Detection of heading changes in tactical displays

A comparison of two symbol sets

Jocelyn Keillor
DRDC Toronto

Laura Thompson
University of Waterloo

Harvey S. Smallman
Pacific Science and Engineering Group, Inc.

Michael.B. Cowen
Space and Naval Warfare Systems Center

Defence R&D Canada – Toronto

Technical Report

DRDC Toronto TR 2003-008

December 2003

Author

Jocelyn M. Keillor, PhD

Approved by

Keith Hendy

Head, Human Factors Research and Engineering

Approved for release by

Kathy Sutton

Chair, Document Review and Library Committee

Abstract

As the technologies available for tactical displays evolve and improve, the development of tactical symbol sets with which to populate these new displays becomes an important issue. A new method for evaluating symbol sets was developed, using a "change blindness", or flicker paradigm to simulate an operators shifts of attention during interaction with the display and environment. In addition to providing measures of an operator's ability to discriminate symbols and detect changes in the display, this method also provides an indication of the extent to which operators may selectively monitor subgroups of similar contacts for change. In the present experiments two symbol sets were compared: MIL-STD-2525B, and Symbicons, a hybrid symbology developed by the U.S. Navy. Overall, Symbicons outperformed the traditional MIL-STD-2525B symbols when participants were required to detect heading changes in contacts. Furthermore, only the Symbicons allowed participants to take advantage of advance knowledge of the type of platform (sea or air) which would change heading. Neither symbol set permitted selective monitoring of all relevant contacts in the display, and further study is required to determine which coding dimensions best support this type of attentional selection.

Résumé

À mesure qu'évoluent les technologies disponibles concernant les écrans tactiques, la mise au point d'ensembles de symboles tactiques pour remplir ces nouveaux écrans devient une question importante. Une nouvelle méthodologie d'évaluation des ensembles de symboles a été mise au point, selon un paradigme de clignotement ou de scintillement, afin de simuler le changement de l'attention chez l'opérateur lors de son interaction avec l'écran et l'environnement. En plus de mesurer la capacité d'un opérateur à discriminer des symboles et à détecter des changements à l'écran, cette méthode permet de savoir dans quelle mesure l'opérateur peut surveiller de manière sélective les changements apportés à des sous-groupes de contacts semblables. Dans les présentes expériences, deux ensembles de symboles ont été comparés : MIL-STD-2525B et Symbicons, une symbologie hybride élaborée par les Forces navales des États-Unis. Globalement, Symbicons a offert des performances supérieures à celles de la norme MIL-STD-2525B classique lorsque les participants ont été appelés à détecter les changements apportés aux en-têtes des contacts. De plus, seule la norme Symbicons a permis aux participants de tirer avantage des connaissances poussées concernant les types de plates-formes (maritime ou aérienne) qui modifieraient un en-tête. Ni l'un ni l'autre ensemble de symboles n'ont permis de surveiller de manière sélective tous les contacts pertinents à l'écran; il faudra procéder à une étude approfondie pour déterminer quelles dimensions de codage appuient le mieux ce type de sélection attentionnelle.

This page intentionally left blank.

Executive summary

As the technologies available for tactical displays evolve and improve, the development of tactical symbol sets with which to populate these new displays becomes an important issue. One of the challenges to any effort to develop tactical symbol sets is the lack of clear guidelines delineating the perceptual and cognitive consequences of design choices. This is further complicated by the variety of ways in which any symbology may be evaluated. This research provides a new methodology for evaluating symbologies, in order to provide measures of not only the ease with which the symbols may be apprehended and discriminated, but also the degree to which they may be selectively monitored for change.

Two symbol sets were compared in terms of the ease with which operators could detect heading changes in the display. Traditional MIL-STD-2525B symbols were compared with Symbicons, a new hybrid symbology developed by the U.S. Navy. Symbicons were designed to facilitate the rapid visual appreciation of their attritibutes by combining the discriminable platform identity of symbols with the conspicuous heading and platform category of icons. The methodology used here enabled a determination of the relative efficacy of the two symbologies for mitigating the otherwise potentially very harmful effects of interruptions on tactical display monitoring. Specifically, the two symbologies were compared in terms of participants' ability to detect changes in heading of contacts using a flicker paradigm that simulates an operator's momentary shifts of attention within or away from the tactical display. After determining that platform categories (Sea and Air) were equally discriminable in the two symbologies, two change detection experiments were conducted. Each experiment compared participants' ability to detect heading changes for the two symbol sets as a function of whether or not their search for changes was constrained by advance information as to the type of contact that would be changing (Sea or Air). The two experiments differed in terms of the background against which the symbols were placed; in Experiment 1 the background water was depicted as blue, and in Experiment 2 it was grey, to facilitate discrimination of the leader line indicating heading. Across the two different background displays the results suggested consistent advantages for the Symbicons, in that heading changes could be detected more rapidly, presumably due to the fact that for these symbols heading is coded by rotating the entire symbol rather than simply a leader line. Furthermore, only for the Symbicons were operators able to make use of advance information as to what platform category the changing contact would belong to, in order to effectively direct their attention to the relevant contacts.

Neither the traditional MIL-STD-2525B symbols nor the newly-developed Symbicons permitted selective monitoring of all relevant contacts in the display, in that operators performance suffered when additional irrelevant contacts were added to the display. That is, in conditions in which operators knew in advance that only an Air contact would change heading, the addition of Sea contacts hindered performance. Further study is required to determine which coding dimensions best support attentional selection of similar contacts relevant to an operator's task, so that symbol sets can be developed to support an operators deployment of attention within the tactical display.

Keillor, J.,Thompson, L., Smallman, H. S., and Cowan, M. B. 2003. Detection of Heading Changes in Tactical Displays: A Comparison of Two Symbol Sets. DRDC Toronto TR 2003-008. DRDC Toronto.

Sommaire

À mesure qu'évoluent les technologies disponibles concernant les écrans tactiques, la mise au point d'ensembles de symboles tactiques pour remplir ces nouveaux écrans devient une question importante. À l'heure actuelle, on a besoin de mettre au point des ensembles de symboles compatibles avec les écrans tridimensionnels d'espaces de combat qui sont en cours d'élaboration. L'un des défis de tout effort de mise au point d'ensembles de symboles tactiques est lié à l'absence de lignes directrices claires délimitant les conséquences, sur les plans perceptuel et cognitif, des conceptions choisies. La diversité des moyens offerts pour l'évaluation des symbologies complique davantage la situation. Cette recherche présente une nouvelle méthodologie d'évaluation des symbologies, dans le but de mesurer non seulement la facilité avec laquelle il est possible d'appréhender et de discriminer les symboles, mais également dans quelle mesure on peut surveiller de manière sélective les changements qui y sont apportés.

Deux ensembles de symboles ont été comparés en ce qui concerne la facilité avec laquelle l'opérateur peut détecter la présence de changements apportés à l'en-tête à l'écran. Ainsi, les symboles MIL-STD-2525B classiques ont été comparés à la norme Symbicons, une symbologie hybride élaborée par les Forces navales des États-Unis, qui combine les caractéristiques des symboles et des icônes classiques. La méthodologie utilisée dans les expériences décrites diffère des méthodes classiques d'évaluation des ensembles de symboles. En effet, on indique dans quelle mesure la symbologie appuie la surveillance sélective de sous-ensembles de cibles pertinentes et on fournit des mesures globales concernant la détection ou la discrimination. Plus précisément, la comparaison des deux symbologies a permis de vérifier la capacité du participant à détecter des changements dans l'en-tête des contacts, d'après un paradigme de scintillement simulant un changement momentané de l'attention chez l'opérateur à l'écran tactique ou à l'extérieur de celui-ci. Après avoir déterminé que les catégories de plates-formes (maritime et aérienne) pouvaient être discriminées de manière égale dans les deux symbologies, nous avons mené deux expériences de changement de la détection. Dans chacune des expériences, nous avons comparé la capacité du participant à détecter la présence de changements dans l'en-tête pour les deux ensembles de symboles, afin de voir si sa recherche de changements était fonction de l'information poussée en ce qui a trait au type de contact modifié (maritime ou aérien). Dans les deux expériences, l'arrière-plan des symboles était différent. En effet, dans l'expérience 1, l'eau était en bleu dans l'arrière-plan, alors qu'elle était en gris dans l'expérience 2, afin de faciliter la discrimination de la ligne de positionnement de l'en-tête. Pour les deux écrans différents de l'arrière-plan, les résultats ont laissé suggérer que Symbicons offrait des avantages constants, dans la mesure où les changements apportés à l'en-tête étaient détectés plus rapidement, probablement du fait que le codage pour l'en-tête de ces symboles est effectué par retournement du symbole entier et non seulement par l'utilisation d'une ligne de positionnement. De plus, seule la norme Symbicons a permis aux opérateurs d'utiliser l'information poussée afin de savoir à quelle catégorie de plate-forme appartenait le contact modifié, dans le but de diriger efficacement leur attention vers les contacts pertinents.

Ni les symboles de la norme MIL-STD-2525B classique ni la norme Symbicons nouvellement élaborée ont permis de surveiller de manière sélective tous les contacts pertinents à l'écran, l'ajout à l'écran de contacts non pertinents supplémentaires nuisant aux performances des opérateurs. Autrement dit, si les opérateurs savaient d'avance que seul un contact aérien changerait un en-tête, l’ajout de contacts maritimes nuisait aux performances. Il faut procéder à une étude approfondie pour déterminer quelles dimensions de codage appuient le mieux la sélection attentionnelle de contacts semblables dans le cadre d’une tâche confiée à un opérateur, de sorte que des ensembles de symboles puissent être mis au point dans le but de favoriser la concentration de l’attention de l’opérateur sur un écran tactique.

Keillor, J.,Thompson, L., Smallman, H. S., and Cowan, M. B. 2003. Detection of Heading Changes in Tactical Displays: A Comparison of Two Symbol Sets. DRDC Toronto TR 2003-008. DRDC Toronto.

This page intentionally left blank.

Table of contents

List of figures

List of tables

Acknowledgements

We thank Matthew Maxwell-Smith and Tonya Stokes and Nada Ivanovic for their assistance with data collection and processing, and Mark St. John for his help with the experimental design. Justin Hollands and Sharon McFadden provided helpful comments on an earlier draft of this paper, and Alexandra Ostaniewicz provided editorial support. We thank Bill Nugent for facilitating our collaboration under the auspices of TTCP HUM TP-9.

Introduction

Symbology for tactical displays

The process of selecting the appropriate symbol sets for tactical displays is shaped by both the tasks of the operators and the available technology. Before the advent of computers, symbols were drawn by hand on paper maps and charts. As technology advanced, symbol sets were developed initially for monochrome monitors and then colour monitors. Conflicts existed because different symbol sets were used for land, air and sea forces. The MIL-STD-2525B Common Warfighting Symbology (Department of Defense, 1999) was developed for use on colour displays by all three branches of the US military (Navy, Army and Air Force).

Recently, a new experimental symbology has been developed by the United States Navy (Space and Naval Warfare Systems Center San Diego and the Pacific Science and Engineering Group) that may be used in either 2-D or 3-D displays. This hybrid *Symbicon* symbology combines the platform information of military symbols with the platform classification and heading information of realistic icons to attempt to create a new symbology that offers rapid appreciation of all depicted track attributes. Thus, the central letter or logo (platform name) and fill colour (threat affiliation) is taken from the Mil-Std-2525B symbols. The shape outline, adapted from realistic icons, codes for platform category (sea or air) and rotates to depict heading (Figure 1).

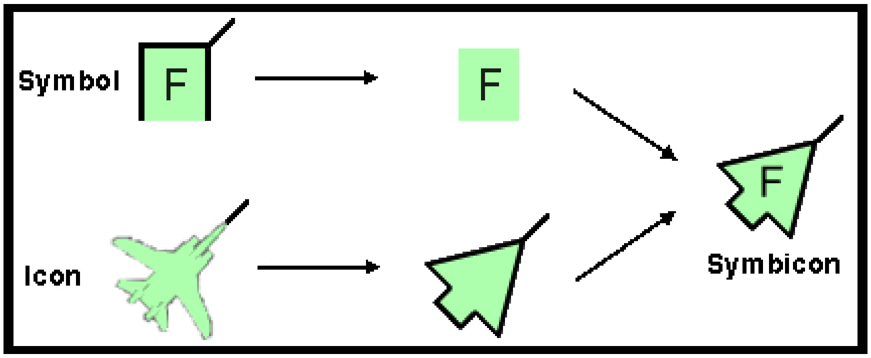

Figure 1: *A Symbicon for a neutral fighter is created by combining the interior of a conventional MIL-STD-2525B symbol with a distinguishable shaped outline of a realistic icon.* [1]

---

[1] From "Symbicons: Advanced Symbology for Two-Dimensional and Three-Dimensional Displays", by H.S. Smallman, H.M. Oonk, M. St. John, M.B. Cowen. (2001). Technical Report 1850 (February). Space and Naval Warfare Systems Center, San Diego, CA. Reprinted with permission from the authors.

Approaches the evaluation of symbologies

Different approaches can be used to evaluate symbologies, depending on the specific aspect of performance that is to be evaluated. Several tasks are commonly employed and they vary in their operational relevance. After a symbol set is first developed a common primary approach is to conduct a naming latency study. In this approach, participants are shown one symbol (contact) at a time and are to verbally identify an attribute of the symbol such as platform name, platform classification, threat affiliation or heading. The naming latency, or the time from when the symbol is presented to when the participant verbally responds, is recorded and analyzed along with error rates for the different symbol sets investigated. This approach gives a direct comparison of the ability to identify contacts between the proposed symbols and conventional symbols. As a drawback this approach is not realistic since the symbols are usually shown larger than normal and out of context. There is no interaction between the target symbol and other symbols that would normally be found in tactical displays.

A naming latency methodology was used to compare the Symbicons with 3-D icons and conventional 2-D symbols (Smallman et al., 2001a) with the four attributes listed above. The platform name was identified faster with Symbicons and 2-D symbols than with 3-D icons. The platform classification (air, surface or subsurface) was marginally faster for Symbicons. There was no difference for threat affiliation and heading. The authors suggested that greater benefits of Symbicons might occur in "more difficult operational tasks."

A more naturalistic approach to comparing symbol sets uses a visual search paradigm. In standard visual search experiments, participants look for a target item among multiple distractor items (Wolfe, 1998). The number of items in the display, or *set size*, is manipulated from trial to trial. On some trials a target is present, on others it is absent. For each trial, participants are required to indicate if the target is present or not. The dependent measures are usually response time and accuracy (percent error). The response time is usually analyzed as a function of set size since response time typically increases as the number of items increases.

Smallman et al. (2001b) compared 3-D icons, conventional 2-D symbols, and Symbicons using a variation on the visual search paradigm. Symbols were placed on a "battle space" background. All displays contained target items. Participants searched for a particular attribute and selected six target items as quickly as possible using a mouse. This methodology is more representative of the operator's task than the naming latency method. Search latencies were found to be generally shorter for Symbicons, however it was not possible to estimate the relative efficiency of these searches, as set size was not varied.

Although operators do perform visual search, this paradigm approximates only a small part of the operator’s task, which is primarily to maintain awareness and understanding of the tactical picture by monitoring changes. As part of routine monitoring tasks, operators scan tactical displays for changes in attributes of contacts such as speed, heading or threat. During monitoring tasks, operators are susceptible to *change blindness*. Change blindness refers to the phenomenon that humans are unable to perceive major changes in objects from one scene to another. Any object in the display that is the subject of focal attention at the time of the change will not be subject to change blindness. Normally, low-level motion transients help observers direct attention toward areas of the display that rapidly change. However, whenever an observer blinks, glances away from the screen, or orients focal attention toward another portion of the display, these transients fail to produce a shift of attention to the changing location, and the observer is left with no awareness that a change has occurred (Rensink, 2000). This effect occurs even when expert observers are monitoring meaningful displays; when expert users were told to expect a change on a tactical display containing only 8 relevant targets, 27% of the time they could not identify which contact had changed after briefly attending to another screen (DiVita & Nugent, 2000). Change blindness has potentially disastrous consequences for operators and therefore it would be beneficial if a symbology could be developed which shows greater resistance to change blindness by permitting larger numbers of contacts to be attended at once.

The present experiments investigate the ability to detect changes in heading in the Symbicons and the MIL-STD-2525B symbols. In both symbol sets, heading is indicated by a black leader line emanating from behind the center of the symbol. A change of heading occurs when the line rotates. Additionally for the Symbicons, the entire symbol rotates to face the compass direction. It is hypothesized that heading changes will be identified faster and more reliably given the more explicit, salient coding used.

A *flicker paradigm* (Rensink, 2000) was employed to investigate the ability to search detect changes in symbol heading by determining how quickly changes can be found and identified. This methodology uses a flickering display to simulate eye blinks or a diversion of attention away from the changing area of the display. In the flicker paradigm, an original image repeatedly alternates with a modified image, with a blank screen placed between successive images (Figure 2). The cycle continues until the user responds to indicate the presence or absence of a change between the two images. In order to detect a heading change, focused attention must be paid to the changing symbol across the blank screen (Rensink, O'Regan, Clark, 1997). Without the focused attention, participants may look at the flickering images for several seconds before seeing the change. Once the target symbol falls within the region of focused attention, the change is easy to notice.

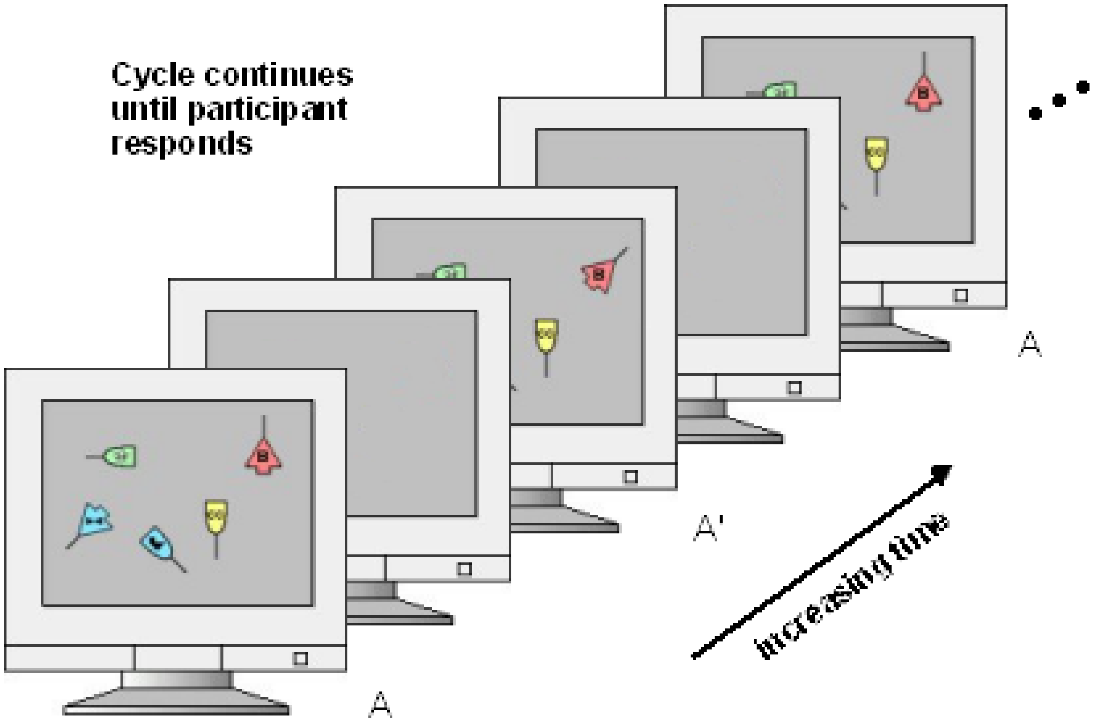

Figure 2. Basic design of the flicker paradigm. An original and modified image continually alternate, with a brief blank screen presented after each image. The cycle continues until the participant responds to indicate the presence or absence of a change between the two images.

During monitoring tasks, an operator may be required to monitoring a certain type of contact while also maintaining a sense of the 'broad picture' of events. Recognizing that these requirements may clearly conflict with each other, various design solutions have been proposed. These solutions primarily entail visually emphasising or de-emphasising large numbers of tracks on the display in order to allow focusing on a class of contact. For example, Osga and Keating (1994) suggested the use of a *Variable-Coded Symbology*, that would allow an operator to monitor a subset of relevant contacts without removing any contacts from the display. This variable-coded symbology could be accomplished by distinguishing the relevant contacts in terms of some coding dimension such as shape, luminance, or colour. More recently,more elaborate, adaptive display filtering or Decluttering algorithms have been proposed that de-emphasize the salience of less threatening tracks have been proposed (St. John, Feher & Morrison, 2002). Initial evaluations have suggested that Symbicons may represent a useful design trade-off for maximizing SA for decluttered tracks while minimizing the distractability of the decluttered tracks (St. John, Feher & Morrison, 2002). . An alternate, and not mutually exclusive, solution is to design a symbology that enables selective monitoring of a class of tracks without decluttering or filtering *any* of them, in order to preserve situation awareness (SA) for the big picture. Symbicons may enable this because the enhanced discriminability of their coding of platform category may enable a perceptual segregation of the display into air vs. sea tracks. It is feasibility of this last solution that is investigated here.

The relative effective of Symbicons versus conventional MIL-STD 2525B symbols was investigated for selective monitoring of a class of contacts. Specifically, in half the trials participants were told to monitor only the sea or air contacts, thus performing a *constrained search*. As can be seen in Figure 3, the sea/air distinction is based on the shape of the symbol frame for the Symbicons, but not for the MIL-STD-2525B symbols. If this shape dimension supports selective monitoring of all contacts in the platform category regardless of heading (orientation) or specific platform, then Symbicons should elicit faster search when the search is constrained to a particular platform category (air vs. sea). That is, if participants can selectively attend to a subset of symbols of the same platform category, performance should be superior on the constrained search trials as compared with the Unconstrained Search trials. This attribute is important since in many tasks, operators are required to monitor only a certain type of contact in large cluttered displays, such as checking through all the air tracks or surface tracks; the symbology must support this task.

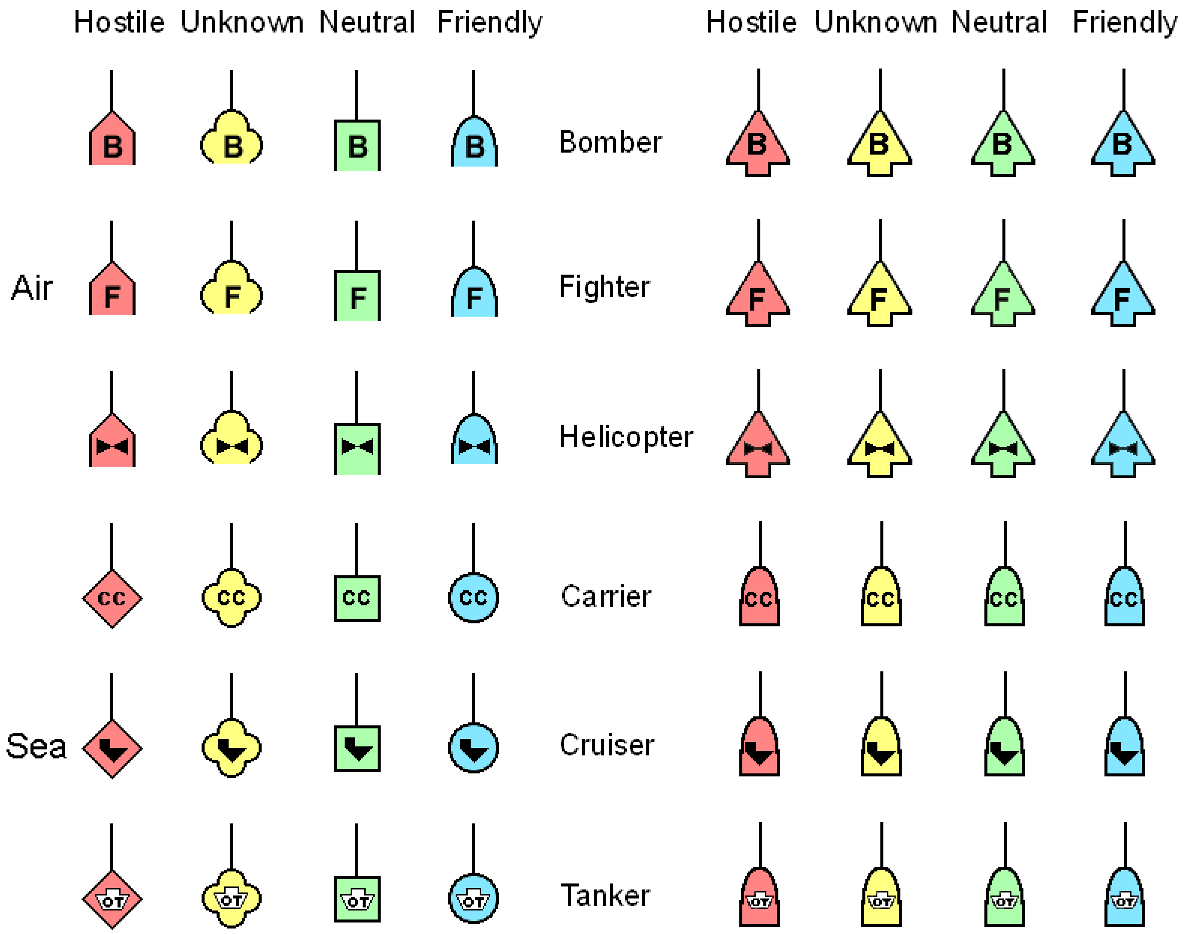

Figure 3. *MIL-STD-2525B and Symbicons Symbol Sets for eight platforms with four threat affiliations and northbound heading.*

Experiment 1

Method

Participants

Eighteen people each participated in one session lasting approximately one hour and 40 minutes. Two participants were dropped from the study because they did not meet the minimum accuracy requirement of 75%. Participants were DRDC Toronto employees, students from local universities or community members, and were paid for their participation. All reported normal or corrected-to-normal vision and were required to be between the ages of 18 and 65. Four participants had prior experience with similar experiments. This study, approved by the DRDC Toronto Human Research Ethics Committee, was conducted in conformity with the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans.

Apparatus

The experiment was run on a Pentium III with a Matrox Millennium G400 graphics card and a ViewSonic 21-inch monitor. The images were presented at a screen resolution of 1024 x 768 pixels and 24-bit colour depth in a dimly lit room. E-Prime Beta 5 by Psychology Software Tools (PST) was used to program and run the displays. Viewing distance was maintained at 55 cm using a chin rest. Responses were collected using the leftmost and rightmost buttons on a PST serial five-button response box.

Stimuli

Symbols:

Two military symbol sets were used as the basis for the stimuli: MIL-STD-2525B and Symbicons. The images were the same as those used by Smallman et al. (2000) and were provided by Pacific Science and Engineering (PSE) and Space and Naval Warfare Systems Center San Diego (SSC San Diego). In the present experiment, six military platforms were used; three were air platforms (bomber, fighter and helicopter), and three were sea platforms (carrier, cruiser and tanker). The missile and submarine platforms were not used in order to simplify the “sea” versus “air” classification task. If the submarine was included, the MIL-STD-2525B set would have three platform designations (air, surface and subsurface), but the Symbicon set would only have two designations (air and sea); this would complicate meaningful comparisons across the symbol sets. The platforms were drawn at eight headings with four threat affiliations. A black leader line emanating from behind the center of the symbol indicated heading. The line was rotated at increments of 45 degrees to indicate the eight headings. At 50 pixels long, the leader subtended a visual angle of 2 degrees, though part of the line was obscured by the symbol. Both symbol sets were of similar size. The Symbicon sea and air symbols subtended 1.0x1.5 and 1.5x1.6 degrees of visual angle respectively. The MIL-STD-2525B symbols subtended approximately 1.3x1.3 degrees of visual angle.

The MIL-STD-2525B symbols were conventional 2-D military symbols drawn according to specifications laid out by the U.S. Department of Defense (1999) as shown on the left of Figure 3. A letter code or shape in the centre designates the platform, while the colour and shape of the frame of the symbol designates the threat affiliation. Red is used to code for hostile contacts, yellow for unknown, green for neutral and blue for friendly. For example, a red CC is a hostile cruiser. A closed frame indicates a sea (or surface) platform, and a frame open at the bottom indicates an air platform. Though not used in the present experiment, a frame open at the top indicates a sub-surface platform.

The Symbicons were developed by PSE and SSC San Diego as a hybrid of 2-D symbols and realistic icons as shown on the right of Figure 3. The centre portion of the symbol was the same as the MIL-STD-2525B, but the frame was changed. The frame of the Symbicon is either the shape of a plane or a ship and is used solely to designate platform category. The threat affiliation is designated only by colour. To indicate heading, the leader line is used but additionally the symbol itself rotates to face the compass direction. Thus the design trade-off made with Symbicons was to accentuate the coding of heading by double-coding it (leader plus icon orientation) and of platform category (through the use of discriminable caricatures of ships and planes), while only single-coding affiliation (with color only, rather than with color and frame completion/incompletion that MIL-STD 2525B employs).

Both symbol sets used the same four fill colours and were placed on the same backgrounds. For the training task, the symbols were placed on a white screen. The RGB values for the colours are listed in Table 1. As well, the device independent luminance (Y) and CIE 1931 chromaticity coordinates (x,y) were measured for these colours using a Minolta CS-100 Chromameter. The symbol colours are similar to the RGB values given in the MIL-STD-2525B. The background colours have a low luminance and so appear very dark and saturated on the screen.

Table 1: RGB and Yxy Values for Display Colours, Experiment 1

NAME	CODING	R	G	B	Y	X	y
Red	Hostile	255	132	132	33.3	0.422	0.318
Yellow	Unknown	255	255	130	79.1	0.368	0.437
Green	Neutral	173	255	173	67.3	0.283	0.393
Blue	Friendly	132	231	255	56.2	0.211	0.256
Navy blue	Water	9	66	129	2.70	0.149	0.103
Silver	Instructions	191	191	191	42.4	0.279	0.293
Med. grey	Flicker screen	128	128	128	14.5	0.281	0.292
Dark grey	Land	63	63	63	14.9	0.298	0.294

Displays

The displays were created using a total of 10, 15 or 20 symbols. These symbols were chosen randomly with replacement from the 192 symbols of a symbol set. Each image contained five symbols of one platform category (those that could change in constrained search) and five, ten or fifteen symbols of the other platform category (those that could change only in Unconstrained Search). Twelve displays were created for each condition, and displays were created in the same fashion for both constrained and unconstrained conditions. However, for the 'change' conditions, two images were created, whereas for the 'no change' conditions, only one image was created. The symbols for each display were placed randomly on one of four randomly chosen backgrounds. In order to facilitate comparison with another study of tactical symbology using the MIL-STD-2525B symbols (Smallman et al., 2001b), a dark blue background was used. Dark grey land segments appeared at the perimeter of these displays and were counterbalanced by creating one land arrangement and flipping it horizontally and vertically. Figures 4 and 5 show examples of stimulus images with 15 MIL-STD-2525B symbols and 15 Symbicons respectively.

In creating the displays, care was taken to avoid lateral masking or crowding effects. The overall image size was 1024 x 768 pixels. By requiring a minimum center-to-center distance between symbols of 120 pixels, the displays were designed so that if the widest symbols were placed side by side there would be at least 1.5º of visual angle separating them. The minimum distance from the edges of the screen was set at 110 pixels. Because distance may affect the ability to selectively monitor groups of symbols, the average distance between all pairs of symbols was calculated for each image. Twelve new images were created with 10 symbols because the average distance was too small for these images compared to the images that contained 15 or 20 symbols. The average inter-symbol distance for the images with 10, 15 and 20 symbols was 390.0, 390.7 and 396.0 pixels respectively.

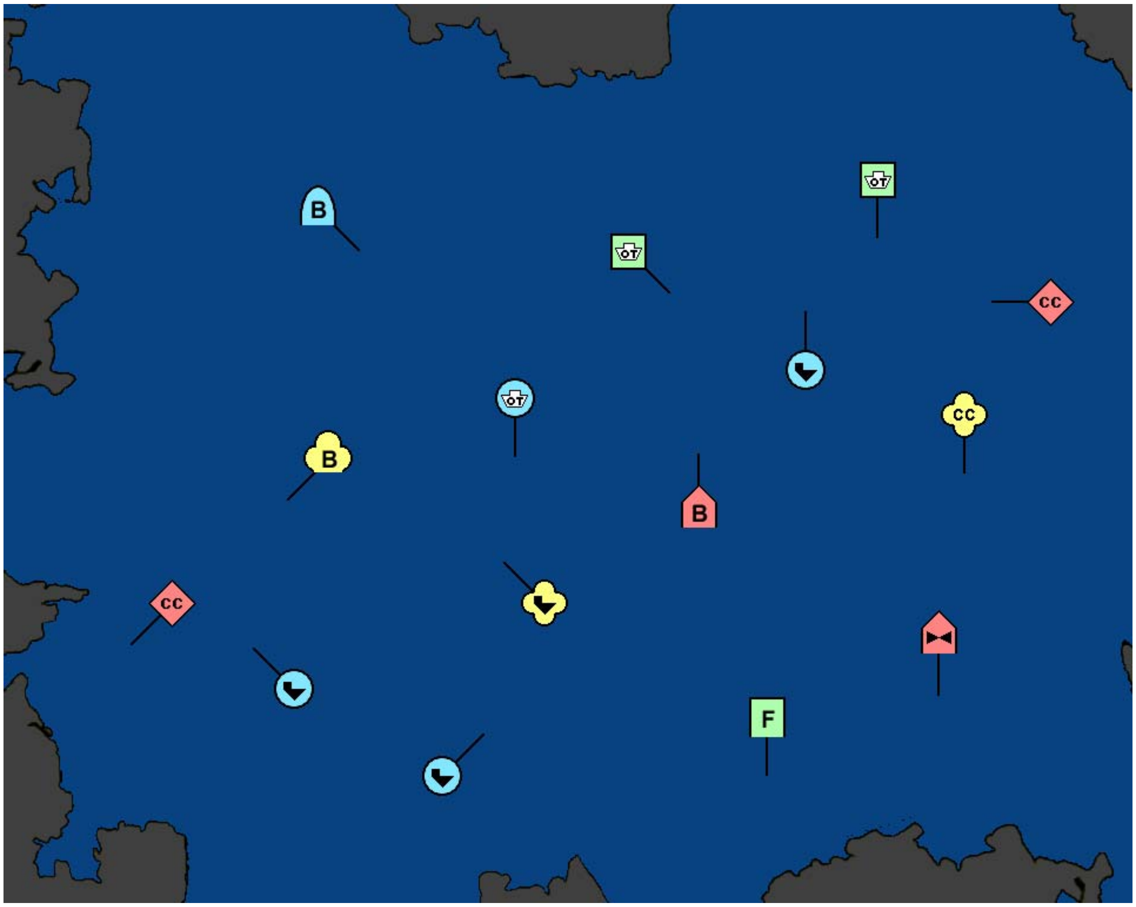

Figure 4. *Example of a stimulus image containing 15 MIL-STD-2525B symbols.*

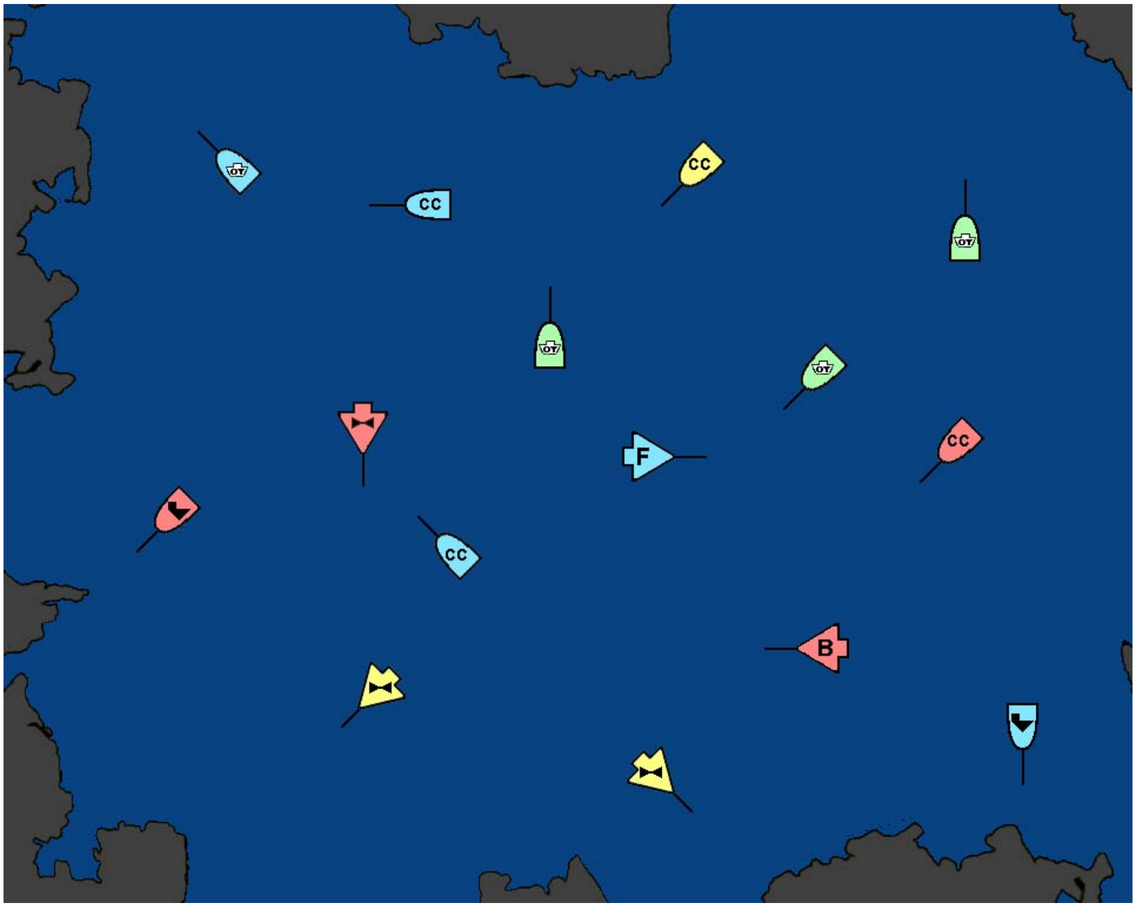

Figure 5. *Example of a stimulus image containing 15 Symbicons*

Procedure

Training Task:

For the training task, participants learned the two symbol sets in sequence. Half (n = 8) of the participants learned the Symbicons first and the MIL-STD-2525B second whereas the other half learned the MIL-STD-2525B first and the Symbicons second. The combination of heading, threat affiliation and platform created 192 different stimuli, so there were 8 blocks of 24 trials for each symbol set for a total of 384 trials. For each block, participants were encouraged to be at least 95% accurate and maintain an average response time of less than 500 ms.

Participants read instructions on the screen describing the task and the symbol sets, and pressed any button to continue. They were instructed to learn the platform category of a series of symbols (i.e. was the symbol representing a sea track or an air track). The next screen displayed samples of one of the symbol sets, similar to that shown in Figure 3. Participants were told to press any button when ready to start the task. The symbol was presented in the centre of a white screen until the participant pressed the leftmost button for an air symbol or the rightmost button for a sea symbol. After they pressed a button, a blue cross (correct) or red minus (incorrect) appeared on the screen for 1 sec and then the next symbol was presented. During the task, they rested one finger of each hand on each button. After each block, participants were given feedback on how they were doing. Specifically, it indicated that they were: responding quickly and accurately, needed to be more accurate, needed to respond faster, or needed to respond more quickly and accurately. After eight blocks a screen showing samples of the other symbol set was given for participants to study. The next eight blocks continued with the same procedure as the first but with the second symbol set.

Change Detection Task:

Trials were blocked according to whether participants were told what type of change to expect, and whether that change would be SEA or AIR. That is, for Constrained Search the participant was told which platform category could change, one of the symbols from that platform category might change heading, whereas for Unconstrained Search a symbol from either platform category might change heading. The heading change was present for half of the trials, and for Unconstrained Search the heading change was equally likely for both platforms categories. Each participant completed 8 blocks of trials (4 using Symbicons and 4 using MIL-STD-2525B symbols). For each symbol type, two blocks were Unconstrained Search and two blocks were constrained search. Each block contained three set sizes (10, 15, and 20 symbols). Within each block and set size, half of the trials were *change* trials in which a heading change was present, and half of the trials were *no change* trials in which no contacts changed heading. There were 12 observations per cell, so that each of the 8 blocks contained 72 trials, for a total of 576 trials. In addition, each participant completed eight blocks with 6 trials each for practice, prior to beginning the experiment.

At the beginning of each block and each trial, participants were given a prompt as to which platform category might change. For example, in constrained search for the sea platform they were told that if there is a change, it would be a SEA symbol, whereas for Unconstrained Search they were told that if there is a change it would be ANY symbol. After reading the prompt, the participant pressed the center button to start the trial, or the second button from the left to start the block.

For each trial, a flicker sequence comprising the original image, a grey screen, the modified image, and a grey screen was presented. The sequence continued until the participant pressed the rightmost button when they noticed a change between the two images, or the leftmost button when they decided there was no change. Both the image and grey screen durations were 212 ms. For the practice trials, feedback was given immediately after the response as a blue "correct" or red "incorrect" presented for 1 second in the center of a light grey screen.

The blocks orders were counterbalanced across participants. Each block represented one condition produced by the factorial combination of Constraint, Platform Category, and Symbol Set. For example, one block consisted of Constrained Search for air symbols of the MIL-STD-2525B symbol set. Sixteen block orders were created using the conditions that:

1. Constrained Search was followed by Unconstrained Search, then Constrained Search, and so on in order to bias against the hypothesis that constrained search should be faster.
2. The first four blocks were to be of one symbol set and the final four of the other symbol set
3. The first and fifth blocks should be the same type of constrained search.

The first symbol set learned in training was the first symbol set for practice and testing trials.

Results and discussion

Training task

In the training, participants learned to discriminate between sea and air platform categories. Mean response times for correct trials were calculated as a function of symbol type and training block number. These data were submitted to a mixed-model analysis of variance (ANOVA) with symbol type (MIL-STD-2525B vs. Symbicons) and training block (1 to 8) as within-subjects factors, and Symbol Order as a between-subjects factor. The symbol order factor was a consequence of the counterbalanced order in which the training was accomplished (MIL STD followed by Symbicons or vice versa). Post-hoc tests were performed using Tukey's HSD procedure with an alpha level of .05. Mean error rates were calculated but were not sufficiently high to analyze (2.7% for Symbicons and 3.2% for MIL-STD-2525B). There was no evidence for a speed-accuracy tradeoff.

Figure 6 depicts mean response times as a function of symbol type and training block. For both sets of symbols, participants were able to rapidly learn to make forced-choice discriminations between sea and air platform $F(7,98) = 22.54$, $p < .0001$. Indeed, learning was so rapid that post-hoc testing revealed response times were significantly slower only for the first block (regardless of symbology). Performance was so similar for the two symbol types that the only significant difference involving symbol type was a three way (symbol type by training block by order) interaction such that participants responded more quickly for whichever symbol type was learned second $F(7,98)=25.73$, $p<.0001$.

The results demonstrate that novice participants were able to learn the classification of platform category quickly for both symbol sets. The decision as to whether each symbol fell into the sea or air category could be made with similar rapidity regardless of which symbol set was viewed. Thus, participants could be considered to have equal expertise with both symbol sets prior to beginning the change detection task.

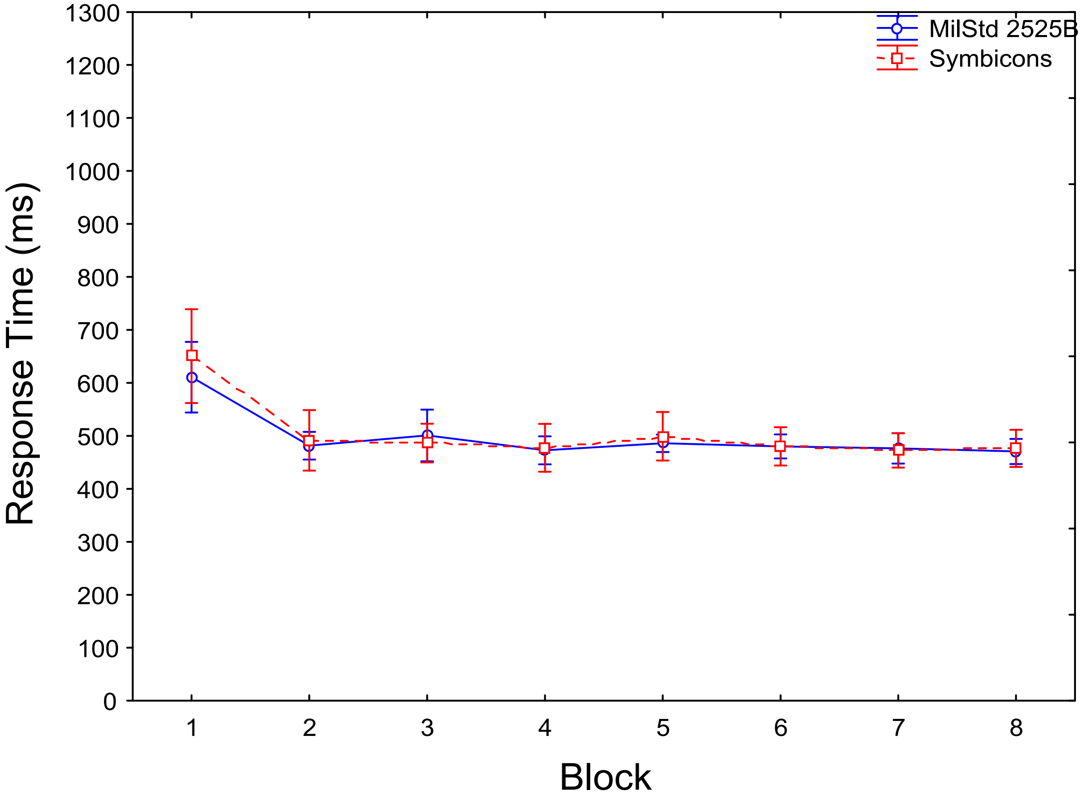

Figure 6. *Mean response times for Symbicons and MIL-STD-2525B symbols for each block.*

Change detection task

Experimental design and analyses

Mean response times for accurate trials were submitted to a mixed-model ANOVA that included the following within-subjects factors: symbol type (MIL-STD-2525B vs. Symbicons), search type (constrained vs. unconstrained), platform category (air vs. sea), and set size (10, 15, 20). Block order was included as a between-subjects factor; however, no main effect or interaction involving block order was obtained, hence subsequent analyses were conducted by collapsing across that factor. Data were collapsed across the two platform categories for both symbol types. Platform category is coded differently between the symbol sets and thus cannot reasonably be compared across symbol types. Both trials with and without changes were initially analyzed; however, reported analyses include only the trials in which a heading change was actually present. From a practical standpoint, the important trials are those where a change actually occurs. One would like to know the extent to which an operator can monitor a display for changes in specific types of targets, and this is difficult to evaluate when no change occurs. Furthermore, it has been suggested by Chun and Wolfe (1996) that different processes are involved in, at least, the termination of visual search when there is no target present. For change present trials, the search terminates as soon as the target is found (before all items of the display have been viewed), whereas in the change absent trials, the search terminates when the operator *decides* to end the search. The reported effects also reached significance in an analysis in which the trial type (change or no change) is included as a factor. Thus, in the principal analysis means for correct response time and accuracy were submitted to a within-subjects ANOVA in which symbol type (MIL-STD-2525B vs. Symbicons), search type (constrained vs. unconstrained), and set size (10, 15, 20) were included as factors.

Effects of instructional constraints

Overall, heading changes were noticed faster for Symbicons than for MIL-STD-2525B symbols $F(1,15) = 68.27$, $p<.001$ (Figure 7). There were also fewer errors with the Symbicons than the MIL-STD-2525B symbols $F(1,15) = 27.79$, $p<.001$. Given the equivalence between symbol types observed in the training task, this performance difference may be best attributed to a specific advantage for the Symbicons in the coding of heading, rather than overall encodability, or ease of apprehension.

In order to determine whether participants were able to use advance information, response times for correct trials and percent errors were compared as a function of instructional constraints. Thus, in constrained search participants knew in advance which platform category the changing contact would belong to, and analyses were conducted to determine the extent to which participants could use this information to direct their attention.

The advantage for Symbicons was more pronounced for trials in which participants were told which platform category would change (constrained search) as indicated by a significant interaction between symbol type and search type for response time $F(1,15)=5.09$, $p=.039$ and accuracy $F(1,15) = 6.39$, $p=.023$. When viewing MIL-STD-2525B displays, participants did not respond significantly faster on trials in which they were told in advance which platform category would be changing F<1. Error rates also revealed no evidence of an advantage for constrained search in displays containing MIL-STD-2525B symbols $F(1,15)=2.2$, *ns*. In fact, the means for MIL-STD-2525B symbols were in the direction of a relative *dis*advantage for constrained search. In contrast, when viewing the Symbicon displays participants *were* able to use information about the platform category of the changing symbol to improve their response time $F(1,15) = 13.2$, $p<.002$. The information about which platform category would be changing also resulted in considerably fewer failures to detect the change in heading $F(1,15) = 6.39$, $p=.023$ when participants were searching for heading changes in Symbicon displays.

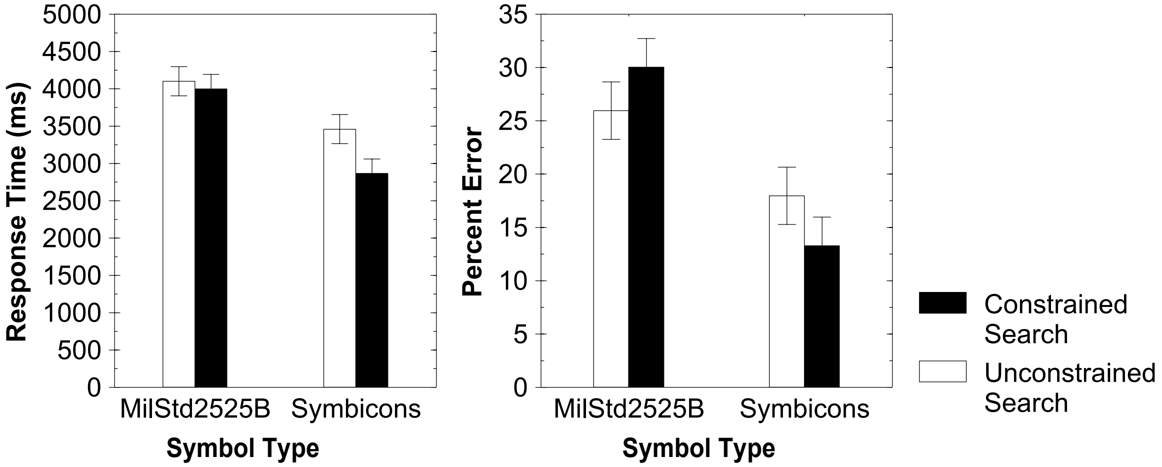

Figure 7. *Response times and error rates for the Symbicon and MIL-STD-2525B symbols with constrained and Unconstrained Search. Changes in heading were detected faster and more accurately with the Symbicons, particularly in the constrained condition.*

Of course, a finding that participants are able to use advance information about the type of targets that may be expected to change does not provide any information about the processes through which this might be accomplished. Such information might be advantageous in a variety of ways, and at a variety of stages of processing, from the decision stage "Is that one really changing?" to the guidance of search (a top down influence on the direction of attention such that display regions containing the relevant subset of symbols are preferentially subjected to focal attention). Ideally, a symbol-coding scheme should permit the observer to attend only to the relevant contacts (sea or air) while ignoring all irrelevant contacts. Given that larger displays were constructed by adding only irrelevant distractors (ie. air contacts when the participant is monitoring sea contacts), increasing the number of (irrelevant) symbols in the display will only increase response time if the observer is unable to filter them out (a failure of selective attention toward the relevant contacts). That is, if an observer is able to attend selectively to all the relevant contacts across the display, response time should not increase with the total number of contacts in the display. However, if attention is not distributed in parallel across all items of the display, top-down constraints may still provide an advantage in that attention may be preferentially deployed toward relevant contacts or groups of contacts. This type of advantage would be revealed as a smaller increase in response time as a function of total number of contacts.

In the present experiment, the manipulation of the number of irrelevant symbols in the display provided additional evidence that constrained search is a more efficient search, in that the effect of increasing the number of symbols from the irrelevant platform category had a greater effect on Unconstrained Search than on constrained search $F(2,30)=12.02, p<.001$. This result was consistent with error data $F(2,30)=3.15, p=.057$ (Figure 8).

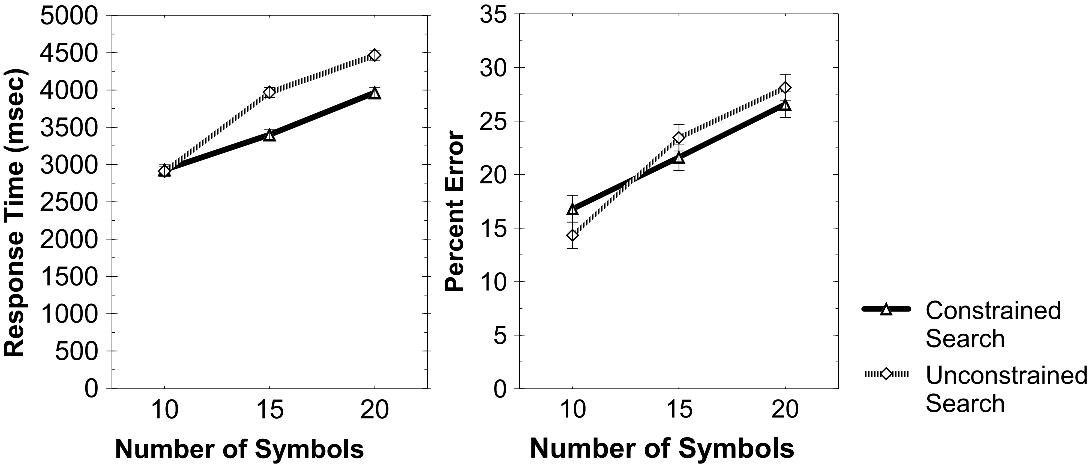

Figure 8. *Response time and error rates for the three set sizes with constrained and Unconstrained Search. The addition of irrelevant symbols to the display had a significantly greater effect on response times with Unconstrained Search than constrained search.*

The overall advantage for the Symbicon displays was also demonstrated through the manipulation of the number of symbols in the display. The addition of irrelevant symbols to the display had less influence on response times for Symbicons than for MIL-STD-2525B, $F(2,30)=3.3, p=.049$, such that the efficiency of the Symbicons was higher overall (Figure 9). This effect was not present in the error data, however there was also no evidence of a speed-accuracy tradeoff.

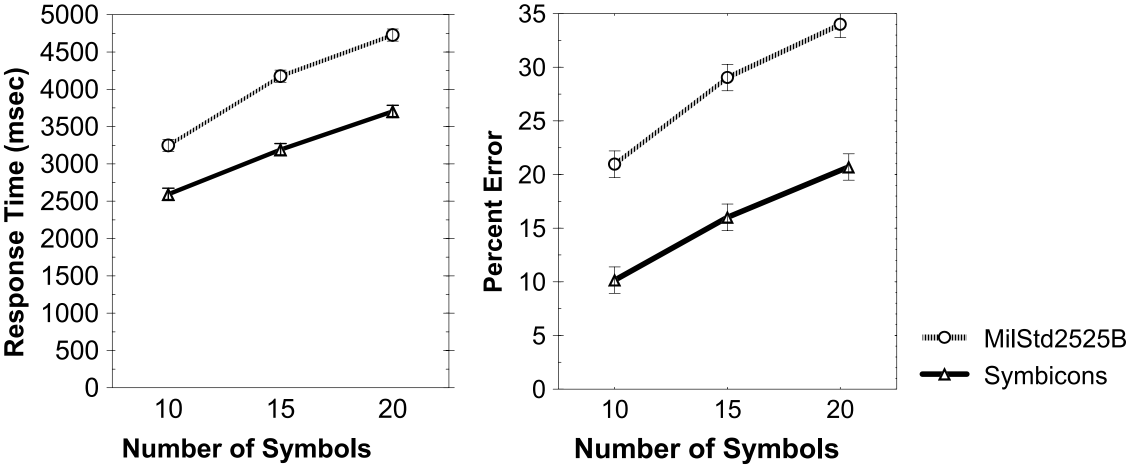

Figure 9. *Response time and percent error for the two symbol sets over the three set sizes. Symbicon displays were less influenced by the addition of irrelevant symbols to the display.*

Despite the evidence that constraining search is more useful when the displays contain Symbicons, that constrained search is more efficient, and that search for Symbicons is more efficient, there was limited evidence that constrained search produced more efficient search preferentially for Symbicons. That is, there was no significant three-way interaction of symbol type, search type, and number of symbols observed for response time $F(2,30)=2.27$, $p=.12$, although such an effect was observed in the error data $F(2,30)=4.47$, $p<.05$. Nonetheless, when considered together with the error data the composite of two-way interactions for response time might suggest that differences in the utility of the platform category constraint might underlie differences in search efficiency observed for the two symbol types.

It should be noted, however, that the constraint did not produce anything close to a parallel attentional selection of relevant contacts for either symbol type. As a measure of efficiency, the search slope, or the increase in response time with larger set sizes, was calculated using linear regression for each of the search types. In a completely efficient search, the search slope should be zero (a flat line) since only irrelevant distractor symbols are added to the display to increase the number of symbols. That is, each display contained the same number of targets and therefore if participants could monitor solely the target symbols during constrained search, the response times for the three set sizes would be the same. This was not the case. The search slope was 103 ms per symbol for Constrained Search in the display and 156 ms per symbol for Unconstrained Search. Search slopes greater than 30 ms/item are considered to be very inefficient search (Wolfe, 1998). In contrast, efficient search for change has been demonstrated for subsets of items defined by polarity (black vs. white) using a similar paradigm (Rensink 2000). For the relatively complex tactical displays studied here, however, neither Constrained nor Unconstrained Search was efficient. The addition of irrelevant symbols to the display resulted in longer response times and more errors for both the Symbicons and the MIL-STD-2525B symbols.

In order to detect a heading change, the symbols must be held in short term memory during the blank screen in order to compare them with the next image. The steep search slopes are an indication that participants are not be able to hold all of the relevant symbols in short term memory. The number of symbols that participants are able to hold in short term memory can be estimated by adding the duration of the image with the duration of the blank screen and then dividing this sum by the search slope (Rensink, 2000). Using this expression, participants were able to hold approximately 3.3 MIL-STD-2525B symbols and 5.4 Symbicons in short term memory during constrained search and 2.5 and 2.9 symbols respectively during Unconstrained Search. Thus, for both symbol types, not all of the symbols in the display can be attended and held in visual short-term memory. This finding has practical implications for display design; it should not be assumed that the operators responsible for maintaining the air or sea “picture” can selectively monitor those aspects of the display for changes to those contacts even if the relevant contacts are similar in appearance.

In summary, experiment one revealed an advantage for Symbicons that was particularly evident when participants were told in advance what type of contact could change heading. The advantage for the Symbicons could result from grouping effects in which groups of similar contacts are simultaneously attended and monitored for change. However, this advantage might also result from improvements in the discrimination of heading that occur particularly for contacts that are not foveated directly. Because the entire frame of the Symbicon rotates to depict heading, whereas only the leader line rotates in the case of the conventional symbols, it is likely that such a difference in discriminability exists. Given the dark blue background upon which the leader lines were presented, heading changes might have required not only focal attention but also focal vision to detect them. In order to evaluate whether differences observed between Symbicons and MIL-STD-2525B symbols for constrained and Unconstrained Search resulted primarily from differences in discriminability of the heading change, the experiment was repeated using a light gray background to indicate water. The gray roughly matched the symbol fills in terms of luminance, and the leader line was highly discriminable against this background.

Experiment 2

Method

Participants

Sixteen people each participated in one session lasting approximately one hour and 40 minutes. Participants were DRDC Toronto employees, students from local universities or community members, and were paid for their participation. All reported normal or corrected-to-normal vision and were required to be between the ages of 18 and 65. In this study, none of the participants had prior experience with similar experiments.

Apparatus & Stimuli

This experiment was run using the same apparatus, stimuli, and procedure used in the previous experiment. It also used the two symbol sets that were used in the previous study: MIL-STD-2525B and Symbicons (Figure 3).

As in the previous experiment, the symbols for each stimulus image were placed randomly on one of four randomly chosen backgrounds. The backgrounds in this experiment were different from the previous study. In place of the dark blue background from Experiment 1, we used a light gray background in order to facilitate change detection. Dark gray land segments appeared at the perimeter of these displays and were counterbalanced by creating one land arrangement and flipping it horizontally and vertically. These segments were also replaced in the present study with land segments of a lighter gray. Sample displays are shown as Figure 10 and Figure 11.

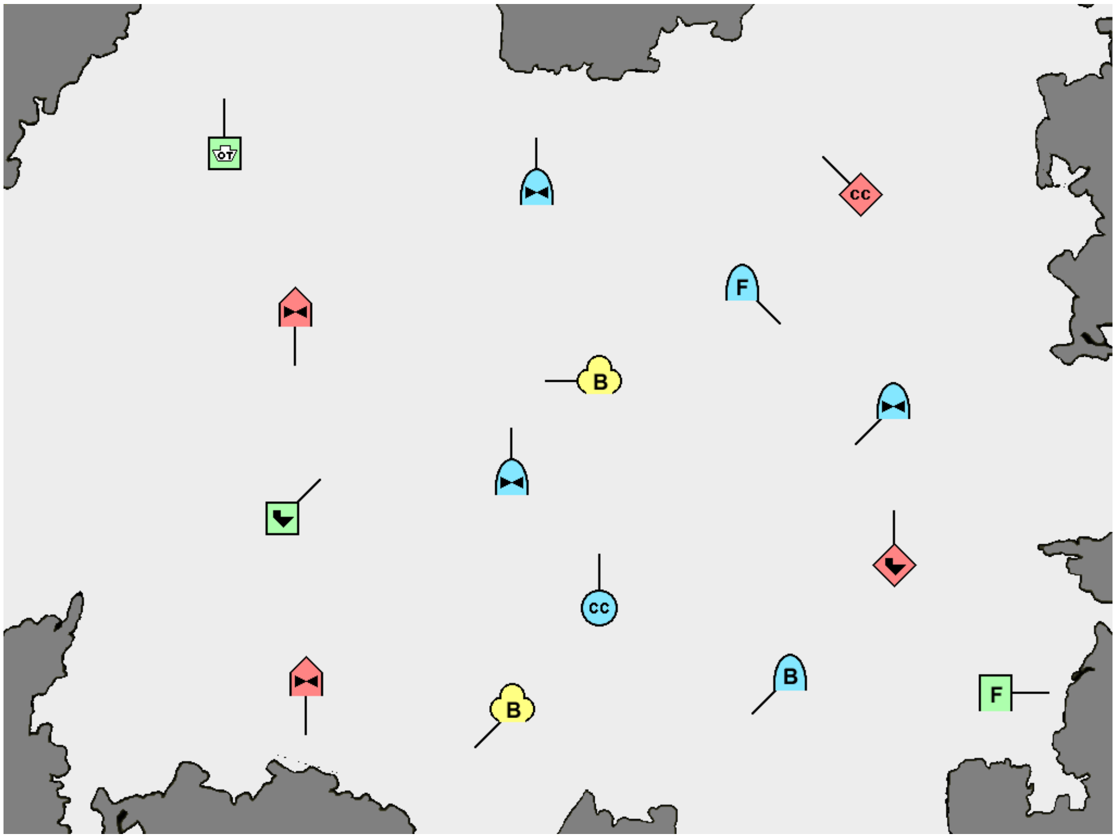

Figure 10. *Sample stimulus image containing 15 MIL-STD-2525B contacts*

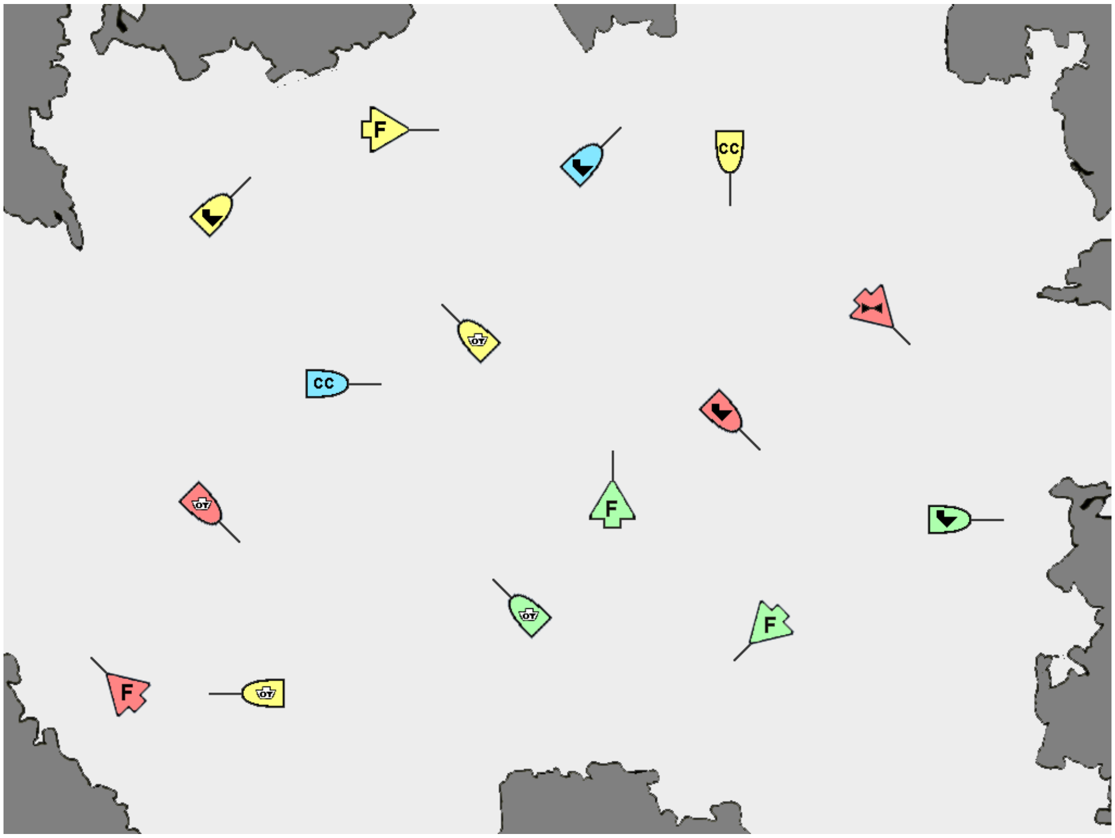

Figure 11. *Sample stimulus containing 15 Symbicons*

Table 2: *RGB and Yxy Values for Display Colors, Experiment 2*

Name	***Coding***	***R***	***G***	***B***	***Y***	***x***	***y***
Light grey	Water	237	237	237	66.5	0.298	0.298
Dark grey	Land	63	63	63	14.9	0.298	0.294

Results and discussion

Training task

The training task used in this experiment was identical to the training task used in the previous experiment; participants were required to discriminate between the sea and air platform categories. As in the previous experiment, a mixed-model analysis of variance (ANOVA) was performed with symbol type (MIL-STD-2525B vs. Symbicons) and training block (1 to 8) as within-subjects factors, and symbol order (learned MIL-STD-2525B first vs. learned Symbicons first) as a between-subjects factor. Post-hoc tests were performed using Tukey's HSD procedure with an alpha level of $p<.05$. Mean error rates were calculated but were not sufficiently high to analyze (7% for Symbicons and 7% for MIL-STD-2525B). The error data were graphed and there was no evidence of a speed-accuracy trade-off.

Figure 12 depicts mean response times as a function of training task. As in Experiment 1, participants were able to learn rapidly to distinguish between air and sea platforms $F(7,98)=14.68$, $p<.0001$, such that for both symbol types significant differences were observed only between the first block and all subsequent blocks. Participants were equally able to discriminate between sea and air platforms for the two symbol types, and this group of participants attained a similar level of expertise to the participants in Experiment 1.

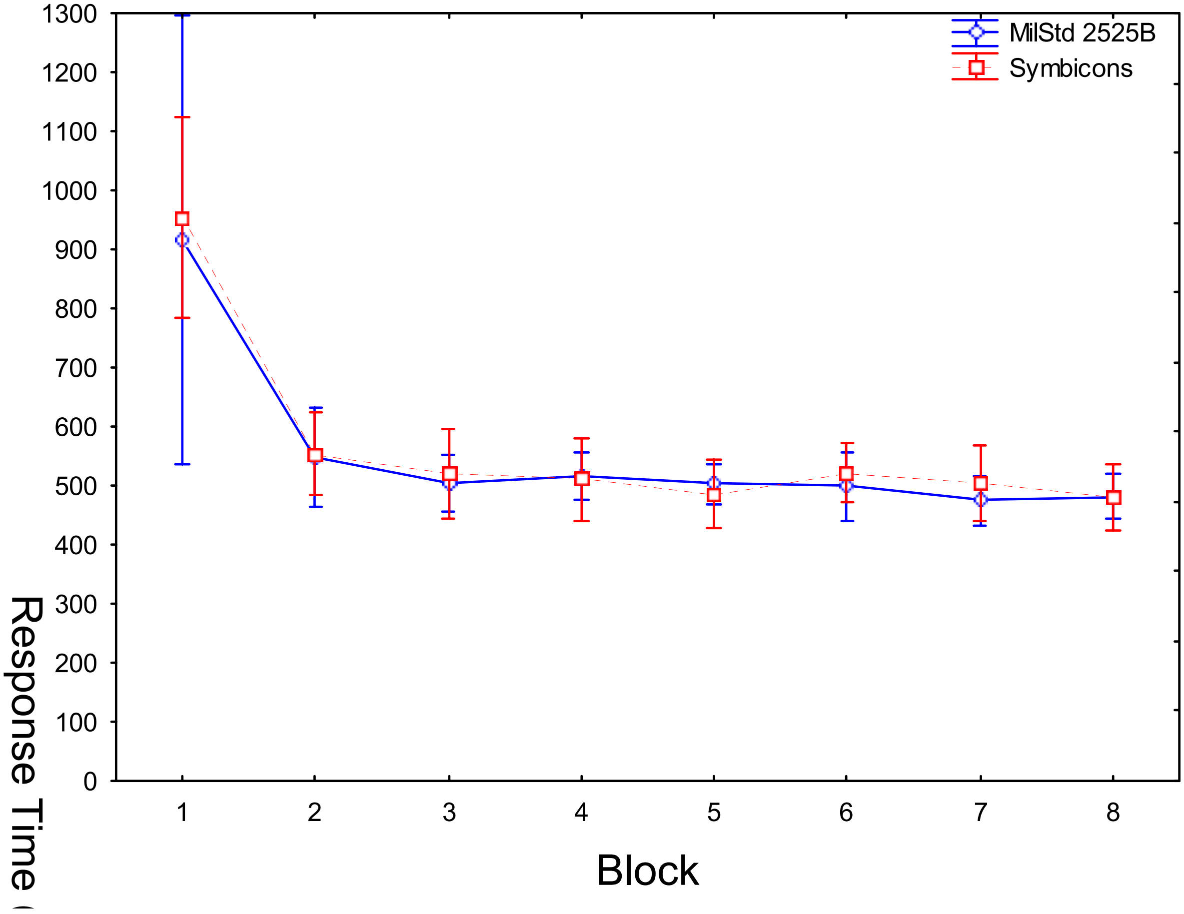

Figure 12. *Response time as a function of block and symbol type.*

Change detection task

As in the previous experiment, for trials in which a change was present, response times and error rates were analyzed using analysis of variance (ANOVA) for the symbol type, search type and set size factors. Only the correct trials were used for the response time analysis. Overall, heading changes were noticed faster for Symbicons than for MIL-STD-2525B symbols $F(1,15) = 18.01$, $p<001$. No significant difference between symbol types was observed for errors. The utility of constraining the platform category was evaluated as a function of symbol type, as in Experiment 1. Although the interaction between search type and symbol type did not reach significance in the second experiment, the finding that constraining search to a particular platform category was more advantageous for Symbicons was largely replicated for response time $F(1,15) = 3.76$, $p=.07$, but not for errors. Post-hoc analyses revealed that the only effect of search type was observed in the form of faster response times for constrained versus Unconstrained Search for Symbicons, a finding that replicates the results of Experiment 1.

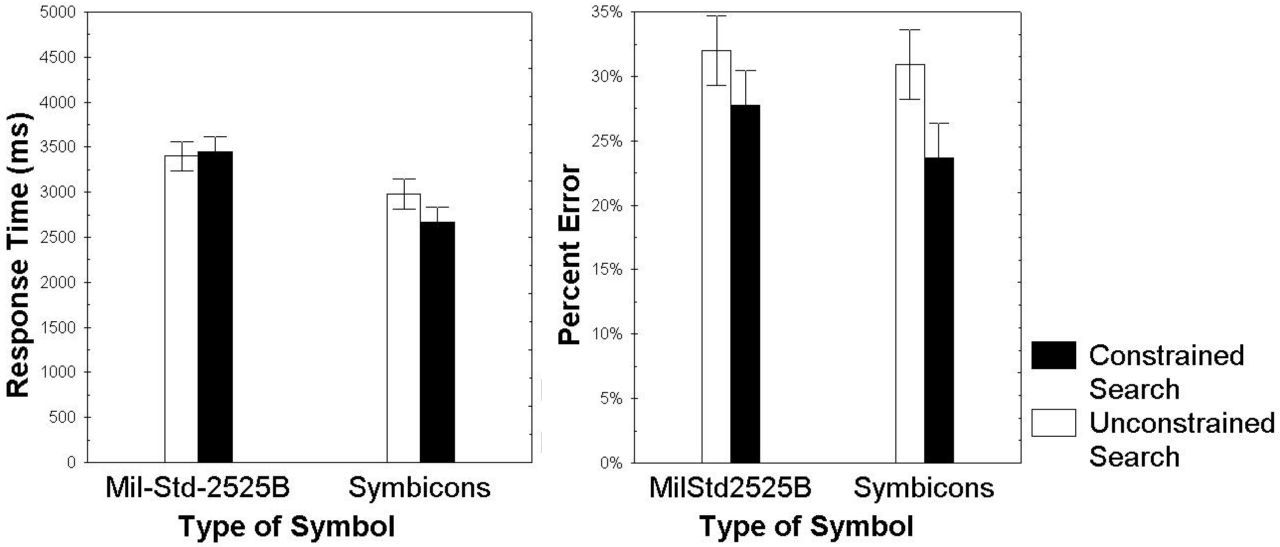

Figure 13 *Response time and percent error for the Symbicon and MIL-STD-2525B symbols with constrained and unconstrained search.*

Unlike the finding observed in Experiment 1, constrained search did not seem to be more efficient search in that the number of symbols in the display had similar influences on response time regardless of whether search was constrained to a particular platform category. However, this interaction was significant in the error data $F(2,30) = 7.09$, $p<.004$—indicating that constrained searches yielded fewer errors than Unconstrained Searches as the number of symbols in the display increased, and providing a broad replication of the findings in Experiment 1.

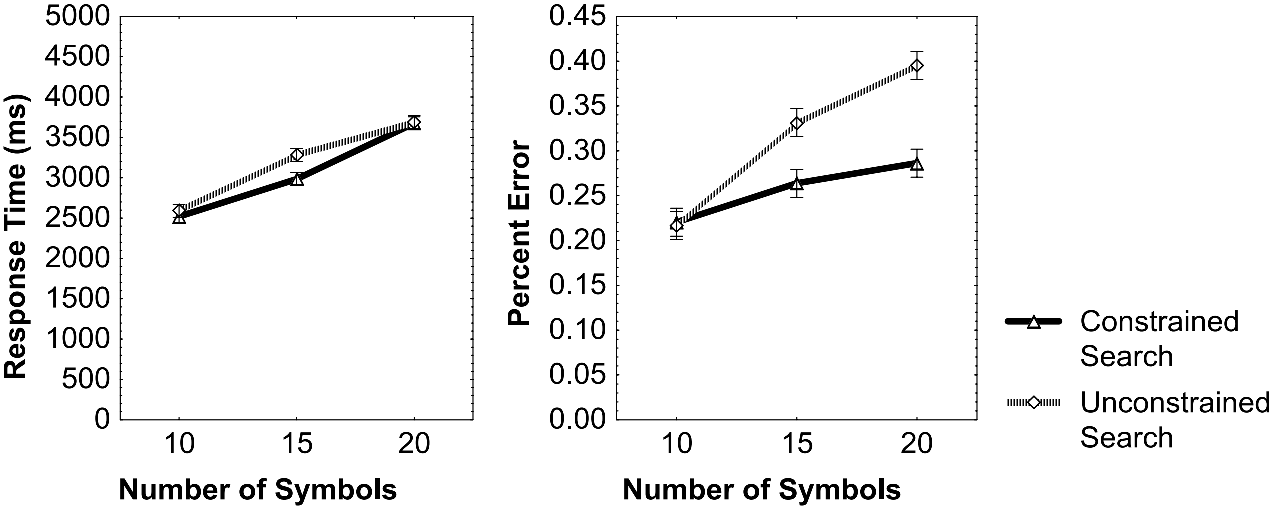

Figure 14. *Effects of constraining search expressed as a function of set size.*

We also analyzed the set size by symbol type interaction to see if the effect of increasing the number of symbols in the display would have a diminished effect on Symbicons compared to MIL-STD-2525B, as shown in the previous experiment. As in Experiment 1, the addition of symbols to the display had less influence on response times for Symbicons than for MIL-STD-2525B, $F(2,30)=6.05$, $p < .007$ (Figure 14), indicating greater search efficiency for Symbicons. This effect was not present in the error data; however, there was also no evidence of a speed-accuracy tradeoff. As in Experiment 1, there was no three-way interaction of search type, set size, and symbol type.

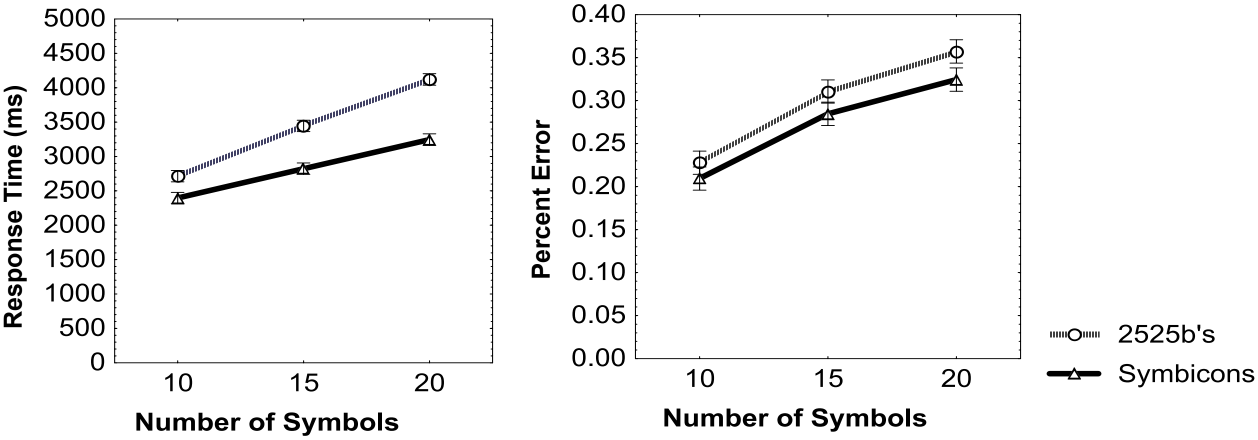

Figure 15. *Effects of symbology expressed as a function of set size.*

In summary, Experiment 2 largely replicated Experiment 1. A number of effects that were present in the response time data in Experiment 1 reached significance only in the error data in Experiment 2, perhaps due to a slight difference in relative weightings of speed versus accuracy between the two groups of participants. Advantages for Symbicons as compared with conventional symbols are present even when a background provides contrast for the leader line. Furthermore, the interaction of search type and symbol type suggests that advantages for Symbicons may result in part from grouping effects whereby groups of Symbicons are simultaneously monitored for change. That is, participants may be able to use information to selectively monitor subgroups of Symbicons for changes in heading, whereas for conventional symbols the number of symbols that can simultaneously be monitored may be smaller. The replication of this result in Experiment 2 suggests that this type of grouping effect underlies differences between symbol sets, as improving the relative discriminability of heading for MIL-STD-2525B did not alter the results.

General discussion

A change detection methodology was used to compare the traditional MIL-STD-2525B tactical symbols with the new Symbicon symbol set developed by the U.S. Navy. The advantage of this method over other evaluation techniques is the fact that it provides estimates of not only the ease with which these symbols may be detected and discriminated, but also quantifies the efficiency of search for changes. The ability to selectively monitor subgroups of contacts that share properties was also evaluated using this method, and the ease with which the symbol sets could be learned was also evaluated.

The results of the training task demonstrated that novice participants could learn the classification of platform category quickly, regardless of symbology. Based on equivalent performance with the MIL-STD-2525B and Symbicon symbol sets, they could be considered to have equal expertise with both symbol sets prior to beginning the change-monitoring task.

When the symbols were placed in tactical displays, heading changes were detected faster and more accurately for the Symbicons. When participants were told which platform category might change, participants could use this information with the Symbicons to improve their response time and accuracy but were unable to improve their performance with the MIL-STD-2525B displays. The manipulation of the number of irrelevant symbols in the display demonstrated that participants were not able to selectively monitor only the target symbols. Increasing the number of irrelevant symbols in the displays caused longer response times and greater errors for both the Symbicons and the MIL-STD-2525B symbols, but to a lesser degree for the former. These results replicate those earlier found with visual seach (Smallman et al. 2001b) in suggesting that Symbicons provide heading information more readily than the MIL-STD-2525B symbols and that this information may be extracted faster from the Symbicons.

The ability to make use of the platform category constraint observed for the Symbicons is most likely a result of their frame shape. Symbicons have more homogeneity, with only two distinguishable frames to code for the platform category. The frame of the MIL-STD-2525B symbols codes for threat affiliation as well, and so the platform category must be determined by whether the frame is open at the bottom or closed. With the MIL-STD-2525B displays, participants were not able to effectively direct their attention to four of the eight different frame shapes, and so were not able to improve their search times when told which platform might change. Although the shape of the Symbicons did not vary within the platform categorization their orientation did. Orientation was consistent across the platform category for the MIL-STD-2525B. Thus, these results suggest that monitoring or grouping by shape may occur across disparate orientations to some extent. Both symbol sets varied in colour across the platform category. Since colour is frequently a very salient dimension, it may have interfered with the ability to group or monitor the symbols according to frame shape.

It may be that no matter how contacts are coded, the complexity required in tactical displays may preclude efficient search. If this is the case then it may not be reasonable to expect that operators can selectively monitor particular platform categories for change. Coding strategies may make the deployment of attention toward subgroups of relevant contacts a little easier, however. Alternatively, changes may themselves be coded more explicitly in the display through the use of track history indicators or animations.

The finding that search times increased substantially when irrelevant contacts were added to the display has implications for the notion of Variable-Coded Symbology. Participants were not able to selectively monitor all of the similarly shaped sea or air contacts for heading changes. However, these experiments do provide some evidence that small subsets of the symbols could be grouped together and monitored for change when the frame (shape) of these symbols was the same. It is possible that low-level visual primitives that contribute to shape (i.e. closure and curvature) might support complete selective attention even in complex tactical displays; however, this was not tested. Further research is required to determine whether other dimensions such as color or luminance permit selective monitoring of larger groups, or "chunks" of symbols. If coding dimensions are discovered that permit attentional selection of all like symbols in the display, it might be possible to take advantage of these grouping principles to overcome the attentional and short-term memory limitations that underlie "change blindness", or failures to notice important changes to tactical displays. In the meantime, designers of tactical displays must be aware that regardless of symbology, operators can be expected to frequently miss important and visible changes in the contacts they are responsible for monitoring, even when such changes are expected.

Conclusion and recommendations

These experiments demonstrate the utility of a novel methodology for evaluating symbologies, through the use of a selective monitoring task in a change blindness paradigm. This methodology permits the comparison of symbol sets on a number of cognitive components of the operator's tasks, including the ability to selectively monitor subsets of contacts for change. The results suggest advantages for Symbicons that are consistent with previous findings. Moreover, these findings highlight the difficulty of selective monitoring tasks. When variable-coded symbology techniques are to be used to facilitate selective monitoring, coding dimensions should be chosen carefully and tested extensively to determine whether human observers can in fact make use of that dimension in the context of the complex displays they will be observing. It is recommended that the relative utility of various coding dimensions be evaluated in terms of their ability to permit grouping or selective attention to subsets of symbols that share physical characteristics. This information should be available to designers of symbol sets, particularly those that are to be used in complex or three-dimensional displays. Only then will it be possible to design truly effective symbols that facilitate the effective deployment of attention and situational awareness of the operator.

References

1. Chun, M.M., Wolfe, J.M. (1996). Just say no: How are visual searches terminated when there is no target present? *Cognitive Psychology*, 30:39-78.

2. Department of Defense (1999). Department of Defense Interface Standard: Common Warfighting Symbology. MIL-STD-2525B. Reston, VA: DISA/JIEO/CFS. Also available online http://www-symbology.itsi.di.sa.mil/symbol/mil-std.htm.

3. DiVita, J.C., Nugent, W. (2000). Managing Critical Events in a Multimodal Watchstation. *Proceedings of the IEA 2000/HFES 2000 Congress*. 6:469-472. Santa Monica, CA: Human Factors and Ergonomics Society.

4. Rensink R.A., O'Regan J.K., Clark J.J. (1997). To See or Not to See: The Need for Attention to Perceive Changes in Scenes. *Psychological Science*, 8:368-373.

5. Rensink, R.A. (2000). Visual Search for Change: A Probe into the Nature of Attentional Processing. *Visual Cognition*, 7:345-376.

6. Smallman, H.S., Oonk, H.M., St. John, M., Cowen, M.B. (2001a). Symbicons: Advanced Symbology for Two-Dimensional and Three-Dimensional Displays. Technical Report 1850 (February). San Diego, CA: Space and Naval Warfare Systems Center.

7. Smallman,H.S., St. John, M., Oonk, H.M., & Cowen, M.B. (2001b) 'SYMBICONS': a hybrid symbology that combines the best elements of SYMBols and ICONS. Proceedings of the 45th Annual Meeting of the Human Factors and Ergonomics Society. (pp. 110-114). Human Factors and Ergonomics Society, Santa Monica, CA.

8. Smallman, H.S., St. John, M., Oonk, H.M., Cowen, M.B. (2000). Track Recognition Using Two-Dimensional Symbols or Three-Dimensional Realistic Icons. Technical Report 1818 (March). San Diego, CA: Space and Naval Warfare Systems Center.

9. St. John, M., Feher, B.A., & Morrison, J.G. (2002). Evaluating alternative symbologies for decluttering geographical displays. Space and Naval Warfare System Center. Technical report 1890: (August). San Diego, CA: Space and Naval Warfare Systems Center.

10. Wolfe, J.M. (1998). Visual Search. Pashler, H. (Ed). *Attention*. Hove, England: Psychology Press / Erlbaum.

11. Osga. G.A. and Keating, R.L. (1994). Usability study of variable coding methods for tactical information display visual filtering (NraD Technical Document 2628). San Diego, CA: Naval Command, Control and Ocean Surveillance Center, Research Development Test and Evaluation Division, Code 441.

DOCUMENT CONTROL DATA SHEET

1a. PERFORMING AGENCY
DRDC Toronto

1b. PUBLISHING AGENCY
DRDC Toronto

2. SECURITY CLASSIFICATION
UNCLASSIFIED
Unlimited distribution -

3. TITLE
(U) Detection of heading changes in tactical displays: A comparison of two symbol sets

4. AUTHORS
Jocelyn Keillor, Laura Thompson, Harvey Smallman, M.B. Cowen

5. DATE OF PUBLICATION
December 17 , 2003

6. NO. OF PAGES
42

7. DESCRIPTIVE NOTES

8. SPONSORING/MONITORING/CONTRACTING/TASKING AGENCY
Sponsoring Agency:
Monitoring Agency:
Contracting Agency :
Tasking Agency: Space and Naval Warfare Systems Center San Diego, 53560 Hull Street, San Diego, CA 92152-5001
Pacific Science and Engineering Group 6310 Greenwich Drive, Suite 200, San Diego, CA 92122

9. ORIGINATORS DOCUMENT NO.
Technical Report TR 2003-008

10. CONTRACT GRANT AND/OR PROJECT NO.

11. OTHER DOCUMENT NOS.

12. DOCUMENT RELEASABILITY
Unlimited distribution

13. DOCUMENT ANNOUNCEMENT
Unlimited announcement

14. ABSTRACT

(U) As the technologies available for tactical displays evolve and improve, the development of tactical symbol sets with which to populate these new displays becomes an important issue. A new method for evaluating symbol sets was developed, using a “change blindness”, or flicker paradigm to simulate an operators shifts of attention during interaction with the display and environment. In addition to providing measures of an operator’s ability to discriminate symbols and detect changes in the display, this method also provides an indication of the extent to which operators may selectively monitor subgroups of similar contacts for change. In the present experiments two symbol sets were compared: MIL-STD-2525B, and Symbicons, a hybrid symbology developed by the U.S. Navy. Overall, Symbicons outperformed the traditional MIL-STD-2525B symbols when participants were required to detect heading changes in contacts. Furthermore, only the Symbicons allowed participants to take advantage of advance knowledge of the type of platform (sea or air) which would change heading. Neither symbol set permitted selective monitoring of all relevant contacts in the display, and further study is required to determine which coding dimensions best support this type of attentional selection.

(U) À mesure qu’évoluent les technologies disponibles concernant les écrans tactiques, la mise au point d’ensembles de symboles tactiques pour remplir ces nouveaux écrans devient une question importante. Une nouvelle méthodologie d’évaluation des ensembles de symboles a été mise au point, selon un paradigme de clignotement ou de scintillement, afin de simuler le changement de l’attention chez l’opérateur lors de son interaction avec l’écran et l’environnement. En plus de mesurer la capacité d’un opérateur à discriminer des symboles et à détecter des changements à l’écran, cette méthode permet de savoir dans quelle mesure l’opérateur peut surveiller de manière sélective les changements apportés à des sous-groupes de contacts semblables. Dans les présentes expériences, deux ensembles de symboles ont été comparés : MIL-STD-2525B et Symbicons, une symbologie hybride élaborée par les Forces navales des États-Unis. Globalement, Symbicons a offert des performances supérieures à celles de la norme MIL-STD-2525B classique lorsque les participants ont été appelés à détecter les changements apportés aux en-têtes des contacts. De plus, seule la norme Symbicons a permis aux participants de tirer avantage des connaissances poussées concernant les types de plates-formes (maritime ou aérienne) qui modifieraient un en-tête. Ni l’un ni l’autre ensemble de symboles n’ont permis de surveiller de manière sélective tous les contacts pertinents à l’écran; il faudra procéder à une étude approfondie pour déterminer quelles dimensions de codage appuient le mieux ce type de sélection attentionnelle.

15. KEYWORDS, DESCRIPTORS or IDENTIFIERS

(U) symbology; tactical displays; heading; MIL-STD-2525B; visual search; change detection; change blindness; attention; flicker paradigm