ABSTRACT:

Icons are graphical images used to represent processes or functions on the interfaces of electronic systems. Effective icons must be easily comprehensible for users. Within the maritime domain, icons used on navigation systems are subjected to technical requirements. However, there is no study investigating the comprehensibility of such standard icons. Face-to-face interviews and an online survey were conducted to evaluate standard icons specified in the performance standards. The results show issues with a number of standard icons prescribed in IEC 62288:2014. Specifically, icons from three groups: a) standard Panel Illumination and Display Brilliance icons have optional features that reduce icon concreteness, b) icons for display orientation modes lack specification for the Course Up mode and the proposed icon is not sufficiently distinctive, c) the standard icon for Radar Performance Monitor depicts a concept familiar to equipment manufacturers but unfamiliar to users.

Standard icons for control functions on navigation systems – design and issues

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Abstract - **Icons are graphical images used to represent processes or functions on the interfaces of electronic systems. Effective icons must be easily comprehensible for users. Within the maritime domain, icons used on navigation systems are subjected to technical requirements. However, there is no study investigating the comprehensibility of such standard icons. Face-to-face interviews and an online survey were conducted to evaluate standard icons specified in the performance standards. The results show issues with a number of standard icons prescribed in IEC 62288:2014. Specifically, icons from three groups: a) standard Panel Illumination and Display Brilliance icons have optional features that reduce icon concreteness, b) icons for display orientation modes lack specification for the Course Up mode and the proposed icon is not sufficiently distinctive, c) the standard icon for Radar Performance Monitor depicts a concept familiar to equipment manufacturers but unfamiliar to users.**

Keywords
Navigation systems, graphical user interface, icon design, usability.

INTRODUCTION
In electronic systems, icons are pictographic representations of functions and processes that support dialogues in human-computer interaction (Gittins, 1986).

The use of icons takes advantage of the capabilities of the human brain, which allows us to process imagery information faster and recognise previously-encountered images more accurately compared to words (Horton, 1993; Paivio, 2013). Additionally, icons take up less space than text commands - saving space for other display elements on the interfaces.

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Within the maritime field, icons are widely used in modern navigation systems such as Radar and Electronic Chart Display and Information Systems (ECDIS).

Despite the advantages, however, icons must be designed to convey the intended messages successfully. Studies on icon design have identified several icon characteristics to affect user performance and inadequate icons can be difficult for users to identify or locate (Ganor & Te'eni, 2016; McDougall, De Bruijn, & Curry, 2000).

In 2015, the International Maritime Organisation (IMO) started developing the Guidelines for the Standardisation of User Interface Design for Navigation Equipment, known unofficially as the S-mode Guidelines. The guidelines provide several regulations for the design of user interfaces for marine navigation systems, including a new set of standard icons for navigation functions and data. During the development process, the S-mode working group (hereby referred to as "the SWG") reviewed icons already in use for navigation systems as required by technical standards and found several them to be improperly designed.

This article discusses three cases of such inadequate icons, detailing design principles that those icons violate and the effects on users.

BACKGROUND
The development of the S-mode guidelines is a part of the IMO e-Navigation initiative, which regulates the future utilisation of information technology to improve safety and efficiency in shipping (IMO, 2008). The S-mode guidelines specifically target the design of user interfaces for navigation systems, aiming to improve usability and decrease diversity in the design of navigation equipment among different manufacturers (Jacobson & Lutzhoft, 2008).

To achieve its purposes, the S-mode guidelines standardise two features of navigational systems: terminology and symbology (icons), and the

arrangement of information on the displays (IMO, 2018).

The new standard icons contained in the S-mode guidelines were developed following a human-centered design approach. The icons were subjected to tests and design iteration to ensure their usability.

At the time of developing the S-mode guidelines, many icons used on navigation systems were already regulated by technical performance standards, among which are the IEC 62288 standards for the presentation of navigation-related information on shipborne navigational displays, issued by the International Electrotechnical Commission [IEC] (2014). However, there was no official document on the development of such standard icons and there was no published research to demonstrate their usability. As a result, the SWG decided to include those icons in their tests.

Factors affecting icon usability

For an icon to be usable, it must be comprehensible to users. Studies in pictograph interpretation have found several factors that affect the comprehensibility of icons. Such factors can be separated into three categories, namely those that concern the design of the icon themselves, those that concern users, and the operational context.

Characteristics of individual icons include concreteness, complexity, and semantic distance. Additionally, icons are seldom presented in isolation, making distinctiveness an important characteristic.

Concreteness refers to the degree to which an icon resembles real objects, material, or people. Concrete icons are easier to interpret than abstract icon. Complexity refers to the number of visual details of an icon and has no effect on icon comprehensibility, but complex icons have negative effects on users' visual search performance (McDougall et al., 2000). Semantic distance represents how closely an icon is related to the underlying concept and significantly affects the accuracy of icon interpretation among new users (Isherwood, McDougall, & Curry, 2007). For icon groups, a principle in icon design is minimising shared features between icons performing different functions while maximising shared features between icons of the same family (Kurniawan, 2000).

Regarding user characteristics, there are three factors affecting the ability to recognise icons; familiarity, domain knowledge, and cultural background.

Familiarity refers to the frequency of which users encounter an icon (Ng & Chan, 2008) or the frequency of which users encounter the object depicted in the icon (McDougall & Curry, 2004). Familiarity significantly improves the accuracy of icon interpretation (Shneiderman & Margono, 1987). Knowledge of the referent concept and cultural background also influences the interpretation of icons (Strauss & Zender, 2017; Zender & Cassedy, 2014).

Finally, context influences the interpretation of icons. The meaning of an icon is created by combining the icon image, the characteristics of the observer, and the context (Horton, 1994). However, for the tests discussed in this article, context was excluded due to complexity. Only icon and user characteristics were considered.

TEST METHODS

Two tests were carried out to assess icon usability. The first was face-to-face interviews with users and the second was an online survey.

Five master mariners took part in the interviews, three from India and two from Denmark. During the interviews, the icons were shown to each participant one by one, the first time without the associated labels and the second time with the labels. For each icon, the participant was provided basic context such as the equipment or the type of functionality and asked to interpret its meaning. The interviewer asked follow-up questions to explore the reasoning behind the interpretation. The participants were encouraged to provide additional comments regarding the design of the icons in question and suggest alternative icons if desired.

The online survey followed the reverse approach to the interviews. The survey showed participants a function and asked them to select among three available options the most suitable icon. Regardless of the answer, the survey would then reveal the meanings of all three icons, and participants could provide additional comments if desired. The number of respondents differs between questions, ranging from 27 to 45.

RESULTS AND DISCUSSION

A total of 59 icons were tested during the development of the S-mode guidelines. However, this article only discusses icons that were standard at the beginning of the S-mode development process.

The results show that many of those standard icons do not always convey their intended meanings. Those icons are regulated by IEC 62288 and belong to three

function groups: setting up brightness level, setting up display orientation, and Radar performance monitoring.

The following sections present results and discuss issues with those icons.

Panel Illumination and Display Brilliance – the issue of concreteness

Panel Illumination and Display Brilliance are used to adjust brightness level for the control panel and the display screen respectively. IEC 62288 (IEC, 2014) provides standard icons for these two functions, as presented in Figure 1.

Panel Illumination   Display Brilliance

Figure 1. Panel Illumination and Display Brilliance icons

According to IEC 62388, both Display Brilliance and Panel Illumination icons have a circle surrounding the main symbol, and this circle is optional (IEC, 2014). We included these circles in all our tests.

In our first test (the interviews), four out of five participants associated the two icons Display Brilliance and Panel Illumination with the concept of brightness adjustment. However, the fifth participant could not make sense of the symbols. He commented that he recognised the main symbol but could not make sense of the surrounding circle and, therefore, could not identify the object being depicted.

Results from the interviews raised the concern that the circle surrounding the main symbol in the two icons Display Brilliance and Panel Illumination could make the symbols less similar to real-life objects and reduce the concreteness of these two icons.

To further investigate if the circles were an issue, we proceeded with the second test using the online survey. In the survey, the icons Display Brilliance and Panel Illumination were compared to the icon for switching display colour combinations. This function is used to provide the best viewing in daytime, night time, and twilight, as presented in Figure 2:


Day/Night

Figure 2. Icon to select Day/Night/Twilight colour mode

Results of the survey are presented in Table 1

Table 1. Survey results for three icons Panel Illumination, Display Brilliance, and Day/Night colour modes (bold numbers highlight the most-selected option).

Which of the following Icons represents the function for setting <u>Panel Illumination</u>?		
10 (33%)	2 (7%)	**18 (60%)**
Which of the following Icons represents the function for setting <u>Display Brilliance</u>?		
9 (21%)	15 (35%)	**19 (44%)**
Which of the following Icons represents the function to toggle between <u>Day/ Night/ display mode</u>?		
2 (5%)	1 (3%)	**34 (92%)**

All three icons under discussion represent functions related to brightness/contrast adjustment and all three depict objects associated with the concept of light. Icon Panel Illumination resembles a lightbulb, icon Display Brilliance resembles the sun, and icon Day/Night resembles the sun and the moon. However, the Day/Night icon does not have a circle surrounding the main symbol.

Results from the survey clearly show that people are more likely to associate icon Day/Night with brightness adjustment than the other two. The circles in the two icons Display Brilliance and Panel Illumination caused the icons to be more abstract and reduce their comprehensibility.

Display Orientation

There are three orientation modes for Radar; North Up, Head Up, and Course Up. The IEC 62288 provides standard symbols for the North Up and Head Up modes (IEC, 2014), presented in Figure 3:

North Up   Head Up

Figure 3. Icons to select North Up and Head Up display orientation

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There is no standard icon for the Course Up orientation. As a result, manufacturers are free to select an icon for this mode, which can lead to a lack of consistency between manufacturers and the potential use of inadequate icons. It is, therefore, necessary to develop a standard Course Up icon.

Using the principles in designing icon groups set out by Kurniawan (2000), the standard Course Up icon must share similar design features with the North Up and Head Up icons while maintaining sufficient distinctiveness. To address this matter, the Comité International Radio-Maritime (CIRM) proposed a standard icon for the Course Up orientation as presented in Figure 4.

Course Up

Figure 4. The proposed Course Up icon

The SWG conducted tests to evaluate the suitability of this proposed icon.

In the first test (the interviews), one out of five participants correctly identified the Course Up icon. The other four participants interpreted the symbol as True Motion, Heading Line or Range.

The proposed Course Up icon uses a dotted arrow to depict the ship's course, and by having the line pointing up, the symbol refers to the Course Up orientation. However, based on feedback from the interviewees, these are also the features that confused them. The dotted line signifies motion, and in combination with the arrowhead, the dotted arrow was interpreted as the depiction of the ship moving forward, leading to the impression of True Motion. The dotted line was also interpreted as disappearing, and when combining with the arrowhead, the symbol was interpreted as the function to temporarily suppress the Heading Line. Additionally, the dotted line also signified distance measurement, causing one interviewee to interpret the icon as range measurement (Variable Range Marker). Results from the interview sessions indicate that the proposed Course Up icon did not clearly convey the message of Course Up orientation.

In the second test (the online survey), icon distinctiveness was evaluated. Results of the survey question are presented in Table 2.

Table 2. Survey results for three icons North Up, Head Up, and Course Up (bold numbers highlight the most-selected option).

The survey results show that the proposed Course Up icon can easily be confused with the standard Head Up icon. The differences between the two are not significant enough to maintain satisfactory distinctiveness. Based on results from both the interviews and the survey, the proposed Course Up icon was not adopted into the S-mode guidelines.

Still, it is necessary to develop a standard Course Up icon to avoid diversity between manufactures. However, the SWG could not develop a suitable Course Up icon within the limited timeline. As a result, the SWG decided to use text labels instead of icons for all three orientation modes.

Performance Monitor

The IEC 62288 provides the standard icon for Radar Performance Monitor switch, see Figure 5.

Performance Monitor

Figure 5. Standard icon for Radar Performance Monitor

Performance Monitoring is a mandatory radar function that helps monitor and detects performance drop (IMO, 2004). This function works based on the following principle: the radar transmits a pulse to an object known as the echo box, mounted on a designed place onboard. This echo box is constructed and positioned in a way so that the energy re-radiated from it resembles returning radar signals from normal targets, despite its proximity to the radar receiver. The returning signal from echo box produces a visible response on the radar display, called performance monitor signal, and is used to monitor and detect any

performance drop on the radar (Bole, Dineley, & Wall, 2005). Examples of such performance monitor signals on a Radar manufactured by Raytheon Anschutz (2014) are provided in Figure 6.
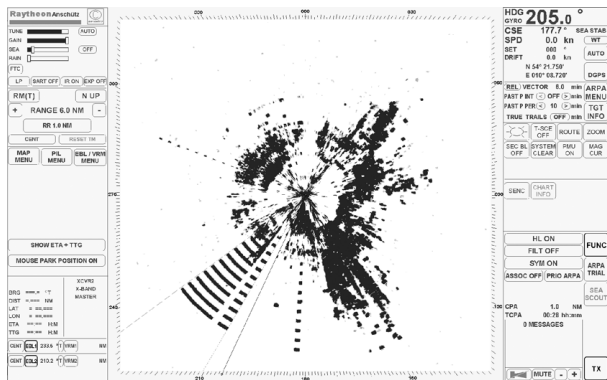

Figure 6. An example of performance monitor signals displayed on the Radar screen

In the interviews, none of the participants could recognise the icon as Performance Monitor. One participant commented that the symbol resembles a ship under rolling motion but could not understand the icon. The other four participants could not recognise the symbol. After the icon's meaning was revealed, all participants commented that the symbol has no visual cue to Performance Monitoring.

The icon did not perform well in the online survey either as 48% of the respondents did not correctly identify the Performance Monitor icon.

As mentioned in the Background, familiarity significantly affects icon interpretation. The standard icon as per IEC 62288 illustrates the working principle of the Performance Monitoring function. It depicts the transmitting and receiving of performance monitor signals from and to the antenna. Engineers who build and repair radars are familiar with this concept. To a seafarer, however, performance monitoring simply means observing and evaluating images of the Performance Monitor patterns displayed on the radar screen, as illustrated in Figure 6. The standard Performance Monitor icon has low comprehensibility because it depicts a concept unfamiliar to users.

While the SWG could not develop an alternative icon due to time constraint, the issue with this icon was forwarded to the IEC to be addressed in subsequent performance standards.

CONCLUSION

During the development of the Guidelines for the Standardisation of User Interface Design for Navigation Equipment (unofficially known as the S-mode Guidelines) as part of the IMO e-Navigation initiative, usability tests were conducted on standard icons used in navigation systems. The icons are specified in performance standards IEC 62288:2014. Issues were found in three icon groups that cause the icons to be difficult for users to interpret.

The icons for Panel Illumination and Display Brilliance have optional design features that reduce their concreteness and consequently their comprehensibility. It is, therefore, recommended that the circles be removed completely from the icons in the performance standards.

Icons for Display Orientation lack provision for the Course Up orientation, which can potentially lead to unnecessary design diversity. The proposed Course Up icon failed to maintain sufficient distinctiveness and, on its own, did not successfully convey the message of Course Up orientation. While the proposed icon was not adopted, the SWG could not develop a suitable alternative. Therefore, it was decided that text labels, instead of icons, would be used for all three Display Orientation modes.

Icon for Radar Performance Monitoring function depicts a process familiar to Radar manufacturers but unfamiliar to users. Consequently, many users cannot interpret the symbol. This issue was forwarded to the IEC to develop solutions in subsequent performance standards.

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