The Use and Understanding of the Proximate Status Indication in Traffic Displays

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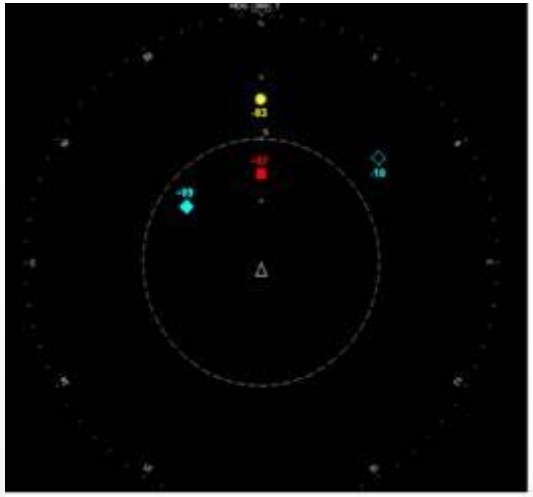
Background: Traffic Alert and Collision Avoidance System (TCAS) Symbols

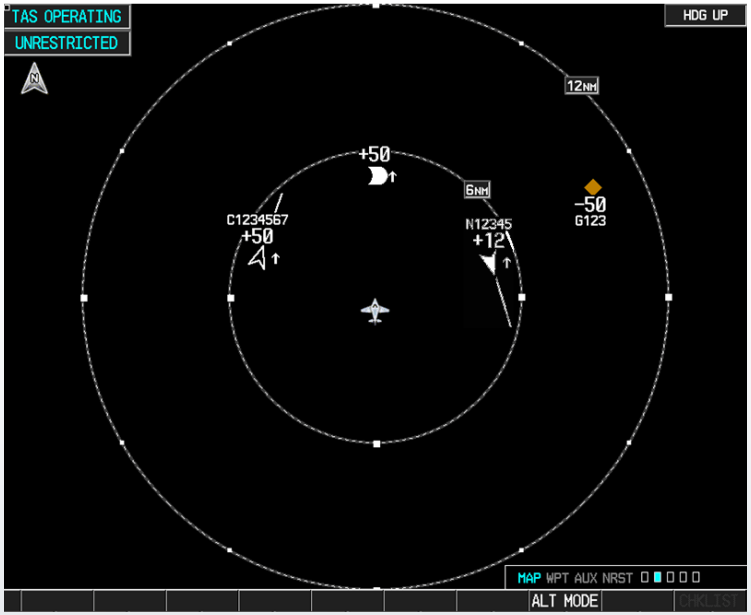


Standard TCAS symbology

TCAS display, photo by Paul Nelson

- TCAS traffic display shows
  - Traffic Alerts (TAs)
  - Resolution Advisories (RAs)
  - Proximate traffic as either ◆ or ◇
  - Relative altitude and climb/descent information

Background: Newer Traffic Displays



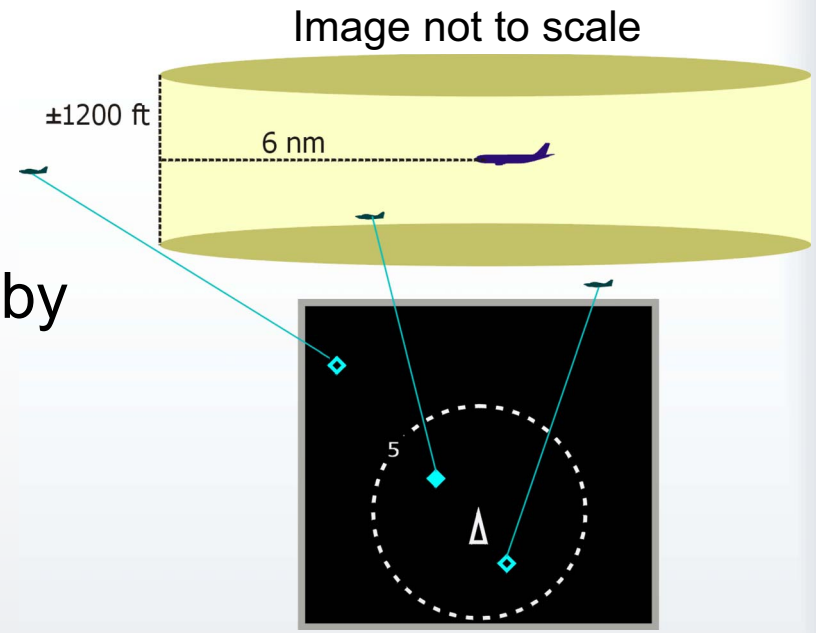
Garmin G-1000 CDTI (RTCA SC-186, 2008)

- New symbols can present more information
  - e.g., data quality, directionality
- Previous research for RTCA examined symbol learning and recall for proposed new symbols
- How much information can be encoded visually in a traffic symbol without confusing the pilot?

Terms

Proximity	Closeness in range and altitude
Proximate Target	Traffic that TCAS can sense that is neither a TA or RA
Proximate Status Indication	An indication to distinguish proximate targets within a specific range and altitude from farther proximate targets. TAs and RAs consider relative velocity, but a proximate status indication considers only proximity.

Proximate Status Indication Issues



- TCAS indicates proximate status by filling the symbol (or not)
- Should symbol fill indicate proximate status on CDTI too?
  - Consistency with TCAS is good, but CDTI manufacturers may want to use symbol fill for other information
- What is the intended function of the proximate status indication and is that function met?
  - Proximate traffic is required, but the intended function of the proximate <u>status indication</u> is not documented

Research Questions and Logic

- We hypothesized an “intended function” for the proximate status indication
  - Expect that the indication helps pilots to assess (a) whether the traffic might turn into a threat, and (b) whether visual acquisition is possible.
- Check for potential overreliance on proximate status indication that could result in missed threats
  - Does it hinder assessment of threats?
- Did we miss any other functions identified by subjects?
  - How is it used in line operations?
- Do pilots understand the TCAS criteria for proximate status indications?
  - If they know the TCAS criteria, the indication is probably useful

Overview of Study

- Online (web-based)
- Recruited over 100 air line and corporate pilots with TCAS experience
  - Approximately one hour to complete the study
  - Thanks to ALPA and NBAA
- Tasks to address each of the research questions
  - Short videos of traffic displays to represent realistic scenarios to assess pros and potential cons of proximate status indication
  - Free-response questions to assess operational experience
  - True/false "quiz" regarding TCAS criteria for proximate status indication, and, for comparison, for Traffic Alerts

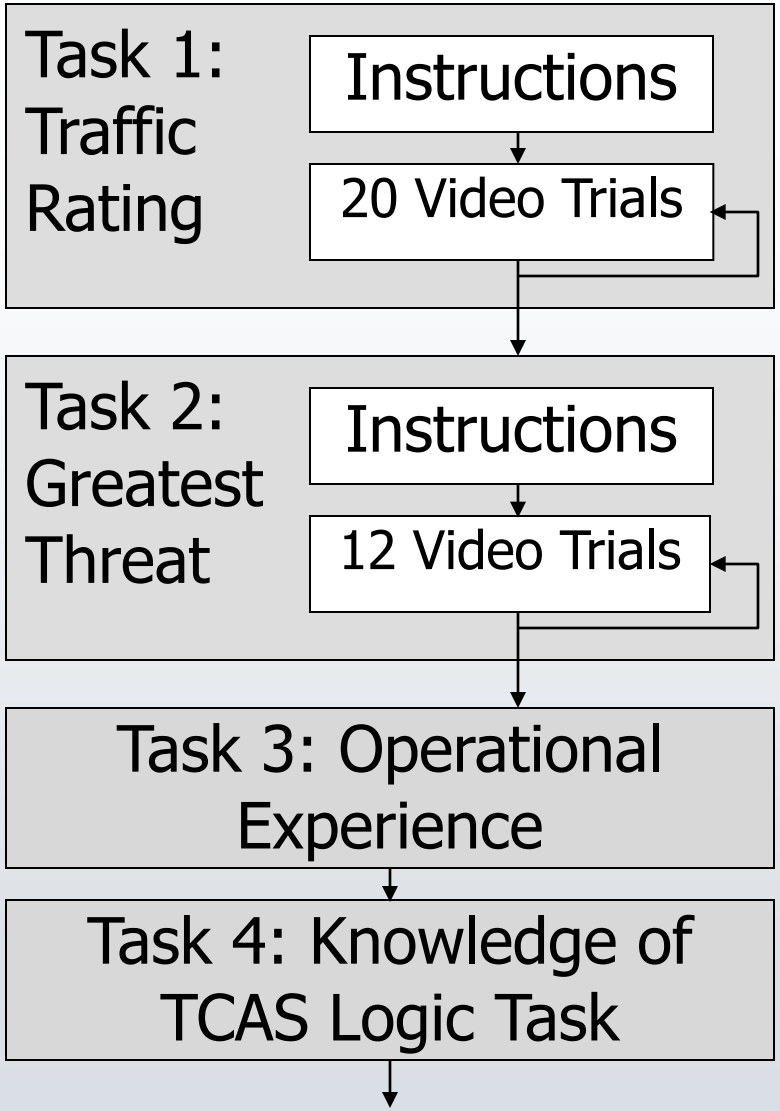
Method

Can the proximate status indication help? . . . . . .

Can it hurt? . . . . . .

How is it used? . . . . . .

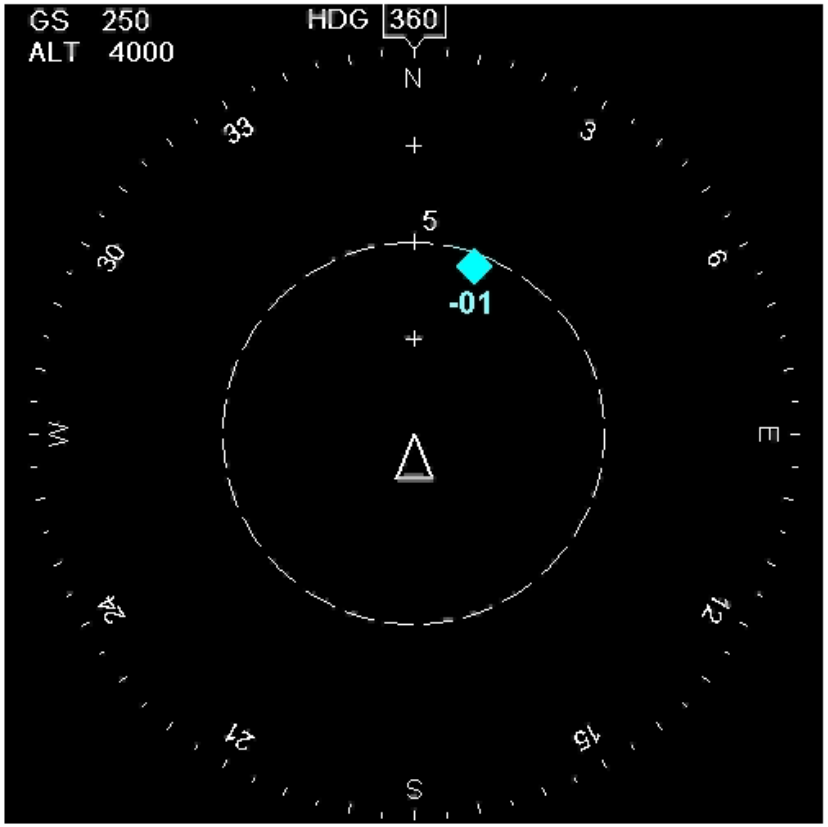
Is it understood? . . . . . .



Task 1: Traffic Rating

Traffic Display Research Study: Task 1 of 4

Trial 1 of 20



What is the chance of this traffic **becoming a TA** in the next 60 seconds?

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

What is the chance that you could quickly **visually acquire** this traffic with visibility unrestricted?

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Submit

Correlate with actual TA and visibility potential

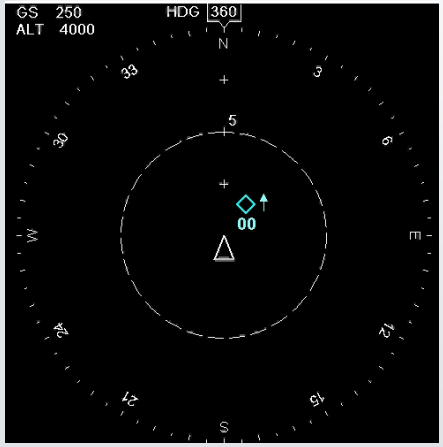
15 second videos

Task 1: Traffic Rating Conditions

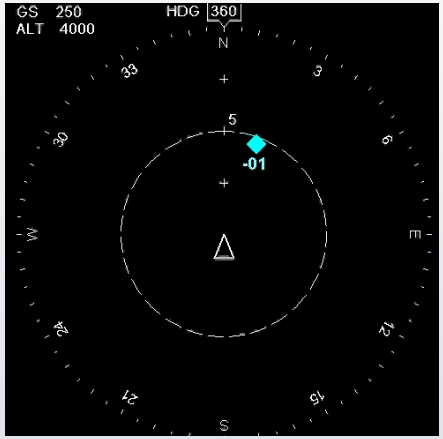
2x2 Between-Subjects design

- Proximate Status Indication (Present/absent)
- Traffic Density (Low or High)

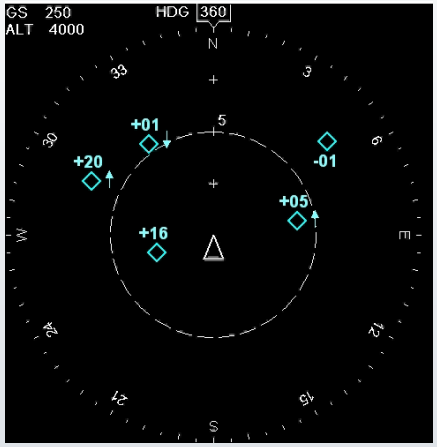
Indication Absent



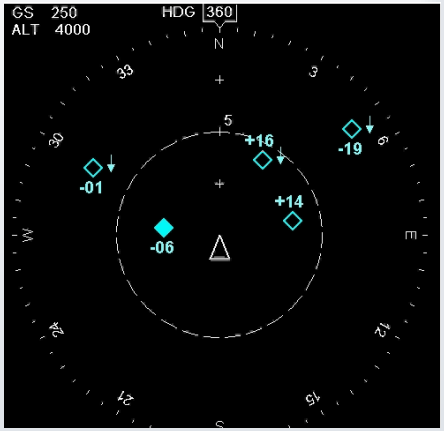
Indication Present



Indication Absent



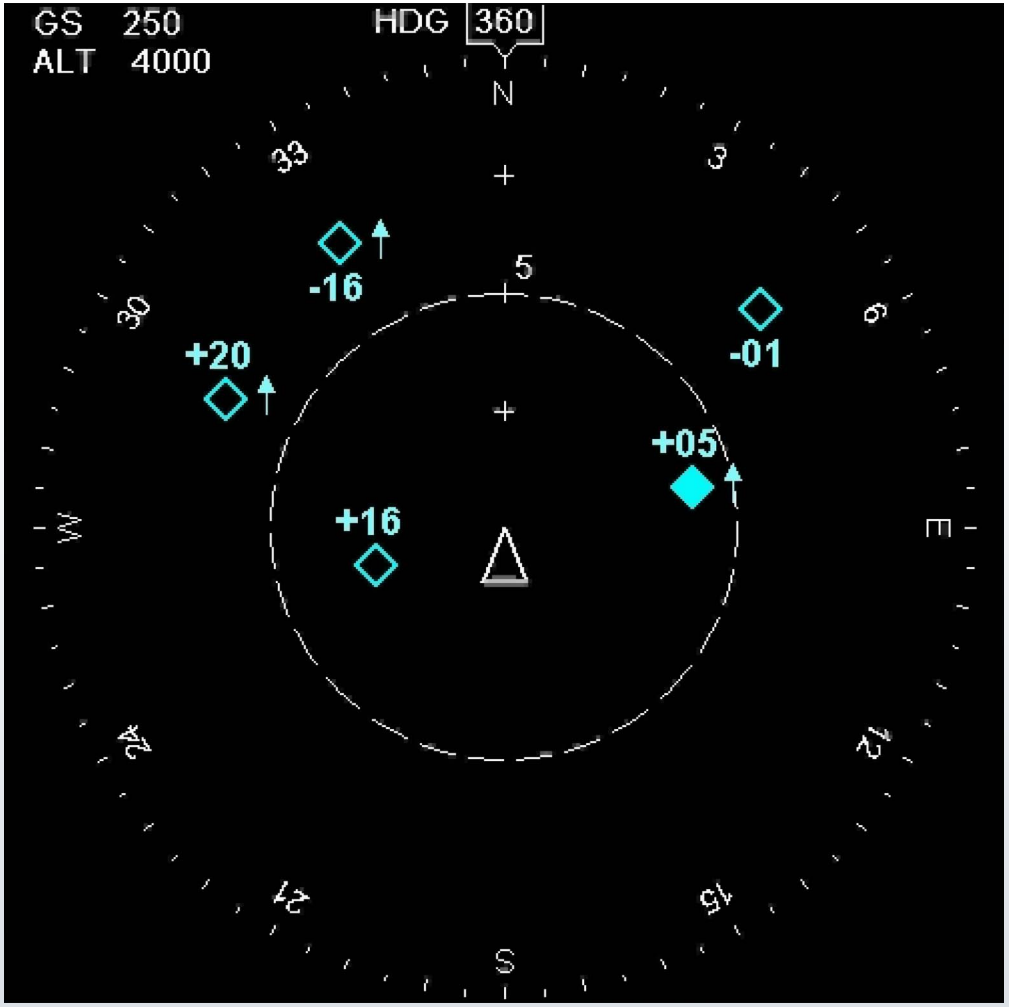
Indication Present



Low Traffic Density

High Traffic Density

Task 1: Traffic Rating Example

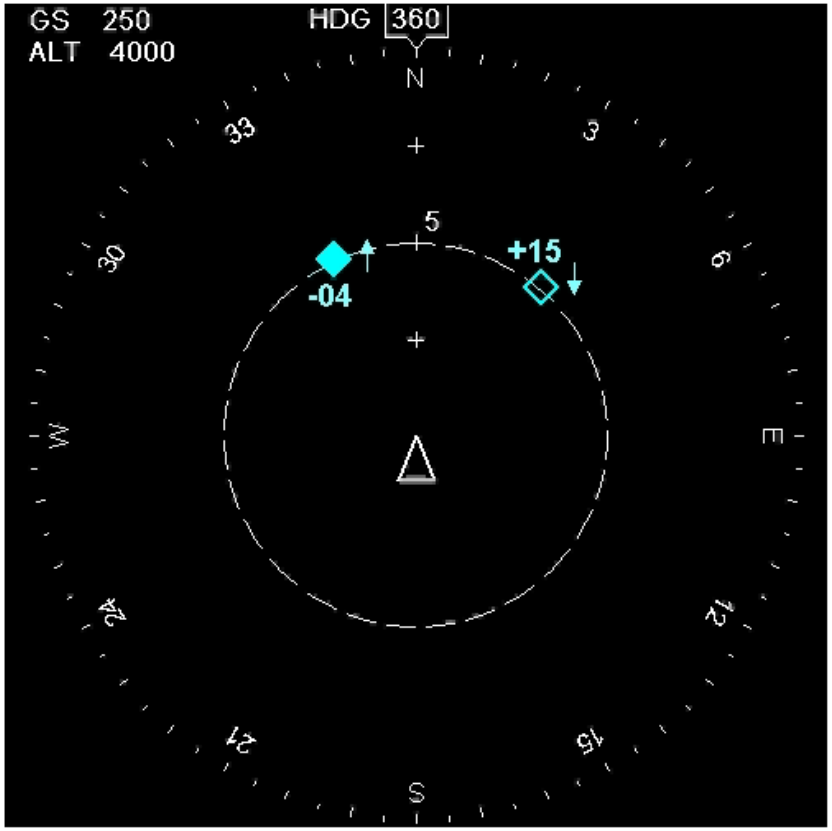


- Proximate Status Indication present
- High Traffic Density
- Target of interest is 20 seconds away from becoming a TA at the end of the scenario
- Video freezes at end of scenario in experiment

Task 2: Greatest Threat

Traffic Display Research Study: Task 2 of 4

Trial 1 of 12



Which aircraft is most likely to produce a TCAS traffic advisory (TA) in the next 60 seconds?

- A
- B

How confident are you that the target you chose is the greatest threat?

1	2	3	4	5	6	7
Complete Guess						Absolutely Certain

Submit

Percent Correct

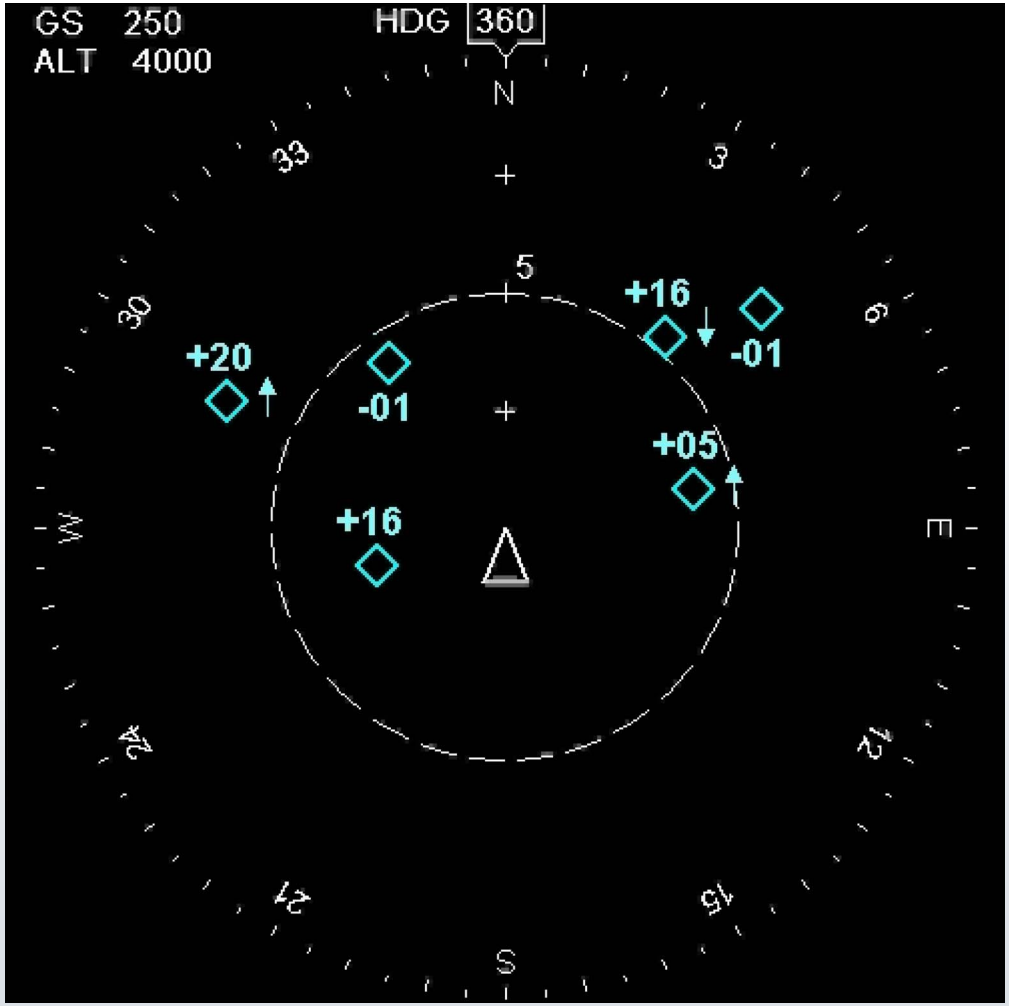
15 second videos

Task 2: Greatest Threat Conditions

- Between-subjects Variables (same as Task 1)
  - Proximate Status Indication (Present or Absent)
    - TCAS-like proximate status indication or only unfilled symbols
  - Traffic Density (Low or High)

- Within-subjects Variable (new)
  - Source of Greatest Threat (Proximate or Non-proximate)
    - Which of the two converging targets is the greatest immediate threat?
    - Proximate vs. non-proximate target (50-50 split)

Task 2: Greatest Threat Example



- Proximate Status Indication absent
- High Traffic Density
- Source of greatest threat is the non-proximate target
- Video freezes at end of scenario in experiment

Task 3: Operational Experience

Traffic Display Research Study

Task 3 of 4

Please answer the questions below based on your **operational experience** with TCAS. There are no correct or incorrect answers.

1. Based on your **operational flight experience**, do you feel that distinguishing traffic with ◇ and the ◆ symbols on TCAS traffic displays is useful?
   ○ **Yes** ○ **No**

   If **yes**, please describe situations where the distinction is useful.

   If **no**, please explain further, with examples if possible.

2. Similarly, based on your **operational flight experience**, are there any situation(s) when you felt that the distinction between ◇ and the ◆ symbols on TCAS traffic displays caused confusion or created complications?
   ○ **Yes** ○ **No**

   If **yes**, please describe situations where the distinction created confusion or complications.

   What changes to the two symbols above would help to clear up the confusion or complications?

Task 3 of 4 completed. When you are ready, please click the **Next** button.

Next

Task 4: TCAS Logic Knowledge

Traffic Display Research Study

Task 4 of 4

The following items ask about the definitions of TCAS symbols. Indicate which of the statements must be true by selecting either the Yes or the No option.

	Yes	No	
1.	○	○	● is always a more imminent collision threat than ◆.
2.	○	○	● is always *within* a certain distance and altitude boundary around your own aircraft, whereas ◆ is *outside* that boundary.
3.	○	○	● always requires more prompt awareness by you than ◆.
4.	○	○	● always requires you follow a vertical speed command.
5.	○	○	◆ is always a more imminent collision threat than ◇.
6.	○	○	◆ is always *within* a certain distance and altitude boundary around your own aircraft, whereas ◇ is *outside* that boundary.
7.	○	○	◆ always requires more prompt awareness by you than ◇.
8.	○	○	◆ always requires you follow a vertical speed command.

Task 4 of 4 Completed. When you are ready, please click the **Next** button.

Next > Study Summary and Feedback

Results: Participants

Operation	Flight Hours	TCAS I Experience	TCAS II Experience	Overall
Air Transport	8793	3	69	70
Corporate	9429	9	45	47
Military	12675	1	16	16
Private Only	630	3	0	3
Overall	8837	12	96	101

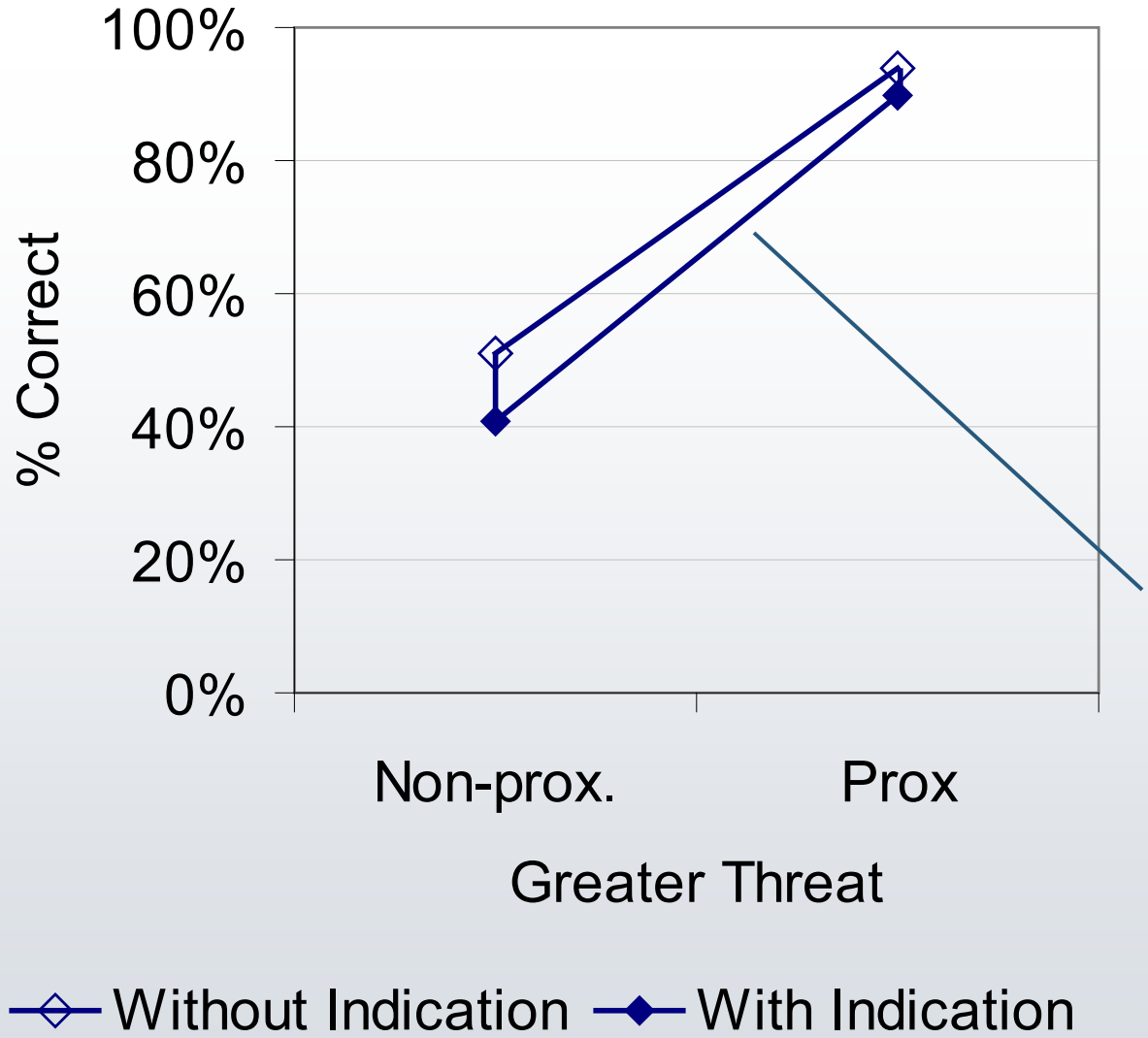
Task 1 Results: Traffic Rating

	TA Potential	Visual Acquisition
Overall consistency between subject ratings and objective measures, across all subjects	$R^2 = 0.472$	$R^2 = 0.477$

No significant performance difference with or without the proximate status indication

(No effects of Traffic Density either.)

Task 2 Results: Greatest Threat



Higher accuracy when the proximate target was actually the greater threat.

9% more accurate on average without the proximate status indication

Task 3 Results: Operational Experience

- Proximate status indication is useful (83% of responses)
  - "It distinguishes [which] target is possibly considered a bigger threat"
  - "I… am more likely to make an effort to begin visual acquisition"
  - "It helps for a quick glance to see something of note"

- Proximate status indication can cause confusion or complications (9% of responses)
  - "Perhaps a short vector symbol on the intruder showing relative closure bearing."
  - "Color coding is best"

Task 4 Results: TCAS Logic Knowledge

Question	Percent of Pilots Agreeing	
	◆ vs ◇	● vs ◆
Closer laterally/vertically	64% ✓	47% ✗
More imminent collision threat	65% ✗	85% ✓
Requires more prompt awareness	68% ✗	85% ✓

✓ indicates that the item was true, so pilots who agreed with the statement were correct.

✗ indicates that the item was false, so pilots who agreed with the statement were incorrect.

Summary of Data Regarding the Proximate Status Indication

Question	Evidence
Can it help?	No improvement in threat/visibility judgments
Can it hurt?	Somewhat (9%) more accurate <u>without</u> the proximate status indication
How is it used?	Often to select potential threats to watch
Is it understood?	Proximity generally thought of as threat indicator

- ∴ Does not appear to be useful based on performance on our tasks, but pilots feel it is useful.

  This may be because pilots emphasize closeness over relative velocity in their mental model for threat assessment.

Future Research: How best to use Symbol Fill?

Potential Use	Research Issues
Use Symbol Fill to indicate proximate status	We found few benefits for assessing TAs and visibility. Are there other intended functions?
Use Symbol Fill as a sub-caution advisory	Is there need for third (lower-level) advisory indication? How would pilots use that?
Use Symbol Fill for other information	Is it okay to define symbol fill differently for TCAS and CDTI? What about integrated TCAS-CDTI displays?

Questions?