Motion-in-Depth from Moving Uncorrelated Textures

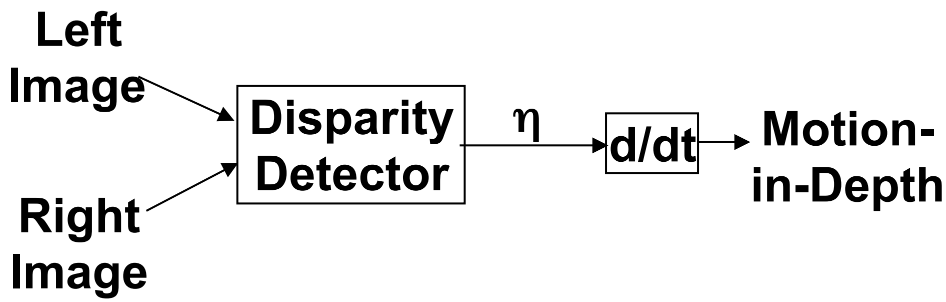
R.S. Allison, I.P. Howard and A. Howard

Centre for Vision Research

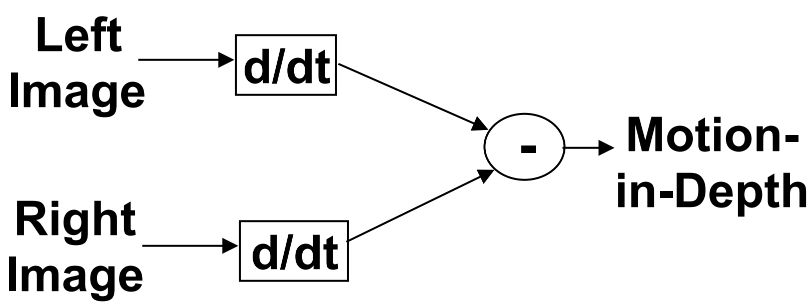
York University, Toronto

Human Performance Lab
CRESTech

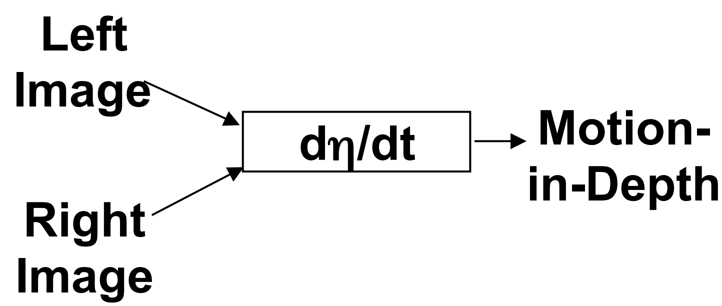
Introduction



'Change-of-disparity'



'Difference-of-velocity'



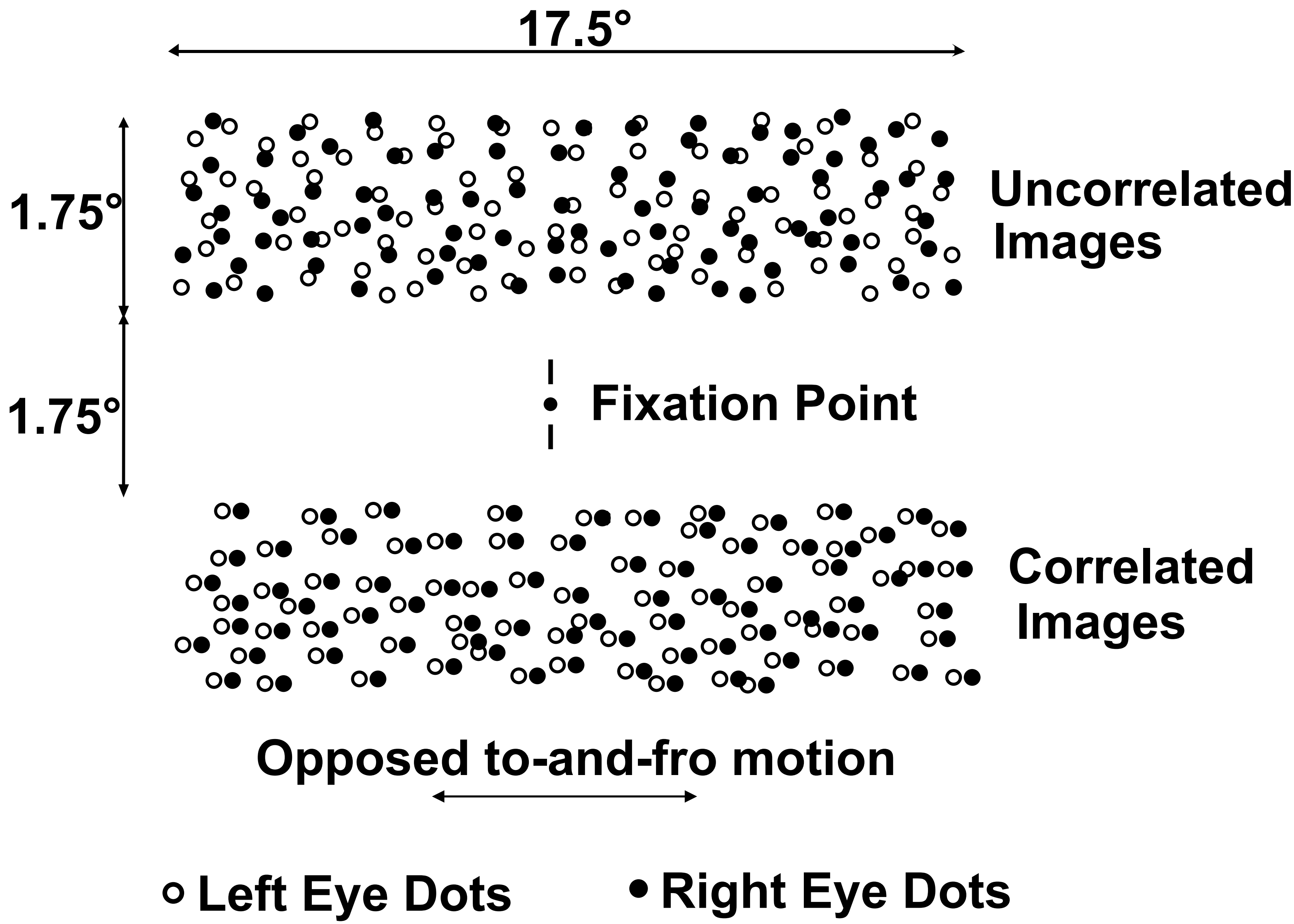
'Dynamic Disparity Detector'

Isolation of ‘change-of-disparity’ signal

- Dynamic random-dot stereogram contains changing disparity but no motion.
- Sensitivity to motion-in-depth is as good as with persisting dots. (Cumming & Parker ‘94)
- Conclusion: motion-in-depth can be created by ‘change of disparity’ alone.

Isolation of ‘difference-of-motion’ signal

- Spatially uncorrelated random-dot images in the two eyes moving in opposite directions.
- Stationary boundaries. No moving deletion-accretion edges.
- Instantaneous mean disparity is zero.
- Coherent change in disparity (dynamic disparity).
- Good motion-in-depth produced by ‘difference-of-motion’ signal (Howard et al, S. Shiori et al ARVO 1998).


17.5°
1.75°
1.75°
Uncorrelated Images
Fixation Point
Correlated Images
Opposed to-and-fro motion
Left Eye Dots
Right Eye Dots

Basic method

- Test display with uncorrelated images.
- Comparison display with correlated images.
- Images in each display moved in opposite directions (triangular wave).
- Subjects adjusted the velocity of the correlated images until the two displays moved in depth at the same velocity.

1. Effect of dot lifetime on motion-in-depth from uncorrelated displays

- Degrading the motion signal should degrade depth in spatially uncorrelated displays.
- Measured the effects of decreasing dot lifetime on perceived depth.

Methods

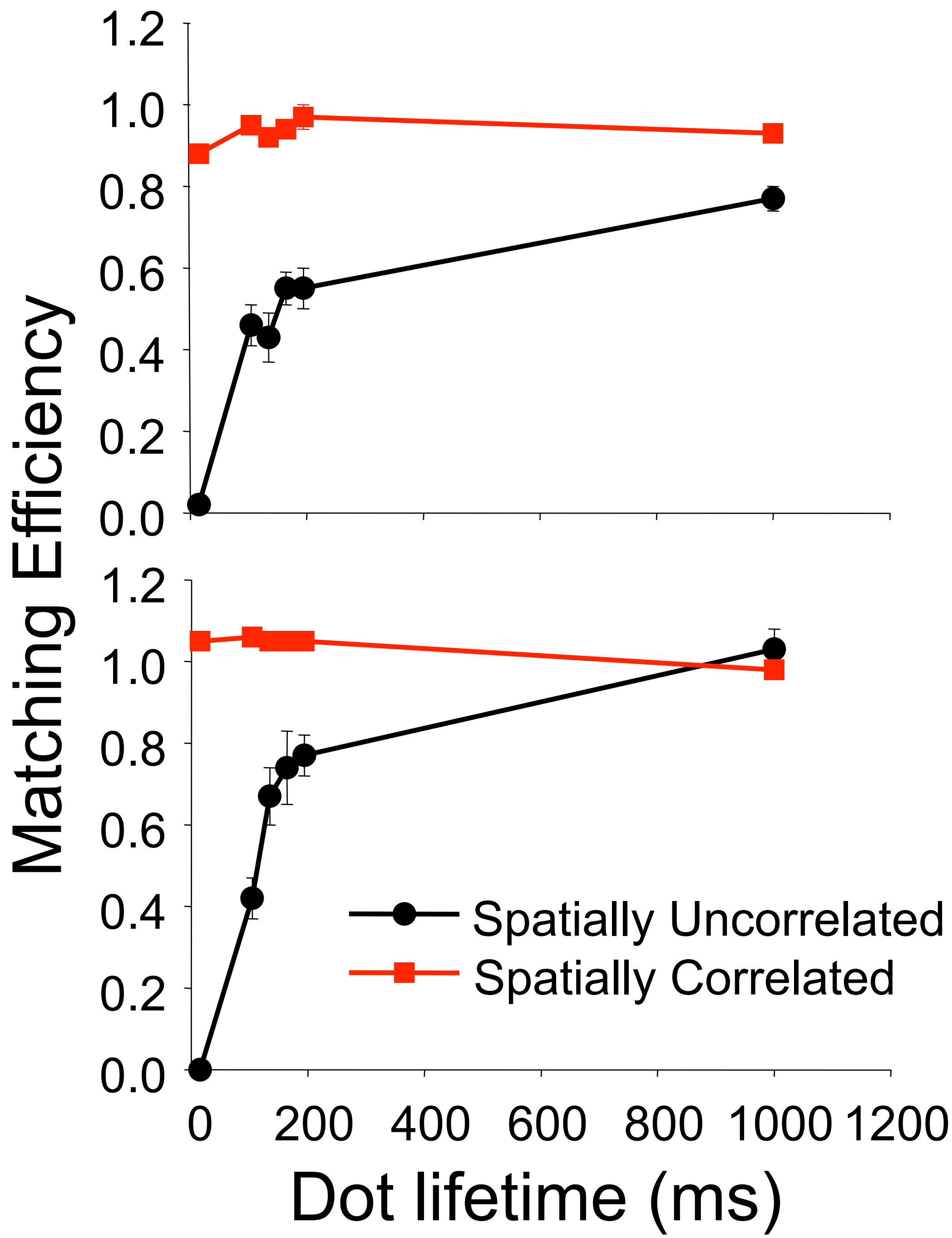
- A portion of the dots disappeared each frame (67 Hz) and were replaced by new dots.
- Spatially correlated and uncorrelated test images.
- Supra-threshold matching:
  - dot lifetime 1,7,9,11,13 or ∞ frames
  - stimulus oscillation: 0.5 Hz, 0.25 or 0.5 deg/s

Methods

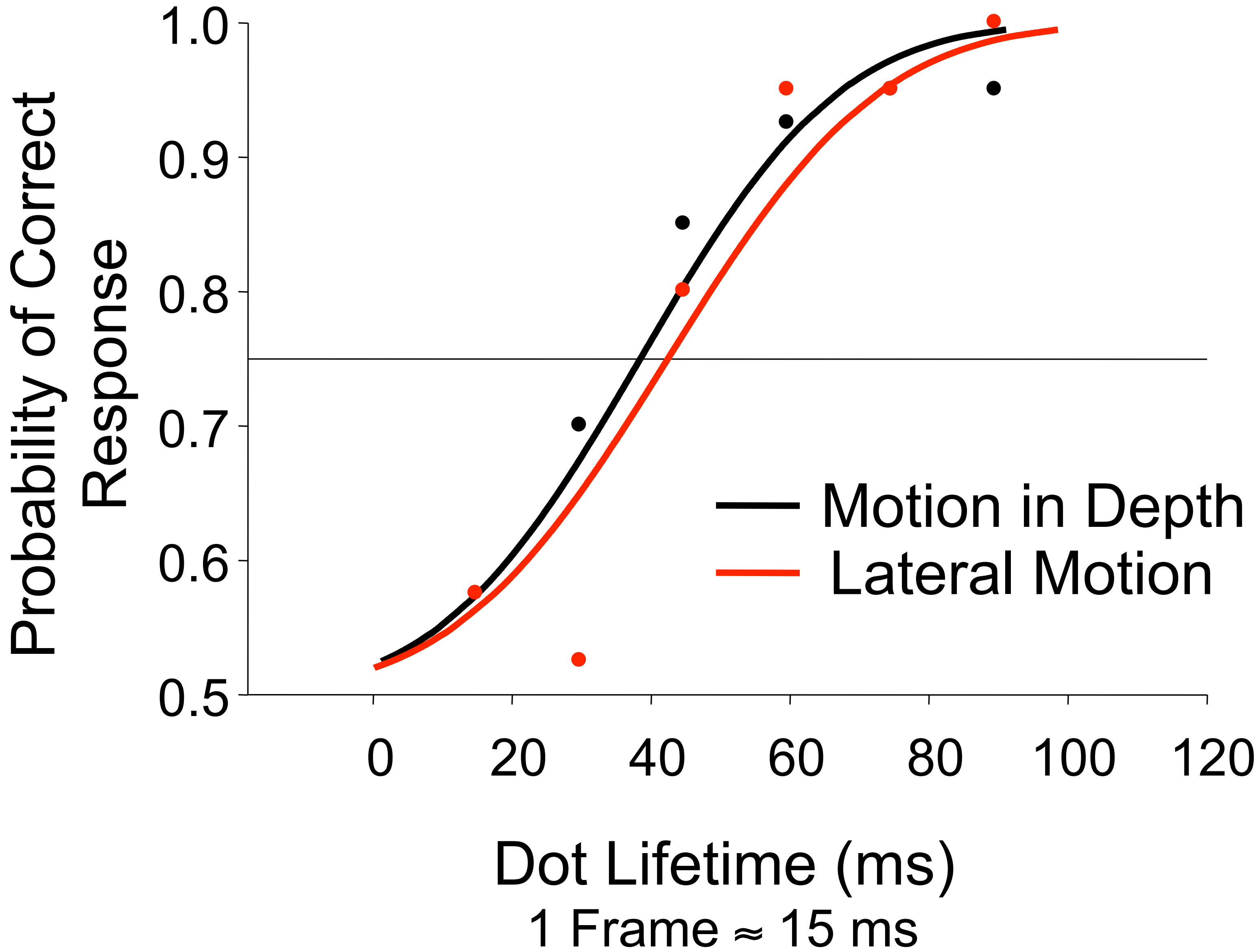
- Motion-in-depth direction discrimination thresholds:
  - Stimulus approached or receded at constant velocity (0.5 deg/s) and disappeared.
  - Forced choice discrimination (recede or approach). Dot lifetime varied by method of constant stimuli.

Results: supra-threshold efficiency

- Single frame lifetime, spatially correlated images created motion-in-depth ('change-of-disparity' signal).
- No apparent motion-in-depth with uncorrelated images (neither a 'change-of-disparity' nor a 'difference-of-motion' signal).
- Apparent depth decreased in uncorrelated images as dot lifetime decreased ('difference-of-motion' signal).



Matching Efficiency
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Spatially Uncorrelated
Spatially Correlated
0
200
400
600
800
1000
1200
Dot lifetime (ms)

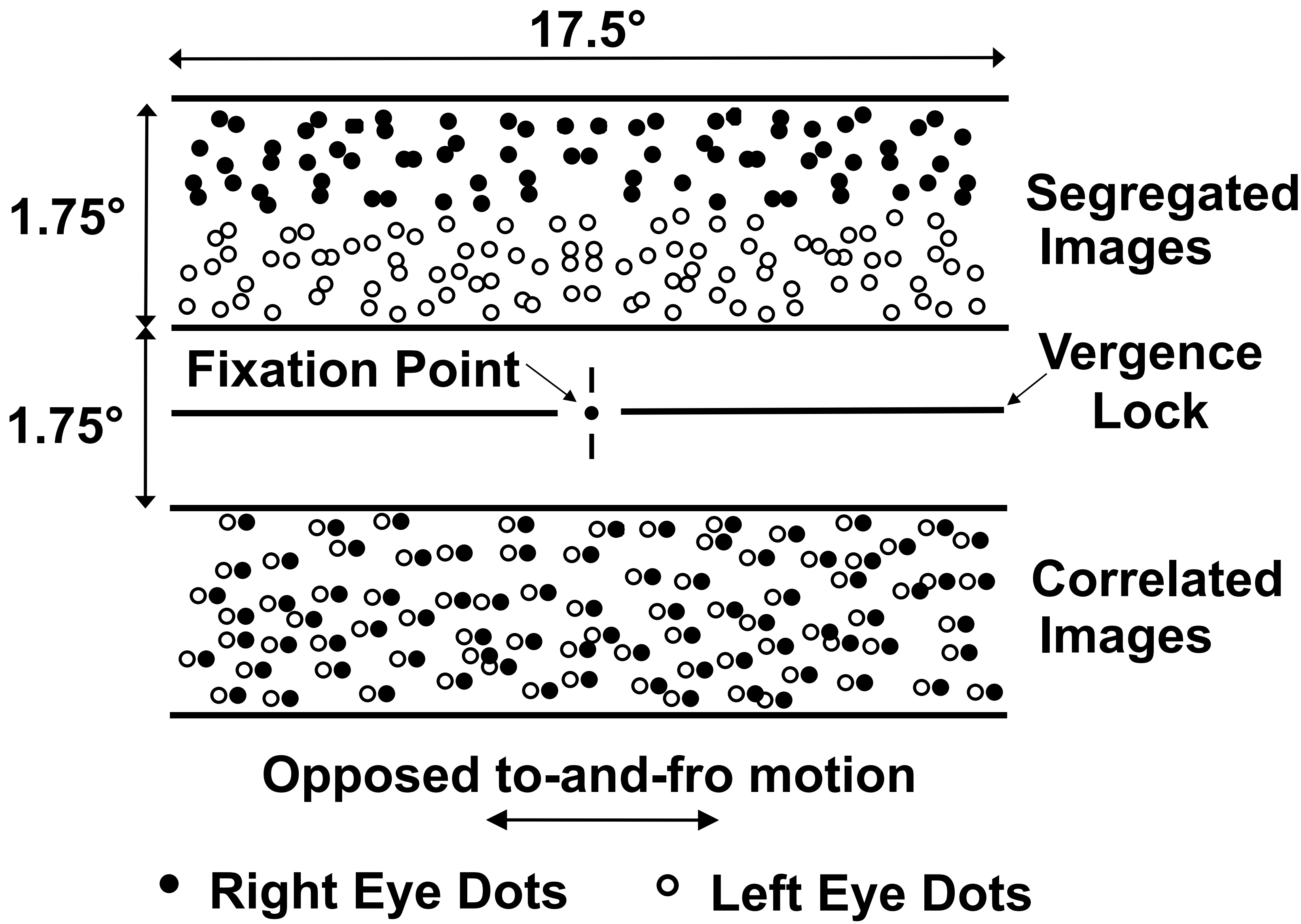

Probability of Correct Response
1.0
0.9
0.8
0.7
0.6
0.5
0
20
40
60
80
100
120
Motion in Depth
Lateral Motion
Dot Lifetime (ms)
1 Frame ≈ 15 ms

Results - dot lifetime thresholds

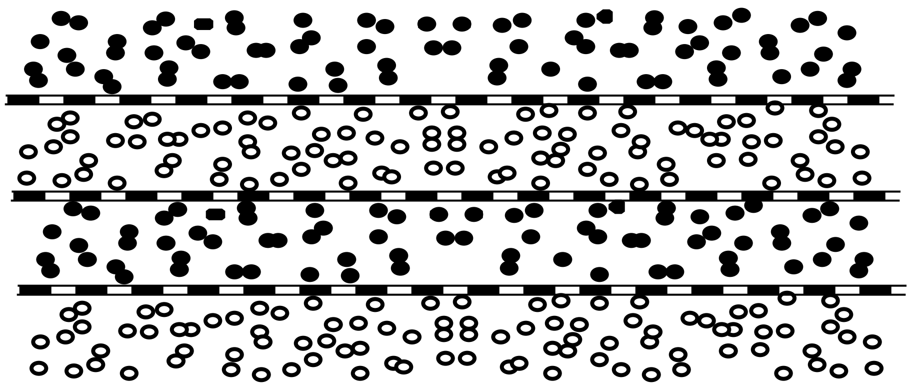
- Spatially correlated images were well above threshold even with single frame lifetime.
- For uncorrelated images discrimination was at chance with a single frame lifetime.
- 75% correct discrimination was achieved by dot lifetimes of 2-5 frames at 67 Hz.
- Lifetime at threshold for motion-in-depth (52.0 ± 5.8 ms) was not significantly different than for lateral motion (41.1 ± 5.1 ms)

2. Effects of Texture Segregation

- S. Shiori et al (ARVO 1998) reported that depth could be obtained with vertically segregated textured displays.
- We had found that depth was not obtained in such displays.
- We investigated under what conditions motion in depth arises from moving vertically segregated displays.


17.5°
1.75°
1.75°
Segregated Images
Fixation Point
Vergence Lock
Correlated Images
Opposed to-and-fro motion
Right Eye Dots
Left Eye Dots

Methods - vertical segregation

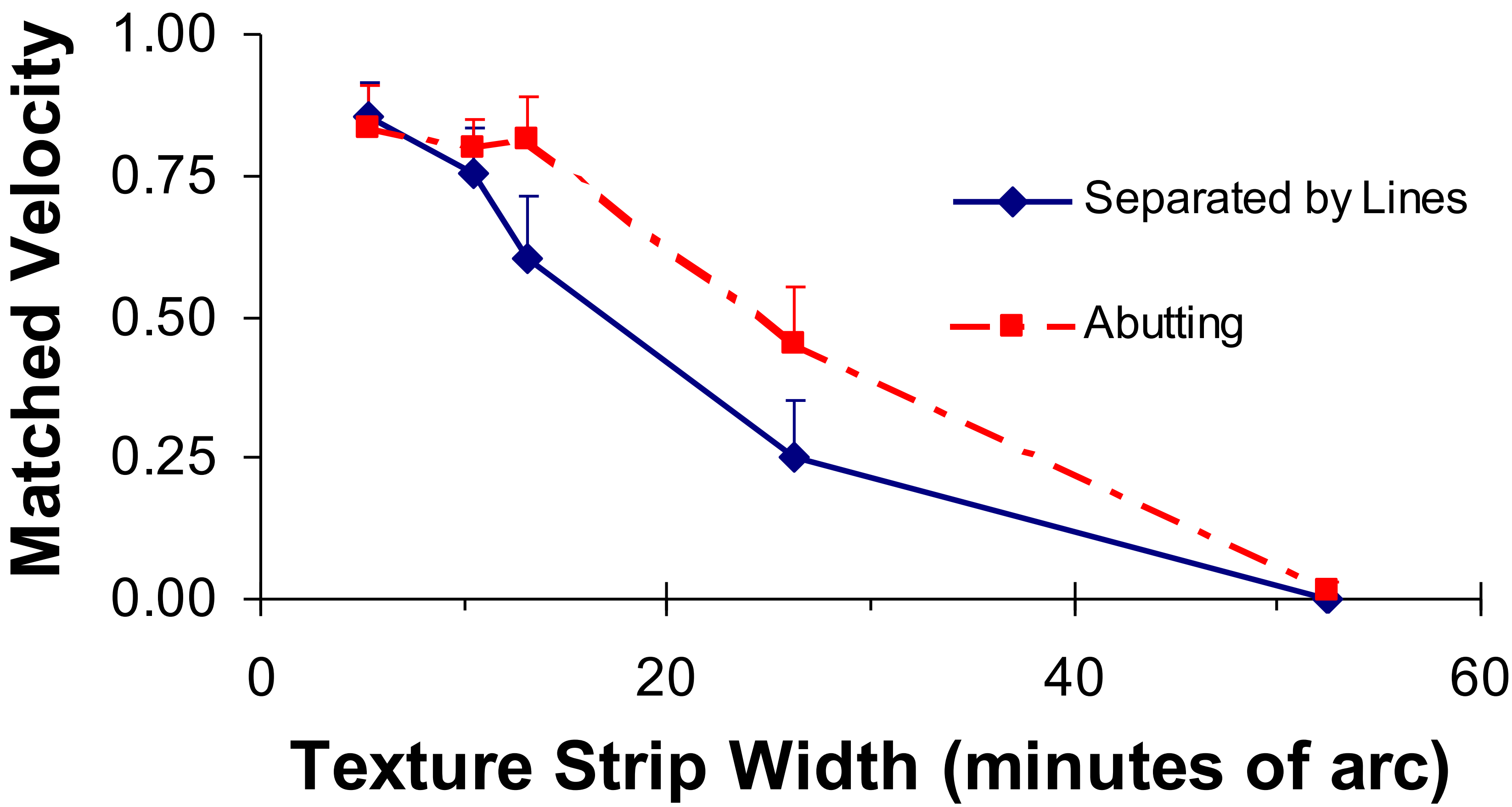


○ Right Eye Dots

● Left Eye Dots

- Strip width 4,8,10, 20 and 40 pixels (2 to 20 strips).
- Alternating strips of left and right eye dots abutting or separated by horizontal line.
- Perceived depth matched with correlated display.

Matched velocity as fraction of test velocity



Results- vertical segregation

- Motion in depth was stronger with narrower bar elements.
- Motion in depth could be due to dynamic disparity in spurious matches along the edges.
- Supported by suggestion that motion in depth was weaker with separation by a horizontal line.

Conclusions

- Motion-in-depth is created by opposed motion of spatially uncorrelated but temporally correlated dichoptic images.
- Motion-in-depth is degraded as the monocular motion signals are degraded
- A dot lifetime of approximately 3-4 frames at 67 Hz is sufficient to evoke motion-in-depth
- Motion in depth from vertically segregated displays may arise from spurious dynamic disparity along the boundaries