Why does S3D work?

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Outline

• Stereo 3D content is exceptionally vivid and gives us a unique sense of physical presence.
• But many people don’t like it or even complain of nausea.
• Are these linked?
How S3D works
How S3D works

- It simulates the different viewpoints of the two eyes.
- Depth depends on screen parallax and viewing distance.
Potential problems

- Incorrect geometry can produce depth distortions such as the “cardboard cut-out effect”.
Potential problems

A wide interaxial...

...can produce miniaturisation.

http://www.cancommunicate.com
The bad news

- To correctly reproduce the 3D world, you need to get the geometry right.
- If you get the geometry wrong, you can produce depth distortions such as the cardboard cut-out effect.
- The geometry will always be wrong for 99% of viewers.
One person in a cinema
Let’s depict a cube in S3D
Back-project to screen...
Desired images on screen

- Red: Left eye's image
- Blue: Right eye's image
Now add a second viewer
Intersection of left and right-eye rays
So the same image specifies two different objects:
Geometry is wrong in 2D too

The camera never lies...
But in 2D, our brains correct for this

Image on screen: Circle, viewed obliquely

Image on retina: Elliptical image on retina

Circle

Ellipse, viewed straight on

Ellipse, viewed obliquely

Elliptical image on retina

Avoiding 2D perceptual distortions

• Our brains feature a smart perspective-projection auto-correct plug-in.

• So in 2D, perceived distortions of shape are rare.
But in S3D...

- Not clear that the auto-correct does/can operate.
  - How can you tell where the image plane is?
- And in S3D, perceived distortions of depth occur even if you get the geometry perfect.
Depth distortions in S3D

Task: Make the cross-section appear circular

Depth distortions in S3D

Shapes that appear circular at different distances

Depth distortions in S3D

- The geometry in these experiments was perfect:
  - Orthostereo: the parallax presented was *exactly* that which a physical cylinder would have produced.
  - And yet the cylinders were perceived as distorted.
  - Pattern of errors suggests we may be using the wrong viewing distance.
  - Apparently our brains don’t know where our eyes are pointing!
The bad news

• If you get the geometry wrong, you can produce depth distortions such as the “cardboard cut-out effect”.
• The geometry will always be wrong for 99% of viewers.

The even worse news

• Depth distortions occur even when the geometry is perfect.
Implications for industry

- Predicting perceived depth is tricky.
- Existing tools generally assume the viewer “knows” their own viewing distance.
- This may not be true.
Why do we not notice depth distortions in everyday life?

1. Many real-life tasks don’t actually require us to know distances.

2. *Perceiving* and *doing* use different parts of our brains.

3. In real life, there are several cues at once, including perspective.
If we can’t judge distances, how do we do this?
Fast and frugal gaze heuristics

“Fielders run so that their angle of gaze elevation to the ball increases at a decreasing rate while their horizontal gaze angle to the ball increases at a constant rate”

McLeod, Reed, Dienes (2003). How fielders arrive in time to catch the ball. *Nature* 426: 244
Why do we not notice depth distortions in everyday life?

1. Many real-life tasks don’t actually require us to know distances.
   - Visual heuristics for, e.g., catching a baseball.
2. *Perceiving* and *doing* use different parts of our brains.
3. In real life, there are several cues at once, including perspective, prior assumptions.
Patient DF

- Brain damage due to carbon monoxide poisoning.
- Damaged an area of her visual cortex.
- As a result, cannot perceive objects.
- But is not blind: can use vision to navigate environment, pick up objects, etc.
Which one is the square?

Um... this one?

⇒ She has no conscious awareness of the object’s shape.

Can you pick up the red one?

⇒ She automatically adjusts her fingers to the correct grip for the shape.

Perceiving and doing use different parts of our brains

- So, it is possible that perceptual distortions don’t apply to actions like reaching out and picking something up.

Aglioti, DeSouza & Goodale (1995) *Size-contrast illusions deceive the eye but not the hand.* Current Biology 5, 679-685
Why do we not notice depth distortions in everyday life?

1. Many real-life tasks don’t actually require us to know distances.
   - visual heuristics for, e.g., catching a baseball.

2. Perceiving and doing use different parts of our brains
   - dramatically illustrated by the case of Patient DF

3. In real life, there are several cues at once, including perspective, prior assumptions.
Perceptual prejudices
Perceptual prejudices

We assume rooms must be cuboid, in the face of evidence to the contrary!

Google Sketchup model by Russell Light, http://sketchup.google.com/3dwarehouse/details?mid=fe278bdcc085f57b636332a51c6540e
Perceptual prejudices

S3D parallax, accommodation + knowledge of real human size

Perspective + prejudice that rooms are cuboid
The good news

- This is good news for S3D.
- If you think this is a cube, you’ll see it as a cube, even if the parallax specifies a parallelepiped!
The good news

- This does not mean S3D information is useless or ignored.
- It gives *highly potent and precise* information about *relative depth*:
  - “A is closer than B”
- But it gives *weaker and less trustworthy* information about *absolute depth*:
  - “A is 2 yards away, B is 3 yards away”
Known and unknown in stereo vision

- We know we don’t know where our eyes are pointing, but we know we don’t need to know to figure out relative depth.

- Parallax, relative depth = known known

- Eye position, absolute depth = known unknown

There are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know.
That’s how we get away with it

- S3D geometry is almost always wrong.
- Despite this, it’s possible to present S3D content which does not appear distorted.
- Our visual systems accept the incorrect geometry because they know S3D comes with a lot of uncertainty,
- and they have other cues to help with shape (e.g. perspective, prior expectations).
- But, S3D gives a highly compelling sense of realism.
Open questions

- Why is S3D so vivid?
- Why are we able to correct distortions in 2D?
Why is S3D so vivid?

- Parallax is not a massively reliable depth cue, and yet our brains believe it in a way they don’t believe any pictorial cue.
- Is this because our brains believe S3D cannot be faked?
- And is this because of something intrinsic to S3D, or is it merely because we have not grown up with S3D?
- How do we learn to see 2D content correctly?
Two very different Annunciations

Iconostasis of the Dormition Cathedral, Moscow, 1497

Lauro de Manfredi da Amelia Piermatteo, ca. 1450
When is a cross crooked?
The case of the shrinking sheep
Why do things look small from a plane?
The Lilliput effect
We need to learn to see.
Open questions

- Do we learn to see 2D content correctly?
- Do we need to learn to see S3D content without being thrown by the incorrect geometry?
- **Do we need to learn that S3D can be faked?**
  - e.g. that our interocular distance can effectively change
- And if so, will this make S3D at once less disturbing but less vivid to watch?