SYNTHESES OF CVNET DISCUSSION ON "CONSEQUENCES OF GOOD AND BAD STEREOPSIS":

The Color and Vision Network (CVNet) is an international mailing list with an accompanying bulletin board system (BBS) for postings related to the study of vision.

Compiled by Jeremy B. Wilmer, University of Pennsylvania, Sept, 2006

Here are some syntheses I have put together, arising from the 155-email discussion on cvnet that followed my Aug. 15, 2006 posting asking "What are the consequences of good and bad stereopsis?"

1) General hypotheses - list of several overarching hypotheses arising from the discussion.

2) Specific hypotheses - list of all specific skills hypothesized on-list or off to depend on, or not to depend on, stereoscopic ability, grouped by source ('systematic study' or 'personal experience').

3) Questionnaire - an exploratory survey measure designed to probe abilities and experiences that may relate to stereoscopic ability (Interested in collaborating? Drop me an email.)

4) References - list of all references mentioned on-list or off, roughly by topic.

5) Archive - full text of all 87 on-list postings (not including the 68 emails I received off-list).

1) **General hypotheses** (first three arising from systematic studies, last three arising from the present discussion) -

a. Medium precision speeded manual dexterity:

Better and worse stereopsis may have consequences for speeded manual tasks (reaching for, grasping, or placing objects) that require some degree of precision, especially in the presence of obstacles. The majority of the studies that have found motor differences between good and bad stereopsis have looked at this type of task. A relatively high degree of motor precision seems attainable through motion parallax (aka 'head bobbing'), but presumably at the expense of speed.

b. High precision manual dexterity

Better and worse stereopsis may have consequences for manual tasks that require a very high degree of precision - for example threading a needle and soldering.

c. Object segmentation and surface perception

While no studies mentioned have compared those with better and worse stereopsis on their object perception, a number of suggestions were made that this may be an important benefit of stereopsis (both currently and evolutionarily).

d. Sports requiring hitting of small, fast moving objects (squash, baseball, badminton, tennis)

Though there were many anecdotal reports of stereoblind individuals who were either proficient or not at such sports, no studies were mentioned that actually compared the performance of folks with better and worse stereopsis (or stereomotion) on such tasks.

e. Driving

Though there is little to no rigorous evidence demonstrating that stereoblind individuals are more dangerous on the road (see posting by Eli Peli), anecdotal reports suggest that differences in driving *strategy* may become apparent at night or on crowded streets.

f. Sports requiring control of an object (soccer, basketball, ice/field hockey)

Guilt by omission? While there were quite a number of reports of stereoblind folks proficient at sports requiring hitting of small, fast-moving objects, there was not a single report of an individual proficient at sports that require one to maintain control over an object.

Jeremy's note: May I suggest that one of the more robust ways of testing any of these hypotheses is by designing well-controlled, population-based studies to identify associations between individual differences in specific stereoscopic skills and specific perceptual or motor consequences. Anyone interested in collaborating?

2) Specific hypotheses -

Systematic studies of perceptions/actions for which stereopsis may be important:
a) Reaching, grasping, pointing...
Greenwald, Knill & Saunders, 2004 - online correction during reaching
Sheedy, Bailey, Buri & Bass, 1986 - placing straws on sticks at varying angles
Anna Ma-Wyatt - pointing while avoiding obstacles
Michael Morgan - picking blackberries w/o getting scratched
Alison Finlay - efficient reaching
b) Object perception
Nakayama, Shimojo & Silverman, 1989 - border ownership and amodal completion
Anderson, 2005 - surface lightness
Julesz, see classic work on random dot stereograms - contour segmentation
Sacks, 2006 (New Yorker article on Sue Barry's experiences)

Systematic studies of perceptions/actions for which stereopsis may not be necessary:
a) Driving
see Eli Pelli's posting, Aug 25, 2006, and subsequent responses
b) Reaching, grasping, pointing in presence of 'head bobbing'
Marotta et al, Eye (9) 333-336 - monocular adults reach precisely when bobbing their heads
Gonzalez et al, Clin Vis Sci (4) 173-177 - children reach precisely when bobbing their heads

(note: numbers in parentheses indicate multiple case reports)

Personal experiences suggest that stereopsis may be useful for the following perceptions/actions:
needle threading(5), button stringing, pipetting into a test tube without touching tube, performing fine surgery (unless use 'head bobbing' to create motion parallax), soldering(4), swatting flies, sandwich making, fine tasks using binocular microscope, pouring liquid into small containers, precise movements in 3D with only visual feedback, fine eye-hand coordination(3), putting key in keyhole at first pass, cricket(2), squash, tennis(2), baseball, driving(2), driving on crowded city streets, driving comfortably and effortlessly, driving at night, parking, attaining good fusion in bright lights, good vergence under low light conditions, good vergence while reading difficult texts/tomes, professional skiing, climbing trees and jumping to the ground, walking/jogging on subtly undulating ground w/o stumbling(3), crispness of object borders, visceral sense of depth, visceral appreciation for depth provided by monocular cues, quality control of computer chips (though this may require free fusion)

Personal experiences suggest that stereopsis may not be necessary for the following perceptions/actions:
performing fine surgery (if use 'head bobbing' to create motion parallax)(2), sandwich making(2), soldering, dentistry (perhaps cause often monocular with small mirror or fiberoptic endoscope)(3), fine eye-hand coordination, squash(2), badminton, professional ice hockey, tennis, professional cricket, parking, driving(3), plane flying, professional skiing, professional ski jumping, avoiding clumsiness, avoiding 20 foot powerlines while setting up large machinery (if use 'head bobbing to create motion parallax), academic achievement

3) Questionnaire (on next two pages so it can be directly printed, and used!) -

Instructions: Please check the box that describes whether, or how often, each statement applies to you. Note: e.g. means 'for example.'

		Never, or Disagree strongly	Rarely, or Disagree somewhat	Sometimes, or Neither agree nor disagree	Often, or Agree somewhat	Always, or Agree strongly
1	I learn to use new tools (e.g. chopsticks) more easily than the average person.					
2	I reach for things quickly without knocking them by mistake.					
3	I would be slower than the average person at picking up, one by one, coins scattered in the grass.					
4	When hammering a nail, I fail to hit it straight on.					
5	I am naturally skilled at sports that require dribbling a ball with hands or feet (e.g. basketball, soccer).					
6	I move my head back and forth to help me see close things.					
7	I bump my head on things by mistake.					
8	I have good posture when I walk.					
9	I drive slower than most persons on crowded streets.					
10	I have difficulty with sports that require hitting a small, fast moving object coming from relatively far away (e.g. cricket, baseball, tennis).					
11	I find it difficult to thread a needle.					
12	I am made uncomfortable by the brightness of a typical sunny day.					
13	I temporarily lose vision in one or both eyes.					
14	I have good hand-eye coordination.					
15	I stumble if the ground is uneven.					
16	I drive as comfortably at night as during the day.					
17	When I was a child my parents or teachers told me that I was holding the book too close to my eyes.					
18	My eyes feel 'tired', especially at the end of the workday.					
19	My sense of 3D depth is better than most.					

		Never, or Disagree strongly	Rarely, or Disagree somewhat	Sometimes, or Neither agree nor disagree	Often, or Agree somewhat	Always, or Agree strongly
20	I drop food on my clothing when I eat.					
21	It is somewhat uncomfortable for me to look a person in the eye when talking to them.					
22	I hit the curb while parallel parking.					
23	I have difficulty with tasks requiring fine motor control.					
24	I would be faster than the average person at picking up, one by one, sunflower seeds scattered					
25	When driving, I have trouble judging where the side of the car is.					
26	When I was a child I would blink my eyes more than most children.					
27	When I unlock a door, the key hits beside the keyhole before going in.					
28	I close or cover one eye when I read.					
29	Were I to carry a long pole, I would be quite good at keeping it from bumping into things.					
30	I pour liquid from one container into another without spilling a drop.					
31	I have good posture after reading for an hour.					
32	I bump into persons or objects (e.g. furniture) by mistake when in a crowded room.					
33	I am naturally skilled at sports that require hitting a small, fast moving object coming from relatively					
34	I act in a clumsy manner.					
35	Were I to race others in picking berries off thorny bushes, I would get fewer than my fair share of					
36	I have difficulty with tasks requiring gross motor control (e.g. throwing and catching)					

4) References -

Visual and performance consequences of long-term monocular vision:

Steinbach, M. J. & Gonzalez, E. G. (2006) Visual development with one eye. In M. R. M. Jenkin and L. R. Harris (Eds.), On Seeing Spatial Form. Oxford University Press. Pp. 385-404 (available from John Steinbach as a pdf to those interested)

Braunstein, M. L. Andersen, G. J., Rouse, M. W., & Tittle, J. S. (1986). Perception & Psychophysics, 40, 216-224.

Rouse, M. W., Tittle, J. S., & Braunstein, M. L. (1989). Optometry and Vision Science, 66, 355-362.

Laberge-Nadeau C, Dionne G, Maag U, Desjardins D, Vanasse C, Ekoe JM. Accident Analysis and Prevention. 1996;28:43-51.

McKnight AJ, Shinar D, Hilburn B. Accid Anal Prev. 1991;23:225-237.

Racette L, Casson EJ. Optom Vis Sci. 2005;82:668-674.

Steeves et al. Vis Res 2002, (42) 143-150

Steeves et al. Vis Res 2000, (40),3783-3789

Marotta et al. Eye, (9) 333-336)

Gonzalez et al. Clin Vis Sci, (4) 173-177

González, Steeves. Kraft, Gallie, & Steinbach (BBR, 2002, (128) 71-80)

Visual consequences of amblyopia:

McKee SP, Levi DM, Movshon JA. J Vis. 2003;3(5):380-405.

Agrawal R, Conner IP, Odom JV, Schwartz TL, Mendola JD. Arch Ophthalmol. 2006 Jun;124(6):844-50.

Performance consequences of taking away stereopsis from viewers with good stereopsis:

Jones RK, Lee DN. J Exp Psychol Hum Percept Perform. 1981 Feb;7(1):30-40

Sheedy JE, Bailey IL, Buri M, Bass E. Am J Optom Physiol Opt. 1986 Oct;63(10):839-46.

Fawcett et al., 2001 JAAPOS 5:342-7

Melmoth & Grant, Exp Brain Res 2005

Documentations of individual differences in stereomotion:

Richards & Regan, 1973, Invest. Ophthalmol.,12, 904-9

Regan, Erkelens & Collewijn, 1986,Invest. Ophthalmol. Vis. Sci.,27, 806-819

Hong & Regan,1989,Vision Res.,29,809-819

Kohly & Regan, 1999,Vision Research, 39,1011-1024

Documentations of stereoanomaly:

Patterson R & Fox R, 1984

Richards W, 1970 & 1971

Jones R, 1977

Case report involving recovered stereopsis as an adult:

Sacks, O. Stereo Sue. The New Yorker. June 19, 2006. (see also Sue Barry's postings)

Aspects of normal stereopsis/stereomotion and discussions of what stereo vision is good for:

Greenwald HS, Knill DC, Saunders JA. Vision Res. 2005 Jul;45(15):1975-89.

Schor CM. Am J Opt Arch Am Ac Opt. 1969 46(11):805-

Tyler CW. Binocular Vision. In Foundations of Clinical Ophthalmology. Ch24.
http://www.ski.org/cwt/CWTyler/TylerPDFs/Tyler_BinocVisionDuanes2004.pdf

Regan D. J Sports Psych. 1997 15(6):533-558.

Nakayama, Shimojo and Silverman. Perception, 1989

Coutant BE & Westheimer G, Ophthalmic Physiol Opt. 1993 Jan;13(1):3-7.
Regan D. Human Perception of Objects. Sinauer, 2000
Hamstra & Regan,1995, Vision Research,35,365-374
Regan & Hamstra, 1994, Vision Research,34,2277-2291.
Gray & Regan , 1997, Vision Res. 38,499-512;Regan & Gray,2000, Trends in Cog. Sci., vol.4 no.3,99-107
Duke-Elder's System of Ophthalmology Vol.1 1957
Walls, 1942
Patterson R, Vision Research, 1999

Models of how stereopsis is accomplished:

Qian, Neural Computation, 1994;
Chen & Qian, Neural Computation, 2004
Sanger, Biological Cybernetics, 1988
Qian, Neuron, 1997

Evolutionary discussions and cross-species examples of stereopsis:

Pettigrew, J.D. (1986) The evolution of binocular vision. In Visual Neuroscience, Eds J.D. Pettigrew, K.J. Sanderson, W. R. Levick
Rossel S, Nature, 1983, 302:821
Mitchell et al. Curr. Biol. 13: 1704-1708, 2003
Mitchell et al. Eur. J. Neurosci. 23: 2458-2466, 2006
Wensveen et al, Invest. Ophthalmol. & Vis. Sci., 46: 2468-2477, 2006
Sakai et al, J. Neurophysiol. 95: 2856-2865, 2006
Pettigrew & Konishi et al, 1970s
van der Willigen Robert & Frost Barrie
Nieder Andreas
Kajiura Stephen
Murphy and Howland Vision Research, 1986, 26,815-817
Samuel Rossel. PNAS 1996, 93, 13229-13232

5) Archives -

Below is the full thread of postings to cvnet in response to the email on top.
(Contact information has been removed).

Date: Tue, 15 Aug 2006 11:49:30 -0400 (EDT)
From: Jeremy B Wilmer
To: cvnet
Subject: CVNet - Stereoscopic vision: advantages, consequences

Hi Folks,

I have what seems a simple question, but multiple literature searches have left me with no clear answer. My question is this...what are the consequences of having particularly good, or particularly bad, stereoscopic vision? Ideally, I would like to know the consequences of small individual differences in stereoscopic vision, but I have found surprisingly little data even for extreme cases of stereblindness.

Can anyone point me to peer reviewed articles that rigorously establish such consequences? I would also welcome clinical/personal observations. Brainstorms for consequences so far include general clumsiness and parallel parking skill...

Many thanks!
Jeremy

Jeremy Wilmer, PhD
Kirschstein-NRSA Postdoctoral Fellow
Department of Psychology
University of Pennsylvania

Date: Tue, 15 Aug 2006 19:13:52 +0200
From: Michael Bach
To: cvnet
Subject: Re: CVNet - Stereoscopic vision: advantages, consequences

Dear Jeremy:

> I have what seems a simple question, but multiple literature
> searches have left me with no clear answer. My question is
> this...what are the consequences of having particularly good, or
> particularly bad, stereoscopic vision?

You know about the difference between depth perception based on the image difference between the eyes (that's stereovision) and other mechanisms of depth perception (most notably motion parallax)?

> Ideally, I would like to know the consequences of small individual
> differences in stereoscopic vision, but I have found
> surprisingly little data even for extreme cases of

> stereblindness.Can anyone point me to peer reviewed articles that
> rigorously establish such consequences?

Extreme would mean one eye only, no? There are papers, I dimly recall Rogers & Anstis (or the other way around or both :-)) where the difference in depth threshold between stereo (which is 1/10th of an arcminute) and motion parallax was a factor of ten -- so motion parallax is quite good.

> I would also welcome clinical/personal observations. Brainstorms
> for consequences so far include general
> clumsiness and parallel parking skill...

Again: if it's only _stereo_blindness, that will have little consequence (apart from specialties, say a stereo microscope), there will be little consequence, especially no parking problems or "general clumsiness" (I know much about the latter, and I'm not stereoblind).

Best, Michael
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Prof. Michael Bach PhD, Ophthalmology, University of Freiburg,

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Date: Wed, 16 Aug 2006 17:25:37 -0400
From: "Odom, J"
To: cvnet
Subject: RE: CVNet - Stereoscopic vision: advantages, consequences

Jeremy,

I thought I would follow up on Michael Bach's comments. I hope they are of some utility.

1. As he indicated the evidence for the importance of stereoscopic vision is limited at best. One reason for this is that the relative contribution of stereo varies with distance becoming effectively zero at about 20 ft. I might add that the formulae used by Schor and Flom to demonstrate this have the implication that for infants and young children the distance may be even shorter because the stereo angle in natural viewing is dependent on interpupillary distance.

Schor CM, Flom MC. The relative value of stereopsis as a function of viewing distance. Am J Optom Arch Am Acad Optom. 1969 Nov;46(11):805-9. No abstract available.
PMID: 5261147 [PubMed - indexed for MEDLINE]

Additionally as Michael pointed out there are numerous other cues for depth, including head motion and relative motion. As a consequence general clumsiness and the other types of things which one might think of such as parallel parking, driving, flying a plane (at least using simulators) etc. are unaffected or minimally affected by the absence of stereo. You would have a very hard time

demonstrating the effect if it is there.

If you choose stereoacuity as a marker task, patients are more likely to differ on near vision tasks which are directly related to stereo. Tasks which I know have been used include reaching, grasping, throwing, hitting, threading a needle, stringing buttons, pouring liquids into small containers, etc. You might direct your literature searches in those directions. There are also some very old references which will not show up on Pubmed or similar computer searches of monocular and binocular depth perception using the Howard-Dolman apparatus (aka two rod test) but be aware that some authors question the utility of the test.
Larson WL. Does the Howard-Dolman really measure stereoacuity?
Am J Optom Physiol Opt. 1985 Nov;62(11):763-7.
PMID: 4073212 [PubMed - indexed for MEDLINE]

One fun reference relating vision to everyday performance is

Regan D. Visual factors in hitting and catching.
J Sports Sci. 1997 Dec;15(6):533-58. Review.
PMID: 9486432 [PubMed - indexed for MEDLINE]

2. Michael suggested that the extreme case is the monocular patient. You might wish to do a search on enucleation or Steinbach, MJ and monocular

Marty Steinbach and his colleagues in Canada did an excellent series of studies on the various characteristics of patients with early enucleation. Terry Schwartz in our own department did a few such studies and found similar results. One difference is that she found that the superiority found by Steinbach's group was limited to those whose enucleation occurred prior to about 8 years of age.

3. Less extreme cases are those patients who are binocular and stereoblind. Most of these patients will have some sort of strabismus or anisometropia and may have amblyopia as well.

There is a huge literature related to the performance of either basic psychophysical tasks and or more mundane tasks and how these may be related to the presence or absence of amblyopia or stereopsis. At least two articles have suggested very strongly that binocular functions are an important characteristic in the categorization of amblyopia.

1: McKee SP, Levi DM, Movshon JA. The pattern of visual deficits in amblyopia. J Vis. 2003;3(5):380-405.
PMID: 12875634 [PubMed - indexed for MEDLINE]

2: Agrawal R, Conner IP, Odom JV, Schwartz TL, Mendola JD. Relating binocular and monocular vision in strabismic and anisometropic amblyopia.
Arch Ophthalmol. 2006 Jun;124(6):844-50.
PMID: 16769838 [PubMed - indexed for MEDLINE]

4. As you no doubt have noticed there is a huge literature related to the advantages of two eyes versus one eye in normal vision as well. This literature includes some performance tasks which may be of interest to you. But generally,

performance on most tasks is better if one uses two eyes rather than one (binocular summation, binocular facilitation). Various models of probability summation (or other models) are typically used to account for these improvements and attempt to evaluate them. But then of course there are the examples of binocular rivalry and interocular suppression. There are also a number of visual illusions which vary depend on the state of binocular vision or which do (or do not) transfer from one eye to the other.

A battery of varied tests of binocular functions might show interesting patterns of individual differences in binocular function.

I hope you will forgive my long winded response and that it proves at least minimally helpful.

J. Vernon Odom, Ph.D.
Professor of Ophthalmology and Physiology
West Virginia University Eye Institute

Date: Thu, 17 Aug 2006 13:01:09 -0400
From: David Regan
To: cvnet
Subject: CVNet - to Jeremy B. Wilmer

Jeremy,

There are several aspects of stereo vision including (1) static stereoacuity,(2) motion in depth perception evoked by a rate of change of disparity and (3) cyclopean perception of motion within a frontoparallel plane. I reviewed the literature on these three visual subsystems and suggestions as to "consequences" in chapter 6 of " Human Perception of Objects" Sinauer ,2000 (Original title " Seeing Through Camouflage" until I was persuaded otherwise)

There is a large literature on (1). Stereoacuity in itself does not at first sight seem of sufficient use in the everyday life of animals with binocular vision to justify the loss of all-round vision caused by having eyes that face the front rather than being placed on the sides of the head unless one considers the old suggestion that the value of stereovision is in breaking animal camouflage.

As to visual subsystem (2), many individuals have areas of the visual field that are blind to stereomotion yet normal for stereoacuity(Richards & Regan, 1973, Invest.. Ophthalmol.,12, 904-9). The large intersubject variability is documented in Regan, Erkelens & Collewijn, 1986,Invest. Ophthalmol. Vis. Sci.,27, 806-819(6 subjects) and Hong & Regan,1989,Vision Res.,29,809-819 (21 subjects). The most serious possible consequence of stereomotion scotoma is due to the fact that judgements of the direction of motion in depth and time to collision/ passage of a small approaching object rely on visual subsystem (2) (Gray & Regan , 1997, Vision Res. 38,499-512;Regan & Gray,2000, Trends in Cog. Sci., vol.4 no.3,99-107), so that steromotion scotoma are a possible cause of some highway accidents. I advised on a proposed study of the stereomotion fields of drivers involved in accidents maybe 25 years ago, but never heard the outcome (if any) and I am

not aware of any subsequent study. An odder possible consequence is as follows. My left visual field is stereomotion -blind though otherwise normal including stereoacuity. It may be no coincidence that ,though strongly right handed, I batted at cricket left handed (so as to present the right visual field to the bowler), and preferred the backhand at squash. Others individuals with left sterescotoma informally report a similar effect on their playing of ballgames.

As to visual subsystem (3) the large intersubject variability in sensitivity to cyclopean frontal plane motion is documented in Kohly & Regan, 1999,Vision Research, 39,1011-1024 (14 subjects).

David

David Regan C.M., Ph.D., D.Sc. F.R.S.C.
Department of Psychology
York University

Date: Thu, 17 Aug 2006 14:53:04 -0700
From: Jay M. Enoch
To: cvnet
Subject: CVNet - To Jeremy Wilmer

Dear Jeremy,

I am one of those individuals with poor binocular vision, particularly at the near-point. This was how I came to enter the field of vision science.

Often it is stated that we should expose subjects for a minute or two at most to stereo targets. Frankly, by chance some years ago, I discovered that perhaps 20 minutes after first exposure, or more, the stimuli would acquire the normal or near-normal stereo appearance. Obviously stereo-vision is not well established in my eyes. However, so-called rules often prove not to be absolute.

Jay Enoch

Date: Fri, 18 Aug 2006 10:07:47 -0700
From: cwtyler
To: cvnet
Subject: CVNet - Diaparity processing

Dear Jeremy,
I reviewed the utility of binocular vision in http://www.ski.org/cwt/CWTyler/TylerPDFs/Tyler_BinocVisionDuanes2004.pdf. I make two key points here that are generally misinterpreted. One is the distance of useful stereopsis. A typical disparity threshold of 10 arc sec means that we have useful stereopsis over distances of at least a mile, a fact that I have checked myself by looking at distant

mountains, although I don't know of any studies validating it.
The other is that disparity means that the stimulus the two eyes are either both on nasal or both on temporal retinas, projecting to two different hemispheres. This is only true for stimuli less than half the disparity away from the midline. Thus, most dots in a random-dot stereogram are a mixture of both retinal fields, projecting to the same hemisphere.

Christopher Tyler

Date: Fri, 18 Aug 2006 13:47:22 -0700 (PDT)
From: Gerald Westheimer
To: cvnet
Subject: CVNet - Binocular Disparity

Those with substantially normal binocular vision who wonder about the role of disparity in everyday life might try some simple housekeeping chore, say making a sandwich, with one eye closed.

Date: Sun, 20 Aug 2006 14:56:38 -0400
From: Eli Peli
To: Gerald Westheimer, cvnet
Subject: Re: CVNet - Binocular Disparity

Hi Gerry,

I have very poor stereo acuity. Yet, I had never had difficulty making a sandwich or any other food (as my body mass will attest). I also was able to do many of the other fine tasks mentioned in this discussion including soldering resistors etc. I Also had interest in the subject of dentists with monocular vision and they seem to be doing fine. I know of no more demanding depth perception task than digging an undercut in a tooth for a filling.
I think that the problems normally sighted people face when covering one eye are related to their lack of need to use the other cues at this range and the fact that congenitally monocular or strabismic people do well on almost all of these is the counter point to your suggestion.

Best,
Eli

Date: Sun, 20 Aug 2006 20:25:19 -0700
From: Steve Buck
To: Gerald Westheimer
Cc: cvnet

Subject: Re: CVNet - Binocular Disparity

Gerald,

But then, those of us without stereopsis efficiently make sandwiches everyday without batting an eye (so to speak). It's a matter of what sort of depth cues one is used to.

Steve Buck

Date: Sun, 20 Aug 2006 23:00:06 -0700
From: Michael Shadlen
To: Steve Buck
Cc: Gerald Westheimer, cvnet
Subject: Re: CVNet - Binocular Disparity

I'll add some noise to the cacophony. First, stereo cues are useful at long distances, else no one would buy a ticket to a 3D Imax show (at least not for seats > 20 ft from the screen). Second, our sense of depth uses information about disparity and lots of other cues, but the actual phenomenology of depth perception does not seem to require a continuous feed of this information. If you are at a 3D movie and you cover one eye, you'll notice that the vivid depth persists for some time. If you provide a new disparity cue -- including 0 disparity by taking off the glasses -- then the perception changes in <50 ms, but you don't need the disparity cue to maintain the sense of depth once it has tagged an object with a 3D value. We've confirmed this hysteresis effect in the lab informally (never published it).
Third, I'm willing to go on record predicting that most of what we think we understand about stereopsis will turn out to be wrong. Here are a few iconoclastic statements. (1) The random dot stereogram set the field back by making us think that there is a correspondence problem. There is no correspondence problem -- even in a RD stereogram, let alone normal vision -- if one is allowed to consider several rows of "dots" at a time. I think Mayhew and Frisby had an algorithm in the 80's that solved RD stereograms by looking at columns of dots. (2) I think there is a texture boundary system that originates monocularly and has flown under the radar of physiologists (like me) who tend to characterize most of visual processing after V1 as binocular. I think the recent Backus & Meister work may be a hint, but we'll see. (3) I think most of disparity processing in V1 may turn out to have little to do with depth perception. Rather, it may simply allow edge detection to occur in a robust manner, despite the lack of binocular correspondence for objects off the horopter (indeed there is no horopter for most of the visal field). In other words, the disparity sensitivity we measure allows circuits in cortex to represent contours in a disparity invariant way (much like velocity tuning in area MT allows the local circuit to extract direction independent of speed -- many will disagree with this statement). I'll stop there.

Cheers,

Mike

Date: Mon, 21 Aug 2006 05:40:19 -0400
From: Walter Makous
To: Steve Buck, Gerald Westheimer
Cc: cvnet
Subject: Re: CVNet - Binocular Disparity

At 8:25 PM -0700 8/20/06, Steve Buck wrote:
I thought Gerald's pont was the same as Eli and Steve's: you can cover one eye and it has no noticeable effect on performance of these tasks. Right?

Walt
--
Walter Makous
Center for Visual Science
University of Rochester

Date: Mon, 21 Aug 2006 09:56:50 -0400
From: vincent ferrera
To: Michael Shadlen
Cc: Steve Buck, Gerald Westheimer, cvnet
Subject: Re: CVNet - Binocular Disparity

My understanding is that with dichoptic viewing, the distance to the screen is more or less irrelevant as long as you scale the images accordingly.

I recently took my 6 year-old to see The Ant Bully in 3D. It's fun to watch the little kids (and some adults) reaching out to "touch" the animated characters. After a while though you get a headache I think because of the mismatch between accommodation cues and vergence cues.

v

Michael Shadlen wrote:
> I'll add some noise to the cacophony. First, stereo cues are useful
> at long distances, else no one would buy a ticket to a 3D Imax show
> (at least not for seats > 20 ft from the screen).

Date: Mon, 21 Aug 2006 10:11:12 -0400
From: Scott Brodie
To: Eli Peli

Cc: Gerald Westheimer, cvnet
Subject: Re: CVNet - Binocular Disparity

I can further attest to the observations of Dr. Peli and Dr. Buck...

A few years ago, I was asked by an insurance company to evaluate the case of an endodontist (a dentist specializing in root-canal procedures) who was claiming disability by reason of a traumatic cataract, which he refused to have excised (!), arguing that the resultant loss of binocular stereopsis had rendered him incapable of continuing in his subspecialty.

I decided to investigate the world of endodontics. It turns out that a great deal of the work is done monocularly anyway -- between the view one obtains using a traditional dental mirror, which is rarely binocular, and the recent trend to doing much of this work with fiberoptic endoscope visualization, which, of course, is never binocular, the case that loss of binocular vision precludes working as an endodontist is inherently suspect.

I was able to locate and interview a professor of dentistry specializing in endodontics as well as a practicing cataract surgeon, both of whom had lost the vision in one eye in their fifth or sixth decade, and both of whom had successfully retrained in their surgical skills and were able to continue their surgical practice without any worsening of their outcomes or complication rate.

The world is a very redundant place, and binocular stereopsis is only rarely a uniquely available cue to depth information!

-- Scott.
Scott E. Brodie, MD, PhD
Mount Sinai School of Medicine
New York

Date: Mon, 21 Aug 2006 18:23:06 +0200
From: Michael Bach
To: cvnet
Subject: Re: CVNet - Binocular Disparity

Dear Colleagues:

I find the wealth of knowledge (and opinion ;-) pouring forth on this topic quite enlightening and entertaining.
The following experience may interest you: Nearly 3 decades ago, one of my eyes was patched for a week following a minor accident. I felt no impact on my life (especially making sandwiches was not impoverished) with one major exception. At that time I was building electronic organs, and the soldering of the intricate superimposed multilayer wiring (in German the appropriate word is related to "harp" due to it's appearance) was next to impossible. Even head movements to create motion parallax did not help.

So: "... you can cover one eye and it has no noticeable effect on performance of these tasks." That depends very much on the task. However, we all seem to agree that driving a car (the original question) is not stereoscopically challenging.

Best, Michael.
--
Prof. Michael Bach PhD, Ophthalmology, University of Freiburg,

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Date: Mon, 21 Aug 2006 12:39:50 -0400
From: Laurie M. Wilcox
To: Scott Brodie
Cc: Eli Peli, Gerald Westheimer,
cvnet
Subject: Re: CVNet - Binocular Disparity

My two cents... There's no question that people manage quite well on depth related tasks without stereoscopic vision. But I often wonder about the quality of the depth percept. This very issue was highlighted in a recent article by Oliver Sacks in a June issue of the New Yorker. In this essay he provides what I believe to be the most eloquent description of the difference between stereoscopic depth perception and depth from monocular cues that I've ever encountered. The real core of this description/comparison comes from Dr. Susan Barry, who has regained her stereoscopic depth perception after 50 years. I highly recommend the article to those interested in stereopsis and 'what is it good for'.

cheers,
Laurie

ps. here's a link to a description of Dr. Barry's experience:
http://news.wnpr.org/templates/story/story.php?storyId=5507789

~.~
Laurie M. Wilcox
Department of Psychology
Centre for Vision Research
York University

Date: Mon, 21 Aug 2006 14:41:54 -0400
From: Jonathan D. Victor
To: cvnet
Cc: Jonathan D. Victor
Subject: Re: CVNet - Binocular Disparity

Especially in the context of Michael's note re fine soldering, it is interesting to note (I hope I didn't miss this in the cvnet stream) that Bela Julesz said he

developed the RDS to determine why some quality-control checkers of chips seemed to pass a much higher frequency of duds than others.

Jonathan Victor

Date: Mon, 21 Aug 2006 17:01:55 -0400
From: David Regan
To: cvnet
Subject: CVNet - binocular disparity

I suspect that the correspondence problem in random dot stereograms may not be so difficult for the visual system as is sometimes described. When viewing a random dot stereogram through red/green or polarising goggles the "hidden" figure cannot , of course, be seen through left or right eye alone. But remove the goggle and a (rather blurred) figure is now visible. So that, in principle, binocular neurons that merely summed the inputs from left and right eyes could detect the location and shape of the 'hidden" figure. If such neurons communicate with disparity-tuned neurons they could provide to the disparity- tuned neurons a hint as to the location, shape and size of the "hidden" figure. That should ease the correspondence problem by providing prior knowledge to aid the computation.

When disparity is increased beyond the point at which depth perception is lost and the "hidden" shape is seen double and with no overlap , plots of orientation discrimination pass smoothy through that disparity. Orientation discrimination threshold is closely similar in the presence of depth sensation and without depth sensation, though the " hidden" bar looks sharper -edged when seen in depth than when depth is lost (Hamstra & Regan,1995, " Orientation discrimination in cyclopean vision" Vision Research,35,365-374). For aspect ratio discrimination also, threshold is little different with and without depth sensation for a random dot stereogram (Regan & Hamstra, 1994," Shape discrimination for rectangles defined by disparity alone, by disparity plus luminance and by disparity plus motion" Vision Research,34,2277-2291.

So far as I know none of the many published models of cyclopean depth and form perception in random dot sterograms and of the correspondence problem have considered any possible contribution to the visibility of the " hidden" form by binocular neurons that simply sum the inputs from the two eyes before relative disparity is computed. My guess is that a model which took this into account would be very different from models that are restricted to the processing of relative disparity, and also that inferences about the sequence of processing of relative disparity and spatial form would differ.

D.Regan

Date: Mon, 21 Aug 2006 18:59:24 -0400

From: Sue Barry
To: cvnet
Subject: CVNet - stereopsis

Dear CVNet,

I have read with interest your discussion of the value of stereovision in normal life and have much to add. I had no stereovision until 48 years of age and the acquisition of stereopsis was one of the most powerful and joyful experiences of my life. I have been cross eyed (strabismic, an alternating esotrope) since early infancy. To avoid double vision and visual confusion, my brain suppressed the vision from one eye or the other at all times. I saw the world one eye at a time, and, although I did not know it then, my view of the world was relatively flat. I had three eye surgeries at ages 2, 3, and 7 which aligned my eyes cosmetically but not functionally. Although I no longer looked cross eyed, I had a vertical disparity between my two eyes between 3 and 5.5 diopters depending on viewing distance. Such a vertical disparity prevented the possiblity of binocular fusion.
At age 48, I saw a developmental optometrist who put a vertical prism in my right eyeglass lens to better align the visual field of the two eyes. But the prism alone would not have allowed me to fuse and see stereoscopically. I needed to break a lifetime habit of interocular suprression.
My optometrist started me on a program of optometric vision therapy, a series of exercises which made me consciously aware of my suppression so that I could break it. Then, I worked on incrementally more difficult fusion exercises. I am now a binocular person with stereopsis and can tell you exactly what it is that stereopsis offers.

To claim that stereopsis is only useful for discrete tasks such as driving a car or threading a needle greatly trivializes the importance of this perceptual skill. Imagine that you had good visual acuity but could only see in shades of gray. Under most circumstances, you could get by in this world quite well. Consider how much visual information you obtain from a black and white photograph. No one would deny however that your black, gray, and white view of the world is far inferior to one seen in color. Color is a type of qualia, a visual phenomenon that cannot be imagined if it is not experienced. The same is true of stereopsis. Although I am a neurobiology professor and have taught the mechanics of stereopsis for years, I had no idea what the experience of seeing stereoscopically would be like. Moreover, I did not miss it. I felt that I was doing pretty well. I enjoyed sports such as tennis. I drove a car, albeit slowly, and I had a good education and career. From my studies on vision, I thought I knew what I was missing, but I was dead wrong.

When I began to see with two eyes, my visual world completely transformed. Trees looked totally different. Consider a leafless tree in winter. Its outer branches enclose and capture a volume of space through which the inner branches permeate. I had no concept of this. Oh, I could infer which branches were in front of others using monocular cues such as object occlusion, but I could not PERCEIVE this. Trees to me looked somewhat like a drawing. Before my vision changed I would not have said that the tree looked flat, but I had no idea just how round a tree's canopy really is.
My first snowfall with my new vision was spectacular.
I could see each snowflake in its own
3D space and I could see the palapable space between each flake.
Prior to my vision therapy, all the snowflakes would have appeared to fall in one plane slightly in front of me. With my new vision, I felt myself within the snowfall, not outside of it. This is true for the way I now perceive my surroundings in general. I feel myself within the 3D space instead of outside, looking in.

When I began to see with two eyes, everything looked crisper and much better outlined. As another formerly stereoblind person wrote to me, "Everything has edges!" The world was not only flatter but less detailed and textured with my monocular vision.

Although I could always use monocular cues such as object occlusion, perspective and motion parallax, I did not get as much out of these cues as I do now that I have stereopsis. Take motion parallax. In the past, before my vision changed, I could infer that one object was in front of another because the closer object
moved more quickly across my
visual field as I walked by. But I could not percieve the actual SPACE between the two objects. Motion parallax is a much more compelling cue now, and I greatly enjoy walking under tree branches to enjoy the sense of space and depth that I now perceive between the branches and leaves.

When I saw the most recently released Star Wars movie
a year ago, I was astonished. Skilled Star Wars cinematographers had used monocular depth cues and motion to create scenes on the flat, two-dimensional movie screen that suggested a dramatic three-dimensional sense of volume and space. Before my vision transformed, I could not experience this sense of space while watching the movie because I had never experienced this sense of space in real life. Now, I finally understood my family's preoccupation with the movie's special effects.

Yes, driving at night is much, much easier. Parking a car and threading a needle take less effort now,
but accomplishing these tasks does
not begin to describe what having stereopsis is like. It has changed the way I experience the world.

I could go on and on about all this

and I did when I wrote Dr. Oliver Sacks a letter about my experiences in late Dec., 2004. He published a story about stereovision and my experiences in the June 19, 2006 issue of the New Yorker and my story aired on June 26 on NPR's Morning Edition. See http://news.wnpr.org/templates/story/story.php?storyId=5507789

After the New Yorker article and radio program, I received over 100 emails specifically from people with strabismus, amblyopia and other binocular vision problems. To a person, all of these individuals had been told that stereopsis cannot be gained if it is not achieved in infancy, that a critical period exists for the development of stereopsis. This is not always true. The trick is to align the eyes sufficiently for fusion and then work on anti-suppression and fusion exercises. Unfortunately, most strabismics who have surgery never get the therapy they need. However, I have now found quite a few individuals like myself who gained stereovision in adult life as a result of optometric vision therapy. Their reaction to their new vision was exactly like mine. It brought them enormous joy.

A person who has normal binocular vision cannot view the world as a stereoblind individual even when they close one eye. Their brain will use a lifetime of stereovision experiences to fill in the missing stereo information. In an analagous way, your brain fills in color in your peripheral visual field and fills in the gap in your vision produced by the blind spot even when you're looking with just one eye. So this brings up a paradox. A normal binocular viewer cannot imagine vision without stereopsis and a stereoblind viewer cannot imagine vision with stereopsis. This is one reason why the importance of stereopsis has been underplayed by scientists and physicians all these years.

Steropsis gives one a great deal more than the ability to thread a needle or catch a pop fly. Like color, stereopsis adds an enormous dimension (no pun intended) to one's vision. Just ask a formerly stereoblind individual. They will certainly let you know.

Sincerely,
Susan R. Barry, Ph.D.
Associate Professor of Biological Sciences
Mount Holyoke College

Date: Mon, 21 Aug 2006 19:48:17 -0400
From: "Swanson, William Howard"
To: cvnet
Subject: CVNet - binocular disparity

One of the approaches clinicians offer for dealing with presbyopia is "monovision" - correcting one eye for distance and the other for near. This can be done with contact lenses, in which case the person spends some time with the lenses out. When Lasik is used in presbyopes, there is no opportunity for the patient to spend time with both eyes having the same referaction. This can lead to reductions in stereoacuity and loss of foveal fusion (Fawcett et al., 2001 JAAPOS 5:342-7).

Some patients enjoy monovision Lasik, some do not. The importance of stereopsis seems to vary considerably from one person to another.

William H. Swanson, Ph.D., F.A.A.O.
Professor of Optometry
Indiana University
School of Optometry

Date: Tue, 22 Aug 2006 11:45:05 +1000
From: Paul Martin
To: CVNET <cvnet>
Subject: CVNet - Binocular Disparity: Did Michael Bach's harp yield chromostereopsis?

Dear CVNetters,

Michael Bach writes:

> Nearly 3 decades ago, one of my eyes was patched for a week
> [...] and the soldering of the intricate superimposed multilayer
> wiring (in German the appropriate word is related to "harp" [...]
> was next to impossible. Even head movements to create motion
> parallax did not help.

I presume that the wires of the "harp" were colour-coded. Could chromostereopsis have yielded conflicting "quasi-binocular" cues which rendered the task so difficult?

[disclaimer: while studying the role of chromatic aberration in colour vision (journalofvision.org/6/2/1/) we looked for literature on chromostereopsis --- the search was rather superficial. The effect (chromostereopsis) appears to be either very variable, or not terribly well-understood, or both. So my question may not be well-founded, and I'm grateful for further comment: the stereopsis topic seems to have galvanised the group!]

This is just my AUD 0.02 worth (~ USD 0.0152)

Paul

Prof Paul R Martin

National Vision Research Institute of Australia
Department of Optometry and Vision Sciences
The University of Melbourne, Australia.

Date: Mon, 21 Aug 2006 22:51:44 -0400
From: Eli Peli
To: Jonathan D. Victor, cvnet
Subject: Re: CVNet - Binocular Disparity

Julesz was very smart to offer this justification at the environment he was working at.

Indeed stereo vision can be used effectively to performed quality control on repeated patterns such as in electronic chips.
If you can free fuse such a pattern and if there is one broken or shifted element it will pop out in depth and will be immediately detected. This trick was used by QC people in electronics and also years before that in searching for misprints in postal stamp pages. A misprint of a 1cent stamp could be worth thousands of dollars and the post office made heroic efforts to avoid them. Of course no random dot stereo is needed for that and it is hard to place that QC task in the evolution path.
The chip errors can also be detected monocularly by running the sample linearly under the microscope and detecting the sudden change in the blur pattern.
The fact that people are smart and learn to use something such as stereo for this task does not tell us much about its use in everyday life in the woods.

Eli Peli

At 02:41 PM 8/21/2006, Jonathan D. Victor wrote:

> Especially in the context of Michael's note re fine soldering,
> it is interesting to note (I hope I didn't miss this in the
> cvnet stream) that Bela Julesz said he developed the RDS to
> determine why some quality-control checkers of chips seemed to
> pass a much higher frequency of duds than others.
>
> Jonathan Victor

Date: Mon, 21 Aug 2006 23:03:57 -0400
From: Jonathan D. Victor
To: cvnet
Cc: mopowers
Subject: Re: CVNet - Binocular Disparity

Julesz said that yes, the RDS test indeed identified the good and bad quality-control workers -- but I don't recall whether he said what fraction of workers had poor RDS.

JV

Date: Tue, 22 Aug 2006 14:15:12 +1000
From: Vaegan
To: David Regan
Cc: cvnet
Subject: Re: CVNet - binocular disparity

Dear CEVnetters'

I would like to 'step back' from the issue of stereopsis and how valuable it is and in what range it applies to focus our attention on one of the commonly accepted universal problems of stereopsis i.e. the matching noise problem - how does the visual system calculate which random dot in an RDS to 'match' with each other dot. Julesz solved it with his spring loaded dipoles and the local cue approach has been dominant ever since. In this discussion I see these same 'local' problems being reiterated.

In my PhD thesis I argued that this was in fact a non problem if one took a 'top down' global to local solution to matching the binocular images. I never published the thesis because when I got to the UK for my Post Doc I found Oliver Braddick was arguing the same thing and had an MRC grant based on it. He has since published the concept but not very widely. Jerry Nelson, with whom I had many discussions, similarly resolved a lot of binocurity problems using ideas about excitatory and inhibitory interactions within and between 'domains' which could be either global or local, His 'domains' covered all dimensions of the stimulus. David Regan has just revived this view in part by pointing out that in colour anaglyphs the central blur can at least partly define the hidden shape, but the idea is not widely promulgated.

There is no matching noise problem in an RDS if your first motor and sensory fusion response is to match the outside edges of the total square! An RDS blurred is a large area of average intensity in a bright field. The matching problem is simple whether you model it in terms of lowest spatial frequencies first or in terms of the largest shapes. The same thing happens in nature. Once the gross edges are aligned the small squares around the perimeter, at a more local grain, lock in readily and only then does the fine structure of the stereoscopic figure finally ememrge. That is why stereofusion is so slow to appear in an RDS, unlike other stereo tasks and why it takes so long to fade from the viewing of natural scenes once established. It also explains why stereoresolution can outperform acuity or 2 point thresholds in the right contex with sufficiently long contours.

My view has always neen that the sensory and motor fusion responses underlying stereopsis are a top down driven process. Once this is appreciated the discrimination of the fine local cues around the horopter fall into a different perspective.

Yrs truly
Vaegan, VisionTest Australia,

Date: Tue, 22 Aug 2006 22:27:28 +1000
From: Bart Anderson
To: cvnet
Subject: CVNet - binocular VISION

Like others, I have been entertained by the exchange that has ensued from a basic question about binocular disparity. Much has now been said, and it has finally reached a stage where I cannot help but add my own comments to this topic. I would like to start at what I think seems like the basics, and move forward.

1) There has been much discussion about stereo that is of the form "what is it good for?" and "what deficits occur if you don't have it?" Responses have focused on anecdotal evidence, to the view that not much seems to be lost for lot of things. We might start, then, by asking the basic question as to why this particular eye placement is so strongly correlated with predation. The loss of such placement is obvious, as we can no longer (literally) watch our asses. Yet the main sense that something is lost is gained from either soldering circuit boards, or some daily activity like washing dishes. I am tempted to point out that never has the strong negative correlation between athletic activity and intellectual pursuits seemed more evident (cudos to D. Regan for his discussion of cricket batting). My suggestion is that, for the unconvinced that have some modicum of athletic ability, grab a ball (and in some cultures, a glove) and go out and throw it around with one eye closed. Or try to hit one. Even a stationary one, like a golf ball. In fact, I find that if I even just close one eye and *imagine* throwing a ball to someone, the deficit becomes obvious. But this seems to miss the point. Evolution took half of the visual field away from predators. If we haven't figured out the best experiments to demonstrate what was clearly gained in the process, we probably need to do better experiments.

Part of the problem is that this question has been couched as a question of "binocular disparity" (although some discussion has emerged over the idea of simple binocular summation; an idea that seems particularly problematic with stimuli such as the much beloved sine grating). What has been missing from this dialogue (and why I just had to add my two cents) is the realization that disparity is just one kind of information that binocular vision provides. This discussion has been almost entirely couched as a problem of recovering "depth" from disparity, but this is just one dimension of binocular vision. Although a fair amount has been said about RDSs, little attention has been paid to the fact that this invention was largely inspired by the fact that stereo provides a means of breaking camouflage. This is the story, at least, that Bela Julesz told about his invention of the (computer generated) RDS. Although depth is part of this story, segmentation is the other.

2) The correspondence problem is indeed something of a red herring, a fact that myself and others have written about extensively. It is based on the (remarkably implausible) notion that the primitives used to establish binocular correspondence are dots (or pixel intensities). If we believe *anything* about what we think we understand about early vision, it is clearly the case that this simply can't be true. RDS patterns are white noise. They have energy on all frequencies and orientations. They are, in fact, one of the LEAST ambiguous stimuli that can be constructed. For smooth surfaces, any good "neighborhood" (or cross-correlation scheme) will easily solve matching in these figures. The problems with such approaches arise in two contexts: at depth discontinuities (that contain mixtures of disparities, as well as unmatched features at occluding edges); and in untextured (or sparsely textured) images (that contain no monocularly localized signals on which to base a disparity computation). This is why such images received so much attention over the past 15 years or so in the stereo psychophysics community (at least by some of us).

3) This discussion has, to this point, focused on stereopsis as a "depth cue." It has ignored the fact that much recent work has shown that stereo is strongly involved in other surface computations (my personal favorites would seem to be lightness and opacity, but I am doing my best to avoid self-promotion here). My Gibsonian roots are also reinvigorated when stereo is treated simply as some "depth cue," when it is almost certainly inextricably involved in a host of visual computations that are used to recover the material properties and structure of 3D surfaces and objects (I can happily provide references to those interested).

4) On this last point, this dialogue reveals just how important texts are in propagating misinformation (such as the distances over which stereo provides useful information), and the need for such texts to be peer reviewed in some meaningful way. Maybe some "Wikipedia" model isn't a bad idea here.

Bart Anderson

Date: Tue, 22 Aug 2006 13:29:57 -0400
From: Ning Qian
To: David Regan
Cc: cvnet
Subject: Re: CVNet - binocular disparity

In the disparity energy model proposed by Ohzawa et al and analyzed by us and others, cells tuned to 0 disparity does sum up the left and right image patches within the receptive fields (before non-linearities are applied). However, for these 0-disparity cells to provide information on the location, shape and size of the hidden figure as suggested by Dr.

Regan, a sophisticated pattern recognition procedure would have to be added. General purpose pattern recognition is a difficult problem by itself computationally (although it's easy for our visual system), and perhaps that's why the approach has not been incorporated into a stereo model. Of course, this says nothing about whether the brain uses the approach.

We showed previously that the disparity energy model and its extensions can compute disparity maps from stereograms without introducing a pattern recognition procedure (Qian, Neural Computation, 1994; Chen & Qian, Neural Computation, 2004), and tons of other less physiologically plausible models can do the same. However, one casual observation makes me feel that something like what Drs. Regan and Shadlen suggested may be operating in the brain. The observation is this: it's much easier for me to fuse a natural-image stereogram than a random dot stereogram, but most, if not all, stereo models can do a much better job on random dot stereograms than on natural stereograms. Perhaps the brain does use pattern recognition (whether monocular texture or object based or binocular based) to facilitate stereovision. And perhaps this facilitation more than compensates for the low contrast, distortion and noise problems posed by natural stereograms. Stereo models without a pattern recognition component suffer from these problems. It would be interesting to merge a V1 model of absolute disparity computation with a higher-level pattern recognition model to arrive at robust relative disparity computation. Pattern recognition could also benefit from disparity computation.

I also think that the correspondence problem may not be as hard as is sometimes described. In particular, I agree that it may be misleading to argue that when faced with a random dot stereogram, the brain has to sort out a huge number of false matches to find the right ones. The argument is based on the assumption that the brain starts with all possible matches between individual dots on the two retinas. However, the receptive fields of visual cells cover image patches instead of individual dots. When the match is done at the level of image patches, the correspondence problem is much easier to solve (see Sanger, Biological Cybernetics, 1988; Qian, Neuron, 1997 for detailed discussions). As we and Fleet at al showed, the disparity energy model solves the correspondence problem though a cross-correlation like procedure enhanced by spatial, orientation, and scale pooling. I do think there IS a correspondence problem for it's not trivial for match image patches.

With regard to distance dependence of stereovision, I think it's easiest to look at the standard equation:

$D = a\ b / d^2$

where a is interocular distance, D is disparity generated by the depth dimension b of an object you are fixating, and d is the distance of the object. Assuming a best stereoacuity D of 5'', and an interocular distance of a = 6 cm, we can obtain a simple relationship between the

depth dimension b and distance d for stereovision to work:

$b = 0.0004 d^2$

where b and d are in meters. For example, at a distance of d=50 meters, the depth dimension b of the object has to be at least 1 meter. Stereo movies are filmed with a very large inter-camera distance so that a is much larger than the 6 cm assumed here. They are further helped by a large screen that scales up disparities, as pointed out by Vince Ferrara.

The above says nothing about the original question of how much we rely on stereovision in our daily life. I don't know any formal studies, but would like to offer one more anecdote. I am amblyopic so my stereovision is very poor. I usually drive faster than my wife does, but I have to slow down greatly when navigating narrow NYC streets with double parked cars. My wife, with normal stereovision, initially wondered why I was going so slowly when there was ample space between our car and the parked cars. I had to tell her that my judgment of fine relative distance is probably not as good as hers. I second Dr. Wilcox's recommendation of a recent New Yorker article by Oliver Sacks on stereovision. I had a discussion with Dr. Sacks on the importance of stereovision. He told me that for people like him who belong to a stereoscopic society and spend hours to view stereograms every day, stereovision is extremely important. He said that he can notice a difference in the world immediately after covering one eye. I certainly don't notice any difference myself. However, if I close one eye, I won't be able to meet my two index fingers quickly so stereovision does help me. Then, most time when I ask a group of students to meet their index fingers with one eye closed, there is often someone who can do it. I guess there are huge individual differences, as pointed out by others.

Ning

Date: Tue, 22 Aug 2006 10:34:03 -0700 (PDT)
From: Jeff Mulligan
To: Jonathan D. Victor
Cc: cvnet
Subject: Re: CVNet - Binocular Disparity

On Mon, 21 Aug 2006, Jonathan D. Victor wrote:
> Bela Julesz said he developed the RDS to determine why some
> quality-control checkers of chips seemed to pass a much higher frequency
> of duds than others.

Another aspect of this story that I heard was that when the RDS's were put into the microscopes, it was discovered that a large fraction of the scopes were so grossly mis-aligned that binocular fusion was impossible!

Date: Wed, 23 Aug 2006 10:46:44 +1000
From: Vaegan
To: cvnet
Subject: Re: CVNet - binocular VISION

Dear CVNet,
When thinking of the link between stereopsis and preadation it is instructive to think of the design of a hammerhead shark. This open ocean predator values stereopsis so much it has evolved with amplified stereopsis by increasing PD and now has a wide base stereo rangefinder, like those we used to be able to buy from army disposal stores, used to localise the precise distance of aircraft in the second world war!

Yrs truly
Vaegan, VisionTest Australia,

Date: Tue, 22 Aug 2006 21:52:27 -0700
From: Ariella Popple
To: cvnet
Subject: Re: CVNet - binocular VISION

At this point, I just had to throw my oar in (for no particularly good reason), with my own pet theory of how and why binocular vision evolved in primates. But first, in response to Bart, losing the ability to see behind your own head is dangerous - but not if you're near the top of the food chain, where such things don't really matter very much. Evolution doesn't work according to a master plan, where one design is replaced with another. Anyway, my theory is that good stereoscopic vision (together with correspondingly good visual acuity, and hand-eye coordination) provided a natural selection advantage to those monkeys best able to pick fleas, which are tiny, fast, and frequently embedded in thick fur. Plus, being a good groomer probably improved a monkey's mating potential, and the offspring's chances of fending off nasty parasites. I would love to hear an evolutionary biologist's view on my theory, as I once calculated that the psychophysical requirements for picking fleas and swinging through branches are very similar.

Ariella Popple
UC Berkeley

Date: Wed, 23 Aug 2006 16:31:35 -0400
From: Bart Farell
To: cvnet
Subject: CVNet - Re: advantages of stereopsis

Dear CVNet-

A very enjoyable discussion.

Last month Suzanne McKee and I were talking over the question of the advantages of stereopsis. She told me of a delightful experiment (unpublished, I think) that Michael Morgan carried out using the students of a class he was teaching as subjects. In my version--now third hand and filtered through what's left of my memory--he divided the class into two groups and sent them blackberry picking. One group picked with one eye patched, the other group picked binocularly. A large difference was found between the groups. But it wasn't in the size of heir harvests, which were found to be equivalent. The difference was in the number of scratches on the students' hands. (Mike and Suzanne: I hope I did reasonable justice to the story^Å)

This result sharply brings up the point that the evolutionary pressure behind stereo vision, and much else, has acted in a very different environment from the one most of us, even those not lab-bound, now live. For animals in the wild, visual shortcomings can carry a price (e.g., when swinging between branches) that has no counterpart for us because of society's various safety nets. Any discussion of what we gain from stereo or any other existing adaptation should 'get real' about the environment, the tasks, the costs and the benefits experienced by those who most directly felt the impact of not having the adaptation.

The other Bart

****

Bart Farell, Ph.D.
Research Professor of Biomedical and Chemical Engineering
Institute for Sensory Research
Syracuse University

Date: Thu, 24 Aug 2006 12:09:21 +0000
From: J Ren
To: cvnet
Subject: Re: CVNet - Re: advantages of stereopsis

I feel I can add some words from another direction to support Sue Barry's story and the advantages of stereopsis.

I had good normal vision and stereopsis before, although one eye was always a bit weaker than the other. In recent years, the wearker eye gradually gets poorer and poorer and can only see blurred and low-intensity image of the world with eye-glasses. This made me realize the eye might have much worse problem than just near-sighted. Anyway, the stereopisis is not totally lost but much impaired.

The result is very unpleasant. I can still play tennis but cannot hit a ball most of the time because I cannot locate it and judge its speed correctly. I cannot solder an electronic component easily because I find it very hard to locate the pins. You can imagine I don't drive, for the error of my judgement of the speed and location of the surroundings is too big to make driving safe. At night, I have to walk much slower than before to avoid stumbling. Not only that, due to the awkwardness of the vision, the brain function seems to have changed. And much much more... I don't believe this kind of bad feeling can be mimicked by people with normal stereopsis in a 3-minute sandwich-making task.

For those who don't think stereopsis is a big issue, get your one eye covered all the time by at least 3 months, you'll know the answer.

Date: Thu, 24 Aug 2006 08:45:21 -0400
From: Esther G Gonzalez
To: cvnet
Subject: CVNet - hammerheads

The hammerhead shark does not use stereo. Because its eyes are laterally placed, it actually has a frontal blind area. This arrangement is unusual for a predator, but it compensates for it with an exceptional electromagnetic sense and agility of head and body. Little is known about its visual system.

Esther G. González, Ph. D.
Vision Science Research Program
Assistant Professor of Ophthalmology
Toronto Western Research Institute
Dept. of Ophthalmology and Vision Sciences
Toronto Western Hospital
University of Toronto

Date: Thu, 24 Aug 2006 16:47:39 +0100
From: Dave Rose
To: cvnet, wilswans
Subject: RE: CVNet - binocular disparity

Monovision is also common following lens replacement surgery for senescent cataract. My optometrist has seen cases of 7D difference between the corrected eye and the remaining presbyopic eye. With bilateral cataracts the second eye is later corrected too but not til after maybe a year of monovision. Studying these cases might provide a good way to compare binocular function before, during and after a prolonged period of its impairment.

And anecdotally, what I've missed while having monovision is being able to swat flies out of the air!

Dave

Dave Rose
Dept. Psychology, Univ. Surrey

Date: Fri, 25 Aug 2006 16:40:58 +0800
From: John Ross
To: cvnet
Subject: CVNet - stereopsis

I can't resist adding this bit of trivia. As David Regan would know, Colin Milburn was a dashing English batsman who played for his country in 1966 and 1968. He lost an eye in a car accident in 1969. He played cricket afterwards but at a lower level and was a mediocre batsman at best. Given that he weighed in at about 18 stone (252 pounds) it is likely that, like Eli Peli, he could make a sandwich or a least lift a beer glass unerringly to his lips. How he was at picking blackberries is unknown, as is how many times the ball hit him rather than his bat.

John Ross
School of Psychology
The University of Western Australia

Date: Fri, 25 Aug 2006 10:39:04 +0100
From: "Finlay, Alison"
To: cvnet
Cc: "Grant, Simon"
Subject: RE: CVNet - binocular disparity

The question of the effect of reduced binocularity on quality of life is certainly a controversial one! Although there is little robust evidence of its advantages, it is difficult to argue with all these reports of the richness that binocular vision adds to visual perception.

We have been working on the effect of degraded binocularity on prehension (reaching and grasping). This subjct has been mentioned before in this CV net debate.

Several groups (ourselves included, Melmoth & Grant, Exp Brain Res 2005) have shown that subjects with good binocular vision peform less well with one eye occluded. The very relevant point has been raised that this tells us very little about the visual function of those who are well adapted to a

monocular condition or degraded binocular vision.

Reaching for an object and picking it up is such a commonly performed daily task that we thought if those with degraded binocular vision are able to adapt to their visual world, monocular subjects will perform this task with no evident disadvantage. We allowed full head movement and plenty of textural cues.

If anyone can adapt to their condition of degraded binocularity, then amblyopes should be able to. By definition, the condition is early onset, so adults will have had many of their early years learning to cope with their degraded level of binocular function.

Despite this, we find that amblyopes (with no measurable binocular function) and strabismics with no demonstrable fusion (using Bagolini Striated lenses) perform remarkably well, but not as well as those with some level of binocular function, and certainly not as well as controls. En masse those with no binocular function take longer to reach the target, make more on-line corrections to the reaching action, are more likely to need to modify their grasp once they have contacted the target and are more prone to their hand colliding with the target. This is currently being written up, so watch this space!

Whether it is binocular summation, vergence specified information or stereopsis that causes these deficits continues to be a matter of debate that we discuss.

We intend extending our work to look at those with a late onset compromise in binocular function. The group we intend examining are elderly patients undergoing a staged cataract procedure. We are working on the premise that their binocular vision will be good before first eye surgery, disrupted between first and second eye surgery and back to normal (or better) following second eye surgery.....any one interested in funding us!!

In effect, we are saying that if adults well adapted to degraded binocular vision from childhood show a deficit during such an 'every-day' action as picking up an object in a cue rich environment (albeit subtle), then surely there will be an effect on more complex or less familiar visuo-motor tasks. How much more affected will those subjects be that have to adapt to a degraded binocular status late on in life?

I'm really enjoying all these anecdotal stories and more robust contributions. It's fantastic to know there is so much interest in this subject.

Thanks CV net!

Date: Fri, 25 Aug 2006 11:18:32 +0100
From: Jenny Read

To: cvnet
Subject: Re: CVNet - hammerheads

Esther G Gonzalez wrote:

> The hammerhead shark does not use stereo. Because its eyes are
> laterally placed, it actually has a frontal blind area. This
> arrangement is unusual for a predator, but it compensates for it with
> an exceptional electromagnetic sense and agility of head and body.
> Little is known about its visual system.

Googling, I find suggestions that the wide baseline, with the nostrils placed at the very tip of the hammer, improves scent tracking -- so maybe it has stereo olfaction if not stereo vision. I'd have guessed that a similar thing would apply to the electromagnetic sense, but the sources I've found just say that a larger detector is more sensitive, rather than suggesting that this gives the shark any additional directionality.

Thanks everyone for the discussion -- extremely stimulating!

--
Jenny Read
Royal Society University Research Fellow
University of Newcastle, Framlington Place

Date: Fri, 25 Aug 2006 08:49:05 -0400
From: Eli Peli
To: J Ren, cvnet
Subject: CVNet - Re: stereopsis and driving

The role of Stereo acuity in driving safety is not at all established despite whatever one person or another reports as a personal experience.

In all countries in the world monocular people are permitted to drive and no evidence for increase risk has been identified, and not for lack of trying. In fact in most jurisdictions monocular people are allowed to drive big trucks as well.

Laberge-Nadeau C, Dionne G, Maag U, Desjardins D, Vanasse C, Ekoe JM. Medical conditions and the severity of commercial motor vehicle drivers' road accidents. Accident Analysis and Prevention. 1996;28:43-51.

In that epidemiology study reported that Truck drivers with binocular problems has increase rate of accidents but they also found that bus drivers with hypertension has a similar increase and I doubt that the latter is vision related.

McKnight AJ, Shinar D, Hilburn B. The visual and driving performance of

monocular and binocular heavy- duty truck drivers. Accid Anal Prev. 1991;23:225-237.

Actually compared truck drivers performance to matched binocular drivers and found them to be as able and as safe.

Racette L, Casson EJ. The impact of visual field loss on driving performance: evidence from on-road driving assessments. Optom Vis Sci. 2005;82:668-674.
Reported from study of the records of rehabilitation center that 79% of the monocular drivers assessed where found to be safe drivers. It is not known what brought these people to the rehab center (it certainly was not only the monocular vision).

I found no evidence in the literature for the value of stereopsis in driving.

Eli Peli

Date: Fri, 25 Aug 2006 15:36:58 +0100
From: Helen Ross
To: cvnet
Subject: RE: CVNet - binocular disparity

Following on Dave Rose's comments about lens replacement surgery: I used to be short-sighted and wore a prescription of -2.50 D for the left eye and -5.75 D for the right eye. I then had PKR surgery for the right eye, followed by the left eye 6 months later. Surgery enlarges the image relative to its previous state, by about 10% for the right eye and 0.05% for the left eye. Life was a bit difficult during the intervening 6 months. The right eye image appeared subjectively to be about 25% larger than the left eye. The world seemed enlarged for about a month. Fusion was difficult, and if successful produced aniseikonia: the floor sloped and wobbled as I walked, going downstairs or down a hill was awkward, and I lost confidence when skiing. I had difficulty pouring water into a cup. I never really adapted, though I managed most things.The only thing I absolutely couldn't do was thread a fine needle - but then who needs to mend clothes in this throwaway age! Stereopsis returned to normal after the second eye was lasered.

The message is that, even if normal binocular vision is not essential, abnormal stereopsis is harmful.

Helen Ross
University of Stirling

Date: Fri, 25 Aug 2006 16:51:11 +0100 (BST)
From: D.J. Tolhurst

To: John Ross
Cc: cvnet
Subject: Re: CVNet - stereopsis

Dear John,

Just to point out to those not up with the mysteries of cricket batting!! The batsman stands sideways onto the bowler and has to turn his head to face the oncoming ball. I think Colin Milburn lost the eye that more directly faced the bowler - his remaining eye had to view past his nose!!!

On the other hand, the Nawab of Pataudi Jnr (yes!!) captained India during the 1960s - he also had one eye, but eye think the remaining one was the more useful for cricket batting.

either way, I'm astonished that anyone dares to stand in line of a 90 mph ball, and is ever able to hit it!!

David

PS. that blackberry story ought really to be the bottom line of vision research!

Date: Fri, 25 Aug 2006 11:53:31 -0400
From: Laurie Wilcox
To: Eli Peli
Cc: cvnet
Subject: Re: CVNet - Re: stereopsis and driving

Dear Eli (and others)
It sounds as if there may be no documented performance deficit (in driving), but the papers you site don't rule out an increase in discomfort and/or stress associated with maintaining performance at a 'normal' level. Just a thought - I don't have data to back this up.

cheers,
Laurie

Date: Fri, 25 Aug 2006 09:40:59 -0700
From: "Sheedy, James E."
To: cvnet
Subject: CVNet - Binocular disparity in task performance

Colleagues,

In a 1986 study we had subjects perform a series of near tasks with normal binocular vision and also with one eye occluded. Time was the measure of performance. Placing pointed sticks into straws at varied angles required 28% more time with one eye, filing 3x5 cards into a file box required 9% more time, and flat tasks such as reading or editing required 3-5% more time with one eye. We occluded a few subjects for 5 days, and did not notice any gain in monocular performance relative to binocular performance.

These results show that binocular cues are normally used to enhance performance of tasks - especially those for which disparity is important. Five days of occlusion do not a lifetime make, so these results do not clearly indicate if loss of an eye results in permanent disability.

Jim Sheedy

Sheedy JE, Bailey IL, Buri M, Bass E. Binocular vs. monocular task performance. Am J Optom Physiol Optics 63(10): 839-846, 1986.

Jim Sheedy, OD, PhD, Dean
Pacific Unversity College of Optometry

Date: Fri, 25 Aug 2006 15:12:02 -0400
From: Dr. Martin J. Steinbach
To: Jeremy B Wilmer, cvnet
Subject: RE: CVNet - Stereoscopic vision: advantages, consequences

Jeremy's query has produced the greatest exchange on CVNET since Pete Kaiser started the listserv some decades ago. Of course, I have something to add:

Because my lab has conducted a number of studies on one-eyed children (recently summarized in Steinbach, M. J. & Gonzalez, E. G. (2006) Visual development with one eye. In M. R. M. Jenkin and L. R. Harris (Eds.), On Seeing Spatial Form. Oxford University Press. Pp. 385-404, and available as a pdf to those interested), I was, some years ago, asked by the Ontario Human Rights Commission to evaluate a wrongful dismissal suit brought by an employee who was fired because he was discovered to be ^Ómonocular.^Ô The man worked as a drill rig operator and he had to set up and operate rigs that obtained soil samples. The rig was about 20 feet high and sometimes had to be erected near overhead power lines. His ^Ómonocular^Ô status resulted from early-onset strabismus and his acuity in the amblyopic eye was less than 20/400, with 20/20 vision in the other eye. He had been doing his job successfully and without incident for a number of years but his employer had recently found out he did not have normal binocular vision and abruptly fired him.

I tested his depth acuity by using the Howard-Dolman apparatus, at 20 ft. distance, and found it to be virtually the same as that of binocular age-matched controls tested under the same conditions. He achieved his excellent depth acuity by making use of motion parallax, spontaneously moving

his head from side-to-side when asked to match the depth of the two rods. I wrote a report describing his successful use of the parallax cue, giving him virtually the same ^Óstereoacuity^Ô as binocular normals, and his suit was dropped when the company hired him back.

This takes nothing away from those describing the powerful depth sensation that stereopsis provides; it merely shows how redundant cues can be exploited by those in need of them.

Regards to all,
Marty Steinbach
--
Dr. Martin J. Steinbach
Distinguished Research Professor, York University.
Professor of Ophthalmology and Director of Research,
University of Toronto.
Head, Vision Science Research,
Toronto Western Hospital

Date: Fri, 25 Aug 2006 14:42:38 -0500
From: Joe Kearney
To: cvnet
Subject: CVNet - Postdoc; Vitrual Environments; University of Iowa
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Applications are invited for a renewable, one-year postdoctoral position in the Hank Virtual Environments Laboratory at the University of Iowa. Our research focuses on the use of virtual environments as a medium for the study of human behavior. Our current project has two primary thrusts: (1) a computational component directed at advancing scenario modeling techniques used to create realistic and controlled conditions for experiments conducted in simulations of outdoor, urban environments and (2) an experimental component investigating children's bicycle riding behavior in simulated traffic. The key instrument for our research is an immersive bicycling simulator.

Applicants should have a strong research record in either the development of virtual environment / interactive simulation software and technology and/or the use of virtual environments to study human action, perception, or visual cognition. The successful candidate will be able to carry out original research in collaboration with graduate and faculty researchers in the lab and contribute (to a limited extent) to teaching.

A PhD degree (or the equivalent) in computer science, psychology, or related disciplines within the last five years is strongly preferred. Depending on the qualifications of the fellow, the research may be more focused on the computational or experimental aspects of the project. The position is available immediately.

The project is supported through grants from the National Institutes for Heath and the National Center for Injury Prevention and Control. Recent support includes grants from the National Science Foundation and Ford Motor Company.

Applications including a CV, copies of (or pointers to) selected publications, two letters of reference, and a short statement of research interests should be sent to:

Joe Kearney

For more information, see the project web site http://www.cs.uiowa.edu/~hank or contact one of the project directors:

Jodie Plumert
Jim Cremer
Joe Kearney

Date: Fri, 25 Aug 2006 15:59:08 -0400
From: Jennifer Steeves
To: D.J. Tolhurst
Cc: John Ross, cvnet
Subject: Re: CVNet - stereopsis

I thought this was a good opportunity to briefly point out the interesting dissociation in form and motion perception from studies of one-eyed people-- the extreme monocular case, as someone mentioned earlier. (Also, who can pass up a chance for self-citation?!)

Odom mentioned some of the work from Marty Steinbach's lab showing enhanced visual performance in early (before age 2) unilaterally enucleated people. Generally this seems to be for spatial vision tasks such as contrast sensitivity (Nicholas, Heywood & Cowey, VIs Res 1996 (36), 175-180), hyperacuity (e.g. Vis Res 2004, (44) 943-949) or acuity (Vis Res 1997, (37), 2465-2469) at low contrast. Further, in the hyperacuity study the one-eyed people were superior to controls viewing dichoptically but far more superior when they were compared to controls wearing an eye-patch. So I think that when we put an eye-patch on in the lab to try to measure monocular vision, we're only approximating a monocular system at best. This also suggests that not all types of monocularity are equal since observers with amblyopia, for example, have quite the opposite pattern of results-- and that early unilateral enucleation has selective 'positive' effects on spatial processing.

On the other hand, the work that I've done to look at motion perception in enucleated people showed poor motion coherence thresholds and poor motion-defined form perception compared to controls (Vis Res 2002, (42) 143-150). Also, with David Regan we found that these one-eyed observers could not accurately estimate time-to-collision using tau (Vis Res 2000, (40),3783-3789). Clearly these people are able to interact appropriately

with the environment (make peanut butter sandwiches...), drive a car but a loss of binocularity (and stereopsis) in early life is specifically detrimental to motion processing. (SO how did the Nawab of Pataudi Jnr manage??!!) Marotta and colleagues showed that one-eyed people may use learned adaptive strategies such as making larger head movements for accuracy in tasks such as reaching and grasping (Eye, (9) 333-336). But I guess this strategy hasn't worked for some who were temporarily patched and trying to do fine soldering!!

I'm really enjoying this lively discussion!
Best,
Jennifer

Jennifer Steeves, Ph.D.
Assistant Professor, Department of Psychology
Faculty of Health
Centre for Vision Research
York University

Date: Fri, 25 Aug 2006 16:53:28 -0400
From: Tony Movshon
To: cvnet
Subject: CVNet - Binocular vision

In between bouts of reading this long and entertaining thread, I happened while in the Russian Museum in St Petersburg upon Ilya Repin's striking "Portrait of the Surgeon Nikolay Pirogov" (http://www.abcgallery.com/R/repin/repin36.html), who was evidently one-eyed, and also "the greatest of all Russian surgeons" (http://www.whonamedit.com/doctor.cfm/2627.html).

Tony Movshon
NYU

Date: Fri, 25 Aug 2006 23:15:20 +0200
From: Lothar Spillmann
To: cvnet
Subject: CVNet - Stereo vision debate - Tony C.

CVnetters:

Remember the great Tony Conigliaro of the Boston Red Socks? He lost much of his depth perception after having been hit by a fast ball on his left cheekbone. At the Massachusetts Eye & Ear Infirmary and Retina Foundation he was diagnosed with a small hole in his left retina and severely blurred vision. Following a remarkable recovery, acuity in that eye

deteriorated permanently depriving him of the exquisite stereo vision needed for hitting the ball. This essentially ended his career as a Major League Baseball player.

Lothar Spillmann
UCDMC
Ophthalmology
Sacramento, CA

Date: Fri, 25 Aug 2006 15:02:12 -0700
From: Chris Bowd
To: cvnet
Subject: Re: CVNet - Stereo vision debate - Tony C.

american football anyone? perhaps a wide receiver with a stereo-impairment? tennis? badminton? squash? very entertaining. c-

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Date: Sat, 26 Aug 2006 13:21:00 +1000
From: mrosa
To: cvnet
Subject: CVNet - CVNet- binocular vision

Not so high-profile as sportsmen or truck drivers, but I did notice an important practical consequence of having to go around for a month with one eye patched, a few years ago.

We used to do experiments involving recordings in visual cortex, in which the electrode had to be moved frequently (>100 electrode penetrations per animal). Part of the trick was to find the gaps in the blood vessel pattern, so that the surface of the brain could be penetrated with minimal damage. This was done through a binocular operating microscope.

These were very fine, parylene-coated electrodes, and hence "bendable". After wrecking the tips of more than a few electrodes, and hitting a few vessels, I had to bow to the evidence, and accepted a ban from driving the electrode, imposed by my students...

As far as I could tell my capacity to do this type of fine work did not improve over a month. However, I accept that people will eventually learn to deal with this situation, particularly if monocular vision is imposed early in life.

On a different note: does anyone know what is the minimal interocular separation that can be useful for stereopsis? I have worked with marmoset monkeys, which have a very small interocular separation (10-15 mm, maximum, off the top of my head). Yet, they have disparity-tuned cells in V1, and can of course do very accurate judgments of distance

(for example, like squirrels, they can make long jumps between fine branches).

Dr. Marcello Rosa
Associate Professor, Department of Physiology
Director, Monash University Centre for Brain and Behaviour

Date: Sat, 26 Aug 2006 05:22:29 +0200
From: Lothar Spillmann
To: cvnet
Subject: CVNet - Stereo-vision debate

Dr. Bowd:

You asked for it, here you are.

Sepp Weiler, blind in his left eye from a shrapnel wound sustained in WWII, was the most successful German ski jumper in the late forties and early fifties. They laid out twigs for him in the snow so that he would be able to better see where to land when he came down.

My apologies to the fans of Tony C. and thank you, Robert Teghtsoonian, for pointing out that I "have been out of the country too long--they're the Red Sox, not Socks :-)

Lothar Spillmann

Lothar Spillmann
UCDMC
Ophthalmology & Vision Science
Sacramento, CA

Date: Sat, 26 Aug 2006 09:55:06 -0400
From: Esther G Gonzalez
To: cvnet
Subject: CVNet - adaptation to the lack of stereo

I would like to add to the comments made by Sue Barry and Jennifer Stevees in this space.

Dr. Barry pointed out that defective stereo is worse than no stereo at all which is in agreement with a number of studies showing that some visual functions in the "good" eye of people with amblyopia are significantly worse than those in one-eyed observers.

Jennifer Steeeves mentioned that Marotta and colleagues showed that

one-eyed people (mean age = 32 yrs) may use learned adaptive strategies such as making larger head movements for accuracy in tasks such as reaching and grasping (Eye, (9) 333-336). In contrast, Gonzalez et al (Clin Vis Sci, (4) 173-177) found that a much younger group of enucleated children (mean age = 12 yrs) did not spontaneously move their head in an alignment task that required either binocular vision or motion parallax. After the first test in which they performed rather badly, the children were instructed to move their head and tested again. This time their thresholds were comparable to those of an older control group viewing binocularly. All head movements were recorded using a sonic digitizer but some children were also videotaped. I clearly remember one little boy who did not move his head with a boring sinusoidal profile but with great rhythm and a hip hop beat. He has always drawn a smile from those scientists who have seen the tape.

Some people adapt to the loss of binocularity very well, but training may make adaptation faster and more efficient.

Regards,

Esther.

Esther G. González, Ph. D.
Vision Science Research Program
Assistant Professor of Ophthalmology
Toronto Western Research Institute
Dept. of Ophthalmology and Vision Sciences
Toronto Western Hospital
University of Toronto

Date: Sat, 26 Aug 2006 18:36:49 -0400
From: Rudiger von der Heydt
To: cvnet
Subject: CVNet - stereopsis

I am enjoying this wonderful discussion. There seem to be answers out there to every question one might wish to ask. So here is my question: What species besides humans have stereopsis? I remember behavioral studies that demonstrated stereopsis in monkey, cat, falcon, and toad. My guess is that almost every creature with two eyes has stereopsis because it's such a basic function and so powerful. Any studies in bees or flys? By the way, stereopsis does not necessarily require good optical resolution. I remember the first autofocus device for cameras that came on the market had receptor arrays of only 4 elements!

--

Rüdiger von der Heydt, PhD
Professor of Neuroscience
Krieger Mind/Brain Institute

Johns Hopkins University
3400 N. Charles Street
Baltimore, MD 21218

Date: Sat, 26 Aug 2006 20:25:06 -0400
From: Matt Peterson
To: Lothar Spillmann
Cc: cvnet
Subject: Re: CVNet - Stereo-vision debate

Don't forget Wiley Post, who was the first pilot to fly solo around the earth.

Date: Sun, 27 Aug 2006 12:42:14 +0800
From: Ai-Hou Wang
To: cvnet
Subject: CVNet - binocular vision

Binocular depth-from-motion (BDFM) is another binocular mechanism more fundamental than stereopsis (binocular depth-from-disparity). As depicted in the picture, http://webpages.charter.net/ahwang/BDFM.htm, BDFM utilizes motion vectors on two retinae to calculate motion-in-depth of the fixated target.

Many stereopsis defective people preserved BDFM. We collected these patients for years to find

* Infantile esotropia patients may preserve BDFM despite random-dot stereopsis is impossible for them.

* After surgery or spectacle wearing , accommodative esotropia patients usually recover BDFM earlier than stereopsis.

* Patients with latent nystagmus (LN) may preserve BDFM. LN is a sure sign of early-onset strabismus.

* Patients with dissociated vertical deviation (DVD) and severe inferior oblique muscles overaction (IOOA) may preserve BDFM. Both DVD and IOOA are bad signs implicating stereopsis defect.

* And many others.

BDFM is different from motion parallax. The former utilizes simultaneous motion cues on both eyes to calculate depth while the latter utilizes sequential motion cues.

The BDFM test we used clinically can be accessed at
http://webpages.charter.net/ahwang/rnd-MD.html

Ai-Hou Wang, MD, PhD

Date: Sun, 27 Aug 2006 13:10:01 +0200
From: Hermann Wagner
To: Rudiger von der Heydt, cvnet
Subject: Re: CVNet - stereopsis

Dear Dr. von der Heydt and CVnetters,

the discussion is really enjoyable! You asked what species besides humans have stereopsis.

Barn owls have stereopsis as well. After Pettigrew and Konishi had demonstrated in the 1970s that this bird possesses disparity sensitive neurons just like monkeys do, Rob van der Willigen and Barrie Frost demonstrated that barn owls can see depth in random dot stereograms. Rob also showed that the owl can generalize depth from stereo to motion parallax. Andreas Nieder recorded from disparity senstive neurons in the barn owl's visual Wulst while the bird was fixating and observed a hierarchy of processing. The most complex cells had the longest latencies and did not respond to anticorrelated random dot stereograms. We suggested that these cells might be able to solve the correspondence problem.
These findings seem interesting from an evolutionary point of view, because the acquisition of stereopsis in the barn owls happened independently of that in mammals.
Regards,
Hermann Wagner

_____
Hermann Wagner
Institut für Biologie II

Date: Sun, 27 Aug 2006 15:44:56 +0000 (GMT)
From: lkaufma
To: Rudiger von der Heydt
Cc: cvnet
Subject: Re: CVNet - stereopsis

I too have enjoyed this discussion. Would it be unreasonable to assume that stereopsis would exist only in a subset of all those species with hemidecussation (or at least partial decussation) of the optic nerves?

Permit me to ask my own question. Thus far I have not seen an explicit distinction between binocular rangefinding (in which animal detects range from itself to a "target" object) and relative disparity, which provides information regarding the order in depth of contours or objects. Both processes may coexist, but I can imagine a creature, e.g., a hawk, who seeks range to capture distant prey, but lacks the nerual machinery to process relative disparity. As is well known (at least

since von Kries), the magnitude of depth between two points at different distances is proportional to the produce of their egocentric distances or, where the distances of both points are great, proportional to the square of their average distance. Of course, the sources of information about distance are not limited to disparity. So, within ~ 8m (Foley, 1981) this information may be gleaned from convergence, while other so-called cues may be employed with varying degrees of accuracy for objects at greater distances. Of course their is the grey area in which an object such as a baseball or cricket ball absolute parallax changes with time as it approaches the batter. May he or she use this time-varying disparity (rate of change of disparity as well as angular size) to compute range? I believe that David Regan might say yes (based on an observation he attributes to Fred Hoyle). One wonders whether this integration would be biologically feasible at 90 mph. In any event, my question is the following: Should we attribute stereopsis to my hypothetical range-finding creature who is incapable of dealing with relative disparity per se?

Lloyd Kaufman

Date: Sun, 27 Aug 2006 15:19:13 -0400
From: David Regan
To: cvnet
Subject: Fwd: CVNet - Stereo-vision debate

According to his biographer, Wiley Post prepared for his flight by spending a great deal of time learning to estimate the distance to objects of known size through his remaining eye

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Date: Mon, 28 Aug 2006 09:54:45 +1000
From: vaegan
To: 'Rudiger von der Heydt', cvnet
Subject: RE: CVNet - stereopsis

Dear Rudiger,

Jack Pettigrew, now U of Qld, Institute for sight and hearing etc did a lot of work on binocularity in birds, who have an area called the Wulst, with many functional and structural properties resembling area 17 in primates. This includes binocular disparity processing. Many birds, even pigeons, have a temporal secondary area of high ganglion cell density subserving the binocular fixation area in the midline. In eagles it becomes the most spectacularly deep fovea of any animal, according to the picture in Polyak's book.

Pettigrew later described the visual system of flying foxes. Flying foxes are a family of hairy gliding animals possibly evolved in the same way as other flying mammals like sugar glider possums. They have more mammalian

than bat like properties in both skeleton and brain and they have a layered LGN with segregation of the two eyes that come together later in the cortex. I hope this is not too coarse a paraphrase of Jack's many comparative anatomy studies.

Also worth noting, in line with your comment about high spatial resolution not being necessary, that area MT is possibly the most strongly binocular visual area. I have wondered whether it is where the detectors are for M Regan's zoom detectors. These units are tuned to objects coming towards or away from the head along the midline and are especially coded for opposite directions of movement across each retina. Are there any physiologists out there with data on that one?

yrstrulyvaegan

CRICOS Provider Code: 00098G

Date: Mon, 28 Aug 2006 22:37:51 +1000
From: Robert Allison
Cc: cvnet
Subject: Re: CVNet - stereopsis

I am also enjoying this thread (although due to a excruciatingly slow hotel room internet connection haven't read most of it yet - so apologies if any of these points have been mentioned).

There is evidence for depth/distance processing even in invertebrates. For example, Rossel contends that mantids (specifically /Sphodromantis viridis) /use binocular disparity when planning their strikes (Rossel S, Nature, 1983, 302:821) and has backed this with behavioural experiments using prisms. As mantids do not have mobile eyes, absolute disparities are available for Lloyd's 'range finder' mechanism and this is presumably what they use.

On the question of the useful range of stereopsis, starting with Christopher Tyler much has been already been said about the theoretical range and the enduring influence of misleading assertions made in general perception texts. Unfortunately, little data exists on stereopsis at large distances and most of the relevant studies are now quite old and rarely cited. Barbara Gillam and I are currently performing experiments under an Australian Research Council grant to look at this issue.

Best

Rob Allison

Date: Mon, 28 Aug 2006 09:24:14 -0400

From: Tony Movshon
To: cvnet
Subject: Re: CVNet - stereopsis

On Aug 27, 2006, at 7:54 PM, vaegan wrote:
> Also worth noting, in line with your comment about high spatial
> resolution
> not being necessary, that area MT is possibly the most strongly
> binocular
> visual area. I have wondered whether it is where the detectors are
> for M
> Regan's zoom detectors. These units are tuned to objects coming
> towards or
> away from the head along the midline and are especially coded for
> opposite
> directions of movement across each retina. Are there any
> physiologists out
> there with data on that one?

MT units with opposite direction preferences in the two eyes were described by Zeki and studied by Maunsell and Van Essen. I believe there was an earlier report by Pettigrew of such units in cat area 18. On the other hand, my experience suggests that such units occur with low frequency (~1-2%) in any area where cells are both binocular and directionally selective, so it would be premature to claim a specific role for MT on the basis of the similarly small proportion of such units found there.

MT is indeed strongly binocular, but AFAIK not more so than any other extrastriate visual area in monkeys.

Tony Movshon
NYU

Date: Mon, 28 Aug 2006 12:01:38 -0300
From: Donald Mitchell
To: cvnet
Subject: CVNet - Posting for the discussion of the benefits of Stereopsis

Another perspective on the discussion of the benefits of stereoscopic vision is provided by recent developmental studies conducted on cats (Mitchell et al., Curr. Biol. 13: 1704-1708, 2003; Eur. J. Neurosci. 23: 2458-2466, 2006; Sengpiel et al., SFN Poster 2006) and monkeys (Wensveen et al, Invest. Ophthalmol. & Vis. Sci., 46: 2468-2477, 2006; Sakai et al, J. Neurophysiol. 95: 2856-2865, 2006) that point to a strong preference for concordant binocular visual input for both the development of ocular dominance domains in the visual cortex and for vision. In both species, short daily periods of concordant binocular input can offset much longer daily periods of monocular exposure (deprivation) to allow development of normal vision in both eyes and

cortical ocular dominance in visual cortex. By virtue of molecular events prior to birth, presumably driven by patterns of gene expression, the neonatal visual system is primed for binocular input and weights it more strongly than other input in early postnatal life. I have presumed that the preference for binocular input is a testament to the benefits of steresoscopic vision. From a developmental standpoint one could suggest that stereopsis may help guide the acquisition of the complex set of skills, presumably involving the use of many visual cues, that are required to intersect with accuracy the path of moving objects as required in many sports. I recall from my youth the benefits of the many hours spent hitting tennis balls against a wall. To hit a moving ball with accuracy and skill requires a lot or repetition.

Donald Mitchell
Psychology Dept.
Dalhousie University

Date: Mon, 28 Aug 2006 13:47:21 -0400
From: David Regan
To: cvnet
Subject: CVNet - binocular depth perception

In " Human Perception of Form" (2000, Sinauer) I assumed that the major evolutionary advantage of binocular depth perception was for animals who hunt and eat other animals , the other animals having evolved so as to match their chosen surroundings in luminance, colour, and texture and who were able to freeze still when in danger. (An old idea put forward by Julesz among others). It is difficult to achieve camouflage against a a predator with binocular depth perception who is close by , though some animals go some way to achieving it by merging into their chosen 3D surroundings. (see plates2,3 & 4 in the book cited).

Just one example of a predator that lacked binocular depth perception would knock this notion down, or at least cause some damage and provoke a rethink. Does anyone know of such an example?

D.Regan

Date: Tue, 29 Aug 2006 00:18:18 +0430
From: Reza Rajimehr
To: cvnet
Subject: CVNet - Monocular vision

Hi,

One additional problem in the case of monocular vision (not necessarily related to the lack of binocular disparity) is the asymmetric pattern of retinal/cerebral activation in response to monocular visual stimulation.

For several anatomical reasons (e.g. density of ganglion cells, size of ocular dominance columns, ...), the temporal visual field is processed better than the nasal visual field. With two normal eyes, this anatomical/functional asymmetry is hidden in our perception; however, people with one eye might have less optimal vision in their nasal visual field, which could make some inaccuracies in their visual judgments.

Reza

Date: Tue, 29 Aug 2006 08:11:10 +1000
From: Jack Pettigrew
To: cvnet
Subject: CVNet - Avian Stereopsis

Further to Regan's prediction in the recent cvnet email, there are many predatory bird species that lack stereopsis. However, these examples support, rather than contradict Julesz' idea (as Regan predicts). All of these species take their prey on the wing where there are other powerful depth cues such as monocular movement parallax and where stereo would be too slow anyway. In contrast, stereopsis is highly developed in nocturnal, perch-pounce predators such as owls, owlet-nightjars and frogmouths that take their off the ground rather than on the wing.

The key evolutionary pressure for the emergence of stereopsis was almost certainly nocturnality, combined with camouflage breaking. Work I did with Rob van der Willigen on owl stereopsis (still unpublished) showed that they achieve a dramatic improvemeent in steroacuity at low light levels compared with humans and macaques. The "root 2" increase in signal-to-noise ratio that comes with combining the two eye's channels is a massive boost when light levels are low and quantal noise high. We think that this was the key consideration and that it would have applied to early mammals, which were also nocturnal.

We have had trouble getting out work published because everyone is dazzled by the fast vergence variety of stereopsis found in anthropoids and are unimpressed by owl stereopsis with its poor or absent eye movements, where the eyes are mostly aligned for binocular vision slowly or developmentally.

Clearly, atereopsis could not have sprung forth fully formed, with the anthropoid variety of high acuity and fast vergence. Instead there must have been some intermediate forms where the oculomotor performance and the stereoacuity was not so high. The tarsier, a little primate with huge immobile eyes that behaves just like an owl, hardly has any eye movements at all, certainly has no fast vergence, and probably is a better model for the earliest stereopsis in primates.

The tarsier is strictly nocturnal, as indicated by its behaviour and the enormous light catching ability of its eyes. In both the owls and owl-like birds and the owl-like tarsier, nocturnality is the key consideration for the emergence of steropsis beccause the camouflage-breaking trick is enormously improved by combining signals from both eyes.

So Julesz was correct, but would have been even more "spot on" if he had mentioned the special pressure for for the emergence of stereopsis that operates because of quantal noise in the nocturnal niche.

Jack

Prof. JD Pettigrew FRS
Vision Touch and Hearing Research Centre
School of Biomedical Sciences
University of Queensland

Date: Mon, 28 Aug 2006 20:47:14 -0400
From: Esther G Gonzalez
To: cvnet
Cc: Stephen Kajiura
Subject: CVNet - binocular depth perception in predators

With his permission, I am sending a reply sent by Dr. Stephen Kajiura, an expert in elasmobranch fishes, to Dr. Veagan and myself regarding hammerhead sharks. It appears that stereo in hammerheads is unlikely, but there is still hope.
Regards,
Esther.

Dear Vaegan

Thank you for your interest in our ongoing investigation of vision in elasmobranch fishes.
Our data indicate that the lemon shark, which possess a typical requiem shark head morphology, does not achieve binocular convergence. We have not yet tested scalloped hammerheads (scheduled for summer 2007 in Hawaii) but suspect that the same is true based upon the morphology and eye placement. We also have bonnethead sharks in our tanks right now which have an intermediate head morphology and which will be tested shortly. It is also unlikely that any of the species achieve rear overlap, as the body occludes their visual field.
As for the fovea, this structure is not present in the typical form in carcharhiniform sharks (which includes requiem sharks and hammerheads). These sharks typically possess a horizontal band of densely packed photoreceptors across the retina in place of a fovea. This band of photoreceptors is referred to as the ^Ñhorizontal visual streak^Ò.

The laterally expanded head of hammerhead sharks provides advantages in maneuvering and in spacing of electroreceptors to locate prey. However, it comes at a cost because of the inherent blind spot immediately anterior to the snout. If they achieve binocular convergence, it will be at a distance significantly anterior to the snout, which may not even be of ecological relevance in turbid water.

Note that work has always been done on eyes in a relaxed state - the visual field will change if the ocular muscles rotate the eyes forward, and if the shark yaws it head. We have documented that there is no significant difference in head yaw between hammerhead and sandbar sharks but have yet to measure the effect of rotating an eye within the socket. Shark vision, especially in hammerheads, is clearly a fascinating question with lots more work ahead.

steve

Esther G. González, Ph. D.
Vision Science Research Program
Assistant Professor of Ophthalmology
Toronto Western Research Institute
Dept. of Ophthalmology and Vision Sciences
Toronto Western Hospital
University of Toronto

Date: Mon, 28 Aug 2006 20:53:08 -0400
From: Esther G Gonzalez
To: cvnet
Subject: CVNet - naso-temporal acuity differences in monocular people
---

González, Steeves. Kraft, Gallie, & Steinbach (BBR, 2002, (128) 71-80) compared the foveal and near-peripheral acuity of enucleated observers and normal controls with the fellow or ^Ñgood eye^Ò of age-matched non-amblyopic and amblyopic strabismic observers^×a different kind of monocular deprivation^×.The eccentric acuity of enucleated observers and normal controls was best, followed by that of the non-amblyopic and lastly, the amblyopic subjects. No naso-temporal asymmetries were found in any group.Also, the foveal acuity of the enucleated observers was better than the monocular acuity of controls at all contrasts, and equivalent to their binocular acuity. The eccentric acuity of the enucleated observers was better at low contrast.

Esther.

Esther G. González, Ph. D.
Vision Science Research Program
Assistant Professor of Ophthalmology
Toronto Western Research Institute
Dept. of Ophthalmology and Vision Sciences
Toronto Western Hospital

University of Toronto

Date: Tue, 29 Aug 2006 12:08:01 +1000
From: vaegan
To: 'David Regan', cvnet, kajiura
Subject: RE: CVNet - binocular depth perception

Dear CEVnet,
David Regan's request for one predator without binocularity comes close to being answered by a previous part of this thread concerning the wide PD of hammerhead sharks but Esther G. Gonzales of York U warned me they may have no binocularity at all.
I made a direct query to the person most knowledgeable about these creatures (Stephen M Kajiura of Florida U)
I wrote
>On your website you do not document the degree of binocular field overlap for hammerhead
>sharks. Is it truly zero frontal overlap and only rear overlap in these animals?
>
>If there is any frontal binocular overlap at all, the next crucial question,
>also not addressed is whether there is a second area of high sensitivity projecting to the front?

He has verified they have a visual streak but probably have little or no frontal or rear areas of binocular overlap because both the snout and rear body prevent it.
The issue is not resolved yet. There may be some binocular overlap far anterior of the snout, even in the relaxed state and the final role of eye movements has not been settled.
If any part of the very far temporal visual streak was able to provide binocular input at large distances ahead, it could be sufficient for efficient predation, as it does in birds. Electroreception would work at nearer distances in this interesting animal.

Stephen M Kajiura wrote:-
Dear Vaegan

Thank you for your interest in our ongoing investigation of vision in elasmobranch fishes.
Our data indicate that the lemon shark, which possess a typical requiem shark head morphology, does not achieve binocular convergence.
We have not yet tested scalloped hammerheads (scheduled for summer 2007 in Hawaii) but suspect that the same is true based upon the morphology and eye placement. We also have bonnethead sharks in our tanks right now which have an intermediate head morphology and which will be tested shortly. It is also unlikely that any of the species achieve rear overlap, as the body occludes their visual field.
As for the fovea, this structure is not present in the typical form in

carcharhiniform sharks (which includes requiem sharks and hammerheads). These sharks typically possess a horizontal band of densely packed photoreceptors across the retina in place of a fovea.
This band of photoreceptors is referred to as the 'horizontal visual streak'.
The laterally expanded head of hammerhead sharks provides advantages in manoeuvring and in spacing of electroreceptors to locate prey.
However, it comes at a cost because of the inherent blind spot immediately anterior to the snout. If they achieve binocular convergence, it will be at a distance significantly anterior to the snout, which may not even be of ecological relevance in turbid water.
Note that work has always been done on eyes in a relaxed state - the visual field will change if the ocular muscles rotate the eyes forward, and if the shark yaws it head. We have documented that there is no significant difference in head yaw between hammerhead and sandbar sharks but have yet to measure the effect of rotating an eye within the socket. Shark vision, especially in hammerheads, is clearly a fascinating question with lots more work ahead.

Steve

Stephen M Kajiura
Biological Sciences
Florida Atlantic University

Date: Mon, 28 Aug 2006 22:53:38 -0700
From: Dennis Dacey
To: vaegan
Cc: 'Rudiger von der Heydt', cvnet
Subject: Re: CVNet - stereopsis

I'd love to add to the thread.
Those hairy gliding animals are mammals!!
Dennis
On Aug 27, 2006, at 4:54 PM, vaegan wrote:

> Dear Rudiger,
>
> Jack Pettigrew, now U of Qld, Institute for sight and hearing etc
> did a lot
> of work on binocularity in birds, who have an area called the
> Wulst, with
> many functional and structural properties resembling area 17 in
> primates.
> This includes binocular disparity processing. Many birds, even
> pigeons, have
> a temporal secondary area of high ganglion cell density subserving the
> binocular fixation area in the midline. In eagles it becomes the most
> spectacularly deep fovea of any animal, according to the picture in
> Polyak's

> book.
>
> Pettigrew later described the visual system of flying foxes. Flying
> foxes
> are a family of hairy gliding animals possibly evolved in the same
> way as
> other flying mammals like sugar glider possums. They have more
> mammalian
> than bat like properties in both skeleton and brain and they have a
> layered
> LGN with segregation of the two eyes that come together later in
> the cortex.
> I hope this is not too coarse a paraphrase of Jack's many comparative
> anatomy studies.
>
> Also worth noting, in line with your comment about high spatial
> resolution
> not being necessary, that area MT is possibly the most strongly
> binocular
> visual area. I have wondered whether it is where the detectors are
> for M
> Regan's zoom detectors. These units are tuned to objects coming
> towards or

Date: Tue, 29 Aug 2006 11:23:28 -0400
From: David Regan
To: cvnet
Cc: j.pettigrew, kajiura, vaegan
Subject: Fwd: CVNet - binocular depth perception

It seems to me that the predator that would challenge the hypothesis that the major evolutionary advantage of stereoscopic depth perception is breaking camouflage is a predator that fulfills the following requirements: (1) it preys on animals who can match their chosen surroundings in luminance, colour and texture and who freeze still when in danger, and (2) it detects its prey entirely visually (eg not using infra red sensors, electrical signals or vibration).

Do sharks fulfill these requirements? Or is their prey usually visible by luminance contrast and/or motion?

Date: Tue, 29 Aug 2006 18:10:26 -0400
From: "Odom, J"
To: David Regan, cvnet
Subject: RE: CVNet - binocular depth perception

David,

You and a couple of others attributed to Bela Julesz (among others) the idea that frontally placed eyes and stereopsis are related to predation. I thought that the idea was attributable to Gordon Walls, perhaps because of my time at Berkeley. So I did some cursory looking. Sure enough on pages 291 and following (Walls, 1942), there is a lengthy discussion of these points. Several review chapters use their diagrams to illustrate the fact that predators are more likely to have frontally placed eyes and larger binocular fields. They frequently attribute them to Duke-Elder's System of Ophthalmology Vol.1 1957. Skimming their chapters on the topic, however, it seems to me that both Walls and Duke-Elder relied heavily on earlier sources, notably German and French zoologists (Duke-Elder also has a fascinating couple of sentences on the technique used to determine the visual field maps of the animals); but it is not clear who - if anyone - should actually get the credit for first !
suggesting the relationship of frontal eye position, binocular fields and stereo to predation.

Jack Pettigrew suggested that nocturnal creatures have a special need for binocularity. According to Duke-Elder, Weale suggested the importance of binocularity at night in 1955 for the same general reason.

About 30 years ago, I first heard Bob Fox from Vanderbilt comment in a lecture that primates with poor stereopsis (literally) fell from the gene pool. (A similar comment was made by an earlier person in the string.) So the idea that stereopsis is important in arboreal environments even in the absence of predation has been around for awhile, but I do not have a good reference for the origins of the idea. Would you think of this as "breaking camouflage", even if the primate (or other arboreal creature) is not a predator?

Lastly, Lloyd Kaufman asked about the possibility of using absolute range finding in the absence of stereo for predation. Two possibilities come to mind that may fit the bill. One might be the Gecko (see Murphy and Howland Vision Research, 1986, 26,815-817). The idea is that with their 4 pupils, images are blurred except at a fixed distance. Knowing that fixed distance might aid the Gecko in catching prey. Another possibility might be the mantids (Samuel Rossel. Binocular vision in insects: How mantids solve the correspondence problem. PNAS 1996, 93, 13229-13232). Mantids clearly use binocular cues to judge prey distance, it is not clear that those are stereo cues in the same way that we use the term in humans. However, I will defer to more knowledgeable folks on both of these possible examples. Is there evidence that the Gecko or the mantids have disparity sensitive neurons?

Vernon

J. Vernon Odom, Ph.D.
Professor of Ophthalmology and Physiology
West Virginia University Eye Institute
Robert C. Byrd Health Sciences Center
West Virginia University

Date: Fri, 29 Aug 2006 14:17:19 -0500
From: Bill Saidel
To: David Regan, cvnet
Subject: Re: Fwd: CVNet - binocular depth perception

At 10:23 AM 8/29/2006, David Regan wrote:
>It seems to me that the predator that would challenge the hypothesis
>that the major evolutionary advantage of stereoscopic depth
>perception is breaking camouflage is a predator that fulfills the
>following requirements: (1) it preys on animals who can match their
>chosen surroundings in luminance, colour and texture and who freeze
>still when in danger, and (2) it detects its prey entirely visually
>(eg not using infra red sensors, electrical signals or vibration).
> Do sharks fulfill these requirements? Or is their prey
> usually visible by luminance contrast and/or motion?

Since A.J. Kalmijn showed ~30 or more years ago that some sharks successfully identify prey buried in the sand (ie, no luminance contrast, no motion, no visualization, the attracting signal being bioelectric (muscle & nerve)), condition 2) above should not be assumed and in specific cases, fails. Moveover, the lateral position of eyes preclude stereopsis since in these animals, binocular overlap is nearly absent.

On the other hand, many bony fishes with lateral eyes posses a small region of binocular overlap (8-30 degrees) and when the optic tectum is stimulated in the small binocular region, vergent eye movements are seen. When stimulated elsewhere in the tectum, conjugate eye movements are seen. Whether the vergent eye movements reflect a process involved in the different tasks of predation depends upon the particular fish (and there are ~20,000 species, unlike Homo sapiens with its singular species).

Date: Wed, 30 Aug 2006 13:09:43 +1000
From: Jack Pettigrew
To: cvnet
Subject: CVNet - Julesz, Walls and Polyak

The idea that predation and binocular vision go together is an old one, as Odom points out. But Julesz^Ò contribution was a completely new one that I think may be lost in the present discussion about binocular depth perception. Julesz was not talking about the role of stereopsis in binocular depth perception, he was talking about the role of stereopsis in the act of seeing itself. This was a completely novel suggestion (with due respect to the precursors of random dot stereograms made by the aerial photographer whose name I forget). There is no reference that I can find in Walls to the fact that stereopsis lets you see something that is otherwise (monocularly) invisible.

In his haste to come to grips with the ^Ómore complex^Ô problems in vision, Marr did not have much patience for the problems of delineating the potential boundaries of objects in images, which he considered a low level task. In fact, image segmentation is very difficult and object boundaries may not exist in the brightness domain, yet become apparent to specialised networks of stereo or colour or motion.

So it may be that stereopsis first appeared in the interests of seeing the prey, not so much in judging its distance, for which other cues are often available to a perch-pounce predator habitually using familiar perches. This is a counter-intuitive idea for which credit must go to Julesz. As well as creating random dot stereograms, I believe that Julesz was the first to create random dot kinematograms (anyone have any views on this?). In the colour domain, there are also familiar examples of colour-mixture camouflage that can be broken with the appropriate array of cones, of which birds would be the best example, easily breaking camouflage that fools humans.

If we are to dig deep for historical accolades on stereopsis, then Polyak deserves some. He was very impressed by the importance of stereopsis in visual evolution, without enunciating the camouflage-breaking idea. Polyak felt that mastering stereopsis would have a general benefit for other neural tasks and so give the proponent a boost. This is along the subtle line that I am pursuing here, where stereopsis is more than a range finder, instead playing a key role in the most difficult parts of vision such as image segmentation.

Stereopsis seems to need to use raw information, hence the fact that stereo pathways eschew the highly-specialised retinal ganglion cells and ^Óskip over^Ô the midbrain in their ^Óhurry^Ô to get the information carried by non-specialised concentric ganglion from both eyes together. Such an algorithm, using basic raw information to solve complex problems instead of relying on pre-processed solution, might be the main part of the primates^Ò shift away from the midbrain-based visual system that dominates the visual system of all other vertebrates. If Polyak was right, stereopsis played a more general role in the development of the cortical algorithms that are responsible for the success of primates.

Prof. JD Pettigrew FRS
Vision Touch and Hearing Research Centre
School of Biomedical Sciences
University of Queensland

Date: Wed, 30 Aug 2006 03:48:21 -0400
From: walt
To: cvnet
Subject: Re: CVNet - Stereoscopic vision: advantages, consequences
---

At the risk of burdening CVNet with near-trivia, some may be interested in adding to the gallery of interesting one-eyed individuals the name of Mohammed bin Awahd bin Laden, father of Osama bin Laden. According to Lawrence Wright's book, The Looming (sic) Tower (2006, pp. 64-71), he lost one eye to a blow from a teacher in his first days of schooling. Aside from amassing a third of a billion dollars (in 1967 dollars) from scratch over a period of 36 years, a task that may not have required good 3-D perception, he also personally marked with chalk the path of the road from Taif to Mecca down the sheer mountain wall that separates the two and set the dynamite charges required to blast the road from the rocky cliff, tasks which probably did require good 3-D perception.

Walt Makous

--
Walter Makous
Center for Visual Science
University of Rochester

Date: Wed, 30 Aug 2006 10:40:45 +0200
From: "ECVP 2007 Chair (SB)"
To: walt, cvnet
Subject: Re: CVNet - Stereoscopic vision: advantages, consequences
---

Hi all,italian skier Fausto Radici lost one eye during his childhood. Nevertheless, he was a leading champion in slalom in the '70s, able to win 2 World Cup races and reach 5 additional times the podium at the time of all time champs like Gustav Thoeni and Ingemar Stenmark. A slalom takes optimal 3d, even as most of the normal cues are lost in a ski slope.
Ciao

Stefano Baldassi, PhD
Executive Chair of ECVP 2007 Arezzo
c/o University of Florence, Department of Psychology

Date: Wed, 30 Aug 2006 05:38:53 -0400
From: Ken Nakayama
To: cvnet
Subject: CVNet - CVNet Breaking camouflage, border ownership, amodal completion
---

Breaking camouflage, defining border ownership, and mediating amodal completion.

I agree with Jack Pettigrew regarding the important role for stereopsis for vision more generally. In late 80s Shimojo and I provided new demonstrations on the role for stereopsic vision (faces are seen better

in back than in front). Thus in addition to breaking camouflage we offered yet another key role for stereopsis, not directly related to the perception of depth, its role in determining border ownership and as a consequence, amodal completion. Von der Heydt's recent work on the relation of border ownership and stereopsis supports this.

Below is an excerpt from our discussion:

"3.5 An alternative role for stereoscopic vision It is generally accepted that stereopsis plays are role in the metrical coding of distances in the third dimension. Our results suggest, however, that this presumed role for stereopsis may be overemphasized. We would like to suggest that there are other more biologically fundamental and phylogenetically ancient roles for stereopisis satisfying the need to detect and recognize patterns. Pettigrew (1986) has suggested that one of the major functions of stereopsis is to break camouflage, especially as it seems to be present only in predatory birds which attach prey against the ground. Stereoscopic vision, for example, does not to be present in predators which attack prey which are flying above. Pettigrew argues that such targets would be clearly seen against the sky and would not require anticamouflage procedures for detection.

The present study suggest yet another role for stereopsis, that of delineating and linking parts of an object which are partially hidden. It is of interest that such a mechanism would only require the most primitive form of stereopsis, one that codes the sign of relative disparity and not its magnitude."

Pettigrew, J.D. (1986) The evolution of binocular vision. In Visual Neuroscience, Eds J.D. Pettigrew, K.J. Sanderson, W. R. Levick (Cambridge University Press) pp 208-222

From Nakayama, Shimojo and Silverman " Stereoscopic Depth: Its relation to image segmentation, grouping and the recognition of occluded objects" (Perception, 1989)

Date: Wed, 30 Aug 2006 06:47:04 -0700 (PDT)
From: Milan Jovovic
To: Jack Pettigrew, cvnet
Subject: Re: CVNet - Julesz, Walls and Polyak

Dear prof. Pettigrew,

I have read your discussion on what seems to be an interesting thread of messages on stereoscopic processing, which I haven't been able to follow fully, though. As a former student of Julesz I have thought to add few lines to this discussion, although now more from the mathematical perspective.

The motive comes from my discussion with prof. Julesz, 15 or so years ago. As a devoted scientist he was very interested in an acceptance of his 'texton' theory. I came to the field of visual psychophysics from the engineering background, as prof. Julesz himself. He tried to convey to me the idea of articulating my work more in a 'language' of mathematics.

I have learned a lot from the prof. Julesz and prof. Van Essen approaches to visual psychophysics and neurophysiology, but have come from there to my own perception of 'scale-space' computation. In some sense my present situation resembles that of prof. Julesz from our early discussions, although from a different endpoint of a view. I believe that a common computational principle unifies stereo-motion-color processing.

It is with this simple statement that I would like to finish my message, hoping, though, to be able to work in the field of vision, once again.

Sincerely,
Dr. Milan Jovovic

Date: Wed, 30 Aug 2006 09:02:23 -0700 (PDT)
From: Hoover Chan
To: cvnet
Subject: CVNet - suggestion for managing discussion thread

First, thanks all for participating in the fascinating conversations on stereopsis. Having this kind of interaction is a part of what CVNet is all about.

What helps keep the threads of the conversation easier to track is the "Subject" line. Wherever possible, it's good to keep the same "Subject" line so that our e-mail programs can sort by conversation threads.

Hoover Chan
Eastwind Associates

Date: Wed, 30 Aug 2006 16:16:17 -0400
From: "Odom, J"
To: Jack Pettigrew, cvnet
Subject: RE: CVNet - Stereoscopic vision: advantages, consequences

Thank you very much for your clarification. Julesz is very much to be credited with the idea of stereo vision's utility in breaking camouflage. Stereo can also be useful in grouping and border ownership, as well.

Stereo has been suggested to be useful for many purposes not the least of which is depth perception, including breaking camouflage, texture segregation, border ownership, grouping, and improved signal to noise (image enhancement) at low light levels. If stereo is so useful, why is it not more universal? Are there evolutionary pressures other than the need to catch prey which lead to good stereo? (Are there animals that are not predators who have frontally placed eyes and good stereo? Two possibilities which you have mentioned are Flying Foxes and Bush babies. If such animals exist, what is the utility of stereo for these animals? Conversely, (as posed by Regan) are there predators which use vision to identify and locate their prey that do not have large binocular fields and stereopsis?

These "ecological questions" return us to the original thrust of this thread. What is stereo vision good for in humans? How can you measure its advantages and consequences in humans? Reading Jeremy Wilmer's original question and following his link to his website, it appears that he was asking how to assess

the individual differences in stereo vision in a way that would help in a genetic understanding of the underlying cortical mechanisms of visual perception. (Is this a correct read Jeremy?)

For example, when examining color vision there are relatively straight forward tests which one can use to detect the color vision defects. Using those tests proved very helpful classifying people according to their individual differences and subsequently in understanding the genetics of visual mechanisms of photoreception. (I might add that it is not clear how predictive they are for everyday performance.) Are there a similar set of tasks for stereo which one could use 1) to investigate individual differences in stereopsis and 2) come to understand the genetics which underlies those individual differences? Would the clinical and laboratory tests that assess crossed or uncrossed disparity of local and global stereopsis be sufficient or would one need additional tests? Would tests like those used by Green and Odom or Nakayama et al. have some additional utility? Or perhaps tests which attempted to assess the types of disparity neurons detected by Poggio? (Much as with color visi! on, I suspect that these tests might not be strongly predictive of everyday performance. They likely do not relate that closely to making a sandwich, how many traffic accidents one has, or how many falls.)

J. Vernon Odom, Ph.D.
Professor of Ophthalmology and Physiology
West Virginia University Eye Institute
Robert C. Byrd Health Sciences Center
West Virginia University

Date: Thu, 31 Aug 2006 09:08:41 -0700 (PDT)
From: Jeff Mulligan
To: "Odom, J"
Cc: cvnet
Subject: RE: CVNet - Stereoscopic vision: advantages, consequences

On Wed, 30 Aug 2006, Odom, J wrote:

> (Are there animals that are not predators who have frontally placed eyes and good stereo?

Does anyone know anything about the vision of the halibut/flounder? This is a fish which starts life with its eye on opposite sides of its body (like most fish), with presumably little binocular overlap; then, as it prepares for a life spent laying flat on the ocean bottom, one eye migrates to the other side, making it look like one of the characters in the old comic strip "Miss Peach." One might think that on the bottom of the ocean that light would be scarce and binocular convergence would be important for noise reduction as previously mentioned... This might seem to require an especially plastic visual system, although I suppose a similar problem is faced by humans and other animals which must adjust to an increasing interpupillary distance during development.

-jeff

Date: Thu, 31 Aug 2006 09:56:46 -0400
From: Bart Farell
To: CVNet
Subject: CVNet - CVNet- Stereoscopic vision: advantages, consequences
---

To CVNet-

Another perspective on the advantages of stereo vision comes from looking at the alternatives. On the surface, binocularity without stereo is simpler computationally (no disparity analysis), but then what do you do with the disparities that are present? Local suppression of one eye's disparate image has obvious drawbacks. Almost all scenes have disparities, so relying on the dominant eye in response to disparate images would jettison the advantages of having two eyes. The alternatives are diplopia and fusion. Diplopia has clear disadvantages, and though it's common in our visual fields, it's usually outside our attentional field and in most cases can be locally corrected with an eye movement. Fusion without stereo is sensible by comparison, but how it's done is all important. Ideally, you'd want to fuse disparate positional information without sacrificing precise lateral position information and somehow combine disparities of luminance, frequency, orientation, etc., so that information loss is minimized and the result can be fit into the depth structure given by non-stereo cues. You might as well go the full stereo route. And then there's the question of what to do with non-corresponding features, which our stereo systems handle so deftly, as in the da Vinci case. So, aside from its many positive advantages, stereo is an elegant solution to problems raised by not having it.

And then there's the situation of two-eyed vision without binocularity. What I've read says that the only mammals without some overlap of their visual fields are marine mammals. Of course, some of them are lucky enough to have sonar as compensation. And some are filter-feeders and deep-water feeders, and they don't need vision to eat. Besides, marine mammals are elongated and their flanks are what's most exposed to conspecifics and predators, so having eyes that monitor the lateral fields is a good thing. And for open-ocean creatures, the visual environment is sparse, mostly what we'd think of as background, so the lack of connectivity between the visual fields wouldn't have the same impact as on land. On land, where visual clutter dominates, you have to wonder about the implications of a strictly lateral visual design and dichoptic input for general visual and cognitive strategies. Would such animals have a unified attentional field? Would they experience rivalry (either visually or attentionally)? Or would they blithely watch as two very different, disconnected and even independent scenes unfold before their eyes and take them both in without interference? It would be a different visual world from the one we experience.

By the way, a friend of mine, Miriem el-Hassni, has worked with chameleons, especially on their visual neuroanatomy, and says that they don't have stereo vision but are very good range finders.

Bart

****

Bart Farell, Ph.D.
Research Professor
Institute for Sensory Research
Department of Biomedical & Chemical Engineering
Syracuse University
****

Date: Thu, 31 Aug 2006 23:03:45 +0200
From: Alexander Heimel
To: cvnet
Subject: Re: CVNet - Stereoscopic vision: advantages, consequences

In answer to David Regan's question, I was wondering if the crocodile isn't a good example of a night predator with little binocular overlap. I don't know my alligators from my caymans, so I could be completely wrong, but a quick search with google images for crocodile eyes only gave me pictures with very little overlap, e.g. http://static.flickr.com/25/52743394_1d6440802b.jpg.

Some more web searching showed a site which credited alligator with good stereovision, but there were no references listed on the topic. A paper by Derobert et al., Anat Embryol 1999 showed that there are no detectable ipsilateral retinal projections to the optic tectum or the thalamus and hardly any to other primary visual areas. To me this would indicate little binocular overlap. This may, however, just show my mammalian bias.

Following up on Bart Farell's suggestions that, to me, seemed to suggest that stereovision is partly just a consequence of binocular vision: could it be that some of the evolutionary pressure for having two frontal eyes is to survive if an animal would lose one? After reading all the examples of famous eyed men, it seems to happen quite often and these people survive pretty well with just one eye. Would they or predators have done as well if what remained was only more lateral vision? Or is the group of animals who lose an eye far too small to have any selective effect?

Regards,
Alexander

J. Alexander Heimel, PhD
Netherlands Institute for Neurosciences

Date: Fri, 1 Sep 2006 12:00:45
From: Jeremy B. Wilmer
To: cvnet
Subject: Stereo Consequences: Thank you & Synthesis

Hello All

Little did I know that such a fascinating and sustained discussion would ensue from my question posted 17 days ago: "What are the consequences of good and bad stereopsis?" Thank you all for generously sharing your knowledge!

As of this moment, I have received 77 on-list and 50 off-list postings (wow)! The best way I can think of to show my appreciation is to offer something of a synthesis of this fascinating and mammoth thread. I have attempted to do so in the following ways:

1) General hypotheses - list of several overarching hypotheses arising from the discussion.
2) Specific hypotheses - list of all specific skills hypothesized on-list or off to depend on, or not to depend on, stereoscopic ability, grouped by source ('systematic study' or 'personal experience').
3) Questionnaire - an exploratory survey measure designed to probe abilities and experiences that may relate to stereoscopic ability (Interested in collaborating? Drop me an email.)
4) References - list of all references mentioned on-list or off, roughly by topic.
5) Archive - full text of all on-list postings to date.

These can all be downloaded as a single (rather large) pdf from the following link:
www.sas.upenn.edu/~wilmer/CVNet_StereopsisConsequences_Syntheses.pdf

Many thanks again!
Jeremy

p.s. I would welcome feedback on any aspect of the above, and would also welcome interest in potential collaborations (esp. on studies of individual differences to learn about consequences or underlying genetic/behavioral/neural mechanisms of stereopsis).

Read on if you've some stereo-stamina to spare...

p.p.s. Thanks to Vern Odom for asking about my interest in genetics. Indeed, in addition to my interest in everyday consequences of individual differences in stereopsis (thanks to all again for your input on this!), we are embarking on a study of genes and environment in the development of stereopsis. Genetics can, of course, only ethically be studied in humans by looking at individual differences

produced by 'nature's experiments,' correlating these individual differences with genetic differences. We have so far collected MIT (van Ee & Richards, 2002) and TNO stereotest measurements on 110 pairs of twins, and hope to get at least an initial sense from this data of the heritability of transient and sustained stereoacuity. I excerpt Vern's email here because I think it expresses well some rewards and challenges of studying individual differences in vision...

> These "ecological questions" return us to the original thrust of this thread.
> What is stereo vision good for in humans? How can you measure its advantages
> and consequences in humans? Reading Jeremy Wilmer's original question and
> following his link to his website, it appears that he was asking how to assess
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> For example, when examining color vision there are relatively straight forward
> tests which one can use to detect the color vision defects. Using those tests
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> and subsequently in understanding the genetics of visual mechanisms of
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> on, I suspect that these tests might not be strongly predictive of everyday
> performance. They likely do not relate that closely to making a sandwich, how
> many traffic accidents one has, or how many falls.)

_____
Jeremy Wilmer, PhD
Kirschstein-NRSA Postdoctoral Fellow
Department of Psychology
University of Pennsylvania

From: Mikki McComb
Subject: CVNet - binocular depth perception
Date: September 1, 2006 8:36:43 AM EDT
To: cvnet, saidel, dregan, kajiura

Dear David Regan and group, I am responding to David's earlier inquiry about depth perception and shark predation. David had written a question, essentially, about whether or not there was a shark that utilized vision only to detect prey (reinforcing the idea that the major evolutionary advantage of stereoscopic depth perception is breaking prey camouflage). My response is that a predation event with these animals is a summary of responses that have channeled through all sensory systems. Sharks have the ability to detect weak electric fields, have a well developed lateral line system to

detect movement, can smell very well and can see -although it is probable that some hammerhead species do not possess binocular overlaps. There are 8 species of hammerhead all with differing degrees of cephalic expansion and we intend to determine the blind spot area and if there is binocular convergence. Hammerheads are fantastic predators and those with large head expansion engage in marvelous acquisitions of squid ! as prey in dark waters. Squid are difficult to capture, especially in the darkness, and therefore visual processing must be rapid. We hope to soon answer the question of whether hammers have binocular vision. Mikki McComb (On behalf of Steve Kajuira)

Mikki McComb
Department of Biological Sciences
Florida Atlantic University

From: Dario Ringach
Subject: RE: CVNet - Stereoscopic vision: advantages, consequences
Date: August 31, 2006 11:56:10 PM EDT
To: CVnet, Jeff Mulligan, Vern Odom

}}Does anyone know anything about the vision of the halibut/flounder?

I am not sure about the flounder.... But I can't resist to point out that some stomatopods (for example, the mantis shrimp) have trinocular vision in each of its eyes (Exner, 1891). This compound eye is divided into three parts, the midband and the dorsal and ventral parts. However, the ommatidia in these sections can be skewed in such a way that they have overlapping visual fields. This information is integrated so each eye can function as an independent range-finder. And he has two of them! Stomatopods are armed with a raptorial appendage that they use to strike its victims. Obviously, to use this effectively, they must have some way of estimating direction and distance of the prey accurately.

S. Exner (1891) Die Physiologie der Facettirten Augen von Krebsen und Insecten, Leiptzig, Vienna: Deuticke.

--
Dario

Dario Ringach, Associate Professor
Dept of Neurobiology and Psychology
Jules Stein Eye Institute fax : (310) 206-5895
Brain Research Institute
University of California, Los Angeles

From: Qasim Zaidi
Subject: Re: CVNet - binocular depth perception

Date: September 1, 2006 2:33:28 PM EDT
To: CVnet

Stereo is the part of vision that I understand the least, but I have followed this interesting post on a slow wireless connection in St. Petersburg, and there are two points that I would like to submit.

1. For years I have been disabusing students of the notion that stereo only works for close distances, by having them look at the trees across Bryant Park from my office window. The monocular percept is vividly different from the binocular at a distance of over 100 meters. This demo works particularly well in Spring when the leaves are not as thick as in Summer. It is easy after the demo to show how this is explained from geometrical calculations.

2. It is tempting to think that pattern recognition processes will obviate the need for solving the correspondence problem (Shadlen?), but this is not going to be simple. Many years ago I made informal measurements for the threshold aspect ratio needed to tell a square from a rectangular outline, for a monitor centered at the eyes and fronto-parallel, centered but slanted, fronto-parallel but to one side of the direction the face was pointing, and slanted and to one side of the direction the face was pointing. I remember thresholds being very low in all conditions. Because of perspective, squares form different trapezoids on the two retinae in these different conditions, so disambiguating all these pairs into the image of a single planar square does not seem easy to me. If somebody has a process model that solves this problem, I would like to hear about it.

Qasim Zaidi

Professor of Vision Sciences
SUNY College of Optometry

From: Zanker J
Subject: RE: CVNet - Stereoscopic vision: advantages, consequences
Date: September 1, 2006 6:37:55 PM EDT
To: CVnet, Dario Ringach, Michael Land

Dario,

multiple eyes with a variety of functional specialisations are actually quite common in a wide range of arthropods (e.g. jumping spiders, Bibionids, etc.), and you can discover a plethora of designs in Mike Land's wonderful book on the evolution of eyes. The latest craze, in another animal group, is Dan-Eric Nilsson's observation of multiple eyes in each of the four sensory organs of the jellyfish (Nature 435, 201-205). Such findings, however, do not mean that that the information from multiple eyes is combined in a stereoscopic mechanism.

Best wishes,
Johannes

Johannes M. Zanker
Department of Psychology
Royal Holloway University of London

From: Dario Ringach
Subject: RE: CVNet - Stereoscopic vision: advantages, consequences
Date: September 2, 2006 12:15:52 AM EDT
To: CVnet, Michael Land

I understand... But in the case of the mantis shrimp these are ommatidia within the *same* eye, so it is like having 3 cameras in a rigid configuration moving together (which makes the integration of information a much simpler problem). I am not sure anyone has any actual electrophysiology to show that single neurons are responsive to depth (does anyone know?). But given that direction and range are critical for these guys survival, I would bet that this must be the case.

--
Dario

From: Walter Makous
Subject: CVNet - Stereopsis etc.
Date: September 3, 2006 9:55:21 AM EDT
To: cvnet

For those who missed the article in today's New York Times ("Snakes on the Brain, p. WK10), Lynne A. Isbell promotes the idea that "snakes, as predators,may have figured promiinently in the evolution of primate vision - the ability...to see the world in crisp, three-dimensional living color." The topic of "distinguishing nearby objects from their backgrounds and...finding camouflaged objects" is touched on.

Walt Makous
--
Walter Makous
Center for Visual Science
University of Rochester

From: Lothar Spillman
Subject: CVNet - Stereoscopic vision
Date: September 4, 2006 2:26:51 PM EDT
To: CVnet

Dear Colleagues:

Last, but not least -

Carl Pulfrich after whom the Pulfrich Effect is named was essentially one-eyed. He had been blind since the age of 16 years when he suffered traumatic injury to his left eye resulting in cataract. How then could he have seen the stereo-motion characteristic of his effect? Read below (from the internet):

From: Michael _ Kaplan <mkaplan@xxxxxxxxxxx>
Subject: P3D Pulfrich and one-eyed depth perception
Date: Wed, 31 Dec 1997 19:12:57 -0500 (EST)

“I'm wondering whether Pulfrich had *always* been blind in one eye, or was it a developed condition? Some while back, I posted results of informal experiments I had done viewing lenticular prints with only one eye. By rotating the prints along a vertical axis and delivering L and R images sequentially to only one eye, the brain (at least, *my* brain) could assemble a 3-D image with full depth. Whether this is a learned rather than unconscious operation, I don't know. However, I suspect Pulfrich was fully able to see his "effect," and referred to his assistants only for confirmation of what he was seeing with one eye. And I also suspect viewers could be trained to see horizontal-scan shots 3-dimensionally *without* the Pulfrich glasses. 2 years ago I mentioned *almost* being able to do this while watching IMAX HD (48 fps).”

Was Pulfrich the first to have noticed the effect named after him or was it brought to his attention by someone else? And did he, in fact, never see it? - Read: Christianson, S. and Hofstetter, H.W. "Some Historical Notes on Carl Pulfrich", Am. J. Optom. & Arch. Am. Acad. Optom., vol. 49, pp. 944 - 947, 1972.

Lothar Spillmann
UCDMC
Ophthalmology and Vision Science
Sacramento, CA

From: Benjamin Backus
Subject: Re: CVNet - Binocular Disparity (1: RDS are conflict stimuli)
Date: September 5, 2006 9:36:06 AM EDT
To: CVnet, Michael Shadlen, Steve Buck, Gerald Westheimer

Note also that the Julesz RDS is a cue-conflict stimulus: texture cues strongly indicate the absence of depth edges (Zabulis & Backus, 2004, http://www.opticsinfobase.org/abstract.cfm?URI=josaa-21-11-

2049). So the time it takes to see depth in these stimuli may mean not that stereo is "slow", but rather that the visual system goes with the texture cue (which agrees with a Bayesian prior for flatness) until the stereo depth edge signal has been around for long enough to have established its trustworthiness in the face of conflicting information.

Ben Backus

On 8/21/2006 2:00 AM Michael Shadlen wrote:
I'll add some noise to the cacophony. First, stereo cues are useful at long distances, else no one would buy a ticket to a 3D Imax show (at least not for seats > 20 ft from the screen)...[see Michael Shadlen's full email above]

From: Benjamin Backus
Subject: Re: CVNet - Binocular Disparity (2: Does disparity have a unique effect on qualia?)
Date: September 5, 2006 9:36:17 AM EDT
To: CVnet, Eli Peli, Gerald Westheimer

As Jim Sheedy, Marty Steinbach, and some others are pointing out, there are two separate questions here: (1) does the world supply other reliable cues besides binocular disparity for estimating depth order and segmenting images (in most situations the answer is yes), and (2) does the visual system of a person who *can* use disparity choose to rely upon it (also yes, which means that disparity is probably the best out of several sources of information). To argue that stereo is unimportant because we don't need it is like arguing that sugar is not important for baking because substitute ingredients are also available. For a few recipes (meringues?) you need sugar, but for most recipes you can use the substitutes.

Now here's a third question for all of you, and especially Sue Barry: Do you think that binocular disparity evokes a qualitatively unique dimension of perceptual experience? Or is it simply that binocular disparity is a very reliable cue to depth (especially the estimation of depth intervals)? There are some stimuli (e.g. snowflakes) that look *very* different depending on whether you have stereo vision, but as Chris Tyler has pointed out, other stimuli with rich depth cues don't look much different with and without disparity. I'd put the hypothesis this way: The visual systems of stereoblind people are capable of representing depth intervals as perceptual attributes or appearances, just like normals. It's just that with certain stimuli, such as snowflakes, a stereoblind person has no sense data from which to estimate the depth intervals, so she/he doesn't construct that perceptual attribute for this stimulus. Thoughts?

Ben

On 8/20/2006 2:56 PM Eli Peli wrote:
Hi Gerry,

I have very poor stereo acuity. Yet, I had never had difficulty making a sandwich or any other food (as my body mass will attest)...[see Eli Peli's full email above]

From: Benjamin Backus
Subject: Re: CVNet - stereopsis (3: Is it important to explain qualia?)
Date: September 5, 2006 9:36:44 AM EDT

To: CVnet, Sue Barry

Dear Sue,

I read the account of your story in the New Yorker with very great interest. But in my experience, many students of visual perception are not sure whether they should be interested in qualia per se. I think this may be part of J.J. Gibson's legacy--he emphasized the effect visual information on behavior, at times claiming to be uninterested in how things look. And in fact, some visually guided behaviors are not mediated by appearance, and in some laboratory settings internal factors cause appearance to vary from trial to trial in the absence of any variation in the stimulus so that differences in appearance are not always reliable indicators of changes in the world. This has made people skeptical of the enterprise of trying to explain appearance: there is some cause for uncertainty as to whether appearance matters for visual function. In addition, objective measurements of change in appearance can be difficult to make (though not impossible--see Haijiang et al 2006, http://www.pnas.org/cgi/content/abstract/103/2/483).

Some scientists (e.g. Proffitt, Barlow, and Bayesians such as myself) agree that it's truly important to study appearance. This still is not because qualia are inherently important to explain, but rather because we believe that appearance constitutes a mental representation that mediates (is essential to) many types of learning and behavior. At the recent ECVP meeting in St. Petersburg, Richard Murray proposed that I write a paper with the title "Behavior is sometimes mediated by the way things look". For now this is working proposition! Accepting this proposition whole-heartedly is part of what I would call a "New Constructivism". The zeitgeist has already started to change, and I think this proposition may be completely accepted 10 years from now. I'd be interested to hear other peoples' views about this--peoples' views, as I have encountered them so far, have been remarkably heterogeneous.

Theorizing about visual function can and should sometimes be done without reference to theories about how the brain constructs appearances. This approach has led to many notable successes. In general, explaining the results of a discrimination experiment typically does not require any discussion of appearance (although interesting discussions do exist--see for example Rubin, Nakayama & Shapley, 1997, Abrupt learning and retinal size specificity in illusory-contour perception. Curr Biol, 7, 461-467).

So I'm with you in thinking that if a visually measured signal (such as binocular disparity) has a dramatic effect on qualia, then the signal is probably important to the visual system and to normal visual function. But this is not a logical necessity, unless you believe, as Helmholtz and Brunswik did, that the visual system constructs appearances (the perceptual representations of which we can become conscious) for a reason, and that it does so in something like a near-optimal fashion.

Cheers,
Ben

On 8/21/2006 6:59 PM Sue Barry wrote:

Dear CVNet,

I have read with interest your discussion of the value of stereovision in normal life and have much to add...[see Susan Barry's full email above]

From: Peter Carras
Subject: CVNet - Binocular depth perception; insects
Date: September 5, 2006 12:08:40 PM EDT
To: CVnet

To the CVNet community:

The following information about insect vision was provided by Cole Gilbert, and insect neurobiologist at Cornell University (not a member of CVNet), in reply to the question about disparity-sensitive neurons raised by Vernon Odom.

Mantids are the best bet for stereo binocularity in insects and Sam Rossel (University of Freiburg) is the fellow who has done the most research on them in this regard. He started with experiments of fitting converging and diverging prisms on them and measuring the predicted associated errors in striking distance. He has also addressed the correspondence problem, as your discussion notes. To date, unfortunately, there have been very few recordings made from mantis optic lobe. To my knowledge there is one unpublished German Ph.D. thesis by Florian Berger and one paper by Gonka et al. 1999 (Fred Prete's lab). Neither work explicitly addressed neurons sensitive to disparity. Florian was just doing a stick-and-stain survey to find any cells in the optic lobe that were stimulated by moving stimuli. Some of the filled cells innervate both optic lobes, others project to central brain areas that also receive input from the contralateral eye. Nevertheless, he used primarily monocular stimuli: spot, bar, grating at different speeds after locating the cell's receptive field. The Gonka study was of visually sensitive descending neurons that take information to the thorax putatively for release of the strike. Presumably binocular assessment has already happened upstream of these neurons, nevertheless such stimuli were not tested.

There may also be another interesting example with the larva of the tiger beetle that is a visual ambush predator, as is the mantis. Yoshihiro Toh's lab in Kyushu has demonstrated that the creature leaps out of its burrow if moving prey is less than 15 mm away, which it assesses binocularly, but withdraws if the moving object is farther than that. He has also published some recordings and fills of optic lobe cells that respond to moving stimuli, but none were tested for binocular disparity.

Thus, there is good behavioral evidence that some insects, even with their small interocular distance. use binocular disparity to gauge nearby distances. They either use stereopsis, as the examples cited above, or motion parallax (Eric Sobel's exquisite work on distance estimation in the jump of a non-predatory insect, the locust). To date, however, no one has seriously begun to probe the neural mechanisms supporting the behaviors.

...

Cheers,
Cole

---Vern Odom wrote...---
Another possibility might be the mantids
(Samuel Rossel. Binocular vision in insects: How mantids solve
the correspondence problem. PNAS 1996, 93, 13229-13232). Mantids
clearly use binocular cues to judge prey distance, it is not
clear that those are stereo cues in the same way that we use the
term in humans. However, I will defer to more knowledgeable folks
on both of these possible examples. Is there evidence that the

Gecko or the mantids have disparity sensitive neurons?

Vernon

J. Vernon Odom, Ph.D.

--
Peter L. Carras, Ph.D.
Department of Neurobiology
University of Pittsburgh

From: Thomy Nilsson
Subject: CVNet - stero blind spot?
Date: September 15, 2006 1:50:58 PM EDT
To: cvnet

Is there a stereo blind spot?

A cyclopean view of an object in mid distance places it in front of, and thus obscures, a portion of the background. Nevertheless the visual system has complete information from each eye about what lies behind this object. Can the brain use information from this obscured background location or does it get lost in the assembly of a stereoscopic image?

Lacking stereo vision my self, I get nowhere trying to see what might happen. When I try it, my visual system simply shifts the border between left eye and right eye fields to “look around” the midfield object. Perhaps there is some advantage in lacking stereo vision.

How a unified visual field is achieved from the two disparate sets of information is to me a greater mystery than that additional bit of depth sensation produced by stereopsis. Persons with non-stereo binocular vision may be in the best position to study this question. However, so far I have not come up with any interesting experiments to pursue this question. Any suggestions? .

Thomy Nilsson, PhD
Professor of Psychology, Director of PEI Centre on Health & Aging
University of Prince Edward Island

From: Adam Reeves
Subject: CVNet - Spatial Vision Special Issue on Stereopsis: Announcement
Date: September 13, 2006 11:15:29 AM EDT
To: CVnet

Contributions are invited for a special issue of Spatial Vision entitled "Unresolved Questions in Stereopsis Papers should be received in electronic format by the Action Editor (Regan) by March 31, 2007, with the expectation that publication will follow in Jan-Feb 2008. Contributors are asked to provide the names of up to 5 potential referees (with e-mail addresses). We plan to motivate discussion by distributing all reviewed manuscripts among all contributors for comments before returning the accepted manuscripts to authors for update. Contributions may range in length from a short note to a full article.

The stimulus for this special issue was the recent CVnet exchange on stereopsis. In the spirit of that exchange the aim is not to present new data (though that is not excluded) but rather to evaluate known data in an attempt to identify issues that are not yet understood, or are currently misunderstood or glossed over.

Contributers are invited to identify and address such issues as, for example, the following:
(1) What are the drawbacks of current models of stereopsis ? For example, there is psychophysical evidence that neurons which merely sum the signals from left and right eyes can detect the location, size and shape of a "hidden" figure in a random dot stereogram, especially for simple cases such as a disparity - defined rectangle. If such neurons communicate with disparity - tuned neurons they could, in principle, simplify the correspondence problem. How can this possibility be incorporated into models of stereopsis in random dot stereograms, and what implications are there for the sequence with which form and disparity are processed ?
(2) To have forward - facing eyes rather than eyes on the sides of the head throws away the advantage of a near - panoramic view and renders the animal vulnerable to attack from the rear. What are the compensating evolutionary advantages of forward - facing eyes as evidenced, for example, by predators who prey on animals that can match the luminance, colour and texture of their chosen surroundings, animals that profit from the improved signal - to - noise ratio consequent on binocular summation, and animals who utilize binocular vision for rangefinding.
(3) In what ways does our understanding of human stereopsis that is based on laboratory experiments using cyclopean stimuli fail to explain human binocular depth perception in everyday life?
(4) What are the roles of static and dynamic stereopsis in visually - guided motor action in humans and other animals?
(5) What changes in human visual function and performance are caused by the loss of one eye when (a) one eye is absent from birth or very shortly after and (b) loss of one eye at an age when visual function is mature?

Contributions are not limited to the above list of topics; they just serve as illustrative.
Please send enquiries and contributions, in electronic format, to [David Regan's email]

David Regan C.M., Ph.D., D.Sc. F.R.S.C.
Department of Psychology
York University