomenon:

Motion in the real world are much complicated ,Things can move in displacement, rotate, expand, contract, deform, speed up or slow down and move in depth. According the investigation documents, We divided the research subjects of real motion into four major areas:

a) Perception of Biological motion (self-motion).

Johansson (1973) attached small points of light at the joints of human actors, and filmed them moving about in the dark. Observers viewing the film reported vivid impressions of human figures, even though the images contained only a few isolated bright points. This demonstration of the effect was created using a computer rather than real actors, but the result is similar. [7]

b) Motor/action.

The main aim is to study how human control their respond action during stimuli.

c) Object motion perception.

Visual motion may be actively generated (for example, in locomotion), or passively observed. These types of documents focus on how human perceive the object motion.

d) Oculomotor.

Eye movements are necessary to direct the fovea to image regions of interest. But making eye movements causes massive retinal image motion.

How do we distinguish retinal motion induced by eye movements from motion of stuff in the world? Eye movements come in several flavors:(1)Saccades: fast movements from one image location to another we make 3-4 of these each second; (2)Microsaccades: small eye movements that occur when we try to fixate a point; (3)Smooth pursuit eye movements：track moving image features,can only make these if something in image is moving.

Each time we make an eye movement, huge amount of motion are induced on the retina. How do we discount this motion? Several theories: one of its is proprioceptive signals from eye muscles; the other is efference copy from motor system to visual system. We can test the proprioceptive theory by poking our eye. And the efference copy theory by paralyzing the eye muscles.

III. RELATED WORK

A. Where do we detect visual motion perception

Within an animal's brain, numerous neural regions located throughout the central nervous system exhibit enhanced activity in response to the presentation of a moving visual stimulus. From this selectivity for moving visual stimuli arises the ability to perceive motion based solely on visual sensory input.

In many animals the direction selectivity cell is found in the retina, but in primates direction selectivity appears much later. The first cell with this property is in our primary visual cortex, area v1. Even within this area, however, only about 20% of cells show this property, confined to particular layers within V1. These directionally selective cells appear to send their output to just a few special areas of the brain.[8]

In one of these projection areas, the middle temporal area MT (often termed V5), nearly all the cells appear to be directionally selective, so it is not surprising that this area is thought of as our “motion center”. The importance of area MT for motion processing has been shown in a number of ways. One is to make a very small lesion within the area: such an animal is still able to see a moving stimulus and report its detail, colors, size and so on; but if the animal has to report its direction or speed of movement, it is severely compromised.[9]

But area MT is not the final point of motion analysis in the brain for at least two reasons. The first is that a motion detector with small receptive field suffers from what is know as the aperture problem. Solutions to the aperture problem suggest the second reason why MT does not have the final say in perceiving visual motion. At their heart lies the idea that motion information must be integrated across detectors in order to reveal the true nature of movement in the world. Integration is also important because detectors in MT cannot tell us about the more complex patterns of regularly experience in daily life. [9]

The cell of area MT do not seem to appreciate the complicated optic flow patterns, but an area adjacent to this known as the medial superior temporal (MST) area contains cells sensitive to movements that expand, contract or deform.[10]

Experiments in humans agree with this idea of a special place for motion. We can compare brain activity when a person is experiencing motion with that activity when it is not.

In conclusion, the evidence from primates and human being studies has a common result, as following list:

hMT/V5+ (human MT/V5 area and satellites): the most important motion processing area, respond to first-order, second-order motion processing, imaging motion and sense motion in depth, et al. [11][12][13]

V3A (V3 accessory): the second important motion processing area, respond to motion direction and speed

analysis, imaging motion and motion contours processing.[14][15][16]

KO (Kinetic occipital): respond to 2-D objects motion processing.[17][18][19]

STS (superior temporal sulcus): respond to Biological motion function.[20]

FEF (frontal eye field): respond to eye movement and attention transfer. [4]

DIPSA (anterior dorsal intraparietal sulcus): respond to 3-D objects motion processing, attention transfer and trace motion objects trajectory, participate in associate search tasks.[4]

B. Theories and models

a) Research Methods

Brain scientists have been able to observe the sensory, perceptual, and cognitive processes of the brain without removing the skull or clobbering people on the cranium. These techniques involve both behavioral data, such as reaction time experiments, and imaging technology, such as PET, CT, fMRI, MEG, ERP et al. Now it is really possible to see the workings of the brain as it perceives information about the world and how those perceptions are routed through the labyrinth of the brain.

b) Research Theories

So far, there are many modules and theories that simulated or interpreted visual motion perception mechanism of primates and human beings. As discussed in the previous, from functional and anatomical view, the theories of parallel processing and hierarchical organization had been already proven to be existed. The others include Pattern motion and component motion [21], motion energy hypothesis [22][23], local sign hypothesis [24] and first-order and second-order motion. [25]

IV. FUTURE WORK

The next we would concerned with analysis of the functional extrastriate visual areas of human beings, with special emphasis on the roles of those areas in processing information about visual motion, form, and color. I am particularly interested in the relationships between visual signals in these areas, and the perceptual decisions activity they support.

ACKNOWLEDGMENT

The author would like to thank Prof. Jinglong Wu for bringing her to the science temple, and the continuous guide and support for her research. The author also would like to thank Prof. Ning Zhong, Prof. Shengfu Lv and Mrs. Shuai Hua for all the efforts they have made for his study and life at the International WIC Institute. At last, specially thank her research fellows Yi Zeng, Jie Xiang et al.

REFERENCES

[1] N. Zhong, J.M Liu, Y.Y Yao, J.L Wu, S.F Lu, K.C Li, “Web Intelligence Meets Brain Informatics”, Lecture Notes in Artificial Intelligence 4845, Springer, 2007, pp. 1-31.

[2] D.L Peng. “General Psychology,” Beijing Normal University Press. Beijing, pp. 73-167, March 2004.

[3] Ungerleider LG, Haxby JV. “what” and “where” in the human brain [J]. Curropin Neurobiol, 1994, 4(1): 157-165.

[4] Hao Jing, Li Kuncheng. Chin J Med Imaging Technol, 2004, Vol 20, No 4.

[5] "Illusion," Microsoft® Encarta® Online Encyclopedia 2007. http://encarta.msn.com © 1997-2007 Microsoft Corporation. All Rights Reserved.

[6] A Dictionary of Psychology 2001, originally published by Oxford University Press 2001. Author: ANDREW M. COLMAN.

[7] Johansson G (1973) Visual perception of biological motion and a model for its analysis. Perception and Psychophysics 14:201–211

[8] R. Snowden, T. Freeman, The visual perception of motion, Current Biology, Volume 14, Issue 19, Pages R828-R831. Available online 4 October 2004.

[9] W.T. Newsome and E.B. Pare, A selective impairment of motion perception following lesions of the middle temporal visual area (MT). J. Neurosci. 8 (998), pp. 2201-2211.

[10] Lagae L. Maes H, Raiguel S, et al. Responses of macaque STS neurons to optic flow components: a comparison of areas MT and MST [J]. J Neurophysiol, 1994, 71(6): 1597-1626.

[11] Zeki S, Watson JD, Lueck CJ, et al. A direct demonstration of functional specialization in human visual cortex [J]. J Neurosci, 1991, 11(2): 641-649.

[12] Watson JD, Myers R, Frackowiak RS, et al. Area V5 of the human brain: evidence from a combined study using position emission tomography and magnetic resonance imaging [J]. Cereb Cortex, 1993, 3(1): 79-94.

[13] Tootell RB, Taylor JB. Anatomical evidence for MT and additional cortical visual areas in humans [J]. Cereb Cortex, 1995, 5(1): 39-55.

[14] Dupont P, Orban GA, De Bruyn B, et al. Many areas in the human brain respond to visual motion [J]. J Neurophysiol, 1994, 72(3): 1420-1424.

[15] Tootell RB, Mendoola JD. Functional analysis of V3A and related areas in human visual cortex [J]. J Neurosci, 1997, 17(18): 7060-7078.

[16] Tootell RB, Hadjikhani NK, Vanduffel W, et al. Functional anaysis of primary visual cortex (V1) in humans [J]. Proc Natl Acad Sci USA, 1998, 95(3): 811-817.

[17] Orban GA, Dupont P, De Bruyn B, et al. A motion area in human visual cortex [J]. Proc Natl Acad Sci USA, 1995, 92(4): 993-997.

[18] Dupont P, De Bruyn B, Vandenberghe R, et al. The kinetic occipital region in human visual cortex [J]. Cereb Cortex, 1997, 7(3): 283-292.

[19] Van Oostende S, Sunaert S, Van Hecke P, et al. The kinetic occipital (KO) region in man : an fMRI study [J]. Cereb Cortex, 1997, 7(7): 690-701.

[20] Ungerleider LG, Desimone R. Projections to the superior temporal sulcus from the central and peripheral field representations of V1 and V2 [J]. J Comp Neuro , 1984, 248(1): 147-163

[21] Huk AC, Heeger DJ, “Pattern-motion responses in human visual cortex”, Nat Neurosci. 2002 Jan;5(1):72-5.

[22] Seiffert A E, Cavanagh P. Position-based motion perception for color and texture stimuli: effects of contrast and speed. Vision Research, 1999, 39(25): 4172-4185.

[23] Werkhoven P, Sperling G, Chubb C. The dimensionality of texture-defined motion: A sing

[24] Whitney D, Bressler DW. Spatially asymmetric response to moving patterns in the visual cortex: Re-examining the local sign hypothesis. Vision Res. 2006.

[25] Lu Z L, Sperling G. Attention-generated apparent motion. Nature,1995,377 (6546):237-239.