Article





Investigations for Ergonomic Presentation of AIS Symbols on ECDIS

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Abstract

Empirical investigations were carried out in a research project for the German Federal Ministry of Transport, Building, and Housing to evaluate the presentation of AIS target information on ECDIS. The investigations were performed at three international simulation centres. The features, colour and filling/size of AIS symbols, as well as the influence of the ECDIS display category on the detection of AIS targets were the main issues of the investigations. Results show that blue (S-52 colour token RESBL) is the most suitable colour of the tested colours for the presentation of AIS targets under all ambient light conditions on the tested IHO S-52 colour tables.

Résumé

Des investigations empiriques ont été effectuées dans le cadre d'un projet de recherche du Ministère fédéral allemand des Transports, de la Construction et du logement, en vue d'évaluer la présentation des informations cibles des systèmes AIS sur les ECDIS. Ces investigations ont été effectuées dans trois centres de simulation internationaux. La couleur des éléments et la teinte /la taille des signes conventionnels des AIS, ainsi que l'influence de la catégorie d'affichage de l'ECDIS sur la détection des cibles AIS ont constitué les principaux thèmes des investigations. Les résultats ont montré que le bleu (code de couleur RESBL dans la S52) est la couleur la plus appropriée parmi celles testées pour la présentation des cibles AIS sous toutes les conditions ambiantes de lumière dans le cadre des tables de couleur testées de la S52 de l'OHI.

Resumen

Las investigaciones empíricas fueron llevadas a cabo en un proyecto de investigación para el Ministerio Federal Alemán de Transporte, Construcción y Vivienda para evaluar la presentación de la información de objetos del AIS en el ECDIS. Se emprendieron investigaciones en tres centros de simulación internacionales. Las características, color y tamaño de los símbolos del AIS, así como la influencia de la categoría de la presentación ECDIS en la detección de objetos del AIS fueron los temas principales de las investigaciones. Los resultados muestran que el azul (muestras del color RESBL de la S-52) es el color más apropiado de entre los colores puestos a prueba, para la presentación de los objetos del AIS bajo todas las condiciones de luz ambiente en las tablas de colores puestos a prueba de la S-52 de la OHI.

Introduction

With the revision of SOLAS Chapter V (IMO, 2000) the mandatory carriage of Automatic Identification Systems (AIS) onboard vessels will be phased in between 1 July 2002 and 31 December 2004. AIS, a broadcast transponder system, operating in the VHF maritime band, offers a variety of important and relevant information for collision avoidance and navigation, exchanged between ships and between ships and Vessel Traffic Service (VTS) stations in real-time (Figure 1).

AIS provides fast, automatic, and accurate information regarding the risk of collision and has the potential to enhance shipborne radar as the primary device for collision avoidance (IMO, 1998). The introduction of AIS will improve the safety of navigation, depending on a optimal ergonomic integration of AIS information into the navigational displays. The implementation of AIS requires a suitable presentation and integration of the information in the bridge information systems to support the mariner in his tasks and to improve effectively the safety of navigation.

The ergonomic design of this information presentation requires empirical investigations. Some of these were conducted in a research project for the German Federal Ministry of Transport, Building, and Housing in cooperation with the Maritime and Port Authority of Singapore, the Memorial University of Newfoundland, Canada, and the Maritime Simulation Centre, Warnemuende, Germany.

International Standards for Display of Navigation-related Information

At present, there is no overall standard for the display of navigation-related information on the bridge of a ship (Alexander et al., 2004). The performance standards for each system or equipment deal with presentation and display differently. During the 47th session of the IMO Subcommittee of Safety of Navigation in 2001, IEC was invited to establish a working group to develop an overall standard for the presentation of navigational information. In 2002, IEC reported to IMO NAV 48 that it had established a new working group, International Electrotechnical Commission (IEC) TC80 WG13, on "Presentation of navigation related information".

In 2003, IEC submitted draft Performance Standards for the "Presentation of navigation related information" to IMO NAV at its 49th session. The draft standards included annexes for the harmonisation of terms and symbols used to present navigation-related information. IMO NAV 49 decided that more detail was needed to resolve conflicts and inconsistencies between individual performance standards, and established a Correspondence Group to further progress the work. Also, IMO NAV 49 felt that new performance standards should take precedence over existing equipment performance standards when conflicts regarding presentation issues occur.

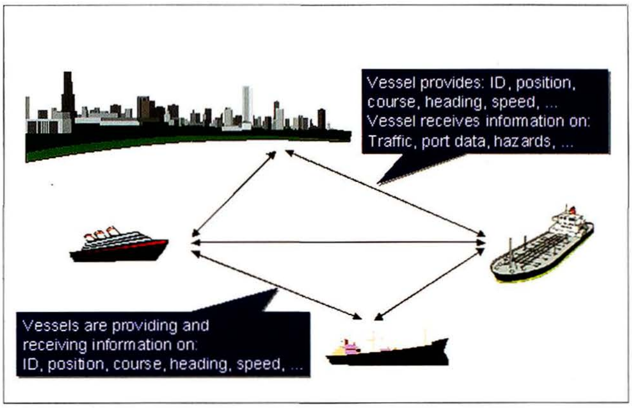

Figure 1: AIS information transfer

In March 2004, the Correspondence Group submitted new draft Performance Standards for the Presentation of navigation related information to IMO for consideration at the 50th session of NAV. These Performance Standards contain more detailed requirements for the presentation of navigation related information and are accompanied by two draft Safety of Navigation Circulars (SN/Circ.) related to Terms and Abbreviations and Symbology. If adopted at IMO NAV50 these harmonised terms and symbols would replace those contained in existing equipment performance standards.

Problem

In 2001 at the 47th session of the IMO Subcommittee of Safety of Navigation interim guidelines on the presentation and display of AIS target information were adopted and issued as SN/Circ. 217 (IMO, 2001). However, at that time no decision could be made regarding a final solution for the presentation of AIS information due to lack of practical experience. Therefore, the accumulation of practical experience for the use and display of AIS information was needed before appropriate AIS display standards could be finalised. Since the deadline for the shipborne installation is December 2004, there was some urgency to conduct empirical trials.

AIS information can be displayed onboard ships by several means:

- Separate (independent) AIS display
- Radar
- Electronic Chart Display and Information System (ECDIS)
- Integrated navigation system (INS) / integrated bridge system (IBS)

The implementation of AIS information onboard ships requires the integration of different information sources which are integrated in a single display, (e.g., radar, ARPA, and AIS information). However, the presentation of AIS information on these various devices must be consistent, and the content and presentation of the information from the different sources should be harmonised.

In particular, there is a compelling need to develop a suitable graphical presentation of AIS information to:

- Improve target identification
- Reduce the mariner's workload by presenting information in a readily assimilated format
- Enhance 'Situation Awareness'
- Reduce the risk of collision and to improve the safety of navigation, particularly in congested waters

For the graphical presentation, the presented information must fulfil the requirements for:

- Detection (determining the presence of an object, target or symbol)
- Discrimination (discriminating between target objects and non-target objects)
- Identification (attributing a name or meaning to some object or target)
- Recognition (determining whether objects in the display have been seen and perceived before)
- Comprehension (understanding the meaning of a given display so that an associated consequent course action is both apparent and possible)

Ideally, the number of new elements (symbols) required for the visualisation of AIS information should be kept as small as possible. Characteristics of symbols that may have effects upon these requirements include, e.g., size, shape, contrast, colour, complexity, concreteness, dynamism, system context and the user's experience with symbols (Motz & Widdel, 2000a). In previous experiments the shape of AIS targets was investigated, resulting in a recommendation for an orientated triangle as AIS target symbol (Motz & Widdel, 2000b and 2001).

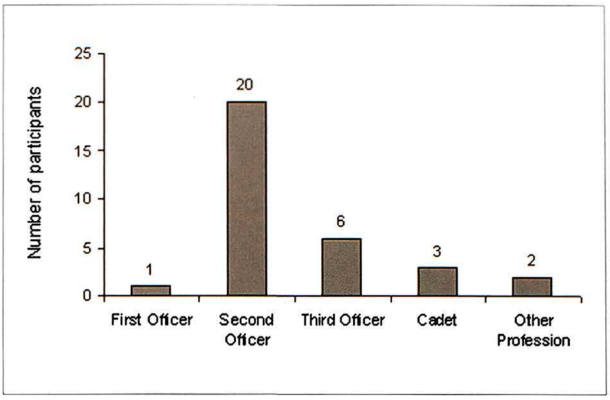

Figure 2: Current position of participants in ISC experiments

Based on what was proposed in IMO SN/Circ. 217, the symbols for AIS targets should be designed, evaluated and harmonised with the displayed information of other sources. This is particularly true for the colours of AIS target symbols when used with ECDIS. Important considerations to be tested are possible modifications that could be made to AIS symbol features that would enhance their detectability on an already cluttered ECDIS display, e.g, filling of symbols, increasing of size.

Empirical Investigations

Organisation

A series of experimental investigations were conducted to analyse different presentation features of AIS symbols on ECDIS. The first investigation took place at the Integrated Simulation Centre of Singapore (ISC) of the Maritime and Port Authority. The features colour and filling/size of AIS symbols, as well as the influence of the ECDIS display category on the detection of AIS targets were the main issues investigated (Motz et al., 2003). The second investigation was performed at the Center for Marine Simulation (CMS) at the Memorial University of Newfoundland, Canada. Using a motion-based simulator, AIS target symbol colour, the ECDIS display category, and the influence of motion were evaluated. For the third investigation, the presentation of AIS targets on ECDIS was evaluated using the ship bridge simulator at the Maritime Simulation Centre Warnemünde (MSCW) of the University of Wismar in Germany. The colour of AIS symbols and the influence of the ECDIS display category were the main issues studied.

For the investigations, two PCs (Laptops) with SevenCs ECDIS simulation software were used. One PC was used to control the experiment by calling up the scenarios and for recording data. The second one was used to display the traffic scenarios on ECDIS. A colour 21' CRT monitor was used to display the scenarios on ECDIS at ISC, while 18' LCD monitors were used at CMS and MSCW. All three monitors were new and calibrated.

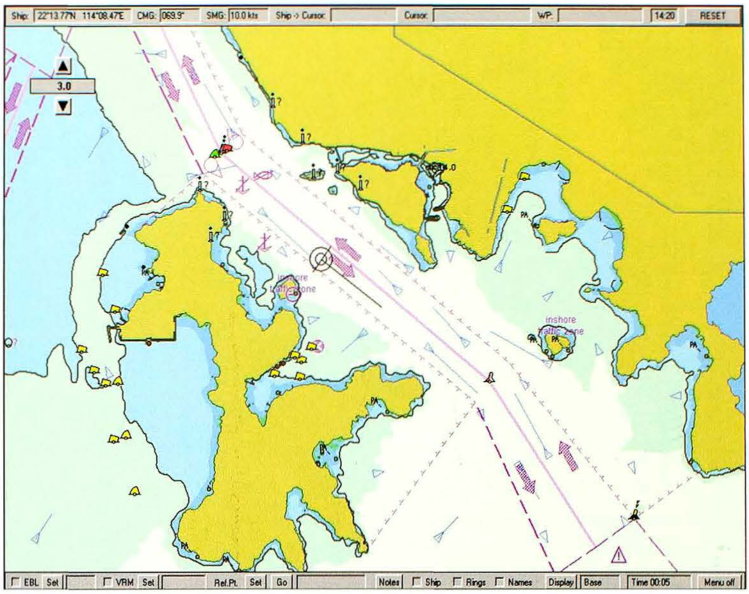

Figure 4: Example of a traffic scenario on Display Base

The three different trial locations involved a range of mariners. At ISC 32 mariners participated as subjects during the investigation. Coming from 10 different Asian countries, almost all were currently working at sea and serving as a Second Officer (Figures 2 and 3). At CMS there were 30 subjects, while at MSCW there were 31. They included master mariners, navigational officers, professors, marine lecturers, and senior cadets of the maritime training institutes.

The investigations consisted of two parts, a *detection experiment* and a following *questionnaire*. For the detection experiments, AIS target symbols were presented in different colours in traffic scenarios on ECDIS. For each scenario the subjects were asked to detect the AIS targets on the ECDIS display. A questionnaire (interview) was then administered to each participant to gain their perspective and views regarding the design and presentation of the AIS symbols on ECDIS.

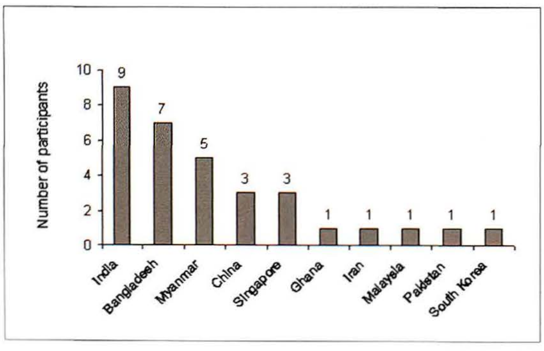

Figure 3: Nationality of participants in ISC experiments

Material

In the detection experiment AIS symbols in three different colours were presented in traffic scenarios on ECDIS:

- Green (IHO S-52 colour token ARPAT)
- Black on white background and white for black background (IHO S-52 colour token SHIPS)
- Blue (IHO S-52 colour token RESBL)

The investigation used just these three colours since they are the only ones that could be selected as an AIS target colour on ECDIS based on the current IHO S-52 colours and symbols specifications for ECDIS (IHO, 1999). Furthermore the AIS symbols were displayed using a 'non-colour fill' and 'colour fill' with a 30 % smaller size. The trials also evaluated the detection of AIS symbols when using the Standard Display and Display Base as specified in the IMO Performance Standards for ECDIS (IHO, 1996).

The investigations were conducted for three different ambient light conditions:

- Daylight (~ 800 Lux)
- Twilight (~ 30 Lux)
- Night

For each of the ambient light conditions, the ECDIS display was configured to show the IHO S-52 background colour schemes (IHO, 1999):

- Daylight - white background (IHO S-52 colour table - bright sun)
- Twilight - white background (IHO S-52 colour table - day white background)
- Night - black background (IHO S-52 colour table - night).

The decision to use the IHO S-52 colour table 'day white background' and not 'day black background' or 'dusk' for the twilight condition was based on preliminary results of a study carried out at the Department of Maritime Studies of the University of Wismar (Herberg & Baldauf, 2003). The results indicate a preference of mariners to use a white background at twilight.

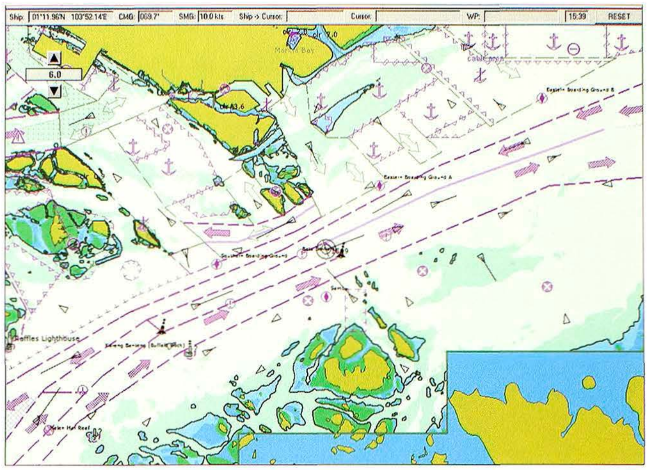

Figure 5: Example of a traffic scenario on Standard Display

Nine traffic scenarios with 20 targets and 17 distractor symbols per scenario were used. This included three traffic situations in the Strait of Singapore, three of the Hong Kong approach, and three of the Strait of Dover. Three traffic scenarios, one of each region, were used for each ambient light condition. Targets to be detected were AIS target symbols without displaying any vector (sleeping targets) and as distractor symbols AIS symbols displaying course and speed vector (activated AIS targets) were defined. Examples of the scenarios are shown in Figures 4 and 5. The ECDIS was displayed with a 15 m *safety contour, traditional symbols, enabled light symbolisation for night, disabled display of names for Display Base and enabled display of names* for Standard Display.

Experimental Design

The experiments at ISC, CMS and MSCW were split into three separate experimental units for the three ambient light conditions (i.e., daylight, twilight and night). A 3 x 2 x 2 factorial design with three independent factors, one grouping factor (between-subject factor) and two within-subject factors, was used for each experimental unit at ISC. A 3 x 2 factorial design with two independent factors was used for each experimental unit at CMS and MSCW.

The factor *symbol colour* (within-subject factor) varied on the three levels

- Green
- Black on white background and white for black background
- Blue

The factor *ECDIS display category* (between-subject factor at ISC and within-factor at CMS and MSCW) varied on the two levels

- Display Base
- Standard Display

At ISC the factor *filling/size* (within-subject factor) varied on two levels

- Unfilled symbols
- Filled, 30 % smaller size

At ISC for each of the three ambient light conditions each target colour was presented in each of the three scenarios, i.e, in each scenario 20 targets and 17 distractor symbols appeared once in green, once in black and once in blue (daylight and twilight) and once in green, once in white and once in blue at night. The trials were conducted once with unfilled and once with filled symbols. Thus, the AIS target symbol appeared in six different variations on both *Display Base* and *Standard Display*. Each display category was tested with half of the subjects. The subjects were numbered serially and the odd numbers were assigned to *Display Base* and the even numbers to *Standard Display*. The factorial combination of colour, filling/size and ECDIS display category comprised the 12 experimental treatments for each ambient light condition. This created 36 different combinations per ambient light condition (12 experimental treatments x 3 scenarios). The presentation order of the trials was balanced to avoid intervening effects. The dependent variables were the frequency of found targets and the frequency of false symbols (distractor symbols).

At CMS and MSCW for each of the three ambient light conditions each target colour was presented once in each of the three scenarios, i.e, in each scenario 20 targets and 17 distractor symbols appeared once in green, once in black and once in blue (daylight and twilight) and once in green, once in white and once in blue at night. They were presented with equal frequency with the ECDIS display categories *Display Base* and *Standard Display.* The factorial combination of colour and ECDIS display cate-gory comprised the six experimental treatments for each ambient light condition (18 trials per ambient light condition). The presentation order of the trials was balanced to avoid intervening effects. At CMS the experiment was carried out without and with full motion. The dependent variables were the frequency of found targets and the frequency of false symbols (distractor symbols).

Experimental Procedure

Subjects were asked to detect as many targets as quickly as possible in the various traffic scenarios, and to identify these targets by positioning the cursor on the target and then clicking with the left button of the computer mouse. Time-on-task was limited to 20 seconds per scenario. After 20 seconds, the trial was interrupted and the display was blocked until the next trial was started. All selected targets and selected distractor symbols were recorded. After two practice trials, each participant had to search for targets for each ambient light condition. This was done first in daylight, second in twilight, and third at night. Before conducting the trials for the ambient light condition *night*, a five minute night vision adaptation time period was provided for the subjects.
At ISC, the experiment was carried out with 16 subjects evaluating *a Base Display* and 16 subjects evaluating *a Standard Display* (between-subject factor). At CMS all the trials were first conducted with *without motion.* Following a break of one hour, each subject repeated the trials *with full motion.* At MSCW the trials were carried out with ECDIS *Display Base* first and then repeated with ECDIS *Display Standard.*
Following the detection experiments, a structured questionnaire was administered to each of the participants to gain insight and opinions regarding the design of the AIS symbols on ECDIS. The questions dealt with the colours of AIS symbols, added filling of symbols, the ability to detect the targets in the different ambient light conditions, the information content of the ECDIS, and the use of ECDIS colour tables during night.

Statistical Analysis

For the statistical analysis of the ISC data a 3 x 2 x 2 model of ANOVA for one grouping and two within factors (SPSS, 2002) was used 3 times for the statistical analysis for the three ambient light conditions with the independent variables described before. For the CMS data a 3 x 2 model of ANOVA for two within factors was run 6 times for the statistical analysis of the investigations *without motion* and *with motion* and for the three ambient light conditions with the independent variables. A 3 x 2 model of ANOVA for two within factors was used 3 times for the statistical analysis of the investigations at MSCW for the three ambient light conditions. ANOVA is a well established inference statistical technique for analysis of variance between different groups (Hays, 1973).
The dependent variables included in all three cases the frequency of found targets and the frequency of false hits (distractor symbols). The measure was the sum of the frequencies for the respective three scenarios of each experimental treatment. They were tested on 5 % level of significance with an analysis of variance in combination with Scheffé post-hoc test. The Scheffé test is used to make unplanned comparisons among multiple means in an experiment (Scheffé, 1963).The results for the false hits are not presented, because of a too low occurrence, leading to invalid interpretation of the statistical results.

Results of the Investigation at the ISC in Singapore

Detection Experiment

Trials for daylight with IHO S-52 colour table 'bright sun'

The results of the ANOVA show main effects for ECDIS display category ($F_{1,30}$ = 44.25; p<0.00), for colour ($F_{2,60}$ = 22.28; p<0.00) and for filling ($F_{1,30}$ = 8.77; p<0.00), and an interaction effect for ECDIS display category and colour (ExC) ($F_{2,60}$ = 6.52; p<0.00). In general, more filled than unfilled targets are found. A more detailed analysis carried out for colour comparing the means in the ECDIS display categories with the Scheffé test on 0.05 significance level shows that on *Display Standard* significant more blue targets than green and black targets are found. More targets are found on *Display Base* than on *Standard Display.*

Trials for twilight with IHO S-52 colour table 'day white background'

The results of the ANOVA show the main effects for

Ambient Light	ECDIS display	Results colour	Results filling
Daylight	Base	n.s.	filled > unfilled
	Standard	blue > green and black	filled > unfilled
Twilight	Base	blue and black > green	n.s.
	Standard	blue and black > green	filled > unfilled
Night	Base	blue > white and green	n.s.
	Standard	blue > green > white	n.s.

n.s. = not significant;
> = significant

Table 1: Results of the detection experiment at ISC in Singapore

ECDIS display category ($F_{1,30}$ = 19.33; p<0.00), for colour ($F_{2,60}$ = 18.06; p<0.00) and for filling ($F_{1,30}$ = 36.70; p<0.00), and an interaction effect for filling and ECDIS display category ($F_{1,30}$ = 7.91; p<0.01). The results of the ANOVA and Scheffé test on 0.05 significance level show significantly higher frequencies of found blue targets and black targets than green targets. The results furthermore indicate higher frequencies of found filled than unfilled targets on *Standard Display* and that more targets are found on *Display Base* than on *Standard Display.*

Trials for night with IHO S-52 colour table 'night'
The results of ANOVA show the main effects for the ECDIS display category (F1,30 = 10.64; p<0.0), for colour ($F_{2,60}$ = 127.95; p<0.00), and for filling ($F_{1,30}$ = 4.94; p<0.03), and interaction effects for ECDIS display category with colour ($F_{2,60}$ = 9.02; p<0.00), and for ECDIS display category with filling ($F_{1,30}$ = 5.19; p<0.03). The results of the Scheffé test on 0.05 significance level indicate that on *Base Display* significant more blue targets than green or white targets are found, and on *Standard Display* more blue than green or white, and more green than white. Furthermore, more targets are found on *Display Base* than on *Standard Display.* In Table 1 the results are condensed for the three different ambient light conditions.

Questionnaire
For daylight the results show that most of the participants prefer black as AIS target colour. For twilight the preferred colours of most of the participants are black and blue. For night white and blue are the preferred colours for *Display Base* and blue for *Standard Display.* A preference for unfilled symbols is indicated by the *Display Base* group. The results for assessment of the most difficult ambient light condition for the detection of the targets indicate that on *Standard Display* the most difficult ambient light condition for the targets was night with ECDIS displaying the IHO S-52 colour table 'night'. The group of participants which conducted the trials with *Standard Display* indicated their preference to display less information on ECDIS to improve target detection. Even 50 % of the *Display Base* group indicated their preference to display less information in order to improve AIS target detection.

Results of the Investigation at the CMS in Canada

Detection Experiment
Trials for daylight with IHO S-52 colour table 'bright sun'
The results of the ANOVA for *without motion* show main effects for ECDIS display category ($F_{1,29}$ = 99.14; p<0.00), for colour ($F_{2,58}$ = 23.10; p<0.00), and an interaction effect for ECDIS display category and colour (ExC) ($F_{2,58}$ = 14.48; p<0.00). A more detailed analysis carried out for colour with the Scheffé test on 0.05 significance level show that on *Display Standard* significant more black and blue than green targets and more black than blue targets are found. More targets are found on *Display Base* than on *Standard Display.*
The ANOVA for *with motion* shows the main effects for ECDIS display category (F1,29 = 109.22; p<0.00). for colour ($F_{2,58}$ = 6.74; p<0.00), and an interaction effect for ECDIS display category and colour (ExC) ($F_{2,58}$ = 15.16; p<0.00). A more detailed analysis carried out for colour with the Scheffé test on 0.05 significance level show that on *Display Standard* significant more black than green targets are found. More targets are found on *Display Base* than on *Standard Display*, except for black targets.

Trials for twilight with IHO S-52 colour table 'day white background'
The results of the ANOVA for *without motion* show main effects for ECDIS display category ($F_{1,29}$ = 74.77; p<0.00), for colour ($F_{2,58}$ = 50.53; p<0.00), and an interaction effect for ECDIS display category and colour (ExC) ($F_{2,58}$ = 5.03; p<0.01). The results of the Scheffé test on 0.05 significance

n.s. = not significant;
> = significant

Table 2: Results of the detection experiment at CMS in St. Johns, Canada

Ambient Light	ECDIS display	Without motion	With motion
Daylight	Base	n.s.	n.s.
	Standard	black > blue > green	black > green
Twilight	Base	black > green	n.s.
	Standard	black > blue and green	black > green
Night	Base	blue and green > white	blue and green > white
	Standard	blue and green > white	blue > green > white

level indicate higher frequencies of found black than green targets on *Display Base* and higher frequencies of found black than blue and green targets on *Standard Display*. More targets are found on *Display Base* than on *Standard Display*.
For *with motion* main effects are found for ECDIS display category ($F_{1,29}$ = 77.08; p<0.00), for colour ($F_{2,58}$ = 18.04; p<0.00), and an interaction effect for ECDIS display category and colour (ExC) ($F_{2,58}$ = 7.08; p<0.00). A detailed analysis carried out for colour with the Scheffé test on 0.05 significance level show that on *Display Standard* significant more black than green targets are found. More targets are found on *Display Base* than on *Standard Display*, except for black targets.

Trials for night with IHO S-52 colour table 'night'
In the statistical analysis for night one participant had to be excluded, because of recording problems. The results of the ANOVA for *without motion* show main effects for ECDIS display category ($F_{1,28}$ = 188.55; p<0.00), for colour ($F_{2,56}$ = 98.08; p<0.00), and an interaction effect for ECDIS display category and colour (ExC) ($F_{2,56}$ = 21.66; p<0.00). The results of the Scheffé test on 0.05 significance level verify that on both display categories significant more blue and green than white targets are found. More targets are found on *Display Base* than on *Standard Display*.
The ANOVA shows for *with motion* main effects for ECDIS display category ($F_{1,28}$ = 62.50; p<0.00), for colour ($F_{2,56}$ = 71.49; p<0.00), and an interaction effect for ECDIS display category and colour (ExC) ($F_{2,56}$ = 18.07; p<0.00). A detailed analysis carried for colour with the Scheffé test on 0.05 significance level shows that on *Display Base* significant more blue and green than white targets are found. On *Display Standard* significant more blue than green and white, and more green than white targets are found. More targets are found on *Display Base* than on *Standard Display*. In Table 2 the results are condensed for the three different ambient light conditions.

Questionnaire
For daylight the results show that most of the participants prefer black as AIS target colour. For twilight the preferred colour of most of the participants is also black. For night the results show a preference of most of the participants for blue as AIS target colour. The results indicate that the most difficult ambient light condition for the detection of the targets was night with ECDIS displaying the IHO S-52 colour table 'night'. Over 60 % of the participants indicated their preference to display less information to improve AIS target detection on *Display Base* and almost all of the participants indicated their preference to display less information on *Display Standard*.

Results of the Investigation at the MSCW in Germany

Detection Experiment
Trials for daylight with IHO S-52 colour table 'Bright sun'
The results of the ANOVA show main effects for ECDIS display category (F1,30 = 27.98; p<0.00), for colour (F1,30 = 42.02; p<0.00), and an interaction effect for ECDIS display category and colour (ExC) (F2,60 = 14.99; p<0.00). A more detailed analysis carried out for colour with the Scheffé test on 0.05 significance level show that with *Standard Display*, significantly more black and blue than green targets are found. More targets are found on *Display Base* than on *Standard Display*, except for black targets.

Trials for twilight with IHO S-52 colour table 'day white background'
The results of the ANOVA show main effects for ECDIS display category (F1,30 = 46.74; p<0.00), for colour (F1,30 = 36.67; p<0.00), and an interaction effect for ECDIS display category and colour (ExC) (F2,60 = 4.75; p<0.01). In general, more targets are found on *Display Base* than on *Standard*

Display. A more detailed analysis carried out for colour with the Scheffé test on 0.05 significance level show that with *Display Standard* significantly more black and blue than green targets are found.

Trials for night with IHO S-52 colour table 'night'

The results of the ANOVA show main effects for ECDIS display category ($F_{1,30} = 116.25$; $p<0.00$), for colour ($F_{1,30} = 93.98$; $p<0.00$), and an interaction effect for ECDIS display category and colour (ExC) ($F_{2,60} = 17.76$; $p<0.00$). In general, more targets are found on *Display Base* than on *Standard Display.* A more detailed analysis carried out for colour with the Scheffé test on 0.05 significance level show that significant more blue than green and white and more green than white targets are found on both display categories. In Table 3 the results are condensed for the three different ambient light conditions.

Ambient Light	ECDIS display	Results
Daylight	Base	n.s.
	Standard	black and blue > green
Twilight	Base	n.s.
	Standard	black and blue > green
Night	Base	blue > green > white
	Standard	blue > green > white

n.s. = not significant; > = significant

Table 3: Results of the detection experiment at MSCW in Warnemünde, Germany

Questionnaire

For daylight the results show that most of the participants prefer black as AIS target colour. For twilight the preferred colour of most of the participants is also black. For night white and blue are the preferred colours. The results show that the most difficult ambient light condition for the targets was night with ECDIS displaying the IHO S-52 colour table 'night' and that the easiest ambient light condition for the targets was daytime with ECDIS displaying the IHO S-52 colour table 'day'. Almost all of the participants indicated their preference to display less information on *Display Standard.* Figure 6 show the preferences which of the objects can be removed of the ECDIS display categories to improve targets detection.

Discussion and Conclusions

Based on the results of these empirical investigations, blue and black are the most perceptible AIS target colours for daylight and twilight, and blue for night. For those conducted at ISC, in daylight and twilight conditions blue and black are superior with a strong tendency to favour blue. For the investigation at CMS, black is superior with one exception, while for the MSCW investigation, there was toss-up between black and blue. These findings were generally confirmed by the questionnaire results. Differences in the advantage between blue and black might be due to monitor characteristics. At ISC, a colour 21' CRT monitor was used while 18' LCD monitors were used at CMS and MSCW. Since colour calibration of the monitors cannot be adjusted ideally and will be a difficult problem to solve on ships bridges where a variety of monitors (e.g., CRT and flat-panel) are used and seldom (or never) recalibrated. Clearly the findings from these investigations indicate that blue is superior in the night condition at the ISC and MSCW and with a strong tendency at the CMS.

These results lead to the conclusion that blue (S-52 colour token RESBL) is the best colour to be used for the presentation of AIS targets based on what is currently available from the current edition of IHO S-52 colour tables. It is at least, as favourable as black in daylight and twilight, and clearly superior at night. This means that no AIS target colour change is needed between day/night ambient light conditions. Finally, 'blue' AIS targets can be easily distinguished by colour from the own ship symbol which is black in colour.

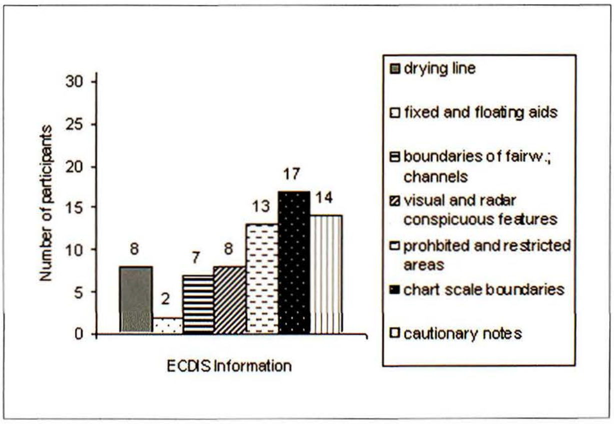

Figure 6: Preferences of the objects which could be removed off Standard display to improve target detection

The results of the detection experiment conducted at ISC indicate that colour filling of symbols even with a reduced target size improves the detection of the symbols on *Standard Display*. Most of the complex background information on *Standard Display* is line or contour coded with the effect that the perception of the line or contour presentation of unfilled targets is hampered seriously, i.e., similarity of visual items impacts their detection. On the other hand, interference with space coding of the filled targets is less distinct. Since the advantage of filled targets is dependent on the ECDIS display category and can also obscure relevant background information their use cannot be recommended generally. One alternative may be the temporary filling of symbols to improve target detection, which should be achieved via a single operator action by a device or function which cannot be left in a permanent 'on' (='active') position. For harmonisation reasons it is recommended to change the colour of the ARPA targets on ECDIS as well to blue (S-52 colour token RESBL), even if the perception of ARPA targets has not been tested in combination with AIS targets on ECDIS.
The results of our experiments also show that, in general, more targets were found on *Display Base* than on *Standard Display*. The likely explanation is that a *Display Base* provides a more homogenous background with less visual information density (i.e., clutter) than a *Standard Display*. As a background the *Standard Display* contains a large amount of chart-related information that can interfere with AIS target detection.

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