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Detection of *Common Warfighting Symbology* (MIL-STD-2525) Air Symbols

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ABSTRACT

The *Common Warfighting Symbology Standard* Bravo version (MIL-STD-2525B) is a contractual requirement for a number of Australian defence projects. To evaluate how well MIL-STD-2525B supports rapid and accurate detection of symbols in clutter the current study examined the speed and accuracy with which 23 participants could detect the presence of each MIL-STD-2525B air affiliation symbol when symbol overlap and icon presence were manipulated. Detection efficiency and accuracy were significantly lower for MIL-STD-2525B friend, assumed friend, suspect and hostile symbols than for neutral and unknown symbols. Symbol overlap significantly reduced detection efficiency and accuracy. Icon presence reduced detection efficiency only. The results indicate that it was difficult to detect important air symbols in MIL-STD-2525B. The study also examined detection of friend, assumed friend, suspect and hostile symbols from the updated version of the standard, MIL-STD-2525C. The MIL-STD-2525C representation of suspect affiliation improved detection efficiency for suspect and hostile symbols compared to MIL-STD-2525B but the representation of assumed friend affiliation produced poorer detection efficiency for assumed friend and friend symbols. Thus the change to the suspect symbol proposed in MIL-STD-2525C appeared to be effective, but further work is required to modify the assumed friend symbol within the scope of the standard to improve the detection performance of friend and assumed friend symbols.

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Executive Summary

Military tactical command and control displays typically use symbols to convey information about the location, affiliation, and identity of objects within the battle space. These symbols must be detected and understood quickly and accurately if they are to effectively support situation awareness and decision making.

Current defence projects, e.g. JP2089 Phase 2A, will introduce the *Common Warfighting Symbology* standard into naval and joint tactical displays and currently mandate the use of MIL-STD-2525B. The proposed implementation of MIL-STD-2525B may make it difficult to distinguish hostile symbols from suspect symbols and friend symbols from assumed friend symbols, particularly when symbols are overlapping and when symbol icons are displayed. A more recent version of the standard, MIL-STD-2525C, has been released in which changes have been made to the suspect and assumed friend symbols. It may be that MIL-STD-2525C will allow these symbols to be more easily distinguished.

The current study aimed to:

1. Measure how effectively each MIL-STD-2525B air affiliation symbol could be detected by operators and how detection is affected by symbol overlap and the presence of icons within the symbol frames.
2. Evaluate the effect of the changes to assumed friend and suspect affiliation symbols contained in MIL-STD-2525C.

Fast and accurate detection of symbol affiliation is a precursor to effective tactical picture comprehension and decision making and the current study used a visual search task to explore the speed and accuracy with which each affiliation could be detected when displayed among a set of all other affiliations.

The current study found that:

- MIL-STD-2525B *assumed friend*, *friend suspect* and *hostile* symbols do not support efficient and accurate detection.
- Symbol overlap caused a substantial reduction in detection efficiency and accuracy, and the presence of icons caused a smaller reduction in detection efficiency only. The presence of icons did not increase the effect of overlap but this may have been due to the specific overlap geometry used in the study.
- The MIL-STD-2525C representation of *suspect* improved detection performance for *suspect* and *hostile* affiliations compared to MIL-STD-2525B.
- However, the MIL-STD-2525C representation of *assumed friend* worsened detection performance for *assumed friend* and *friend* affiliations compared to MIL-STD-2525B.

Several recommendations arise from the current study:

- Changes should be made to how the *Common Warfighting Symbology* standard is implemented in RAN projects. At a minimum, changes are needed to suspect and assumed friend symbols. The changes could either involve continuing to use MIL-STD-2525B but changing the colour of suspect and assumed friend symbols or moving to MIL-STD-2525C.
- In either case further work is required to develop and empirically evaluate new assumed friend and suspect symbols that are consistent with the chosen version of the *Common Warfighting Symbology* standard and will allow these symbols to be easily distinguished from other symbols within the symbols set. Other relevant symbol recommendations proposed in MIL-STD-2525C, such as the use of purple to denote civilian air tracks, should also be investigated.
- Conduct a follow-on study to clarify the effect of icon presence on symbol detection under different overlap conditions.
- In addition to detection performance, examine the ability of the symbols and icons to support the higher-level tasks of symbol classification and tactical picture comprehension.
- Identify and experimentally evaluate display options that eliminate symbol overlap but still allow accurate picture comprehension for use in future tactical displays. However, given that symbol overlap is likely to be an ongoing problem with current and future displays the effects of symbol overlap should continue to be explored in future studies.

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1. Introduction

Military tactical command and control displays typically use symbols to convey information about the location, affiliation, and identity of objects within the battle space. These symbols must be detected and understood quickly and accurately if they are to effectively support situation awareness and decision making. A range of symbology sets exist, including the Naval Combat Data System (NCDS) which is currently used on some Royal Australian Navy platforms, the *North Atlantic Treaty Organisation Standardisation Agreement* (NATO STANAG 4420) and the *Common Warfighting Symbology* standard (MIL-STD-2525). Current Australian defence projects, e.g. JP2089 and SEA4000, will introduce the *Common Warfighting Symbology* standard into naval and joint tactical displays and this symbol set is the focus of the current study.

Symbols in the *Common Warfighting Symbology* set are composed of a frame which uses shape and colour to denote the category (space, air, surface or subsurface) and the affiliation (*friend*, *assumed friend*, *neutral*, *suspect*, *hostile* or *unknown*) of an object. Frames may be filled, in which case the interior of the frame is filled with the affiliation colour, or unfilled, when the interior of the frame is transparent but the frame border is the colour of the affiliation. Symbols may also contain an icon or letter located inside the frame that represents the platform type of the object (e.g. fighter, helicopter, missile) and use modifiers to provide additional information about an object such as leader lines that denote course and speed and text modifiers to denote track number, call sign, altitude/depth, IFF mode and engagement status.

The *Common Warfighting Symbology* standard recognises that different operational requirements may require that different amounts of information about an object be displayed. Accordingly it provides the flexibility to allow for frames, fill and icons to be independently turned on or off (DoD, 2007, p. 62). The standard also recommends default colours for each affiliation but advises that "implementors should include sufficient usability testing to ensure effective operator performance when selecting colours to render the symbology" (DoD, 2007, p. 71).

The *Common Warfighting Symbology* has also undergone a number of revisions since its initial release in September 1994. The most recent update has been from MIL-STD-2525B Change 2 to MIL-STD-2525C in November 2008 (DoD, 2008) which, among other things, introduced changes to how the *assumed friend* and *suspect* affiliations are displayed. MIL-STD-2525B uses a small question mark near the upper-right corner of the symbol frame to denote these affiliations whereas MIL-STD-2525C uses a dashed white and coloured frame. These changes were a result of empirical studies conducted by the Naval Surface Warfare Centre (Davidson & Wetzel, 2007) and, although details of the studies were not published, suggest that usability problems may exist with MIL-STD-2525B. One of these problems may be that the use of a question mark made *assumed friend* and *suspect* affiliations difficult to detect on cluttered displays. *Common Warfighting Symbology* also allows for icons to be displayed with the symbol frames. While this may provide classification information about tracks, the presence of icons within the symbol frames has been shown to increase detection time (McFadden, Jeon, Li, & Minniti, 2008) and the presence of icons may exacerbate the difficulty of detecting MIL-STD-2525B *suspect* and *assumed friend* symbols by obscuring the question marks.

Current defence projects mandate the use of MIL-STD-2525B and require that icons be displayed. Given the possible problems identified above, the current study had two objectives:

1. To evaluate the detection of MIL-STD-2525B air symbols and how detection is affected by symbol overlap and icon presence.

2. To evaluate the effect of the changes to assumed friend and suspect symbols contained in MIL-STD-2525C.

The current study used a visual search task to identify the speed and accuracy with which affiliation symbols could be detected when displayed among other affiliation symbols while symbol overlap and icon presence were manipulated. In support of objective 1, the current study included each MIL-STD-2525B air affiliation symbol (*friend*, *assumed friend*, *neutral*, *suspect*, *hostile*, *unknown*). To support objective 2, detection of *assumed friend, suspect, friend and hostile* affiliations from the MIL-STD-2525C symbol set was tested. *Assumed friend* and *suspect* affiliations were tested as changes have been made to these symbols in MIL-STD-2525C. *Friend* and *hostile* were also tested as, although these symbols did not change, their detection may be affected by the changes to the *assumed friend* and *suspect* symbols. The study used only air symbols in order to control the number of symbols that needed to be tested and also because detection of air and missile threats is particularly time-critical.

Fast and accurate symbol detection must occur prior to tactical picture comprehension, and measures of single-symbol detection performance under simple display conditions provide a controlled means of identifying symbols which may hinder picture comprehension and therefore decision making in the more complicated displays that are likely to be encountered in real military operations.

2. Method

2.1 Participants

Twenty-three employees of the Defence Science and Technology Organisation (DSTO), Australia, participated in the study. The mean age was 38.1 years (*SD* = 8.0 years). All had normal colour vision tested using the 12-plate Ishihara colour test. Participants wore their normal corrective lenses (glasses, contact lenses) as required.

2.2 Materials and Apparatus

The experiment was controlled using PsyToolkit (Stoet, 2010) and run on a computer using Ubuntu 10.10 with a P4 3.6 GHz processor, 1 Gb of RAM and a NVIDIA GeForce 7800 GTX 256 Mb dual-link DVI video card to drive a Dell 30" monitor at its native resolution of 2560 x 1600 pixels at 60 Hz.

Each trial presented a visual stimulus that displayed a number of symbols located within a circle of radius of 600 pixels (151 mm) centred in the monitor. The circle subtended a

visual angle of 26 degrees at the approximate viewing distance of 650 mm. The symbols were randomly distributed on a uniform regular grid within the circle with a minimum spacing of 98 pixels.

The symbol set used is shown in Figure 1. The frame of each symbol had height of between 23 and 35 pixels and a width of between 21 and 27 pixels, subtending a visual angle of approximately 30 minutes of arc at the approximate viewing distance of 650 mm. The R:G:B values were 255:48:49 for *hostile* and *suspect*, 0:255:255 for *friend* and *assumed friend*, 0:255:0 for *neutral* and 255:255:0 for *unknown*. The white in the 2525C *assumed friend* and *suspect* frames was 255:255:255.

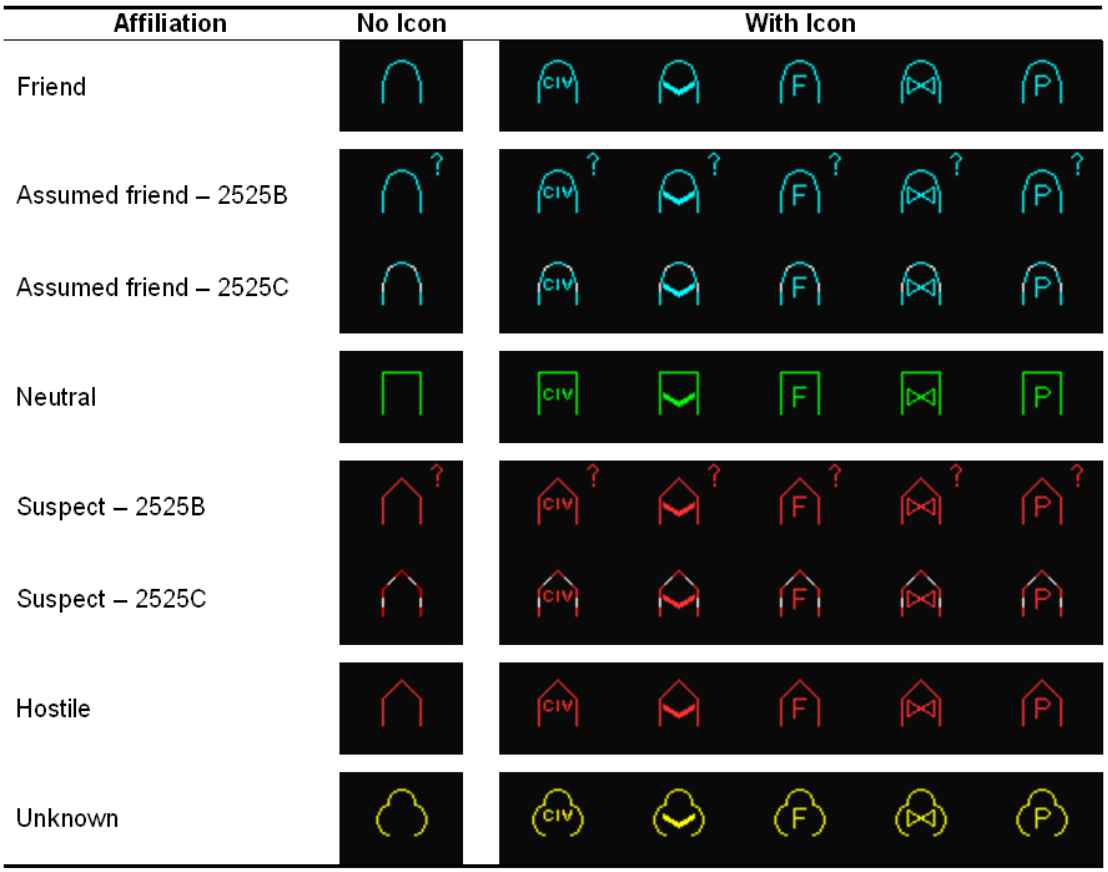


Figure 1 The symbols used in the current study

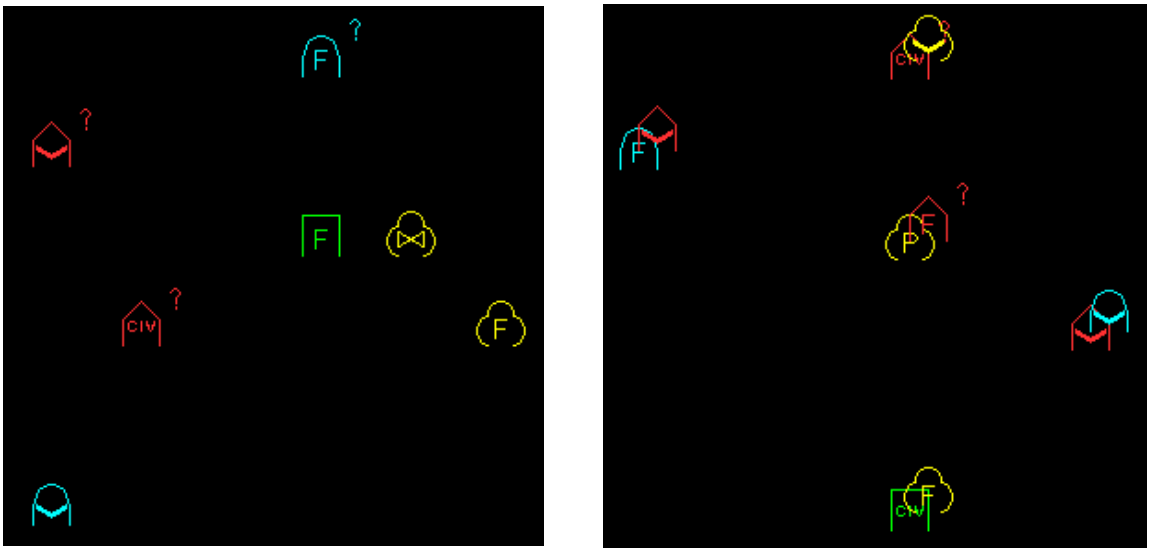
2.3 Measures

Response time and accuracy were recorded for each trial. Response time was the period between stimulus display and when a participant indicated, via a key press, whether a symbol of a particular affiliation was present or not. Accuracy was whether the decision was correct or not.

2.4 Design

The study tested the detection performance of each affiliation symbol in MIL-STD-2525B (*friend*, *assumed friend*, *neutral*, *suspect*, *hostile* and *unknown*) and a subset of affiliation

symbols from MIL-STD-2525C (*friend*, *assumed friend*, *suspect* and *hostile*). In each case the target symbols were displayed among all other affiliation symbols within their symbol set. Symbol overlap and icon presence were manipulated. Symbols were either not overlapping or two symbols overlapped by approximately 50% along an axis rotated 45 degrees from horizontal as shown in Figure 2. Symbols were displayed either with or without icons as shown in Figure 1. Either 10 or 40 symbols were displayed which allowed the response time slope to be calculated as described in 2.6. The target symbol was present for 50% of trials. Each condition was fully crossed and five trials were presented in each condition which required 10 (affiliation) x 2 (10 or 40 symbols) x 2 (icon or no icon) x 2 (overlap or no overlap) x 2 (target present or not present) x 5 = 800 trials. Trials were grouped in blocks of symbol affiliation with block order determined by a balanced Latin-square design. The presentation order of trials within blocks was randomized. Each participant completed all conditions.



Non-Overlapping Symbols Overlapping Symbols

Figure 2 Example of the non-overlap (left panel) and overlap conditions for symbols with icons

2.5 Procedure

Participants were seated in front of the computer monitor, briefed on the experimental task and undertook a short gaze-direction calibration procedure to allow the collection of eye-tracking data not reported here. Participants then completed a block of 16 practice trials, one of each condition, using a *neutral* affiliation target. Participants then completed a seven-item mood scale, not reported here, before commencing the first of the 10 trial blocks. Each block took approximately 5 minutes to complete and participants were given the opportunity to break between blocks. Immediately after the completion of the final block participants again completed the seven-item mood scale and the colour vision test. The entire experimental session lasted for approximately 70 minutes.

2.6 Analysis

Response time and accuracy will be analysed separately. The average response time of trials with a correct response was calculated for each condition. From this the response

time slope (RT slope) was calculated as the difference in response time between 40-symbol trials and 10-symbol trials in each condition divided by the difference in the number of symbols in each trial. RT slope provides a measure of the efficiency of the visual search independent of set size which can be compared to other studies (Wolfe, 1998). The percentage of trials in each condition with an incorrect response was used as the measure of accuracy. Repeated-measures analysis of variance (ANOVA) was used for the analyses with Greenhouse-Geisser corrections applied when violations of the assumption of sphericity were identified.

3. Results

The effects of overlap and icon presence on detection performance for MIL-STD-2525B symbols will be presented initially. This analysis will combine target-present and target-absent trials to explore how these factors influence the ability to detect or reject the presence of particular symbols. Next a comparison of the detection performance of each MIL-STD-2525B affiliation will be presented. This analysis will use only target-present trials as the focus is on how effectively each symbol can be detected and will allow the RT slope results to be compared with other studies. Finally a comparison of the detection performance of the MIL-STD-2525B and MIL-STD-2525C representations of *friend*, *assumed friend*, *suspect* and *hostile* symbols will be presented. This analysis will also use only target-present trials.

3.1 Effect of Symbol Overlap and Icon Presence in MIL-STD-2525B

Plots of the RT slope and error for the symbol overlap and icon presence manipulations for the MIL-STD-2525B symbols are shown in Figure 3. Overlapping symbols had a significantly higher RT slope and error rate than non-overlapping symbols, $F(1,22) = 168.23$, $p < .001$, $\eta_p^2 = .884$ and $F(1,22) = 159.94$, $p < .001$, $\eta_p^2 = .879$ respectively. Thus searching overlapping symbols was less efficient and more error prone than searching symbols that did not overlap. The presence of icons significantly increased RT slope, $F(1,22) = 11.31$, $p = .003$, $\eta_p^2 = .340$, but not errors, $F(1,22) = .02$, $p = .889$, $\eta_p^2 = .001$. Thus searching for symbols with icons was less efficient than searching for symbols without icons but this did not translate into increased errors. The overlap x icon interaction was not significant for RT slope or error, $F(1,22) = 2.08$, $p = .164$, $\eta_p^2 = .086$ and $F(1,22) = .03$, $p = .866$, $\eta_p^2 = .001$. This indicates that the effect of symbol overlap was not moderated by the presence of icons.

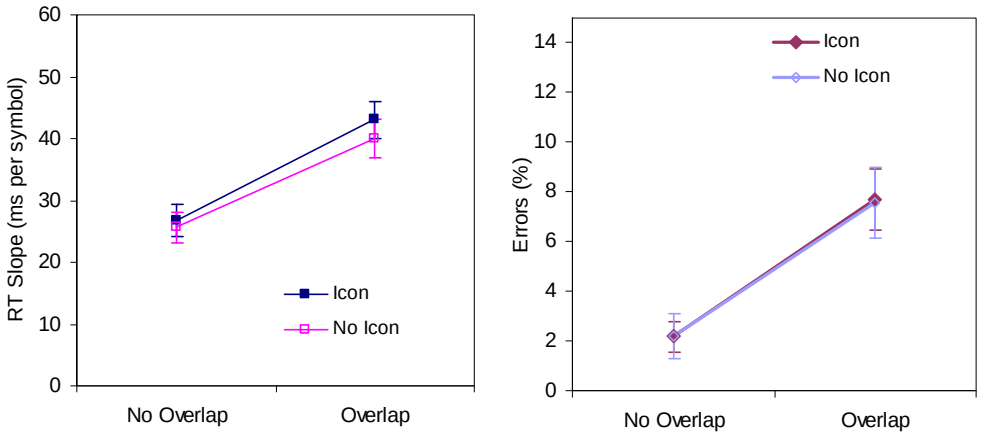


Figure 3 Mean RT slope (left plot) and errors (right plot) for the overlap and icon manipulations for MIL-STD-2525B symbols. Error bars represent 95th percentile confidence intervals.

3.2 Comparison of MIL-STD-2525B Symbol Detection Performance

The next step was to compare the detection performances of each MIL-STD-2525B symbol using only target-present trials and plots of average RT slope and error for overlapping and non-overlapping symbols are shown in Figure 4. Icon presence was collapsed across trials due to its small effect size. There were significant differences in RT slope and error between symbols, $F(5,110) = 32.39$, $p < .001$, $\eta_p^2 = .595$ and $F(5,110) = 9.31$ $p < .001$, $\eta_p^2 = .297$ respectively. Pairwise comparisons indicated that *unknown*, *neutral* and *assumed friend* did not differ in RT slope but had significantly lower RT slopes than *friend*, *suspect* and *hostile* which did not significantly differ from each other. *Unknown* and *neutral* symbols had RT slopes of approximately 12 ms / symbol whereas the other symbols had an average RT slope of approximately 25 ms / symbol. A similar pattern was obtained for error, with the exception that *assumed friend* grouped with *friend*, *suspect* and *hostile* affiliations. There was also a significant overlap x ID interaction for both RT slope and error, $F(3.05,67.03) = 8.86$, $p < .001$, $\eta_p^2 = .287$ and $F(5,110) = 14.64$ $p < .001$, $\eta_p^2 = .400$ respectively. Overlap decreased efficiency and increased errors more for *assumed friend*, *friend*, *suspect* and *hostile* symbols than for *unknown* and *neutral* symbols.

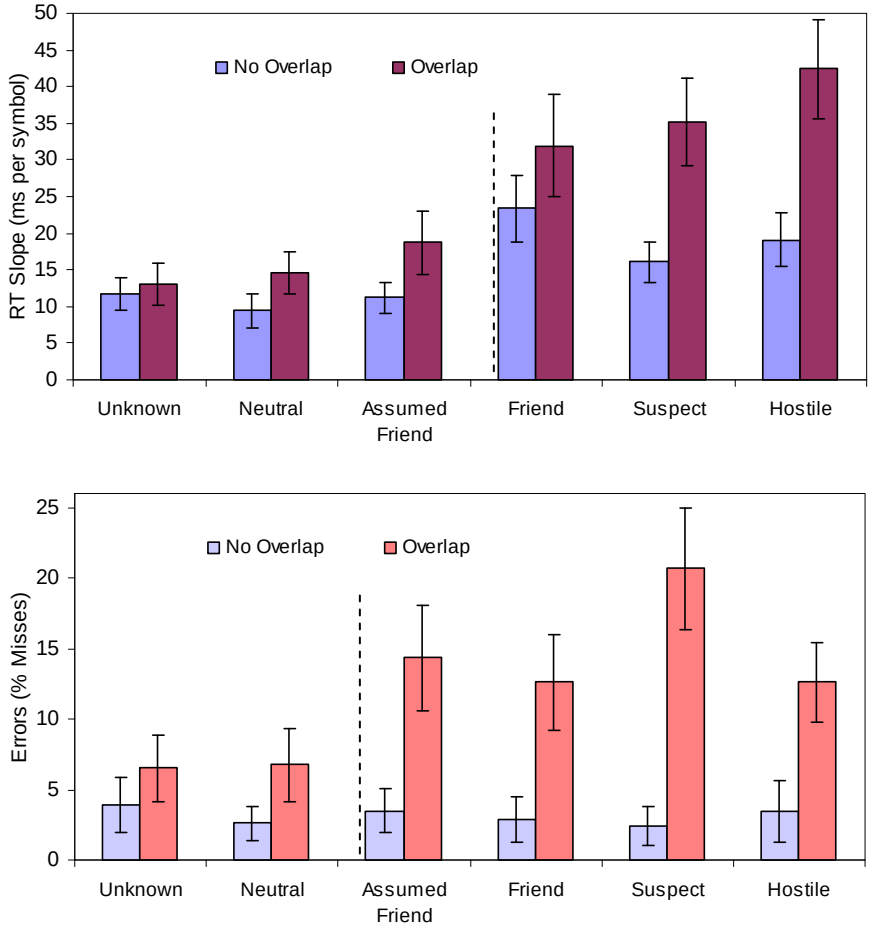


Figure 4 Mean RT Slope and Error for each MIL-STD-2525B affiliation symbol for target-present trials. Error bars represent the 95th percentile confidence intervals. The dotted line separates the two post-hoc test groups.

3.3 Comparison between MIL-STD-2525B and MIL-STD-2525C *Friend, Assumed friend, Suspect* and *Hostile* Symbols

MIL-STD-2525C introduces changes to *assumed friend* and *suspect* symbols which may influence their detection performance and also that of *friend* and *hostile* symbols which they closely resemble. The RT slope and error results for *assumed friend* and *friend* symbols in MIL-STD-2525B and MIL-STD-2525C are shown in Figure 5. Overall, the MIL-STD-2525C representation of *assumed friend* led to worse detection performance for both *assumed friend* and *friend* symbols than the MIL-STD-2525B representation, with a higher RT slope and greater errors, $F(1,22) = 102.9$, $p < .001$, $\eta_p^2 = .824$ and $F(1,22) = 62.69$, $p < .001$, $\eta_p^2 = .740$ respectively. Detection of *assumed friend* symbols was more efficient than *friend* symbols, $F(1,22) = 15.29$, $p = .001$, $\eta_p^2 = .410$, and although this gap appeared to reduce in MIL-STD-2525C the symbol x symbol set interaction just failed to reach significance for RT slope, $F(1,22) = 3.96$, $p = .059$, $\eta_p^2 = .152$. The symbol x symbol set interaction was significant for error, $F(1,22) = 24.85$, $p < .001$, $\eta_p^2 = .530$, with *assumed friend* having a higher miss rate than *friend* in MIL-STD-2525C whereas they had similar miss rates in MIL-STD-2525B.

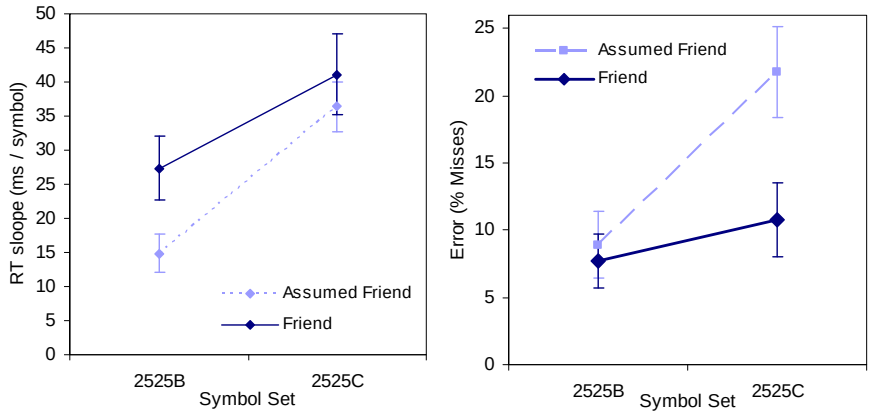


Figure 5 *Mean RT Slope (left plot) and error (right plot) for the MIL-STD-2525B and MIL-STD-2525C representations of assumed friend and friend affiliations. Error bars represent the 95th percentile confidence intervals.*

The RT slope and error results for *suspect* and *hostile* symbols in MIL-STD-2525B and MIL-STD-2525C are shown in Figure 6. Unlike *assumed friend*, the change to the *suspect* symbol in MIL-STD-2525C improved search performance for both *suspect* and *hostile* symbols. Overall both their RT slope and error were lower for MIL-STD-2525C than MIL-STD-2525B, $F(1,22) = 96.85$, $p < .001$, $\eta_p^2 = .815$ and $F(1,22) = 5.73$, $p = .026$, $\eta_p^2 = .207$ respectively. There was a significant set x symbol interaction for both RT slope and error, $F(1,22) = 23.13$, $p < .001$, $\eta_p^2 = .512$ and $F(1,22) = 6.89$, $p = .015$, $\eta_p^2 = .239$ respectively. *Suspect* symbols were detected more efficiently than *hostile* symbols in MIL-STD-2525B, but this was reversed in MIL-STD-2525C where *hostile* symbols were detected more efficiently than *suspect* symbols. The miss rate for *hostile* symbols was also decreased in MIL-STD-2525C without changing the miss rate for *suspect* symbols.

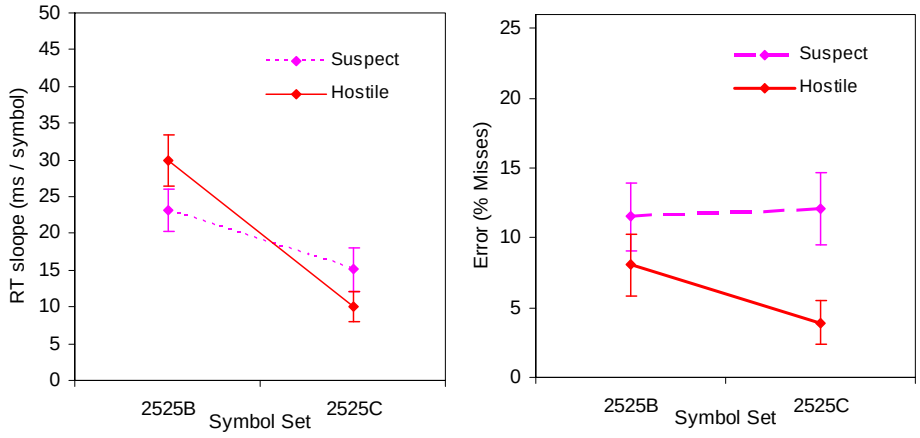


Figure 6 *Mean RT Slope (left plot) and error (right plot) for the MIL-STD-2525B and MIL-STD-2525C representations of suspect and hostile affiliations. Error bars represent the 95th percentile confidence intervals.*

4. Discussion

The current study investigated how symbol overlap and icon presence affected symbol detection and performance and how quickly and accurately each MIL-STD-2525B affiliation symbol could be detected when displayed among all other affiliation symbols in the set. The study also examined how the changes to *assumed friend* and *suspect* symbols proposed in MIL-STD-2525C affected detection performance of these symbols and any effect that these changes may have had on *friend* and *hostile* symbols which are similar in appearance.

4.1 Effect of Symbol Overlap and Icon Presence in MIL-STD-2525B

Symbol overlap substantially reduced search efficiency and increased errors. It was easier to detect a symbol when it is displayed in isolation than when it was overlapping another symbol which created a more complicated combined figure from which its shape must be identified. In this regard symbol overlap might be considered similar to a non-uniform background, and other studies have found background characteristics to have a substantial effect on the detection of even simple, familiar targets (Yamani & McCarley, 2011).

As suspected, icon presence led to a less efficient search. However, the size of the effect was only moderate and did not lead to any change in error rates. While the presence of icons may provide amplifying information about objects that may assist tactical picture comprehension, if they are not needed they should be turned off. Hence it is recommended that icon presence be operator selectable.

While there was a tendency for search efficiency for overlapping symbols to be less efficient when icons were present than when they weren't, this effect did not reach significance. This was contrary to expectations that the presence of icons would obstruct the shape and colour of the overlapping frames and make targets more difficult to identify, especially for the MIL-STD-2525B *assumed friend* and *suspect* symbols. However, it may be that the specific overlap geometry used in the current study masked a potentially larger effect of icons. An inspection of Figure 2 indicates that in the overlapping symbol pairs the question mark of one symbol overlaps with the frame, not the icon, of the other symbol. This meant that the question mark was equally obscured in the icon and no icon conditions and may explain why the effect of overlap was independent of icon presence. It may be that a different overlap geometry in which the question marks coincided with the icon and not the frame of the other symbol may reveal a more substantial effect of icons.

4.2 Detection of MIL-STD-2525B Symbols

The results of the current study clearly indicate that substantial differences exist between the detection performance of individual MIL-STD-2525B symbols. *Unknown* and *neutral* symbols were detected more efficiently and with fewer misses than *friend*, *assumed friend*, *suspect* and *hostile* symbols. The target-present RT slopes for *unknown* and *neutral* symbols were approximately 12 ms / symbol which is considered to be an efficient search (Wolfe, 1998) and indicates that these symbols tend to "pop out" of the display. In contrast the

average target-present RT slopes for the other symbols were around 25 ms / symbol which indicates that inefficient searches were required to detect these symbols.

The difficulties observed with MIL-STD-2525B *friend*, *assumed friend*, *suspect* and *hostile* symbols are particularly evident in the overlapping condition where their detection performance degrades substantially more than the *unknown* and *neutral* symbols and where their presence was missed on an average of approximately 15% of trials. This would seem to be a worryingly high error rate.

Another possible problem with the MIL-STD-2525B symbol set is that *friend* symbols are detected with less efficiency than *assumed friend* symbols and that *hostile* symbols are detected with less efficiency than *suspect* symbols. It would seem desirable for this situation to be reversed, as it would appear important to be able to quickly identify the location of friendly assets among a background of civilian or other *assumed friend* tracks and to be able to distinguish *hostile* tracks that can be engaged from tracks that are *suspect* but cannot be engaged. These relative detection efficiencies are likely to be caused by the use of a question mark to denote *assumed friend* and *suspect* affiliations. The presence of a feature is easier to find than its absence (Treisman & Gormican, 1988; Treisman & Souther, 1985), and it appears more difficult to detect the symbol that does not have a question mark than one that does.

Thus problems exist with the MIL-STD-2525B representation of *friend*, *assumed friend*, *suspect* and *hostile* symbols which appear to require the redesign of the *assumed friend* and *suspect* symbols.

4.3 Evaluation of Symbol Changes in MIL-STD-2525C

It may be that the problems observed in the detection performance of the MIL-STD-2525B *friend*, *assumed friend*, *suspect* and *hostile* symbols can be overcome by adopting the changes proposed in MIL-STD-2525C that *assumed friend* and *suspect* symbols use a white and coloured dashed frame line. However, the results of the current study present a mixed assessment of this approach. The MIL-STD-2525C representation of *suspect* led to a substantial improvement in detection performance for both *suspect* and *hostile* symbols compared to the MIL-STD-2525B representation. Search efficiency for the MIL-STD-2525C *suspect* and *hostile* symbols reduced to approximately 15 ms / symbol and 10 ms / symbol respectively, which is near the results obtained for *unknown* and *neutral* symbols. The MIL-STD-2525C representation also resulted in *hostile* symbols having higher search efficiency than *suspect* symbols.

However, the MIL-STD-2525C representation of *assumed friend* used in the current study led to worse search efficiency and error performance for *assumed friend* and *friend* symbols than the MIL-STD-2525B representation. Participants found it difficult to distinguish the dashed cyan and white frame of the *assumed friend* symbol from the solid cyan frame of the *friend* symbol and commented that there was not sufficient contrast between the cyan and white colours. However, the observed effect might have been caused by any combination of colour contrast, dash length, frame shape, line width or other frame characteristics. The specific monitor used may also have contributed to the problem. What is obvious is that a different implementation of *assumed friend* is required than was used in the current study.

4.4 Limitations of Current Study

A number of limitations associated with the current study need to be noted. First, the experiment used a single-target detection task. This obviously differs from how tactical displays are used in operational settings, which is to generate a comprehensive understanding of the battle environment and support effective decision making. However, fast and accurate detection and recognition of symbols is a necessary first step to this higher goal and problems with symbol detection will interfere with this process. It may be that the reduction in detection efficiency observed when icons are present is offset by an increase in situation awareness made possible by the additional information that icons can provide about battle-space entities. Future studies should evaluate whether this is the case.

A second potential limitation is that the current study used a display that is likely to be simpler than would be experienced in an operational environment. Relatively few symbols were present which had no leader lines or modifiers such as track number or engagement status. The symbols were also presented on a uniform black background with none of the background clutter that may be present on operational tactical displays due to background mapping or radar return video. However, these limitations are likely to make the results of the current study conservative, almost a "best case" outcome, and it may be that the effects observed here will be magnified in operational environments.

A third limitation is that the current study used air symbols only. Air tracks are fast moving and must be identified and responded to quickly, however, air, surface and sub-surface symbols will be simultaneously present on many naval and joint tactical displays and future studies should include symbols from all battle dimensions.

5. Conclusions and Recommendations

The current study found that:

MIL-STD-2525B *assumed friend*, *friend suspect* and *hostile* symbols do not support efficient and accurate detection.

Symbol overlap caused a substantial reduction in detection efficiency and accuracy, and the presence of icons caused a smaller reduction in detection efficiency only. The presence of icons did not increase the effect of overlap but this may have been due to the specific overlap geometry used in the study.

The MIL-STD-2525C representation of *suspect* improved detection performance for *suspect* and *hostile* affiliations compared to MIL-STD-2525B.

However, the MIL-STD-2525C representation of *assumed friend* worsened detection performance for *assumed friend* and *friend* affiliations compared to MIL-STD-2525B.

Several recommendations arise from the current study:

Changes should be made to how the *Common Warfighting Symbology* standard is implemented in RAN projects. At a minimum, changes are needed to suspect and assumed friend symbols. The changes could either involve continuing to use MIL-STD-2525B but changing the colour of suspect and assumed friend symbols or moving to MIL-STD-2525C.

In either case further work is required to develop and empirically evaluate new assumed friend and suspect symbols that are consistent with the chosen version of the *Common Warfighting Symbology* standard and will allow these symbols to be easily distinguished from other symbols within the symbols set. Other relevant symbol recommendations proposed in MIL-STD-2525C, such as the use of purple to denote civilian air tracks, should also be investigated.

Conduct a follow-on study to clarify the effect of icon presence on symbol detection under different overlap conditions.

In addition to detection performance, examine the ability of the symbols and icons to support the higher-level tasks of symbol classification and tactical picture comprehension.

Identify and experimentally evaluate display options that eliminate symbol overlap but still allow accurate picture comprehension for use in future tactical displays. However, given that symbol overlap is likely to be an ongoing problem with current and future displays the effects of symbol overlap should continue to be explored in future studies.

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19. ABSTRACT

The *Common Warfighting Symbology Standard* Bravo version (MIL-STD-2525B) is a contractual requirement for a number of Australian defence projects. To evaluate how well MIL-STD-2525B supports rapid and accurate detection of symbols in clutter the current study examined the speed and accuracy with which 23 participants could detect the presence of each MIL-STD-2525B air affiliation symbol when symbol overlap and icon presence were manipulated. Detection efficiency and accuracy were significantly lower for MIL-STD-2525B friend, assumed friend, suspect and hostile symbols than for neutral and unknown symbols. Symbol overlap significantly reduced detection efficiency and accuracy. Icon presence reduced detection efficiency only. The results indicate that it was difficult to detect important air symbols in MIL-STD-2525B. The study also examined detection of friend, assumed friend, suspect and hostile symbols from the updated version of the standard, MIL-STD-2525C. The MIL-STD-2525C representation of suspect affiliation improved detection efficiency for suspect and hostile symbols compared to MIL-STD-2525B but the representation of assumed friend affiliation produced poorer detection efficiency for assumed friend and friend symbols. Thus the change to the suspect symbol proposed in MIL-STD-2525C appeared to be effective, but further work is required to modify the assumed friend symbol within the scope of the standard to improve the detection performance of friend and assumed friend symbols.