The effect of interocular delays on the perception of 3D movies

23.410

*Zoltan NADASDY, [1,2] Barna KANTOR [2] • [1]Seton Brain & Spine Institute & UT Austin, TX • [2]University of Texas at Austin TX

Introduction

Motivation

We investigated the effect of interocular delays (IOD) on the quality of 3D percept. With the recent invasion of 3D technology, this question has also become practical. IOD also play a role in several eye diseases, causing perceptual distortions such as the Pulfrich effect.

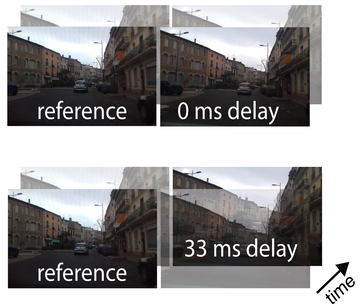
Background

While disparity-sensitive neurons in V1 accomplish stereo fusion between binocular signals within a 20 ms time window, psychophysical studies demonstrated a 30-100 ms delay tolerance. Here we asked human observers to rate the quality of 3D percept after watching stereoscopic movies under various binocular delay and speed conditions. The delays were varied between 0 and 2 s in 33 ms increments, and the movies were rendered at eight different speeds, presented in random order. We found that for natural scenes the visual system is able to fuse frames across 500 ms (maximum 2 s), a much longer delay than reported earlier. We computed the image correlation between successive frames and constructed a model for the progressive decline of the 3D percept with increasing delays. We compared the predicted decline function with the observed data but the linear model does not completely account for the observed function. In order to explain the sustained 3D experience despite long delays we considered a number of factors, such as top-down effects, anticipation, inhomogeneity of motion vectors in space and time, attention and eye dominance. The flexibility of the visual system in aligning parallel visual streams over 500 ms and the ability of fusing them despite the mismatch between simultaneous frames calls for a revision of the feed-forward models of 3D perception and suggests a higher than V1-level 3D motion processing with larger temporal buffer and a larger perceptual editing capacity yet to be explored.

References

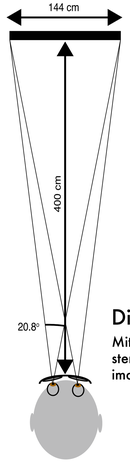
Ludwig I, Pieper W, Lachnit H. 2007. Temporal integration of monocular images separated in time: stereopsis, stereoacuity, and binocular luster. Percept Psychophys 69:92-102
Ogle KN. 1963. Stereoscopic Depth Perception and Exposure Delay between Images to the Two Eyes. J Opt Soc Am 53:1296-304
Perez R, Gonzalez F, Justo MS, Ulibarrena C. 1999. Interocular temporal delay sensitivity in the visual cortex of the awake monkey. Eur J Neurosci 11:2593-5
Read JC, Cumming BG. 2005. Effect of interocular delay on disparity-selective v1 neurons: relationship to stereoacuity and the pulfrich effect. J Neurophysiol 94:1541-53
Zhang ZL, Cantor C, Ghose T, Schor CM. 2004. Temporal aspects of spatial interactions affecting stereo-matching solutions. Vision Res 44:3183-92

The Inter Ocular Delay (IOD) paradigm for movies

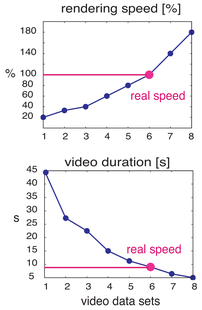


Methods

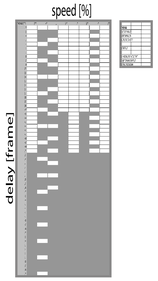
Display



Stimulus set



Test scales



Display

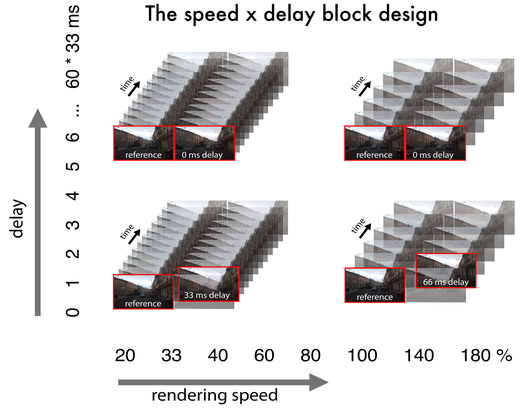
Mitsubishi 82" DLP back-projection display using an active stereo system provided by nVidia that provides clear 3D images.

- Resolution: HD 1920 x 1080p
- Rendering rate:120 Hz (60 Hz left eye, 60 Hz right eye)
- 2 Intel Xeon 5355 quad-core processors (8 cores total)
- 16GB of RAM, 1.5TB local disk
- nVidia Quadro FX4600 Graphics Card, 1.5GB memory
- nVidia 3D Vision Active Stereo System
- Software: editing: Final Cut Pro 7.0.3

Subjects' task:

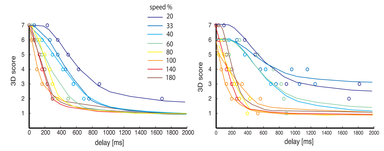
We asked the subjects to rate their experience on the scale of 1 to 7, giving 1 if there was no 3D experience at all and 7 when the 3D experience was perfect. The subjects entered their rating in a computer immediately after viewing a clip. The experiments were done in multiple sessions with breaks. A single experiment took 3 to 3.5 hours to complete.

The speed x delay block design



Results

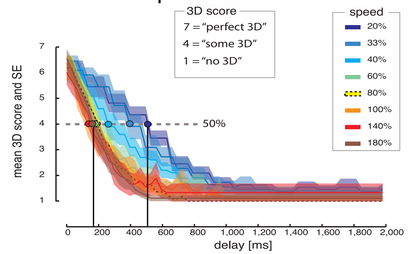
Individual data



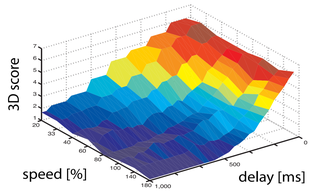
Results from two individual subject. Each point represents a rating at a given binocular delay. Only points where the subject changed the rating relative to the nearest smaller delay are represented. The curves are the sigmoid fittings to the data. Colors represent viewing speeds. Note the monotonic decline of 3D perception with increasing delays and the decreasing slopes with decreasing viewing speeds. A small 3D effect was still detectable at 500 ms delays even at the normal speed. Note that the subject at the right maintained the 3D percept across all delays at 20-33 % speed.

A

Population mean



B



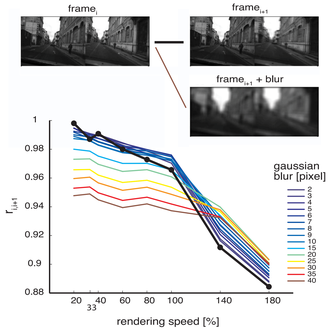
C ANOVA

Source	SS	DF	MS	F	P
delay	7.4586e+03	60	124.3105	155.4368	**0**
speed	502.9035	7	71.8434	89.8323	**9.1030e-122**
interaction	395.1799	420	0.9409	1.1765	**0.0105**
error	3.1222e+03	3904	0.7997		
total	1.1479e+04	4391			

(A) Average of 11 subjects. The curves represent the mean 3D ratings given to different delay and speed combinations. Monotonic declines with increasing delays and increasing slopes with increasing speeds are evident. Bands around the mean are SEM. **(B)** Same as **(A)** in 3D view. **(C)** The two-way ANOVA on the 'delay' and 'speed' conditions revealed a significant interaction.

Model

Correlation between successive frames



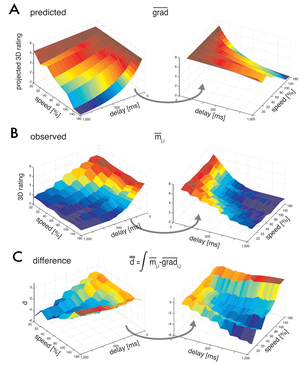
We estimated average displacements between successive frames by computing the pixel-to-pixel correlations between a given frame and the next one (black curve). In addition, we constructed different low-pass filtered versions of the second frame by applying different blurring levels by a 2-D gaussian kernel (color curves). Up to 10 pixel blurring the correlation between the original and successive frames is relatively well reproduced.

Fitting the speed-delay model to the data

(A) We computed a model decline function based on the physical pixel-to-pixel image correlations (predicted). Next we subtracted the model from the actual 'speed x delay' function.

(B) The original 'speed x delay' function.

(C) The difference of the predicted and actual 'speed x delay' functions. As evident from the figure, the subtraction did not nullify all the 3D effects in the corrected data. Thus, 3D effects, beyond those that are accounted to the physical similarity between the images, remains to be explained.



Conclusions:

- The 3D percept is maintained between 0 to 500 ms interocular delays (IOD). Because this IOD far exceeds the integration time window of disparity selective neurons in V1, we propose that an extrastriate visual cortical 3D integration may contribute to the low-level disparity features extracted in the early visual cortex.
- When IODs were varied across different rendering speed conditions a significant speed x delay interaction was observed.
- The model of progressive pixel-pair degradation only accounts partially for the speed x delay interaction.

Correspondence: zoltan@mail.utexas.edu