
Preattentive Attributes in Visualization Design: Enhancing Combat Identification

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Overview

- Background of the Problem
 - CID Definition
 - Fratricide Rates – challenges ahead
 - Historical Examples of Deadly HMIs
 - Training or Usability?
 - Characteristics of Stressful Environments
 - Effects on Decision Making
- Preattentive Processing
 - Examples
 - Preattentive Attributes
- Practical Application Examples

Combat Identification (CID)

“... the process of attaining an **accurate** characterization of detected objects to the extent that high confidence and **timely** application of military options and weapon resources can occur.”

- Joint Chiefs of Staff

The overarching goal of CID is more than avoiding fratricides; the goal is to win conflicts, and win them decisively.

Fratricide Rates

10%

Fratricide incidents accounted for a minimum of 10% of the total U.S. casualties in World War II, Korea, Vietnam, and the first Persian Gulf War.

(Shrader, 1982; Steinweg, 1995)

The Challenge

Technology allows more lethal, higher precision weapons

Increased speed of action, longer range targeting, and reliance on coordinates passed via remote systems actually may raise the risk of fratricide and complicates C²

Network Centric Warfare

- Implications
 - The HMI for every link in the kill chain, from sensor to shooter, must be optimized for human use
 - No such thing as a “stand alone system”; risks of all types impact all connected levels

Deadly HMIs

- 1988 - U.S.S. *Vincennes* shot down an Iranian airliner filled with civilian passengers, killing all aboard.
 - Though operating normally, a poorly designed weapons control interface and crew training were blamed for the tragedy
- Operation Iraqi Freedom – accidental destruction of British and U.S. fighter aircraft in two separate incidents, killing three aircrew members
 - Confusing and overly complex interface design of the air defense artillery system, along with inadequate crewmember training, were implicated

Training vs. Usability

In technologically dense environments, errors are often attributed to human operators and poor training

Research indicates that often the fault lies with the system design. Good design dramatically lowers the need for training.

Situational Awareness

The Navy's TADMUS project found that Situational Awareness plays the key role in decision quality under stress. Situational Awareness is built on experience and expertise

(Cannon-Bowers & Salas, 1998)

Other research indicates that in C2, HMI usability may be the primary determinant of Situational Awareness.

(Bolia, Vidulich, Nelson & Cook, 2004)

Improve Training

The Navy's TADMUS project found that operator training must emphasize adaptive decision making skills, encouraging operators to be able to respond flexibly and effectively to non-routine events

(Cannon-Bowers & Salas, 1998)

Other research indicates that at a certain point, no amount of pre-selection and training of personnel can compensate for a flawed HMI or system design

(Crisp, McKneely, Wallace, & Perry, 2001)

Characteristics of Stressful Environments

- “Fast-changing, complex and uncertain situations
- ...in which the performance in decision-making carries high stakes
- ...in which critical decisions have to be made under extreme time pressure
- ...in which decisions are made and carried out collectively by multiple individuals in a team setting”

Effects of Stress on Decision Making

- Moderate Stress - vigilance increases to a constructive level, and search, situational appraisal, and contingency planning are all improved.
- Excessive Stress - people become hypervigilant, resulting in incomplete search, appraisal and contingency planning.

(Janis and Mann; Xiao & MacKenzie).

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- “Fear, nervousness, excitement and exhaustion numb the mind and cause miscommunication and misunderstandings. These circumstances are a recipe for error.”

- Col David Hackworth

- “...Things intended to be used under stressful situations require a lot more care, with much more attention to detail”

- Donald Norman

Preattentive Processing

- Researchers have identified a limited set of basic visual attributes
- Perceived very accurately and rapidly by the human visual system (within about 200-250 milliseconds)
- Occurs outside of conscious thought or reasoning

(Treisman & Gelade, 1980).

Processing Mechanisms

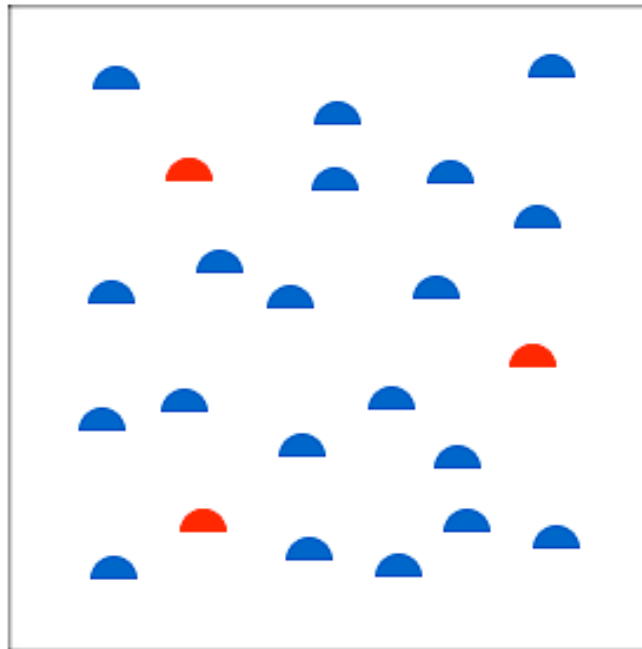
Preattentive:

- Parallel
- Very fast & accurate
- Relatively unlimited capacity
- Tasks are completed with little effort

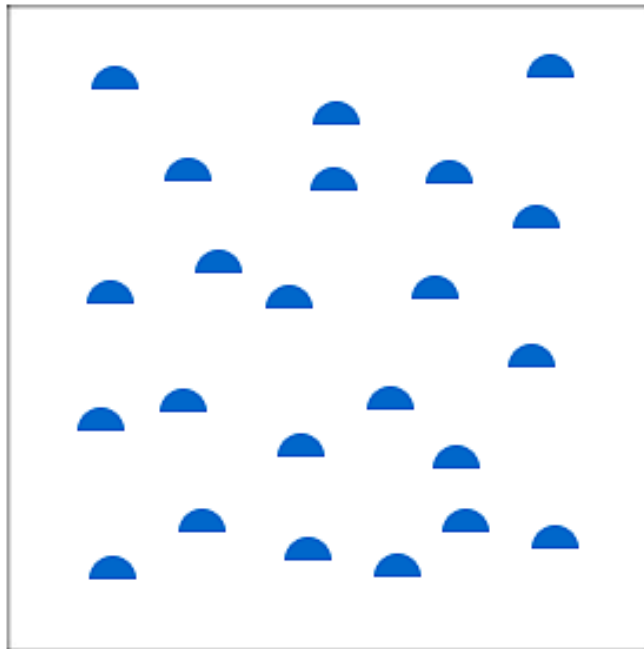
Attentive:

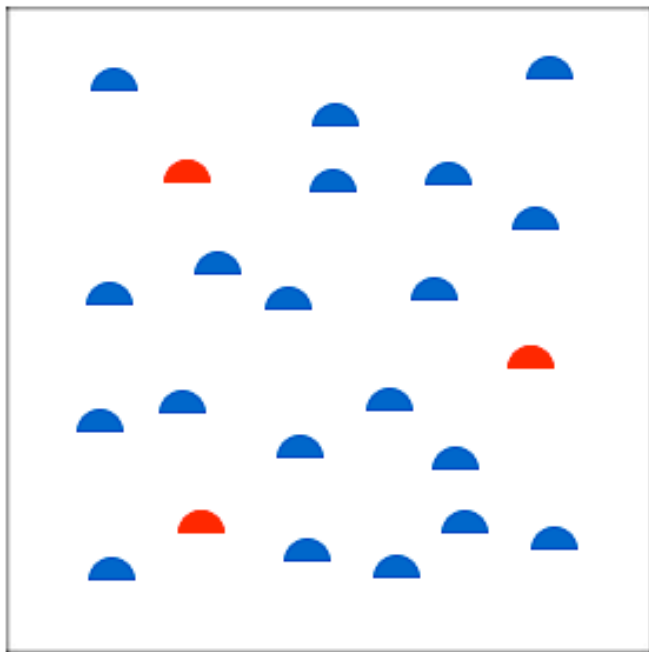
- Serial
- Relatively slow
- Limited capacity
- Requires conscious effort & attentional resources

Demo #1 – Red Semi-circles (a)

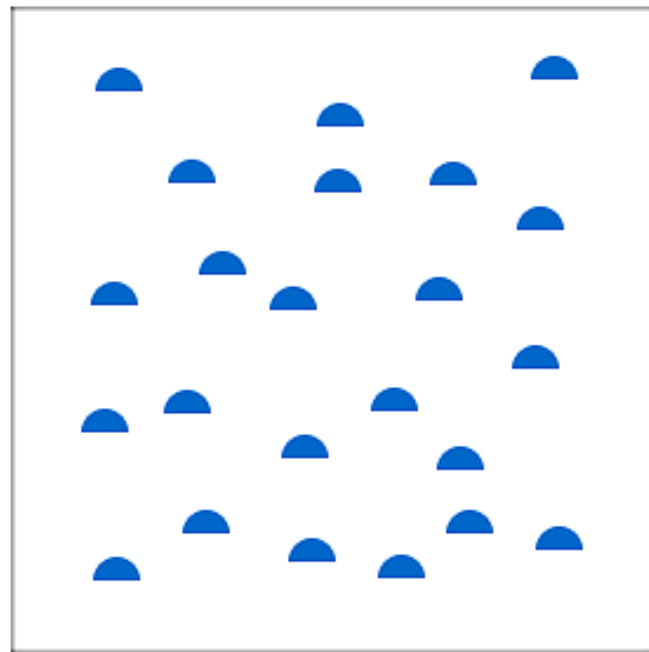


Demo #1 – Red Semi-circles (b)



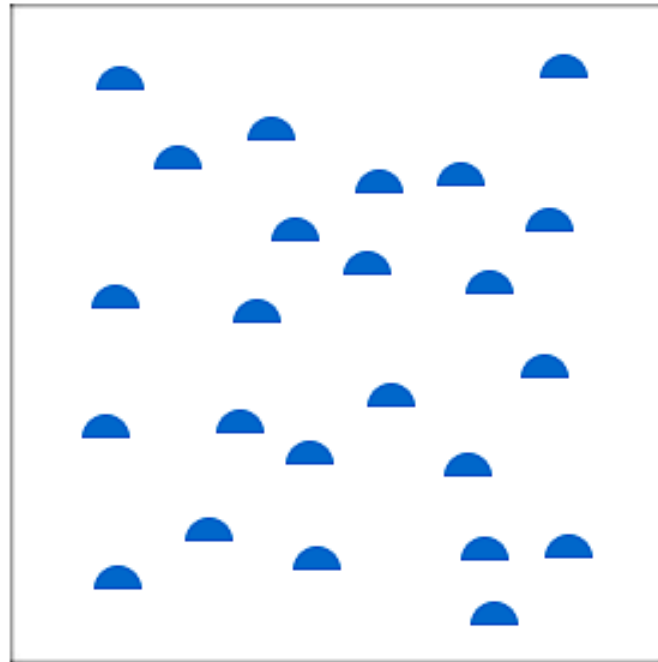


(a)

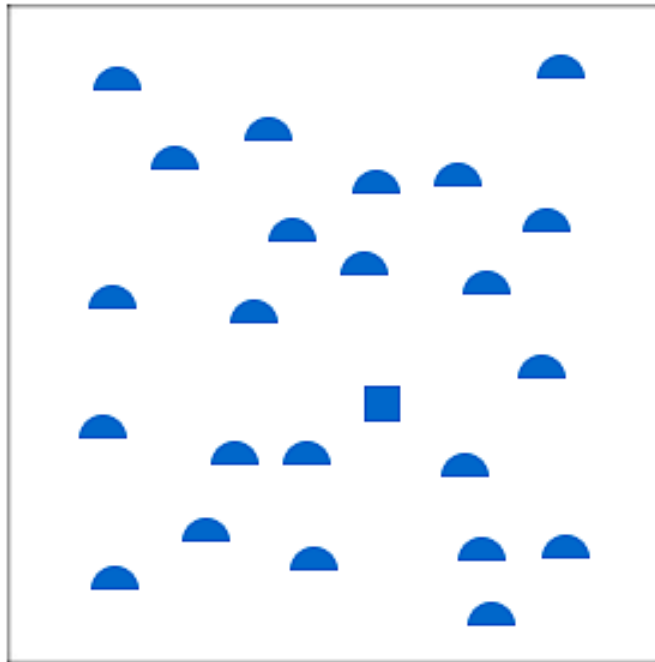


(b)

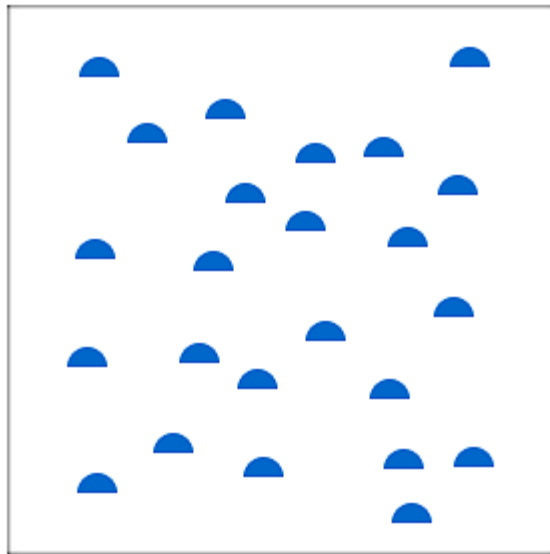
Demo #2 – Blue Square (a)



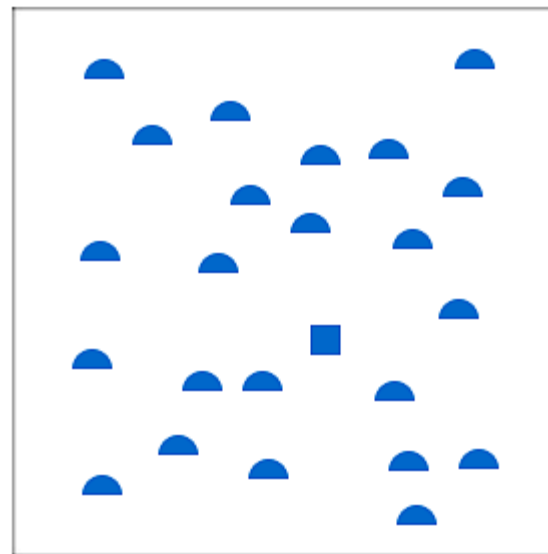
Demo #2 – Blue Square (b)



Demo #2 – Blue Square

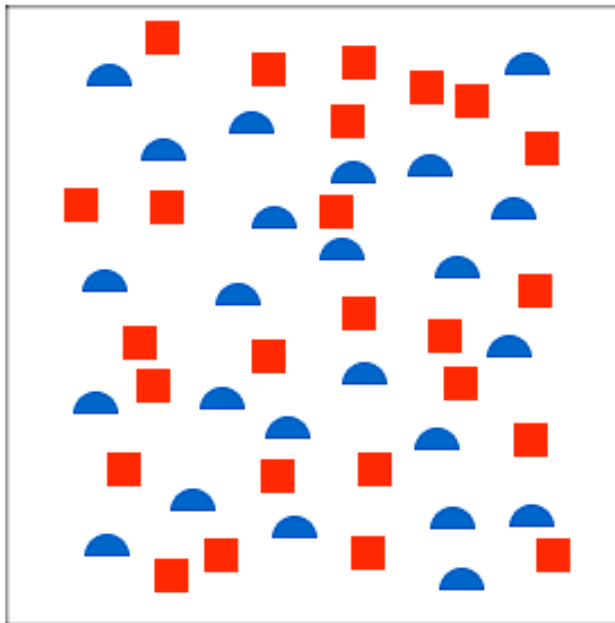


(a)

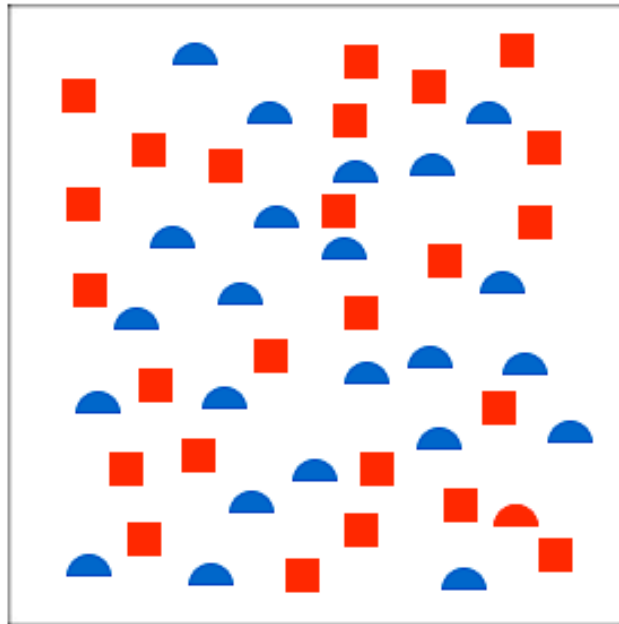


(b)

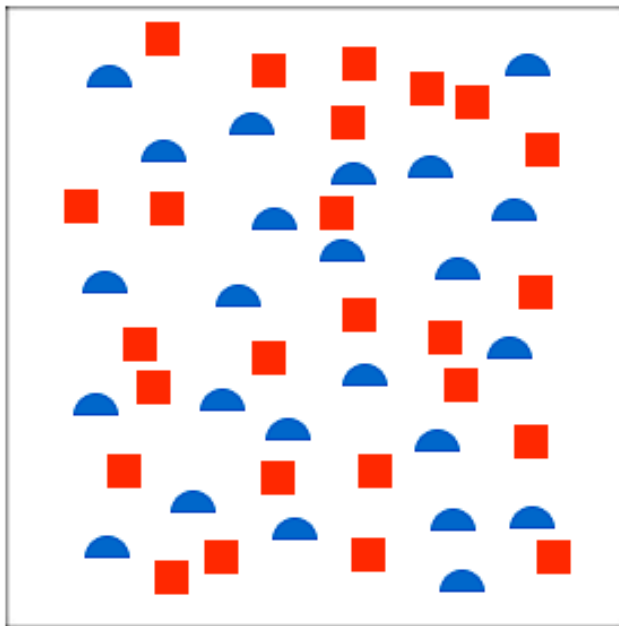
Conjunction Target – Red Semi-circle



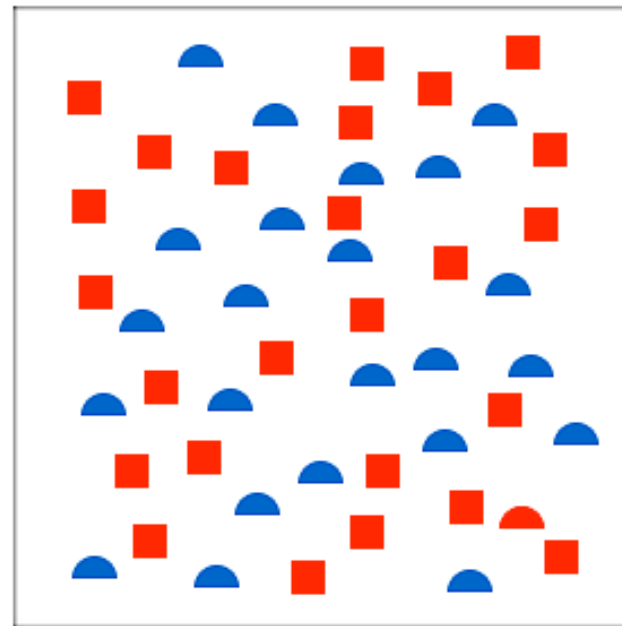
Conjunction Target – Red Semi-circle



Conjunction Target – Red Semi-circle



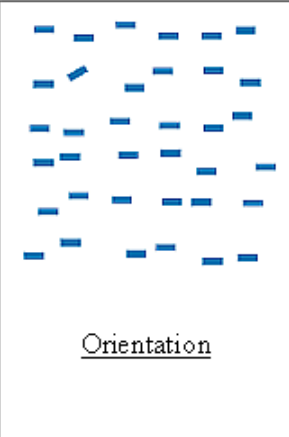
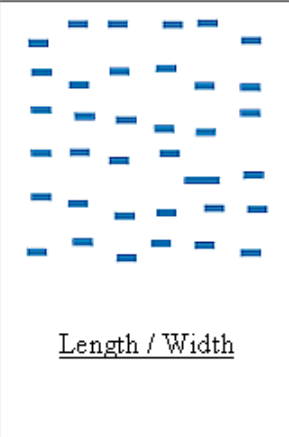
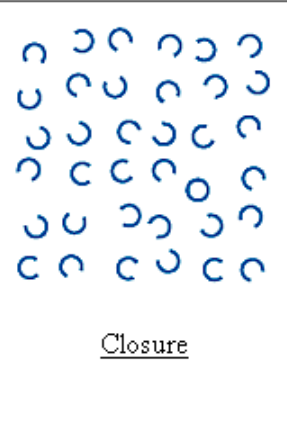
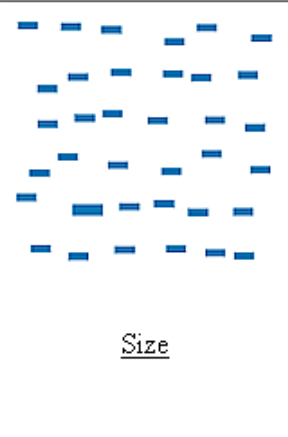
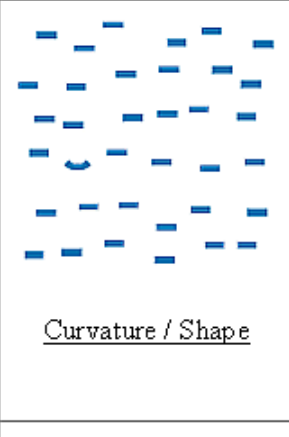
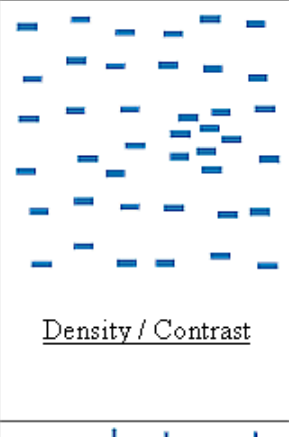
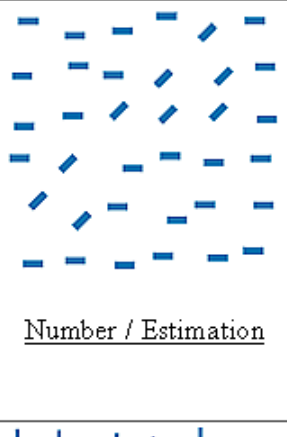
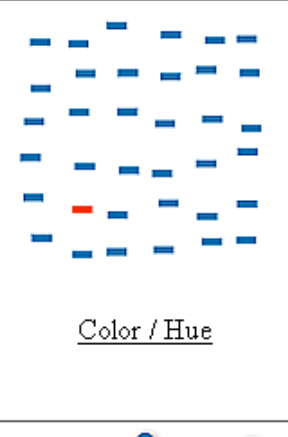
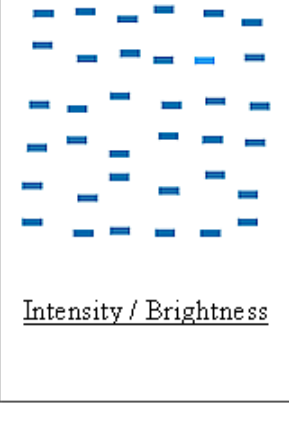
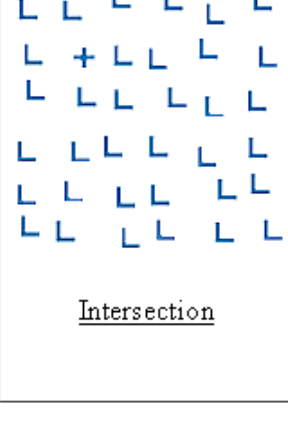
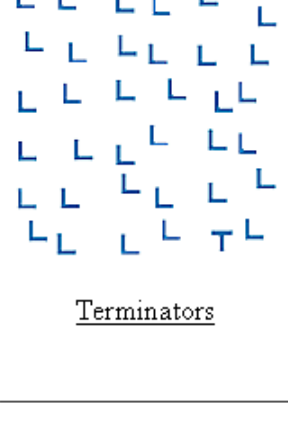
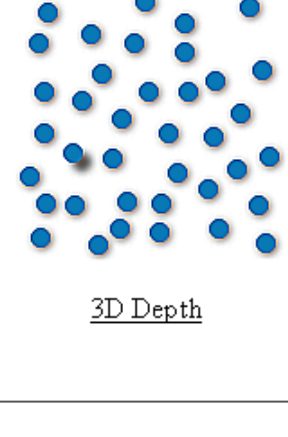
(a)



(b)

*A partial listing of
preattentive basic features*

Feature depictions adapted
from *Perception in
Visualization*, by
Christopher G. Healey,
located at:
<http://www.csc.ncsu.edu/faculty/healey/PP/index.html>.
Used with permission.

 <p><u>Orientation</u></p>	 <p><u>Length / Width</u></p>	 <p><u>Closure</u></p>	 <p><u>Size</u></p>
 <p><u>Curvature / Shape</u></p>	 <p><u>Density / Contrast</u></p>	 <p><u>Number / Estimation</u></p>	 <p><u>Color / Hue</u></p>
 <p><u>Intensity / Brightness</u></p>	 <p><u>Intersection</u></p>	 <p><u>Terminators</u></p>	 <p><u>3D Depth</u></p>

Practical Application

“In fact, what we mean by information - the elementary unit of information - is a difference which makes a difference”

- Gregory Bateson

“Making differences *is* making information.”

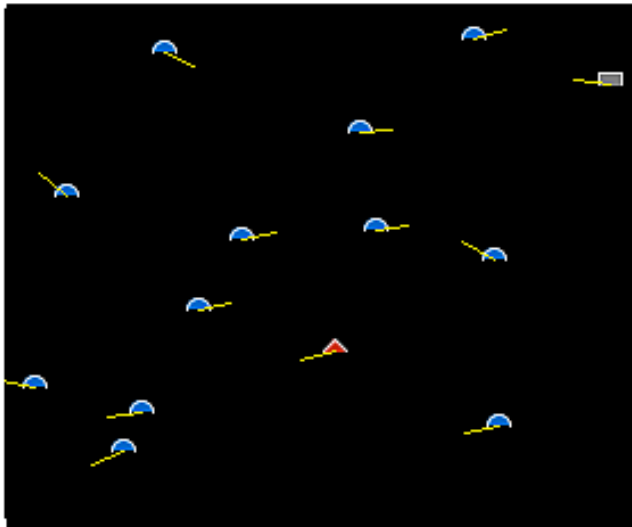
- Edward Tufte

Practical Application

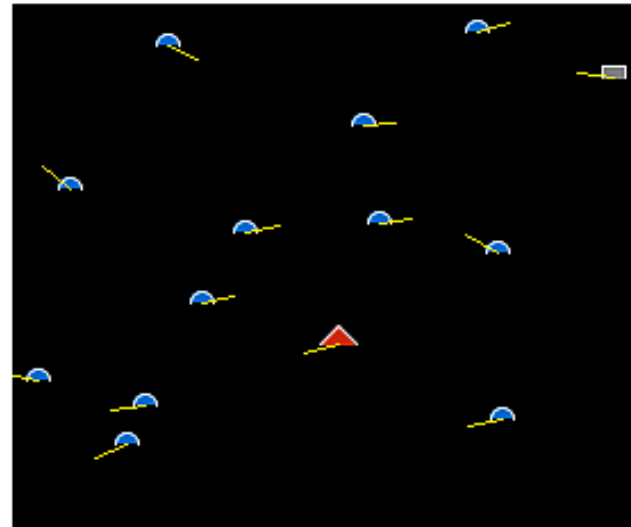
Some CID differences that make a difference:

- Track Identity
- Track Heading & Platform
- Track Altitude
- Track Location
- Presence of Friendly
- Controlling layer brightness

Track Identity



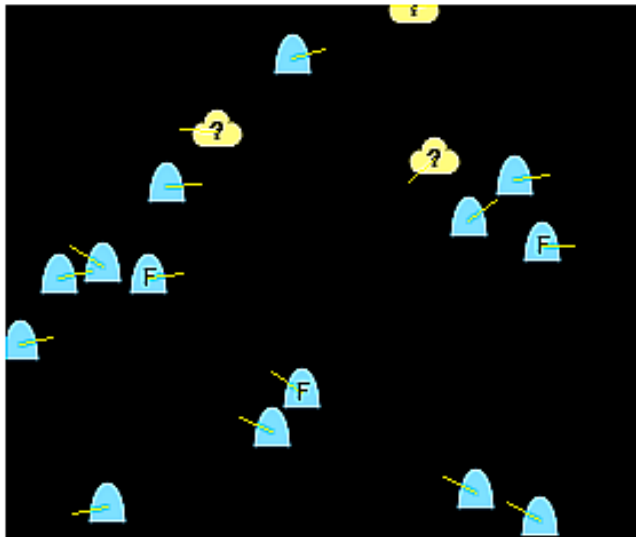
(a)



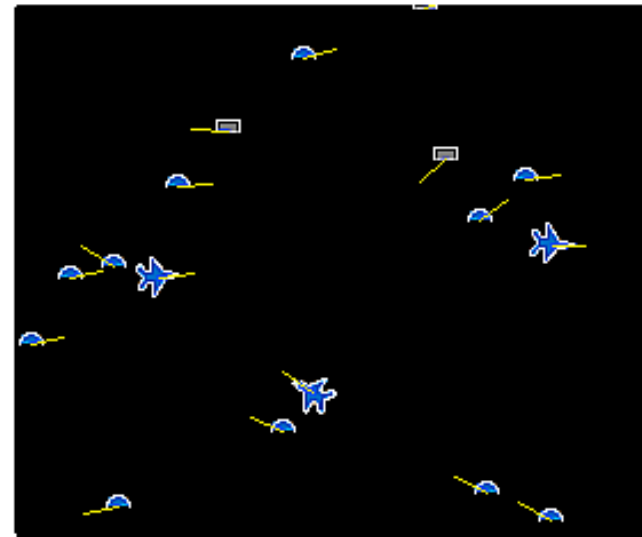
(b)

An example depicting variable symbology sizing to make a hostile air track more salient. (a) Target is scaled identically to non-target tracks; (b) Target is scaled 200% larger than non-target tracks, improving target saliency.

Track Heading & Platform



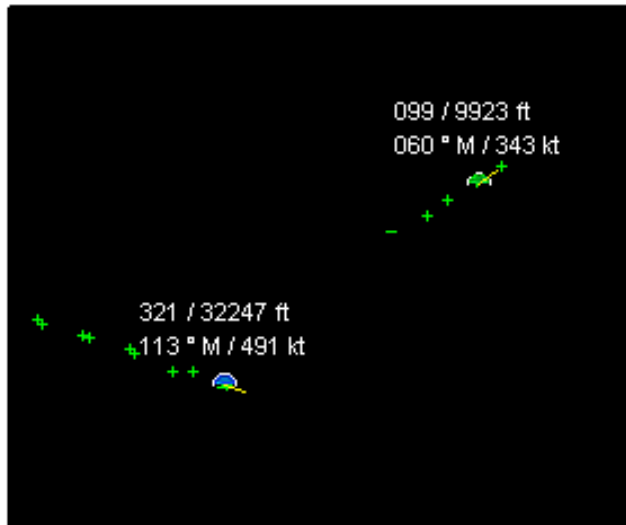
(a)



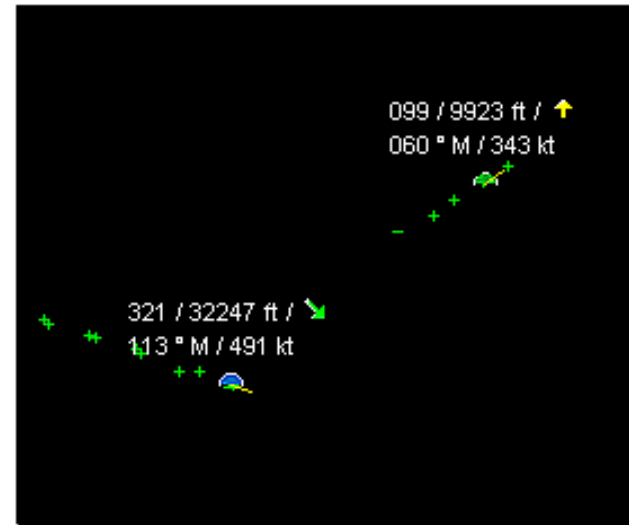
(b)

An example contrasting two symbology sets with regard to communicating target heading. (a) Three targets (Fighter aircraft) depicted using the MS-2525b symbol set. (b) Identical air picture as depicted by Raytheon Solipsys Iconic NTDS symbols.

Track Altitude



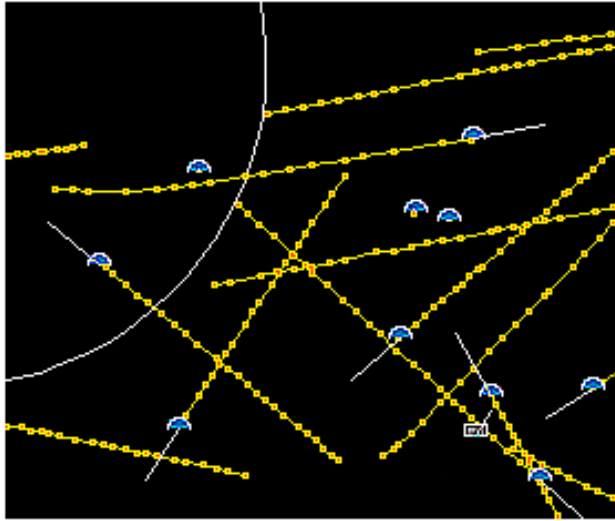
(a)



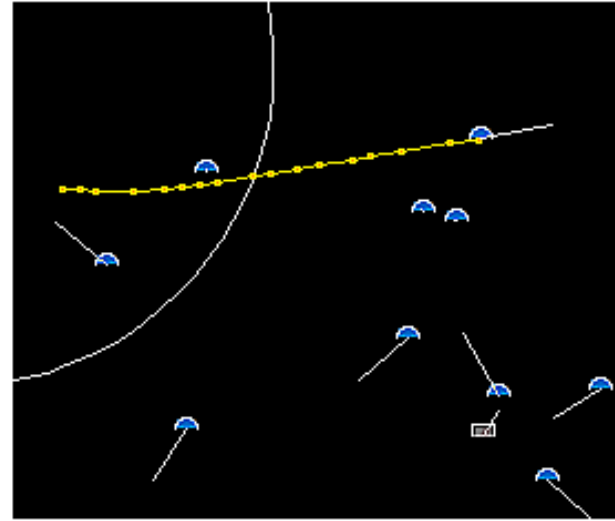
(b)

An example contrasting use and non-use of an icon designed to preattentively communicate track vertical speed trend information. (a) Track altitude information presented solely via text; trend information would need to be determined manually, over time. (b) Identical track textual information, but with vertical speed indicator icons shown next to altitude information, providing ascent or descent information at a glance.

Track Location



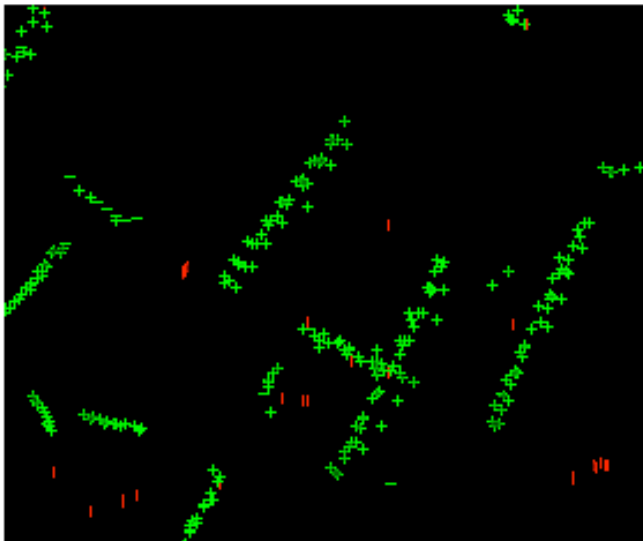
(a)



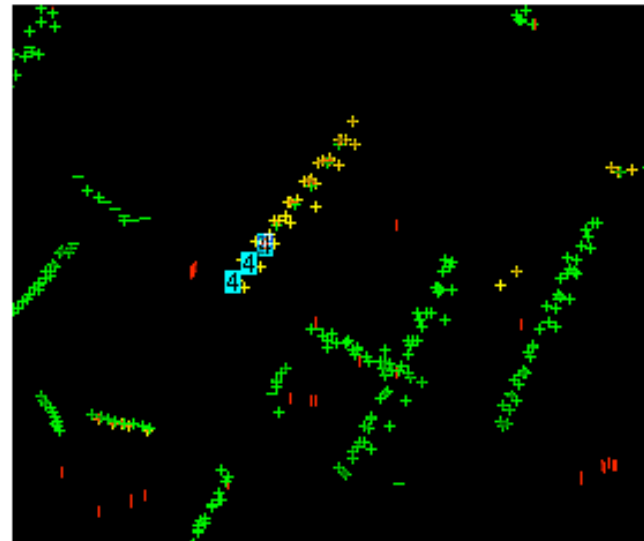
(b)

An example illustrating the need to support history trails on not simply all tracks, but for individual tracks as well. (a) Track display showing history trails on all tracks. (b) Identical track picture with a history trail displayed for only a single track of interest.

Presence of Friendly



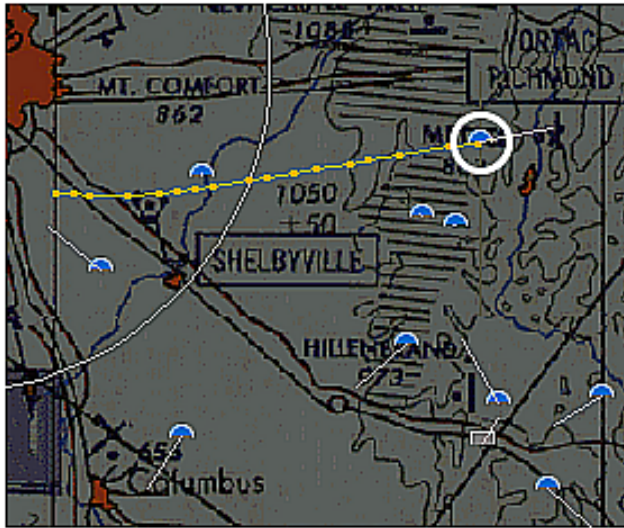
(a)



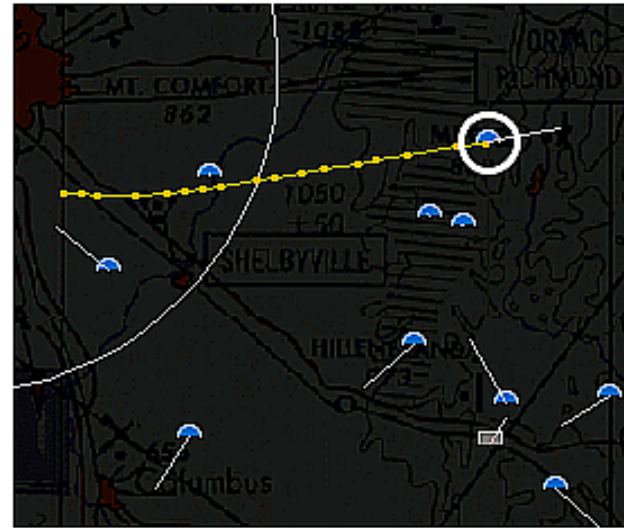
(b)

An example depicting effectiveness of communicating friendly IFF/SIF information. (a) Radar sensor plots without distinguishing coloration. (b) Identical track picture using preattentive attributes of hue and shape to distinguish IFF Mode 2 (orange), and unique Mode IV symbol (cyan).

Controlling Layer Brightness



(a)



(b)

An example illustrating results of layer brightness adjustment to optimize track presentation. (a) Background chart imagery shown in native brightness reduces contrast and visibility of tactical picture. (b) Map layer individually adjusted for brightness to emphasize track presentation, while still allowing map viewing as a secondary visual reference.

At a minimum, consider having individual layer brightness or transparency controls for: **maps, lines and areas, points and markers, sensor plots, and track symbology.**

Conclusion

- Design Implications
 - Use of preattentive attributes may help conserve “Human Attentional Units”
 - Working with users, identify the characteristics that are critical to the CID process
 - Use preattentive attributes to emphasize differences “Making differences *is* making information”.
- Research Questions
 - Does use of preattentive attributes improve performance in stressful situations via bypassing impaired conscious cognitive processes?
 - Are iconic symbols more efficient in communicating heading and platform information than military standard symbology sets?

Questions and comments...

Plot Summary

RDR	BCN	RNF	TOTAL
1558	652	3214	5,424

Sensor Status Summary (30 Sensors)

25 (83.3%)

2 (6.7%)

3 (10%)

Plots Per Sensor (30 Sensors)

SENSOR	RDR	BCN	RNF	TOTAL	SENSOR	RDR	BCN	RNF	TOTAL	SENSOR	RDR	BCN	RNF	TOTAL	SENSOR	RDR	BCN	RNF	TOTAL	SENSOR	RDR	BCN	RNF	TOTAL
BIHNS HALL	0	0	0	0	DU BOIS	20	6	72	98	HANNA CITY	20	6	72	98	HARTISBURG	20	6	72	98	ROANOKE	20	6	72	98
BENTON	20	6	72	98	ELWOOD	0	0	0	0	HUTCHINSON	20	6	72	98	NASHWALK	0	0	0	0	SAGHAW	20	6	72	98
BUCKS HARBOR	20	6	72	98	EMPIRE	20	6	72	98	KIRKSVILLE	20	6	72	98	NEWBURGH	20	6	72	98	SPRINGFIELD	20	6	72	98
BUFFALO	20	6	72	98	FORT FISHER	20	6	72	98	LA GRANGE	20	6	72	98	NORTH TRURO	20	6	72	98	ST ALBANS	20	6	72	98
CARBOU	0	6	72	78	GIBBSBORO	20	6	72	98	LONDON	20	6	72	98	OCEANA	20	6	72	98	TERRA HAUTE	20	6	72	98
COOPERSVILLE	20	6	72	98	OWNH	20	6	72	98	LYNCH	20	6	72	98	RIVERHEAD	20	6	72	98	TYLER	20	6	72	98

Enable Alerts at 0 plots Count Plots Per: s