Analysis Across Multi-sensor Image Displays: Using the Capacity Coefficient

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Introduction

The additional information available from infrared sensors can aid in decision making when combined in visual information.

Despite the potential benefits of having multispectral information, recent research indicated limited capacity whether images were combined in a single image or presented side-by-side.[5]

We are interested in whether rapidly switching between sensor images can overcome the capacity limitations previously reported because:

1) None of the information available from an image is filter out before presentation.
2) The correspondence between spatial attributes is preserved.

Experimental Design

Visible

Thermal

Fused Image

Laplacian Pyramid Transform

Multi-sensor Presentation Conditions (450ms) :

1) **Side-by-Side (SxS):** Display the two images directly next to one another with no overlap.
2) **Flicker (Flick):** Flipping back and forth between the individual sensor images at a rate of 75ms per flip.
3) **Algorithm (Alg):** Display a single, composite image that combines relevant information from each individual sensor image using the Laplacian pyramid transform.

Model Comparisons

Capacity Coefficient[7,8]:

$$C_{OR} = \frac{\hat{H}_{1..n}(t)}{\sum_{i=1}^{n} \hat{H}_i(t)}$$

- **C = 1: Unlimited**
- **C < 1: Limited**
- **C > 1: Super**

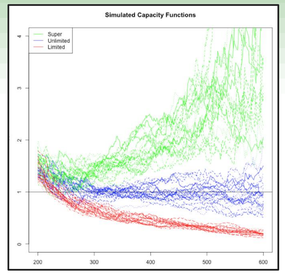
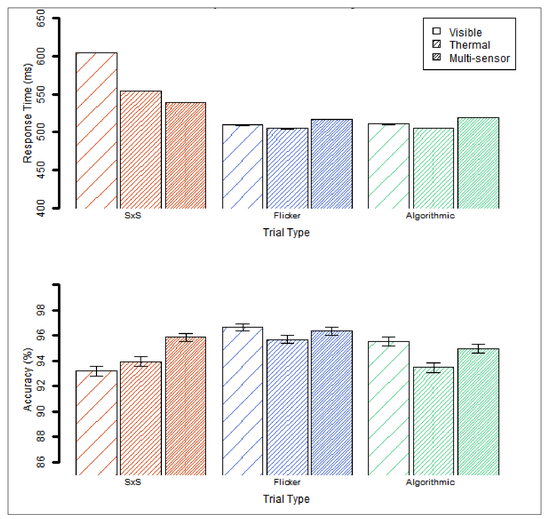


*Figure from Godwin, H.J., Walenchok, S.C., Houpt J.W., & Goldinger, S.D. (2015).[6]

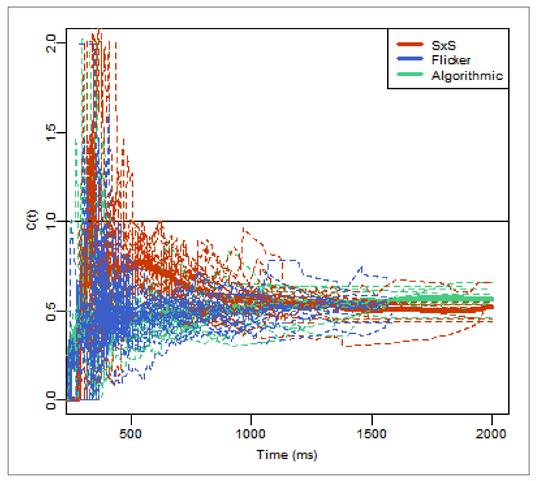
Results

Response Time and Accuracy



		Response Times		Accuracy	
	df	*F*	η	*F*	η
# of Sensors x Condition	2,38	45.62***	0.03	3.14+	0.02
# of Sensors (single, multiple)	1,19	3.90+	0.00	6.83*	0.03
Condition (Alg, SxS, Flick)	2,38	17.45***	0.07	3.35*	0.06
Multi-sensor presentation	2, 38	2.88+	0.02	1.67	0.05
Single-sensor presentation	1, 19	13.82**	0.02	4.79*	0.01

Capacity Coefficient



Capacity z-score values significantly differ by presentation condition, $F(2, 38) = 47.07$, $p < .05$, $\eta = 0.50$.

z-score (range, *M*):

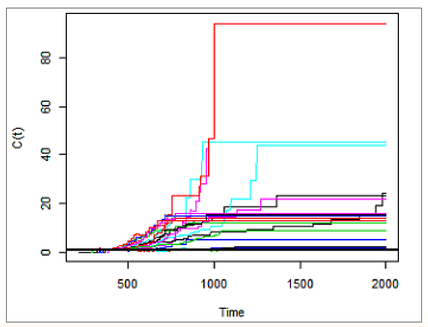
Side-by-Side: -7.13 to -1.59 (*M* = -4.23)

Flicker: -12.20 to -5.00 (*M* = -8.35)

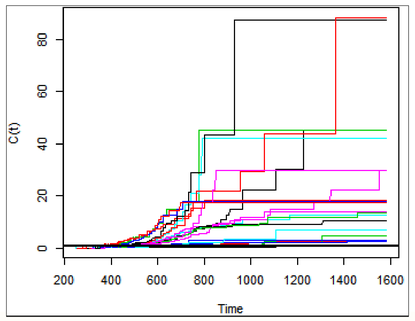
Algorithmic: -11.30 to -4.47 (*M* = -8.43)

Assessment Functions

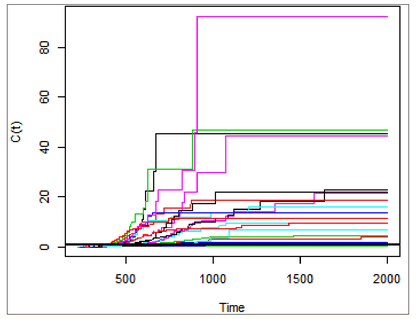
SxS



Flicker



Fused



Discussion

1) Multi-sensor presentation, at best, still shows less efficient processes than we would expect given the processing of each sensor alone.
   - Perhaps providing multiple sensors hinders situational awareness or requires more attentional resources.[9,12]
2) The use of a single-sensor image that provides adequate information to make a decision may be more beneficial than additional, redundant information.[10]

Conclusions

- Response time and accuracy performance significantly varies based on the sensor and the multi-sensor presentation method.
- For these stimuli, all multi-sensor fusion methods result in limited workload capacity and capacity varies by condition.

Future Research

- General recognition theory (GRT[3,11])
- Response classification[1,2,4]

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