Cognitive Neuroscience of Language:

15: Binocularity and real reading

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Goals



Look at some of what goes on in real reading

Reading

Liversedge, S.P., White, S.J., Findlay, J.M. & Rayner, K. (2006). Binocular coordination of eye movements during reading. *Vision Research*, *46*, 2363-2374.

Understanding FD

Begin with the reality of the visual system

Binocularity and depth perception

Fixation disparity is normal



Precise conjoint fixation often does not happen in reading (Liversedge et al., 2006)

Fixation disparity is normal



Precise conjoint fixation often does not happen in reading...

Fixation disparity is normal

... or in close-viewing tasks (see, e.g., Enright, 1998; Cornell et al., 2003)

Background issues: two eyes are better than one; one eye may be better than the other







Fixation and retinal disparities

 Objects beyond the fixation plane give rise to uncrossed retinal disparities

 Objects in front of the fixation plane give rise to crossed retinal disparities

Crossed FDs are adaptive

- Any FD increases the span of the input
- Immediate coordination of hemifoveal contents
- Crossed FDs allow a broader range of information for stereofusion Dengler & Kommerell, 1993



Crossed FDs are adaptive

- Less impaired Richards, 1970
- Developmental priority Birch et al., 1982; Blythe et al., 2006; cf. Zaroff et al., 2003
- More stable over the duration of the fixation, and between fixations
 Liversedge et al., 2006; Jaschinski, 1997
- This is also true in the vertical dimension Breitmeyer et al., 1975
- Less asthenopia

Pickwell, 1989, 1991; Jenkins, Pickwell & Yekta, 1989

Crossed FDs are adaptive

 Also true in perceptual recognition of words briefly presented stereoscopically cf. Dare, Obregón & Shillcock, 2007

 Haptic, kinaesthetic, proprioceptive, intentional support in the zone of crossed FDs

 Crossed FDs may be the default, as found in dark vergence Jaschinski, 1997

The FD data vary





Largely crossed

Largely uncrossed

Why do the FD vary so?

 Eyelink II and DPI eye-trackers can both record crossed and uncrossed disparities accurately.

 A single individual can flip robustly from crossed to uncrossed after dimming the light Shillcock et al., 2007

 Reduced luminance, increased target blur cause a shift to uncrossed FDs Jaschinski-Kruza, 1994; Pickwell, Jenkins & Yekta, 1987

Why do the FD vary so?

- There are substantial individual differences; rejected eye-tracking participants obscure the issue Jaschinski, 1997
- Head restraint is a non-trivial issue, with respect to projecting text to the upper or lower hemifield
- Fundamentally the difference reflects the adaptive ability to zoom in on the text in question

Conclusions

- Fixation disparities in reading are normal
- There are individual differences
- There are crossed and uncrossed disparities
- Crossed disparities are adaptive allowing zooming out on reading
- There are methodological and technological implications for eye-tracking

Two types of retinal disparity



Crossed and uncrossed retinal disparities are computationally different problems, dealt with in different processing domains

Crossed RDs deal with close-up objects

Crossed RDs are more robust, prioritized

Crossed RDs facilitate stereofusion













Words are different

pinnacle

Words are the quintessential visual artifact

Words reinvent the functional architecture of visual cognition and increase the importance of even peripheral aspects of the anatomy of the visual system











Fixation disparity over lines of text





Proportions of crossed and uncrossed fixation disparities vary between studies

A sex difference in FD



Female readers tend to have larger fixation disparities than male readers

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Binocularly unaligned images occur in both reading and depth perception





In reading, some measure of fusion occurs; reading with two eyes is better than with one

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Reading involves mechanisms established in depth perception

Uncrossed fixation disparities \approx crossed retinal disparities ...

... more robust, prioritized, facilitate stereofusion

Fixation and retinal disparities



Rather small text was used

Rather small text was used

Align the two images appropriately



Larger text was used ... in texts in a light room Larger text was used ... in texts in a light room

Do the processing fast and well

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What advantage is there for crossed fixation disparities?

(They are the marked case in development, less robust in processing, more vulnerable to impairment)

Haploscope experiment Obregón & Shillcock (submitted)

+

Right eye

Left eye

+





Haploscope experiment Obregón & Shillcock (submitted)

+

Right eye

Left eye

+







Three fixation "strategies" crossed: intermediate 3 3 3 4 3 3 1 conjoint: intermediate 0 3 3 3 3 3 3 3 3 3 3 3 3 0 uncrossed: .intermediate.

The implications for sex differences, dyslexia and beginning reading

Data from dyslexics

00009200 ms

00009766 ms

If someone told you you'd won a free holiday, you might at least

be tempted to find out how to claim it. But beware. This is

exactly how thousands of unwary tourists at popular resorts

around Europe risk being lured into the murky world of holiday

clubs this summer.

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Any letters in the disparity span are immediately projected to both hemispheres More qualitiative variability in disparity span in

dyslexics, thus far

П

Sex differences

crossed: intermediate. 1 1 3 3 3 4 4 3 3 3 1 1 conjoint: intermediate 0 3 3 3 3 3 3 3 3 3 3 3 3 3 3 0 uncrossed: 2 2 3 3 3 3 2 2 3 3 3 3 2 2 3

Larger fixation disparities in female readers Larger fixation disparities project more letters bilaterally; female cortical processing is more bilateral

Beginning readers

crossed:

intermediate

1 1 3 3 3 3 4 4 3 3 3 3 1 1 conjoint:

intermediate

uncrossed:

intermediate.

More crossed fixation disparities in children (Blythe, 2006)

Crossed FDs produce a more focused perceptual span onto the line of text

Conclusions

Anatomy matters in understanding reading: hemifoveas, contralateral projection, hemispheres, depth-processing domains

Understanding fixation disparities in reading may help us to understand normal, skilled reading, its development, and one aspect of developmental dyslexia



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 $E \cdot S \cdot R \cdot C$ ECONOMIC





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