Can Linear Light Sources Be of Benefit to Pilots?

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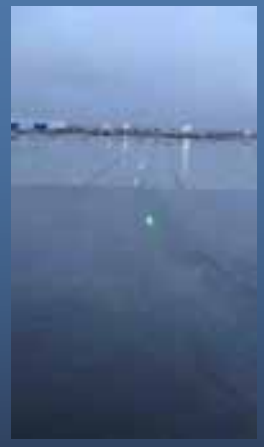
Study Objective

- To identify whether linear configurations of runway/taxiway edge lighting systems offer benefits over conventional practices using discrete “point” sources of light

(Gallagher 2005)

www.luminaerospace.com



www.ledline.net

Representative Delineation Practices

Representative edge and centerline practices for airfield lighting.

Application	Condition	Minimum Spacing (ft)*
Runway Edge Lighting	General	200 ft
Runway Centerline Lighting	General	50 ft
Taxiway Edge Lighting	Short Section	50 ft
	Intermediate Section	100 ft
	Long Section	200 ft
Taxiway Centerline Lighting†	Very Tight Curved Section	25 ft
	Tight Curved Section	50 ft
	Wide Curved Section	100 ft
	Straight Section	200 ft

*Special situations (e.g., very complex geometries) may require shorter spacing.
†Spacing should be halved when airfield is used under low-visibility conditions.

Potential Benefits of Linear Delineation

- Increased visual acquisition distances (Gallagher 2005)
- Pilots at one airport judged a linear element favorably (Stauffer and Hyland 2014)
- In roadway applications:
  - Continuous delineation markings had longer visibility distances than dashed/intermittent markings (Zwahlen and Schnell, 1997)
  - Lighted guidance tube (Griffith and Brooks, 2000) and linear delineation systems (Haas, 2004) elicited desirable driving behavior/speed

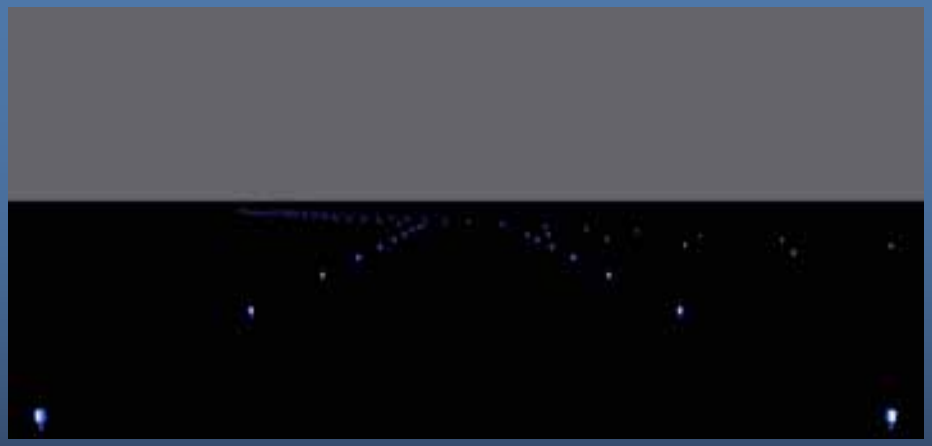
(Griffith and Brooks, 2000)

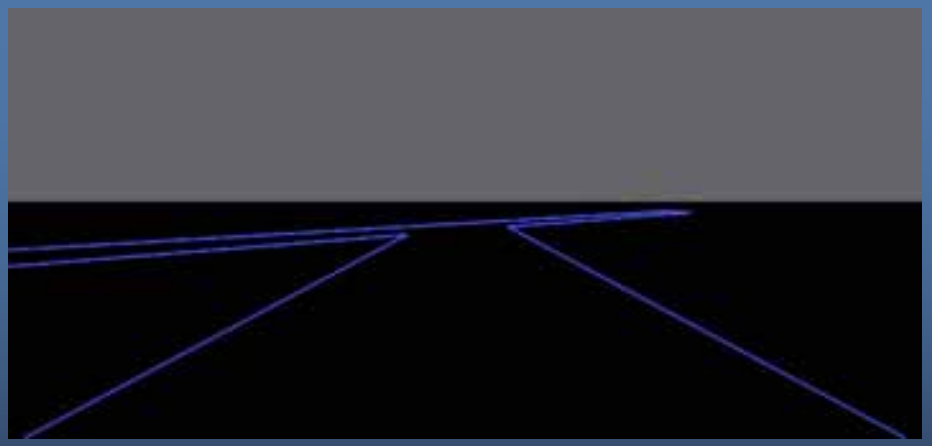
Study Approach

- Simulation based evaluations using static images and subsequently, dynamic animations
- Initial objective to confirm geometric relationships
- Displays always presented on a computer screen
- Automated stimulus presentation and data collection/storage
- Primary outcome measures: response times and identification accuracy

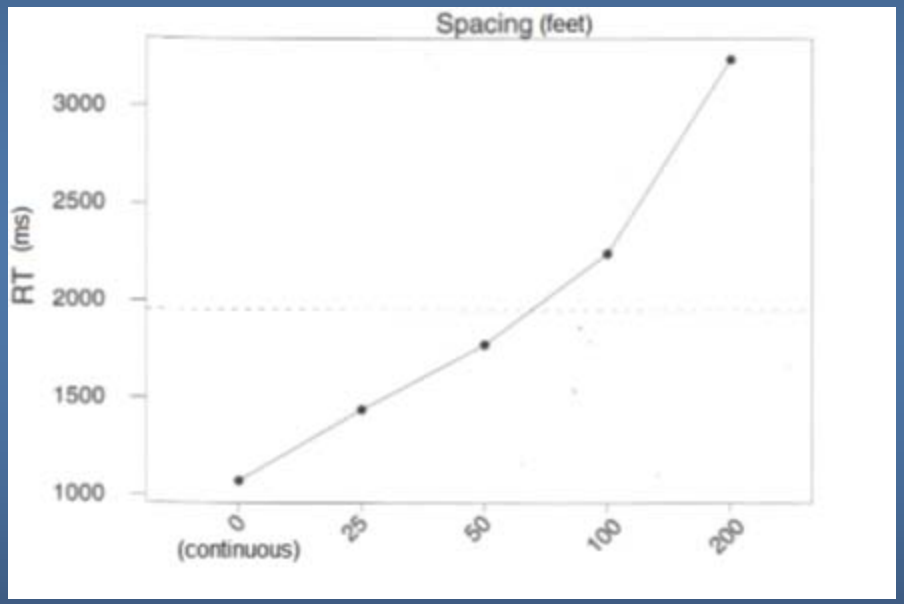
Experiment 1

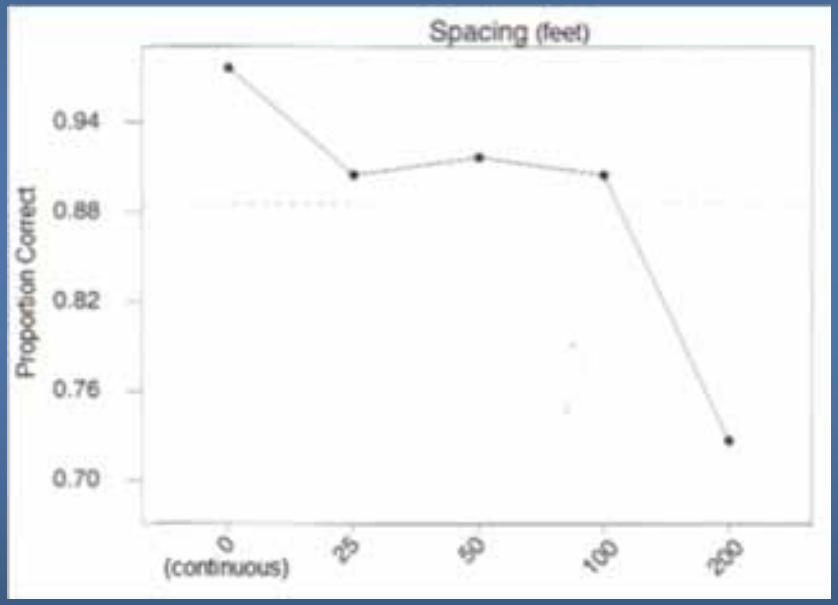
- Compare point source edge light fixture spacing of 25, 50, 100, 200 ft to continuous edge delineation (blue)
- Subjects identified cross, tee, skew left/right geometry





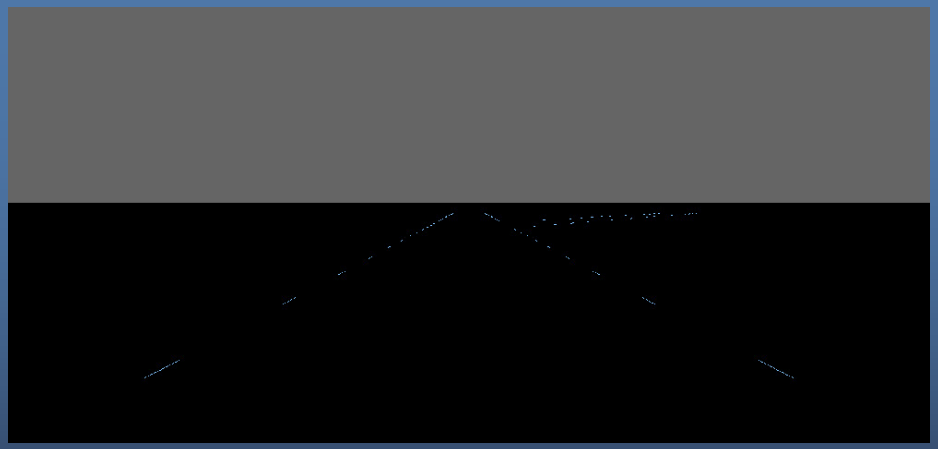
Experiment 1 Results



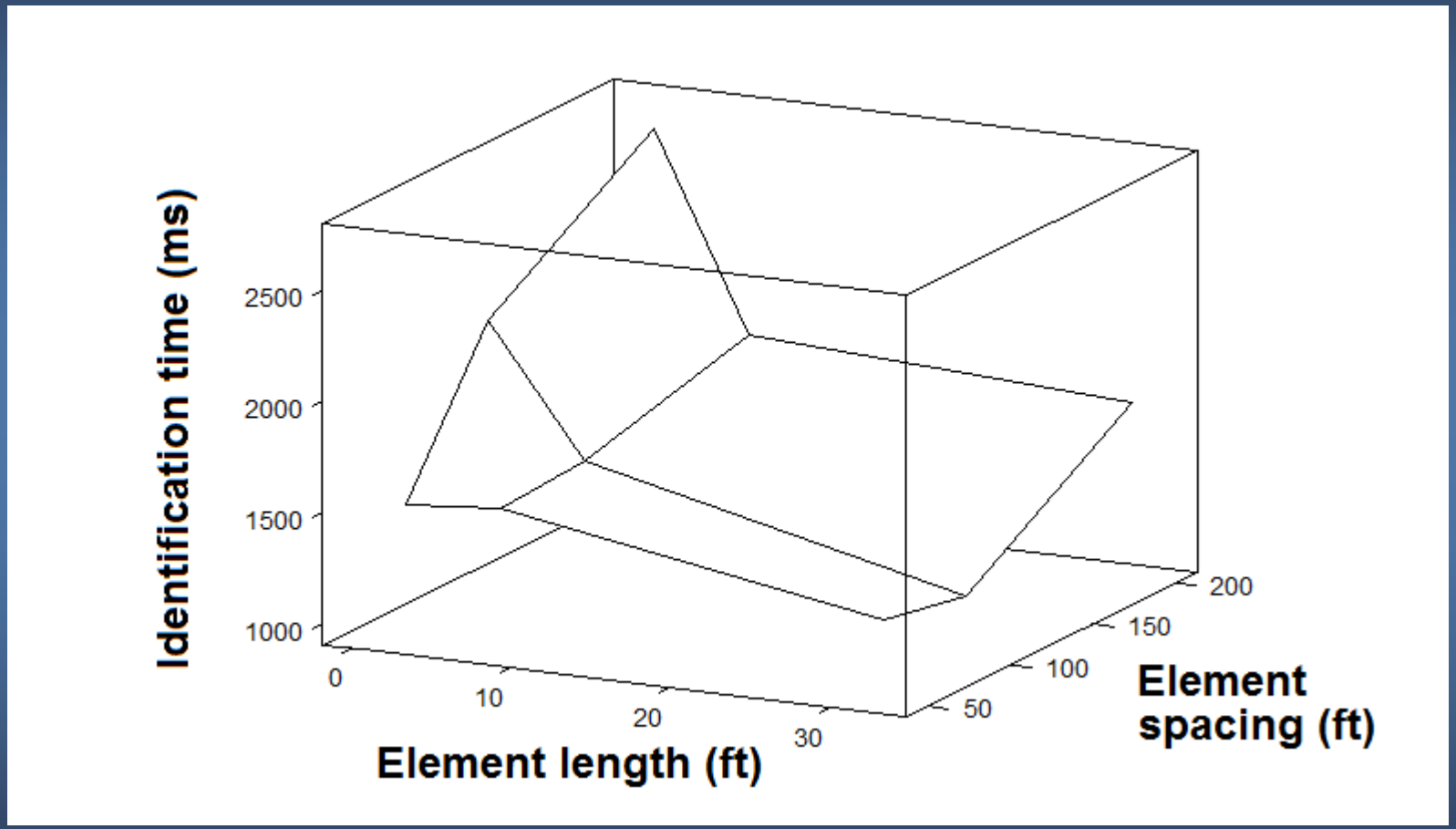


Experiment 2

- Right/left, 90°/30° angle
- 2, 8, 32 ft element length
- 50, 100, 200 ft spacing
- Edge lighting (all blue)

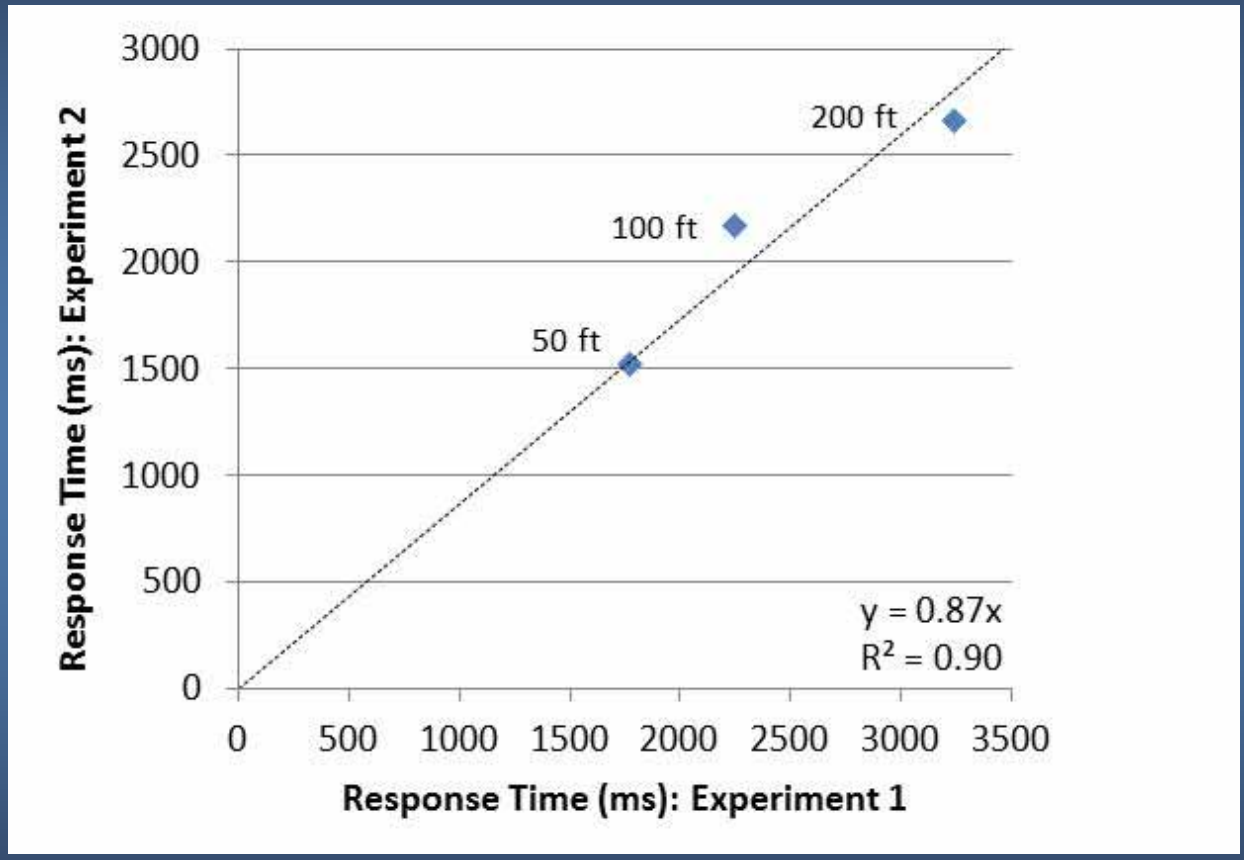


Experiment 2 Results



RT (ms) = 286 – 607 log *L* + 989 log *S*

Comparison Between Point Edge Light and 2-ft Element Length

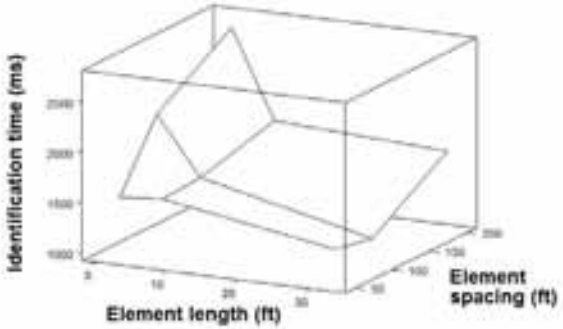


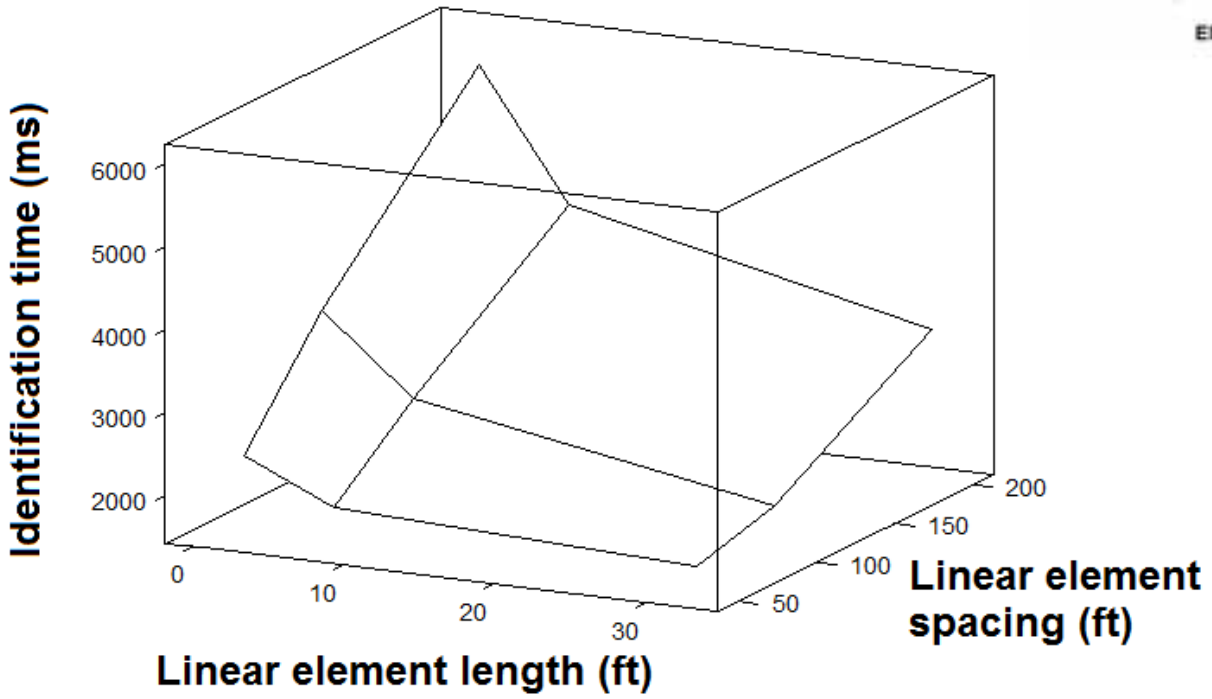
Data suggest there is little benefit to a linear element length of 2 ft when matched for spacing

Experiment 3

- Right/left, 90°/30° angle
- 2, 8, 32 ft element length
- Edge lighting (all blue)
- 50, 100, 200 ft spacing
- Visual noise present (multicolored)

Experiment 3 Results





Values with visual noise were strongly correlated (r^2=0.86) to those without

Factor: 1.8x

Experiment 4

- Dynamic animation starting from 2000 ft away, 50 mph
- 30°/90° left/right taxiway from runway
- Centerline delineation (white/runway, green/taxiway)
- 2, 8 or 32 ft element length; 50, 100, 200 ft spacing

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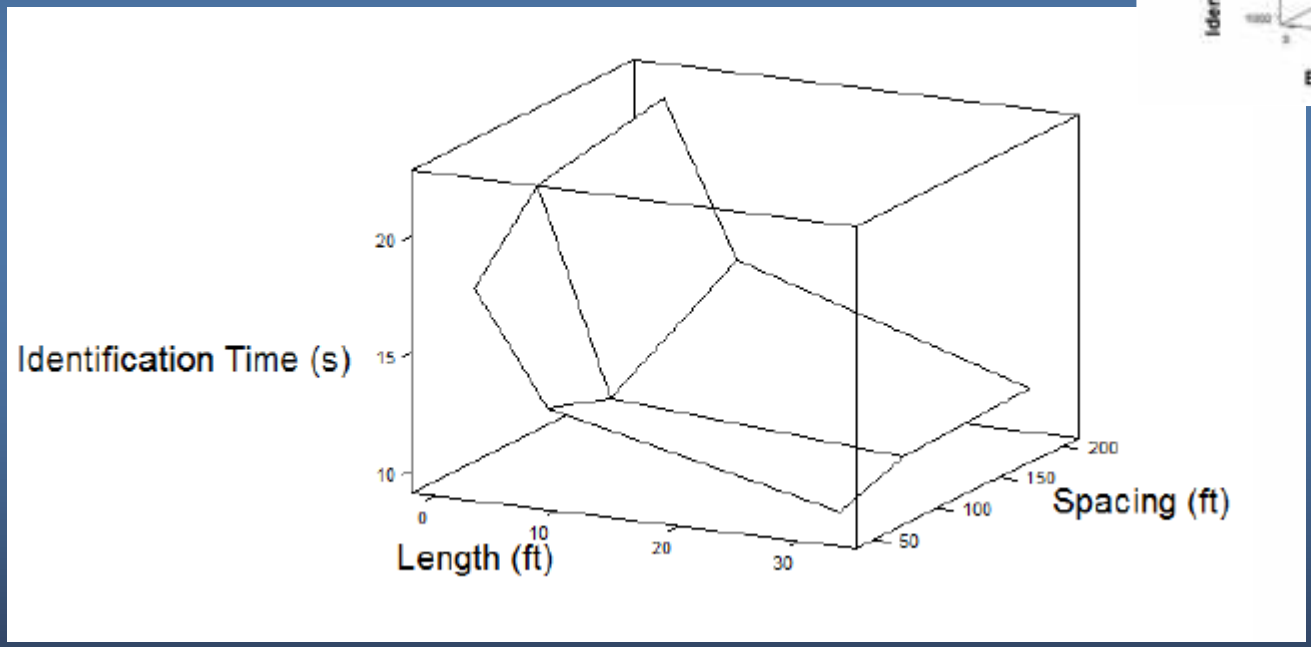
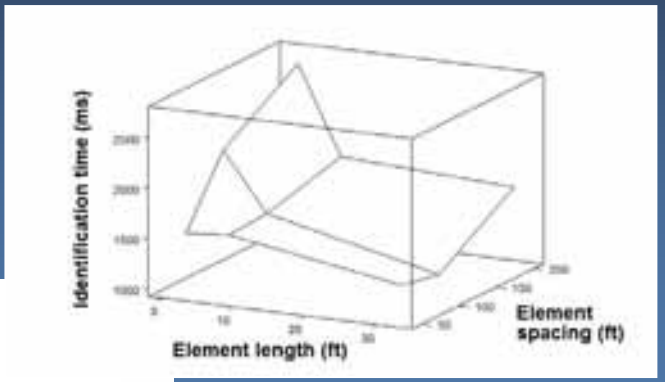
Display Characteristics and Procedure for Experiment 4

- White elements: 120 cd/m²
- Green elements: 70 cd/m²
- Blue elements: 7 cd/m²
- Background: 1 cd/m²

- Subjects stopped the animation as soon as they could reliably discern the geometry

Experiment 4 Results





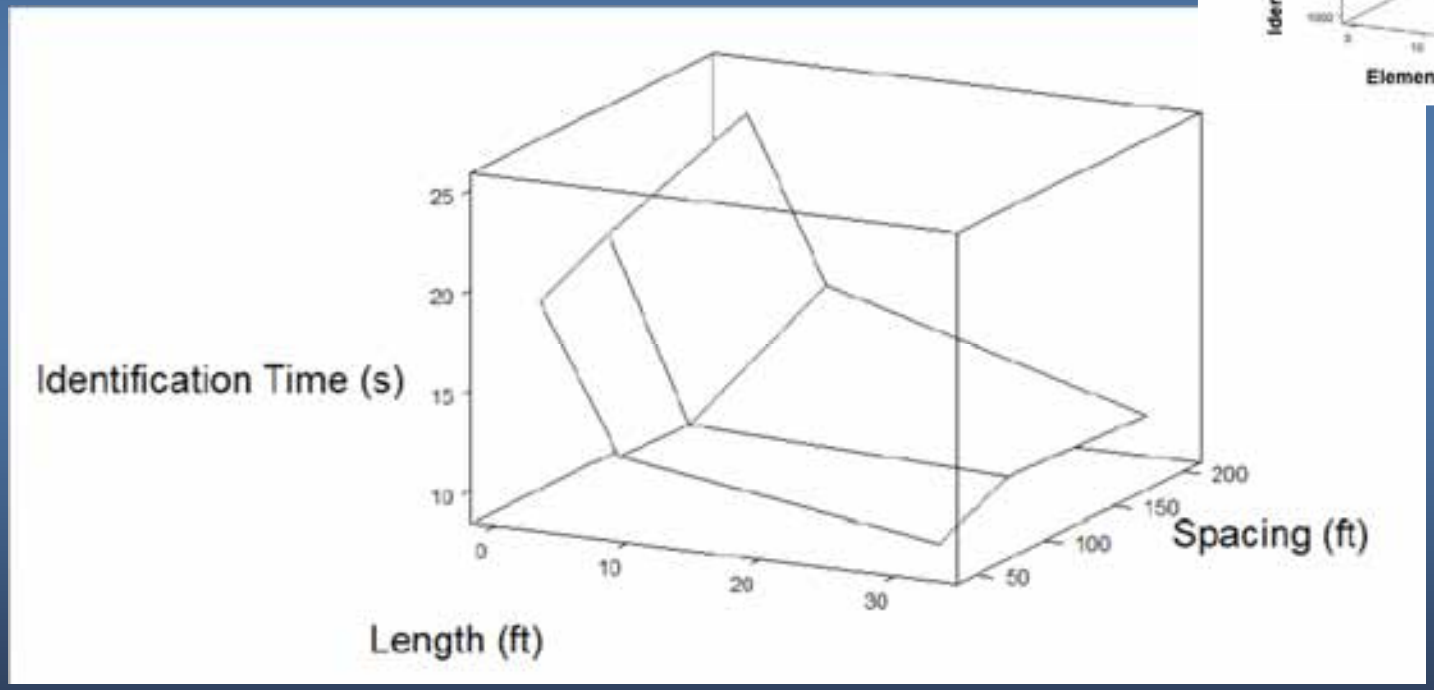
Correlated (r^2=0.73) to Experiment 2 results

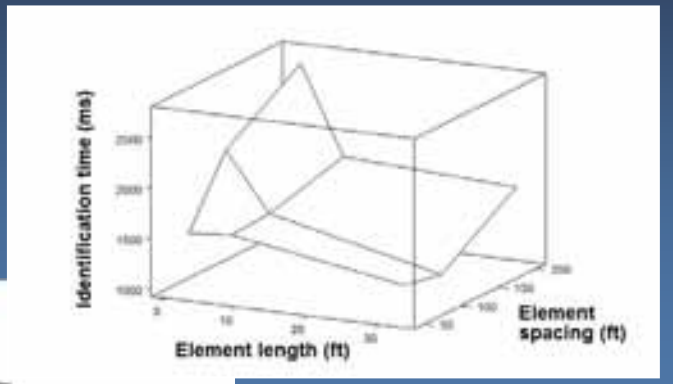
Factor: 8.6x

Experiment 5

- Dynamic animation starting from 2000 ft away, 50 mph
- $30^o/90^o$ left/right taxiway from runway
- Centerline delineation (white/runway, green/taxiway)
- 2, 8 or 32 ft element length; 50, 100, 200 ft spacing
- Screen filtered: White luminance 30 cd/m², green 18 cd/m², blue 1.8 cd/m², background 0.25 cd/m²

Experiment 5 Results





Correlated (r^2=0.69) to Experiment 2 results

Factor: 8.8x

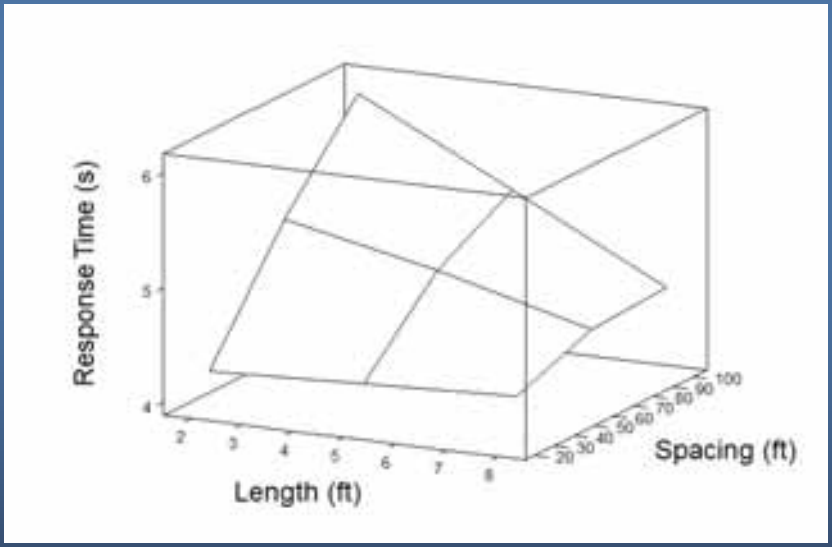
Experiment 6

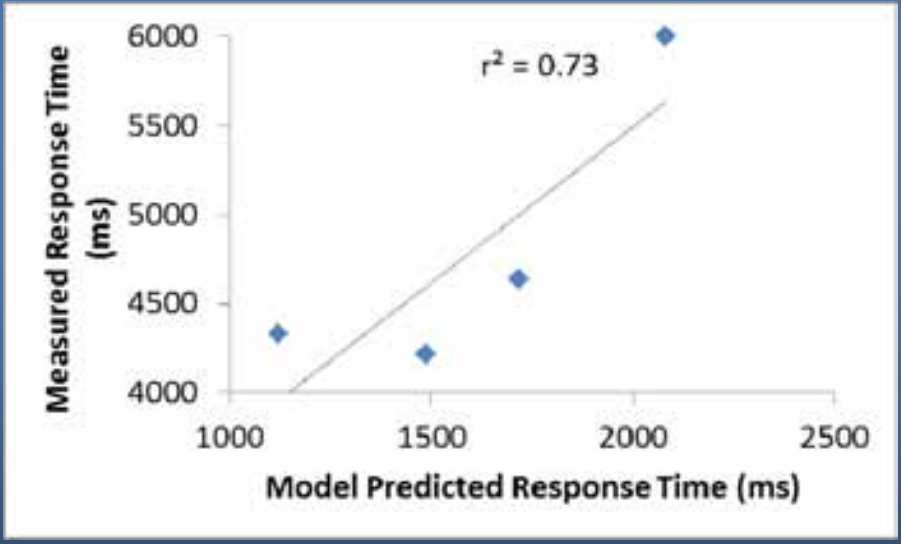
LED lights were located to represent centerlines along an intersection (shown: right side, 30° angle)

Participants viewed scenes through the window (with room lights off) and recorded their responses on a laptop computer

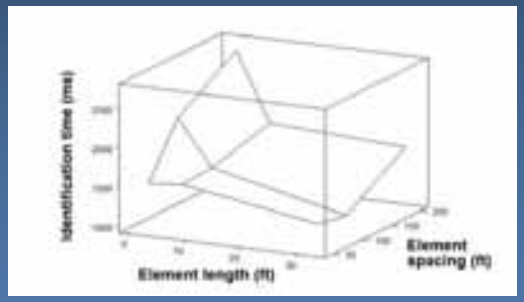
Experiment 6 Results

- Present data are consistent with model predictions based on laboratory study data





Discussion: Trading Off Length and Spacing



RT (ms) = 286 – 607 log *L* + 989 log *S*

Combinations of delineation element length and spacing to achieve the same relative response times expected from 2-ft-long delineation elements spaced at 50 and 100 ft.

Base Case 1	Element length	2 ft	**6.2 ft**	**12.0 ft**	**19.2 ft**
	Element spacing	50 ft	100 ft	150 ft	200 ft
	Relative response time	1784 ms	1784 ms	1784 ms	1784 ms
Base Case 2	Element length		2 ft	**3.9 ft**	**6.2 ft**
	Element spacing		100 ft	150 ft	200 ft
	Relative response time		2081 ms	2081 ms	2081 ms

Discussion: Photometric Considerations

- Luminance may be a more meaningful predictor of performance than luminous intensity for extended elements

- Based on present findings with blue and on luminances of effective road pavement markings (Schnell and Zwahlen, 2000; Molino et al., 2003) a preliminary minimum luminance of **7 cd/m²** is suggested

Caveats and Recommended Next Steps

Caveats

- Background luminance range (0.25-1 cd/m²) limited
- Potential non-uniformity and installation issues identified by Gallagher (2005)

Next Steps

- Field validation is recommended to validate conclusions regarding minimum luminance

Conclusions

- Data for varied edge/centerline configurations differing in color and in movement (static vs. dynamic) were highly consistent
- Results could provide basis for quantitatively trading off linear element length and spacing for various configurations
- Field validation will be necessary

Thank You!

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- Robert Booker, FAA
- Mayor Michael Manning and Recreation Supervisor Robert Loya, City of Watervliet