Piers D. L. Howe, Ph.D.

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Education

1994-1998	Masters and B.A. Physics Oxford University, UK - Prof. Keith Burnett
1999-2003	Ph.D. Cognitive Science, Boston University, USA - Prof. Stephen Grossberg

Academic Positions

1998	Visiting Scientist	Mathematical modeling. Prof. Stephen Grossberg, Boston University
2003-2006	Postdoctoral Fellow	fMRI, behavioral investigations, neurophysiology Prof. Margaret Livingstone and Prof. David Hubel, Harvard Medical School, Boston, USA.
2005	Lecturer	Designed and taught undergraduate course: Psych 475: Experimental Methods: Learning & Perception University of Massachusetts (Boston)
2006-2007	Affiliated Fellow	fMRI. Sponsor: Prof. Livingstone Harvard NeuroDiscovery Center
2006-2007	Research Associate	Promotion from Research Fellow Prof. Margaret Livingstone and Prof. David Hubel Harvard Medical School, Boston
2008	Lecturer	Designed and taught graduate course. CN520: Principles & Methods of Cognitive & Neural Modeling 2 Boston University
2007-Present	Postdoctoral Fellow	fMRI & behavioral investigations Prof. Jeremy Wolfe and Prof. Todd Horowitz. Brigham & Women's, Hospital & Harvard Medical School

Grants and Fellowships

1997	-----------	Exhibitioner Magdalen College, Oxford University
1997	-----------	Commendation for Excellence for Practical Work, Oxford University
1999-2003	$66,000	Presidential University Graduate Fellowship, Boston University
2004-2006	$129,000	Helen Hay Whitney Postdoctoral Research Fellowship
2005-2008	$300,000	Co-Pi ARO 46961-LS. Principle PI: Prof. Margaret Livingstone

Teaching Assistantships

2001	Teaching Fellow	CN530 – Neural and Computational Models of Vision, Boston University, post-graduate course
2003	Guest Lecturer	CN810 –Topics in CNS: Vision in Man, Monkey, and Machine, Boston University, post-graduate course
2004	Tutor	Human Nervous System and Behavior, Harvard Medical School, post-graduate course
2004-2006	Teaching Fellow	Neurophysiology of Visual Perception, Harvard Medical School, undergraduate course
2005	Guest Lecturer	CN730 – Models of Visual Perception, Boston University, post-graduate course
2006	Guest Lecturer	PS222 – Perception and Behavior, Boston University, undergraduate course
2006	Substitute Tutor	Human Nervous System and Behavior, Harvard Medical School, post-graduate course

Courses That I Would Especially Like to Teach

Research Methods, Statistics, Cognitive Modeling, Cognitive Science, Behavioral Neuroscience, Sensation and Perception, Physiological Psychology, Introduction to Psychology, Neuroimaging, Attention.

Students Mentored

Ian Cinnamon (2009, high school student), Michael Cohen (2008-2009, postgraduate research assistant), Dwight Curtis (2006, high school student), Ayman Jarbaren (2009, high school student), Hersh Sagreiya (2006-2007, undergraduate honors student), Cheng-Cheng Zheng (2006, postgraduate student).

Membership

Association for Psychological Science, Cognitive Science Society, International Neural Networks Society, Vision Sciences Society.

Invited Talks

2002-2005	Harvard Vision Group (3 times)
2005	Boston University, Department of Cognitive and Neural Systems
2006	The College of the Holy Cross, Department of Psychology
2007	Harvard Medical School Friday Seminar Series
2007	Boston University, Tuesday Evening Lecture Series, College of Fine Arts
2007	Visual Attention Lab Seminar Series, Brigham and Women’s Hospital

2008	University of Massachusetts, Boston, Department of Psychology
2008	University of New South Wales, Sydney, Australia
2008	Plymouth University, Plymouth, UK

Service

2007-2009	Organization of the Visual Attention Lab Continuing Education Seminar Series
2007, 2009	Organization of high school visits
2007-	Maintenance of the Visual Attention Lab computer systems

Ad hoc reviewer for 16 journals/encyclopedias/grant agencies: Cambridge University Press, Brain Research, Cognitive Science Society, Encyclopedia for Consciousness (Elsevier), Journal of Neurophysiology, Journal of Neuroscience, Journal of the Optical Society of America, Journal of Vision, Information Fusion, Neural Networks, Neuron, Perception, Perception and Psychophysics, Spatial Vision, Vision Research, Wellcome Trust (UK).

Journal Articles

These can be downloaded from: http://search.bwh.harvard.edu/new/staff_files/howe_pubs/howe.html
My students are in bold.

1) Howe PD (2001). A comment on the Anderson (1997), the Todorovic (1997), and the Ross and Pessoa (2000) explanations of White's effect. Perception, 30(8), 1023-1026. Commentary with original data.

2) Howe PD & Watanabe T (2003). Measuring the depth induced by an opposite-luminance (but not anti-correlated) stereogram. Perception, 32(4), 415-21.

3) Grossberg S & Howe PD (2003, authorship alphabetical, equal contributions). A laminar cortical model of stereopsis and three-dimensional surface perception. Vision Research, 43, 801-829.

4) Howe PD (2005). White's effect: removing the junctions but preserving the strength of the illusion. Perception, 34(5), 557-564.

5) Howe PD (2006). Testing the coplanar ratio hypothesis of lightness perception. Perception, 35(3), 291-301.

6) Howe PD & Livingstone MS (2006). End-stopping and the stereo aperture problem in macaque V1. Cerebral Cortex, 16(9), 1332-1337.

7) Howe PD, Thompson PG, Anstis SM, **Sagreiya H**, Livingstone MS. (2006). Explaining the Footsteps, Bellydancer, Wenceslas and Kickback Illusions. Journal of Vision, 6, 12(5), 1396-1405.

8) Howe PD & Livingstone MS. (2007) The Use of the Cancellation Technique to Quantify the Hermann Grid Illusion. PLoS ONE 2(2): e265

9) Howe PD, **Sagreiya H**, **Curtis DL**, **Zheng CC**, Livingstone MS. (2008) The double-anchoring theory of lightness perception: A comment on Bressan (2006). Psychological Review, 114(4), 1105-1110. Commentary with original data.

10) Howe PD, Horowitz TS, Wolfe JM (2008). Transient signals per se do not disrupt the flash-lag effect. Behavioral and Brain Sciences, 31(2), 206. Commentary with original data.

11) Hubel, DH, Howe PD, Duffy, AM, Hernandez, A (2009). Scotopic foveal afterimages. Perception, 38(2), 313-316.

12) Howe PD, Livingstone MS, Morocz I, Horowitz TS. (2009). An fMRI investigation into multiple object tracking. Journal of Vision, 9(4), 1-11.

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13) Howe PD, **Cohen MA**, Pinto Y, Horowitz TS. (submitted) Eight objects can be tracked in parallel.

14) Howe PD, Livingstone MS, Morocz I, Horowitz TS. (submitted) Undirected graphs for neuroimaging: A principled model-free method for determining the causal relationships between brain areas.

15) Howe PD, **Cohen MA**, Pinto Y, Horowitz TS. (submitted) Distinguishing between parallel and serial accounts of multiple object tracking.

16) Howe PD, Pinto Y, Horowitz TS. (submitted) The coordinate systems used in visual tracking.

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17) Howe PD & Horowitz TS. (in preparation) Is identity tracking a parallel process?

18) **Cohen MA**, Pinto Y, Howe PD, Horowitz TS. (in preparation) Tracking identities affects location tracking.

19) Pinto Y, Howe PD, **Cohen MA**, Horowitz TS. (in preparation) Complex familiar objects can be tracked better than unfamiliar objects.

Theses

PhD thesis: *Cortical mechanisms of depth and lightness perception: neural models and psychophysical experiments.*

Master's thesis: *An investigation into the range of validity of the recollision model of intense field upconversion.*

Review Chapters

1) Howe PD, Evans KK, Pedersini R, Horowitz TS, Wolfe JM., Cohen M (2009). Attention: Selective Attention and Consciousness. Encyclopedia for Consciousness. Elsevier, UK.

2) Howe PD (2009). Attention, Awareness and Neglect. Encyclopedia for Consciousness. Elsevier, UK.

3) Evans KK, Horowitz TS, Howe PD, Pedersini R, Kuzmova Y, Reijnen E, Pinto Y, Wolfe JM. (submitted). Visual Attention. In Nadel L (Ed) Wiley Interdisciplinary Reviews: Cognitive Science John Wiley & Sons Ltd.

Conference Presentations

1) Howe PD & Grossberg S (2002). A laminar cortical model of monocular and binocular interactions in depth perception. Journal of Vision, 2(7), 324.

2) Howe PD & Grossberg S (2002). Laminar cortical architecture in depth perception. 6th International Conference on Cognitive and Neural Systems, 6.
3) Howe PD & Livingstone MS (2005). Binocular vision and the correspondence problem. Journal of Vision, 5(8), 800.
4) Livingstone MS & Howe PD (2005). White's effect: removing the junctions but preserving the strength of the illusion. Journal of Vision, 5(8), 563.
5) Howe PD & Livingstone, M.S. (2005). Binocular vision and the stereo correspondence problem. Ninth International Conference on Cognitive and Neural Systems.
6) Howe, PD (2005). Stereoscopic depth discrimination in the visual cortex: V1 partially solves the single object correspondence problem. 48th Annual Meeting of Helen Hay Whitney Fellowship Society.
7) Howe, PD & Livingstone, M.S. (2006). A simple context-dependent and luminance driven model of lightness perception. Journal of Vision, 6(6), 704.
8) Howe, PD & Livingstone, M.S. (2006). A simple luminance- and contrast- driven model of lightness perception. Tenth International Conference on Cognitive and Neural Systems.
9) **Sagreiya, H**, Howe, PD & Livingstone, M.S. (2006). The footsteps illusion is caused by motion capture. Tenth International Conference on Cognitive and Neural Systems.
10) Howe PD, Thompson PG, Anstis SM, **Sagreiya H**, Livingstone MS. (2007). Explaining the Footsteps, Bellydancer, Wenceslas and Kickback Illusions. Journal of Vision, 7(9), 982.
11) **Cohen M,** Howe PD, Horowitz TS, Wolfe JM(2008). Support for a postdictive account of the flash-lag effect. Journal of Vision, 8(6), 600.
12) Howe PD, Livingstone MS, Istvan M, Horowitz TS, Wolfe JM(2008). A neurophysiological model of multiple object tracking derived from fMRI. Journal of Vision, 18(6), 220.
13) Howe PD, **Cohen M**, Yair Pinto, Horowitz TS, (2009). Distinguishing between parallel and serial accounts of multiple object tracking. Journal of Vision, 9(8), 239.
14) Horowitz TS, **Cohen M**, Howe PD (2009). Do multiple object tracking and letter identification use the same visual attention resource? Journal of Vision, 9(8), 247.

References

Prof. Stephen Grossberg,
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Prof. Margaret Livingstone
Department of Neurobiology, Harvard Medical
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Boston, MA 02115, USA
Tel: 00-1-617-432-1664
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Prof. Jeremy Wolfe
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Teaching Philosophy

I love to teach and have always sought opportunities to teach beyond what was expected of me. For example, I volunteered to teach a course at the University of Massachusetts (Boston) even though, due to visa regulations, I could not accept any payment. Similarly, I sought out an opportunity to teach at Boston University, after I had moved on to Harvard Medical School.

I believe in....

- **a supportive learning environment**

  Perhaps the important part of my job as a lecturer is to provide a supportive learning environment. I show that I care about the progress of my students by, at all times, treating the students with respect, answering their emails promptly and taking the time to present clear lectures that follow a well-defined syllabus.

- **the importance of motivating students**

  It is crucially important that I appear enthusiastic and communicate this enthusiasm to the students. However, sometimes this is not enough. The last course I taught met once a week for three hours on Tuesday evenings. There I discovered the importance of regularly "changing gears". Every twenty minutes, I would stop the lecture and spend a few minutes doing something else. Sometimes, I would show a brief video clip. Other times, I might discuss the practical significance of what they had just learnt. In this way, I was able to ensure that the students remained focused.

- **learning by doing**

  I believe that students learn best when they repeatedly use the material they have heard in lectures. This is why, if at all possible, I always set a weekly problem set. These problem sets enable me to monitor each student's progress and intervene, if necessary. Also, during class, I will occasionally have the students work through a short problem. By watching their reactions when I present the answer, I can tell whether I need to recap the material that I just covered.

- **relating the course material to the real world**

  Students are most motivated when they can readily see the importance of what they are learning. For this reason, I take the time to link the class material to ongoing research and to the real world. For example, for the introductory cognitive science course I taught at Boston University, I found that in every lecture I was able to relate the lecture material to the work of at least one faculty member in the department. The students responded extremely positively to this.

Teaching Evaluations

I have been a tutor for two classes, a teaching fellow for three classes and a guest lecturer for three other classes. In addition, I have taught two classes as sole instructor, being responsible for all aspects of the class from constructing the syllabus to marking the homework assignments. When I first started, I had not yet found an effective teaching style. Consequently, my overall rating for my first course, Psych 475, was respectable but not excellent (3.75 out of 5.0). By my second course, I had learned from my previous mistakes and achieve an excellent overall rating, **4.75 out of 5.0**.

Psych 475: Experimental Methods: Learning & Perception
University of Massachusetts (Boston) Fall 2005
Overall rating: **3.75/5.0** (scale runs from 1 (poor) to 5 (excellent))
Copies of the original student comments and evaluations may be obtained by contacting the head of the department, Professor Jane Adams jane.adams@umb.edu

Examples of anonymous student comments:
Dr Howe was obviously knowledgeable and experienced in his field. He had valuable insights into research and experimental design.

Instructor was available for questions and provided very useful feedback.

He was always open to respond to any & all emails quickly. He gave us his personal phone number to reach him when it was necessary. He responded to student requests to minimize homeworks while doing project.

CN520: Principles and Methods of Cognitive and Neural Modeling 2.
Boston University, Spring 2008
Overall rating: **4.75/5.0** (scale runs from 1 (poor) to 5 (excellent))
Copies of the original student comments and evaluations are available from the departmental secretary Robin Amos, ramos@cns.bu.edu.

Examples of anonymous student comments:
Prof. Howe is by far one the most knowledgeable and compassionate teachers I have every had the pleasure to learn from. His strong grasp of the material is clearly displayed by his ability to explain topics in multiple ways. His compassion for teaching is blatantly obvious by the level of effort he puts into actual teaching the material, instead of simply presenting it. [Underlining was the student's.]

The course is helpful, exactly what I want. Piers is very patient, well-prepared. Excellent course & instructor.

Very good course and instructor. This is the first course that I got to know what was going on actually.

Mentoring

I have mentored 6 students, 4 of whom obtained an authorship on at least one journal article. The other 2 were high school students that I supervised as part of the RSI program run by MIT. My research area is well suited for student collaborations. The students only have to acquire a very rudimentary knowledge of the MATLAB® programming language before they can fully participate in my research. Once they have assisted in running an experiment, I find that they can often devise interesting extensions. For example, the work in my first *Journal of Vision* article was initiated by my student Hersh Sagreiya and formed the basis of his honors thesis at Harvard University. He is now a medical student at Stanford University. Similarly, Michael Cohen extended one of my tracking studies and is about to submit the resultant paper as first author. He is now a graduate student in the psychology department at Harvard University. Below I have pasted the references I received from them. They would be happy to answer any questions you may have.

Hersh Sagreiya
sagreiya@gmail.com

October 9, 2009

Dear Sir or Madam,

I worked with Dr. Piers Howe for two years as an undergraduate at Harvard. He was always helpful, caring, and attentive, and he provided an ideal research experience that was a highlight of my college experience. This work lead to two co-authorships on publications, two conference abstracts, one of which I presented at Boston University, and three undergraduate research grants. Dr. Howe also supervised my undergraduate honors thesis.

These research experiences have been instrumental to me at Stanford Medical School and helped me win the HHMI Research Fellowship for Medical Students. I would whole-heartedly recommend Dr. Howe to any student seeking a mentor.

Sincerely,

Hersh Sagreiya

Michael Cohen
michaelthecohen@gmail.com

Michael A. Cohen
Vision Sciences Laboratory
Department of Psychology
Harvard University
William James Hall
33 Kirkland St
Cambridge, MA 02138

To whom it may concern,

Dr. Piers Howe advised me for two years during my time as a research assistant at the Visual Attention Lab (Harvard Medical School/Brigham and Women’s Hospital). For the most part, Dr. Howe supervised me on projects that he was leading but for which I was assisting with data collection and analysis. With every project, Dr. Howe always made sure that I fully understood the motivation and rationale for what we were doing. Rather than simply give me work to do, he took a personal interest in my own understanding of the material that we were researching. Near the end of my time at the lab, he began mentoring me on a series of experiments that I myself was running. His helpful comments and suggestions proved invaluable to both my understanding of the relevant issues and to the overall success of the project. Time and time again, when I found myself uncertain or frustrated, Dr. Howe took the time to really help clarify the issues and make sure that I was making solid progress.

In sum, Dr. Howe’s guidance throughout the years aided me in incalculable ways. I struggle to believe that I could have successfully matriculated into the doctoral program at Harvard University without his advise and support. As an advisor, I give him my highest recommendation.

Sincerely,

Michael A. Cohen

Research Statement

In my initial research, I used a variety of techniques (behavioral experiments, fMRI, extracellular recordings and computational modeling) to study various aspects of human and macaque visual processing: lightness perception, depth perception, motion perception, and the perception of time (please see the attached research summary for more details). Recently, I have become interested in more cognitive issues, in particular attention.

Attention plays a central role in cognition. Because we have limited capacity, to avoid being overwhelmed, we use attentional mechanisms to select some stimuli at the expense of others. Given attention's importance, it is unsurprising that disorders of attention are characteristic of a wide variety of clinical disorders and diseases including attention deficit disorder (Mason et al., 2003), autism (Burack, 1994; O'Riordan et al., 2001), schizophrenia (Mathalon et al., 2004), Parkinson's Disease (Berry et al., 1999; Briand et al., 2001; Horowitz et al., in press), borderline personality disorder (Posner et al., 2002) and obsessive-compulsive disorder (Clayton et al., 1999; Cohen et al., 2003). Furthermore, changes in attention also characterize the normal aging process (Bherer et al., 2005; Greenwood & Parasuraman, 2004; Lee et al., 2003), response to a variety of drugs (Carter et al., 2005; Marrocco & Davidson, 1998) and the response to sleep deprivation in naïve subjects (Horowitz et al., 2003; McCarthy & Waters, 1997; Sanders, 1982) and medical personnel (Lockley et al., 2004). An effort to understand these changes in the normal workings of attention requires a comprehensive understanding of that normal state. There are therefore many good reasons to study how attention operates in normal subjects.

I am particularly interested in the selection mechanisms that allow an observer to chose which object(s) they attend to. At the present, much of my research uses a "multiple object tracking" task because this proves to be a particularly productive way to study the *dynamic* aspects of attentional selection. In this task, the observer is shown a number of identical objects, a subset of which are identified as the targets to be tracked. The objects then move around the display in a random fashion. The objects then stop and the observer is asked to identify the targets. Because all the objects are identical, the only way this task can be performed is by attending to the targets. The key point is that, because objects need to be tracked before they can be attended, an understanding of tracking is a prerequisite to an understanding of attention.

Another reason to use the multiple object tracking task is because it is a distillation of tracking tasks that we perform in the real world. For example, when driving we need to keep track of moving cars. Similarly, radar operators/air traffic controllers need to keep track of moving airplanes. I have found that the knowledge that I gained from studying the multiple object tracking task has helped me in several of my practical projects. For example, I am currently investigating how to design radar displays that will improve the tracking ability of radar operators. A second project investigates whether the tracking task can be used to identify which stroke patients are likely to experience driving difficulties. These patients would then be referred to a traditional road test.

Finally, I am happy to collaborate on projects that do not involve studying visual attention. For example, I am currently developing a visual acuity test to be administered to patients who suffer from dry eye syndrome. Dry eye patients can often pass traditional visual acuity tests (e.g. the Snellen eye chart) if the tests are administered quickly. Conversely, my test operates over an extended period of time, so is likely to be difficult for dry eye patients.

Research Summary

To download my papers: http://search.bwh.harvard.edu/new/staff_files/howe_pubs/howe.html

1. Depth Perception: Computational Investigations

Computational models play a crucial role in vision research. They summarize what we know and suggest which experiments need to be performed. I constructed a model of depth and lightness perception that simulated, and thereby explained, twenty visual phenomena in terms of known neuroanatomy and neurophysiology (Grossberg and Howe, 2003; Figure 1). This formed the basis of my supervisor's subsequent work in visual perception and was the inspiration behind several of my subsequent psychophysical and neurophysiological investigations.

2. Depth Perception: Behavioral Investigations

Models need to be tested to reveal their flaws. I performed a psychophysical investigation to test a prediction of the above model. I showed that the model's prediction that under certain conditions opposite-luminance stereograms should produce stereo-depth was correct (Howe and Wanatabe, 2003; Figure 2). This finding proved to be important in my subsequent neurophysiological study into depth perception.

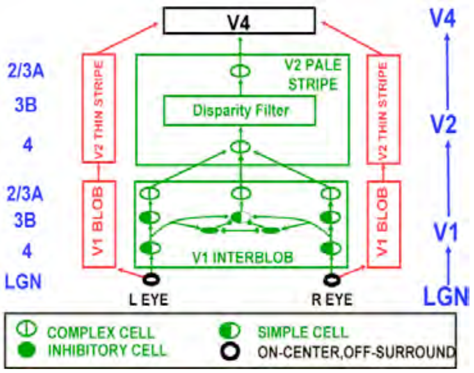


Figure 1. The model of Grossberg and Howe (2003). It was able to correctly simulate 20 visual phenomena based on known brain neurophysiology.

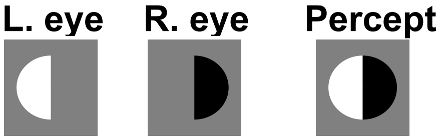


Figure 2. A stereogram used by Howe and Watanabe (2003) to test a prediction of the Grossberg and Howe (2003) model.

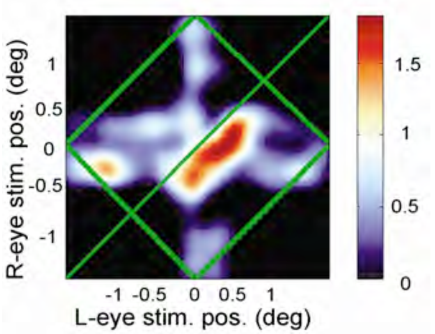


Figure 3. A figure from Howe and Livingtone (2006) that shows the response of a cell in the macaque primary visual cortex as a function of the position of the stimulus in the left -and right-eye receptive fields. The elongation of the area of high activity along the green diagonal indicates that this cell was sensitive to stereo disparity.

3. Depth Perception: Neurophysiology

I have recorded extracellularly from neurons in the primary visual cortex of macaque monkeys. Such cells have very small receptive fields, so sometimes generate spurious depth signals, an issue knows as the stereo aperture problem. I investigated how subsequent stages of the visual system could ignore these spurious depth signals and so create a valid depth percept (Howe and Livingstone, 2006; Figure 3). Our finding proved to be compatible with previous work on the motion aperture problem suggesting that similar principles might be generally applicable throughout the visual system, wherever an "aperture problem" occurs.

4. Lightness Perception: Behavioral Investigations

Lightness perception is a fundamental aspect of vision. Previously, it was thought that either T-junctions or coplanarity were the major determinants of lightness. I showed that their importance had been exaggerated (Howe, 2001; Howe 2005; Howe, 2006; Figures 4 & 5). When subsequently investigating the double anchoring theory of lightness perception, I proved that, contrary to this theory, perceptual grouping does not always determine an object's lightness (Howe et al., 2007). It seems that lightness is determined by a number of different, and sometimes conflicting, principles, so it cannot be explained by a single, unified grand theory as has been the implicit assumption of many previous investigations. If true, this would require a paradigm shift in our thinking of how lightness research should be conducted.

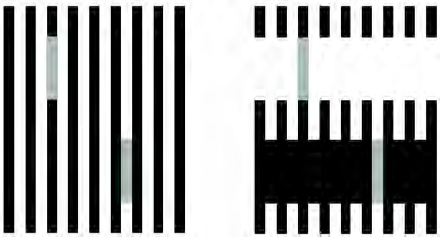


Figure 4. Stimuli used by Howe (2001) to demonstrate the inadequacy of various T-junction accounts of lightness perception.

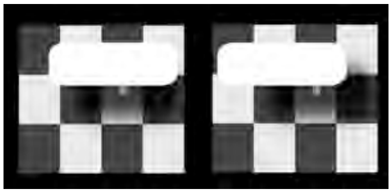


Figure 5. Stimuli used by Howe (2006) to test the coplanar ratio hypothesis of lightness perception.

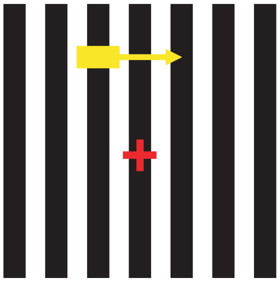


Figure 6. The Footsteps Illusion stimulus used by Howe et al. (2006). Although the yellow bar moves at a constant rate, observers may perceive it to repeatedly stop moving.

5. Motion Perception: Behavioral Investigations

The Footsteps Illusion (Figure 6) demonstrates the dramatic effect a background can have on the perceived speed of an object. This can be important in situations where a person needs to accurately estimate the speed on an object (e.g. when driving). In this illusion, a yellow bar moves over a black and white background. Although the yellow bar moves at a constant rate, most subjects perceive it to come to a complete standstill when it reaches a white stripe. In the past, this illusion has been explained in terms of the variations in contrast at the leading and trailing edges of the yellow bar. I demonstrated that this explanation was incomplete and the illusion is mainly caused by a competition between the vertical and horizontal edges of the moving bar (Howe et al., 2006).

6. The Herman Grid Illusion

In the Hermann grid illusion (Figure 7), illusory dark gray smudges are seen at the intersections of the grid (when viewed under the appropriate conditions). The illusion has been extensively studied because it thought to directly reflect the functioning of the early visual system. Often, its strength is measured by placing a disk at an intersection and measuring the luminance of the disk required to nullify the corresponding illusory dark gray smudge. I showed that this technique is invalid because this manipulation creates an entirely different illusion, which I called the blanking illusion. The latter can be explained by Weber's law and collinear facilitation (Howe and Livingstone, 2007).

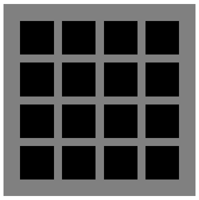
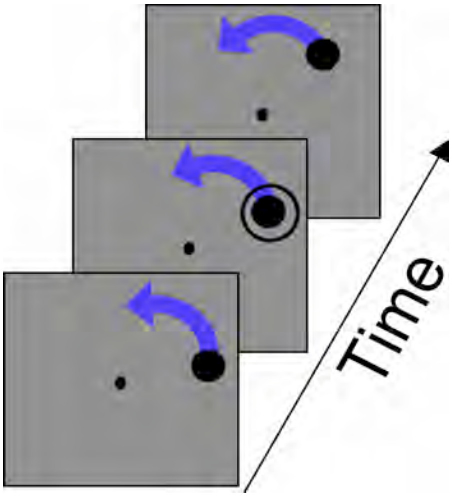


Figure 7. The Hermann grid illusion. Illusory dark smudges are seen at the gray intersections



7. The Flash-Lag Effect

A stationary ring flashed over a moving dot will appear behind the moving dot, an illusion known as the flash-lag effect. This illusion is of interest because it shows how the brain compensates for the delays inherent in neural processing. By investigating how the visual system handles transient signals, I demonstrated that the commonly accepted explanation for this illusion requires a substantial modification (Howe et al., 2008).

Figure 7. The flash-lag effect. If a stationary ring is flashed over a moving dot it will appear to lag the moving dot. This illusion is thought to demonstrate how humans compensate for the delays inherent in neural processing.

8. fMRI Investigation Into Sustained Attention

Multiple Object Tracking (MOT) is of interest because it allows us to study sustained attention. Previous fMRI studies identified the brain areas involved in MOT by comparing the brain activity when the subject tracked multiple objects to the brain activity when the subject passively viewed the same stimulus. However, when one tracks objects one must also attend to them, but when passively viewing a scene one neither attends nor tracks the objects. Consequently, these previous studies could not determine whether the reported brain areas were responsible for attending to the objects or for tracking the objects. By using a baseline condition that involved attention, I was able to avoid this confound and show that the areas responsible for tracking were fewer than previously thought (Howe et al., 2009). This finding allowed me to create a tentative neural model of MOT that I will use as the basis for future fMRI investigation into sustained attention.

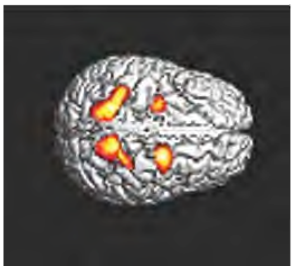
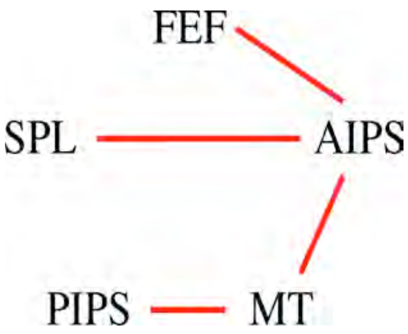


Figure 8. An fMRI scan revealing some of the brain areas active when an observer tracks multiple objects.



9. Development Of Novel fMRI Data Analysis Techniques

Once one has used fMRI to identify which brain areas are active when an observer performs a given task, the next step is determine how these brain areas interact when the observer performs the task. I have recently developed a new fMRI data analysis technique that does this and calculates the effective connectivity of a given set of brain areas (Howe et al. submitted). This technique can be used in a wide variety of fMRI investigations regardless of their exact subject matter. In the future I intend to make the underlying computer code publicly available.

Figure 9. The connectivity structure recovered from the fMRI data. The brain areas are frontal eye fields (FEF), anterior intraparietal sulcus (AIPS), superior parietal lobule (SPL), posterior intraparietal sulcus (PIPS) and medial temporal area (MT).

10. Scotopic Foveal Afterimages

If, after being in the dark for many minutes, one views an extended surface in a dimly lit room, one fails to see any hint of the dark spot at the center of gaze that might be expected from the absence of rods in the fovea. This suggests that some sort of "filling-in" mechanism must operate by which the brightness of the surround propagates into the center. We found that if after viewing the surface for some seconds it is suddenly completely darkened one sees a relatively bright spot, about two degrees in size, at the point of fixation (Hubel, Howe, Duffy and Hernandez, 2009). The spot gradually fades over many seconds. If the surface is now restored to its original luminance a dark spot of similar size appears where one fixates, that again lasts for several seconds. It is hoped that by studying this phenomena we will gain insight into "filling-in", a phenomenon that appears to be ubiquitous in visual perception.

Figure 10. Rods are photoreceptors used by the visual system to see in low illumination levels. In the fovea there are very few rods, so one would expect that, in low illumination levels, there would be a blind spot at the point of fixation. Surprisingly, this blind spot is often "filled-in".

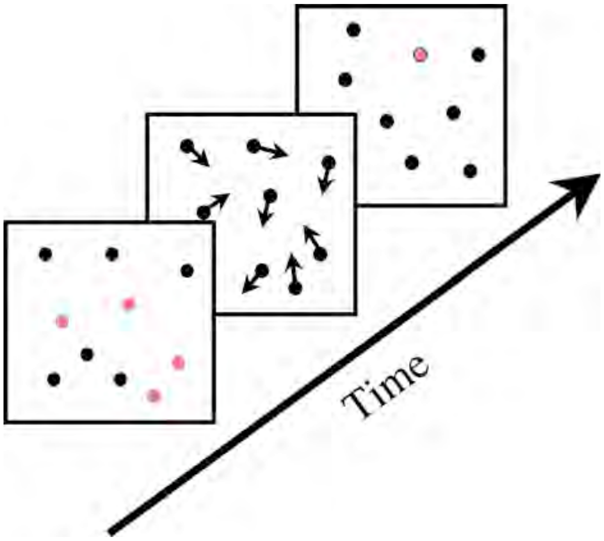


Figure 11. A typical multiple object tracking experiment. At the start of the trial 4 of the 10 disks turn red to indicate that they are targets to be tracked. The disks then all become the same color and move about the display for several seconds. At end of the trial the disks freeze and the observer indicates which were the targets.

11. Multiple Object Tracking: Serial or Parallel?

In a world without moving objects, attention could simply be directed to locations. However, because objects do move, they first have to be tracked before they can be attended. Tracking is thus a fundamental attentional operation and, to some extent, the limits of object-based attention are determined by the limits of tracking. Humans can track multiple moving objects. Is this accomplished by attending to each object in turn (the serial model) or do we attend to all the objects simultaneously (the parallel model). In our displays, the objects moved either sequentially or simultaneously. The serial model predicts that tracking performance should be greatest in the first condition. Conversely, a parallel model predicts equal performance in the two conditions. Our data was consistent only with a parallel model (Howe et al., submitted, 2 papers).

11. The Coordinate Systems Used In Object Tracking

Here we ask which coordinate system is used to track objects, retinal (retinotopic), scene-centered (allocentric), or both. While maintaining gaze on a fixation cross, observers tracked three of six disks, which were confined to move within an imaginary square. Relative to the imaginary square, the disks all moved at the same speed. By moving either the imaginary square (and thus the disks contained within), the fixation cross, or both, we could increase the disk speed in one coordinate system while leaving it unchanged in the other. Increasing the disks' speeds in either coordinate system reduced tracking ability by an equal amount. These data support the hypothesis that humans track objects *simultaneously* in both retinotopic and allocentric coordinates (Howe et al., submitted). This finding imposes a strong constraint on models of multiple object tracking.

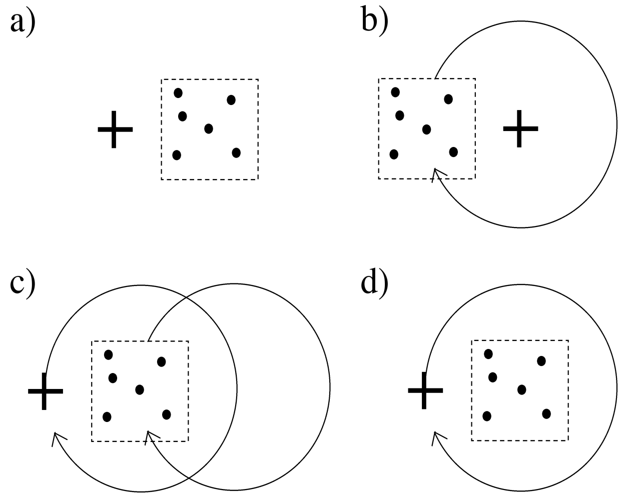


Figure 12. The four stimulus conditions used in the experiment. In all cases the disks were confined to move within an imaginary square. Either the fixation cross, the imaginary square or both would move, thereby causing each disk to have a different speed in the retinotopic and allocentric coordinate systems.

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