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Perceptions of Integrated Electronic Marine Systems – A Preliminary Study

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Integrated electronic marine systems have been put forward as one way of reducing information overload for officers of the watch and other personnel who work on ships' bridges or in fishing wheelhouses. It may be that such systems will improve safety records which, in the case of fishing, are amongst the worst in the world. This article builds on previous work about issues for the systems designer by using a small study of fishing skippers to ascertain their perceptions of using integrated electronic systems in the wheelhouse. Semi-structured interviews were used with 11 skippers from one port who were all familiar with integrated electronic marine systems but did not use them on their vessels. The main reasons for this were a perception of unreliability of both the hardware and the software, together with concerns about data integrity and user control.

KEY WORDS

1. Integrated systems; 2. marine electronic aids; 3. systems reliability; 4. user control.

1. INTRODUCTION. For a number of years, marine safety experts have been concerned with the problem of information overload in the wheelhouses and on the bridges of merchant ships. The general consensus of experts is that this may be caused by too many screens within the location of the officer of the watch with the consequence that vital information may be ignored at a critical time in the voyage. Fisher (2005) has suggested that an integrated marine electronic system should reduce the number of screens and hence increase safety in terms of less information overload; IEC 61924 (on integrated navigation systems) supports this idea but is still not fully implemented after more than five years of work. In a recent article (Mills, 2006), some issues for the designer were identified which focussed on the possible problems which users may have when using integrated marine electronic systems. In particular, an argument was made that integrated electronic systems may not increase safety especially given that particular aspects of their design at present are far from ideal for ease of use at sea. In this article, some of the issues are re-focussed from a user's viewpoint and then tested through interviews with fishing skippers; thus, the present article complements the arguments made in Mills (2006) by ascertaining how potential users of integrated electronic marine systems

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Table 1. Categories of characteristics.

Category of characteristic	Characteristic of integrated system (based on Mills (2006), Table 1, Column 1 but slightly modified)
Cost	Inhibits usage in smaller vessels
Hardware reliability	Network failure Hardware components' failure
Software reliability – automated agents	Automated routine tasks Sub-systems' communication Selection of data Priority of data Possible corruption of data User's perceived lack of control
Software reliability – information presentation	Sufficient information for timely and correct decision by user Small screen space (multiple windows) Larger overall screen

viewed their use from a safety perspective. Before relating this fieldwork and the corresponding results, we give a summary of the main areas of concern which Mills (2006) listed.

2. BRIEF OVERVIEW OF POSSIBLE ISSUES FOR THE USER.

In Table 1 of Mills (2006), a list of characteristics of integrated marine electronic systems was given without any priority or grouping of these characteristics which were then associated with potential design problems or issues. However, it is possible to rearrange these characteristics into three different categories: cost issues, hardware reliability and software reliability, with the last being further divided into automated software characteristics generated by the systems' artificial intelligence and characteristics of presentation of information, including visualisation. Table 1 lists the characteristics of an integrated electronic marine system based on that of Table 1 in Mills (2006) but slightly modified in order to cover more specific issues under each category.

Although the cost of integrated electronic marine systems has fallen in recent years, it may well be that it still remains a significant factor in the purchase of such systems and, as such, forms a barrier to their usage, particularly on smaller vessels. Although cost may be linked to hardware acquisition, in terms of safety, there will be a minimum standard required for type approval by the government of the country. This may limit the reduction in cost possible as manufacturers must meet the type approval standards. However, there are other aspects of hardware safety which should be considered, in particular, reliability of the hardware to stand the rugged conditions at sea. Possibly because the market base is relatively small, manufacturers have been slow to respond to the need of rugged built laptops and personal computers, basing most integrated systems on standard network topologies and hardware intended for office computers.

Software reliability, too, is needed for a safe system, both in terms of the information presented by automated agents and the way in which all information is

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displayed. Automated intelligent agents would be responsible for automating routine tasks which may well entail selection and prioritising of data as well as communicating data (not always displayed) between sub-systems. Poor design of software could lead to the corruption of data as well as a perceived lack of control of the system by the user.

Another aspect of software reliability which would affect safety could be that of the information being displayed. This needs to be timely and sufficient, as well as accurate enough for the user to make the correct decision intentionally. Although integrated electronic marine systems use a larger screen than individual displays, multiple windows (on the larger screen) can lead to an overall reduction in display space for certain information and this could possibly lead to confusion by the user so that the wrong information is read or the information is interpreted incorrectly.

There are, then, at least four areas of safety which need to be evaluated in order to discover whether these characteristics of integrated systems are perceived as being problematical for the users. To this end, a small study was undertaken which was intended to be a preliminary investigation into how integrated systems are perceived by fishing skippers; those in charge of fishing vessels are responsible for the safety of both the vessel and the crew and so seemed the right choice for indicating some confirmation or otherwise of the points made above.

3. METHOD OF THE STUDY.

Semi-structured interviews have been used many times for gathering data which are specific to a topic but where the data need to be sufficiently subjective to give some personal opinion (Faulkner, 2000). In this work, the semi-structured interview was used since the interviewees were all available and willing to participate on the same day and in the same place. In addition, the semi-structured interview allows the researcher to ask further questions for clarity at the time of the data gathering; this was important here since time was short for each participant (Faulkner, 2000). An alternative method such as focus groups was considered but rejected since it was not possible for the participants to gather together (in a group) at the same time. In addition, focus groups by their nature allow for the ideas of one participant to influence the thoughts of another (Shneiderman, 1998) and, in this research, the individual responses were considered important since each skipper would have his own reason for his views which may differ from another skipper's reasons. Qualitative questionnaires could have secured the information gained here but were considered to be too intrusive into the fishing skipper's routine. In addition, it is unlikely that sufficient returns would have been received by the researcher, given the usual percentage of return is around 20% and the port is relatively small.

The questions for the interviews were drawn from the researcher's previous experience and were designed to explore the design issues raised in Mills (2006). In particular, Table 1 above (derived from Table 1 of Mills (2006)) was used to focus the discussion around three areas: cost, reliability of both hardware and software, and also need. This last was added in order to gain at least an inkling as to whether an integrated electronic system would be considered useful rather than a necessity. Because the researcher wanted initial reactions, the questions were kept very short and simple and the skippers were given an opportunity to explain their views on integrated marine electronic systems. In addition to general data about each vessel,

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an initial question ascertained whether the vessel of each skipper used an integrated electronic system of any kind and this allowed discussion to clarify what was meant by this so that both participant and researcher were discussing the same entity. The questions were trialled with an experienced prawn fishing skipper from the same port as that in which the study was conducted; his return is not included in the data below but proved valuable in rephrasing the questions around the safety of both the vessel and personnel rather than focussing directly on the reliability of both the hardware and software of the system.

4. PROCEDURE. The port selected is a small fishing port on the East coast of Scotland, UK which has come to specialise in prawn fishing although other catch is landed there too. Generally, the boats are out of port for up to 24 hours but most leave either in the evening and return early the next morning or leave in the early morning, returning that night. Thus, the usual time at sea is around 12 hours but can be longer and the fishing is mainly in-shore, relying on the fishing skipper's experience. Most, but not all, boats put to sea with a skipper and a crew of one or two mates. The registered Length Overall (LOA) of the vessels of the skippers who participated in this sample varied from 9·5 metres (two vessels) to 17·5 metres (two vessels) with only these two latter vessels being over 16·5 metres LOA. Indeed, there is a local by-law which prevents vessels of over 18 metres LOA from entering the near area. In all, 11 skippers were interviewed for the sample (not including the one who piloted the questions), each being from a different vessel; the catch in all cases was prawns except for one vessel which landed squid and lobsters. The average catch per vessel, observed by the researcher, was six boxes.

In addition to the fishing skippers, one person from the Scottish Fish Producers Association (SFPA) was interviewed; this participant's view gave much useful background information as well as confirming that in many fishing boats, and particularly those of larger LOA, there is a need for information overload to be reduced.

5. RESULTS. Of the 11 fishing skippers interviewed, no vessel associated with them had an integrated electronic marine system resulting in the reducing of screens and automating of data being used for navigation and/or fishing. The vessels all carried the usual traditional equipment of plotters, radar, echo-sounder and, in most cases, sonar. However, they all had knowledge of such systems and one skipper had used such a system while acting as crew member on a bigger vessel while another skipper had used integrated systems as a crew member of the lifeboat in a neighbouring port. His answers concerning this part of his sea life will be considered separately since the work tasks and hence goals of the users of the integrated systems on a lifeboat are different from those of fishing. However, it is interesting that these two skippers were the most vociferous by far in their comments, at times rather scathing, about integrated electronic systems.

Six of the 11 participants had serious concerns about the reliability of the integrated electronic system. These six were very specific about the failure of the hardware and the need for backups should the system fail while at sea. All the skippers were concerned about loss of life and related this to possible systems' failure,

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hence the need for backups. As one skipper put it: *if a system fails I still need to be able to get her [the vessel] back home without loss of life*. Four skippers mentioned lack of reliability of data (rather than hardware reliability) and they were not happy with the idea that the data *might not be true* in that it could be *wrong*, *insufficient* or *redundant*. Three skippers did not think that a large screen, replacing several smaller ones, would be beneficial since the one screen could still lead to confusion caused through screen division (multiple windows on one screen).

Surprisingly, only four fishing skippers felt that the cost of the integrated electronic system was relevant and, of these, one remarked that the cost had fallen sharply in recent years, thus emphasising that cost was not a factor in his decision not to have one. The other three skippers did not say that they could not afford to buy an integrated system but they all felt the money could be spent more profitably in terms of furthering their businesses in other ways. Perhaps this is linked to the fact that none of the skippers felt any need of an integrated electronic system. This perhaps is not surprising given the type of fishing and size of vessels involved in this study.

In addition to the actual questions asked, two skippers offered further thoughts; the one skipper who had landed squid and lobsters wanted a wider frequency sonar which integrated frequencies from around 50 kHz to 200 kHz in order to identify the fish species more easily. While this is actually beyond the scope of the present article, it is yet another example of systems failing to meet the perceived needs of the user. The second skipper's comments referred to his experience while acting as a crew member aboard the local off-shore lifeboat, to which allusion was made above. The lifeboat is usually manned during foul weather and this skipper related how the hardware, and the screens in particular, could not take the punishment of heavy seas and salt water from the air and so became unreliable. From his experience of using the system on the local lifeboat, he had concluded that integrated systems were not helpful for two further reasons: first, there was some redundant data which were not needed and secondly, there was no user control over the system's display. As a consequence of these problems, he felt that separate screens (individual systems and displays) were much to be preferred since not only was there user control of which data were to be displayed but separate screens also allowed the user more flexibility of the choice of displayed data for decision making. Furthermore, separate screens allowed for the reliability problem in that if one screen 'went down' then another system could still provide sufficient data to arrive safely in port.

The results, then, show concern about the reliability of the systems from the hardware angle, problems of lack of confidence in the data displayed and confusion from multiple screen (windows) displays. Underlying much of what was said by the skippers is the lack of user control which an integrated system must exhibit when using automated intelligent agents to integrate the information.

6. DISCUSSION. The skippers interviewed have raised a number of issues which can be grouped into four areas, first, the need for reliable hardware systems which can withstand the rough use which is characteristic of sea-life. Another aspect of reliability is the need for data which are known to be true and so reliable for navigation and fishing purposes. Linked to this, in the skippers' minds, is the lack of user control over integrated systems. Several skippers remarked that integrated electronic systems gave them no control from where the data had come,

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thus emphasising the possibility of incorrect or corrupted data. Finally, there is concern that the screen space used for integrated displays may be too small and so information given may be confusing or too compressed to be useful especially when the skipper may be walking about in the wheelhouse or standing at an angle to the screen. It was felt by the skippers that these issues impinged on the safety of the vessels and their personnel. These four areas will now be discussed in more depth.

On land, users have become accustomed to hardware which rarely fails and which supports the user in the tasks needed to achieve a goal. However, it is well-known that life at sea can include very rough use of hardware simply because there is always salt (an abrasive) in the air and, in any case, the air is also usually damp. These two characteristics produce a stickiness which can play havoc with hardware; for example, it is well known (Mills, 2005) that office mice are not durable in such conditions since the mouse-ball becomes polluted with the damp salt and, consequently, does not roll evenly on the desktop which may itself be damp and so not sufficiently smooth. In such cases, a trackball may be better or even a light-pen or some other selection device which minimises the problems of the damp salt. Add to this the fact that some fishermen may want to use the equipment wearing heavy duty gloves which may have been used for sorting fish from the catch and the problem of suitable hardware devices is compounded. However, such issues as these were not mentioned by the skippers interviewed who restricted themselves to giving information about using integrated electronic systems. The hardware problems cited were all to do with reliability in the sense of the screen failing to display the information needed.

The law requires that certain backup systems are carried in fishing vessels; for example, every vessel needs, by law, two independent outputs giving depth readings and most fishing skippers, conscious of the safety factors involved, carry backups of other outputs too. This is to enable the necessary information for navigating home to be available should one system fail (Mills 1999). With an integrated system, it is still possible to carry backups, of course, as maritime law demands (Mills, 2006) but the skippers felt that this rather defeated the point of an integrated system if it were still a necessity to carry the backups as before. While the law demands the carrying of such backups, the vessel will still be able to make the journey back to port should the integrated system fail but there is a need for the hardware of the integrated system to be tested in the rough conditions of being at sea. Indeed, studies need to be made of the actual reliability of integrated electronic systems so that accurate data can be used to inform opinion amongst fishing skippers. These studies should not rely on manufacturers' data for obvious reasons of possible bias but will need to be undertaken by an independent researcher whose work is trusted by the fishing industry. Fishing communities are close knit in general (Sacchi, 2006), and much information is passed on by word of mouth and in social discussions; only when there is a consensus of perceived reliability will the fishing skippers have faith in the data outputted by integrated electronic systems.

Assuming hardware reliability exists, software reliability is another cause for concern for the fishing skippers. In Table 1 above, reliability of data presented and possible data corruption were included under this category. Interestingly, the fishing skippers identified this problem as being very significant since it is also associated with lack of user control. In essence, the skippers were not happy with the system

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prioritising the information which it then displayed nor with the system being responsible for selecting the data to be displayed (Mills, 2006). Generally, the skippers wanted to know from where the raw data had come so that they would also know its reliability. On their own vessels, they carried and used multiple individual displays which enabled them to select the most reliable system for the task in hand. With an integrated system, this choice is removed leaving the fear of corrupted data or data which may be unreliable (Mills, 2006).

Associated with the lack of software reliability is the problem of lack of user control. As has become apparent from the previous paragraph, the skippers wanted to be able to control the data in such a way as to know from where it had come. This harks back to user experience in that most skippers use data for certain tasks from certain instruments, cross-checking (MAIB, 2005) when necessary. With an integrated system this cross-checking is undertaken by the system's intelligent agents and so it is usually impossible for this to be checked 'manually' by the skipper. It was obvious in the interviews that the skippers had real fear of being at sea without duplicate data to confirm their accuracy. User control is essential if the user is to feel comfortable when working with the system and a way must be found to overcome this problem; perhaps system identification of the source of the data may be helpful as a 'halfway house' solution in which both user and system share the initiative for presenting information (Dix *et al*., 1993). Interestingly, none of the skippers mentioned that, in safety critical situations, such automation is helpful and often necessary (Redmill and Rajan, 1997).

Limited screen space and the necessary reduction in information presented, whether it be as symbols which must be learnt or whether it is omitted altogether (Table 1 above), caused concern for the fishing skippers. There was a perceived need of screens being large enough to display the necessary data and several skippers could not see the point of having four windows on a larger screen when four separate screens were more useful in that they each displayed independent data, useful for cross-checking (MAIB, 2005) and more clearly seen. There was also concern about confusion in that sub-screens (individual windows) displaying similar but different information could be confused, thus making a wrong decision. In any case, such information should always be placed apart to avoid confusion (Mills, 1999). This was related back to cross-checking by some skippers who were unsure how any cross-checking could be achieved. Of course, in theory, the integrated system should do this automatically but little or no confidence in the reliability of these actions was perceived by the skippers. Visualisation of data is generally not easy and there must always be a trade-off between what is included and what is left out (Mills, 2006). The skippers were not happy with leaving this trade-off to the system as, in the final analysis, the safety of the vessel and personnel is paramount and their responsibility. In order to arrive safely in port, navigation information and its associated needs must be accurate and timely. The solution offered for this problem is generally training (Mills, 2006) but this would not necessarily remove the lack of confidence in the integrated system. Clearly, there needs to be a cultural shift from the perceived integrity of individual displays to that of multiple windows within one larger screen, as in an integrated system, but this is unlikely to happen until the problems perceived by these fishing skippers have been overcome. This will require time, but above all, the use of integrated systems alongside their older siblings so that, hopefully, confidence in the integrated systems can grow by comparison of data from each system.

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Interestingly, network reliability and cost (Table 1 above) both figured less prominently than the researcher expected; the skippers were experienced in the reliability of networks through their communications systems and none had any worries about these. However, cost was used as a reason for not buying an integrated system in only three cases, and in these cases, other reasons such as hardware and software reliability were given higher priority. Thus, it seems that this group of fishing skippers was not really deterred by cost from purchasing and using an integrated electronic system; it was hardware and software reliability and data integrity which featured much more prominently in their perceived views of such systems.

7. LIMITATIONS OF THIS STUDY AND SUGGESTIONS FOR FURTHER WORK.

There are a number of limitations with this study which may impinge on the findings. Apart from the low number of interviews undertaken, there are concerns that only one of the skippers had used integrated electronic systems for fishing while on a bigger vessel as a crew member and only one other skipper had used them in a different context (a lifeboat). This is perhaps the most important aspect of this study in terms of limitations because it means that the views expressed by the fishing skippers are only perceptions. However, the perceptions of potential users are important not only for marketing purposes but also for designing such systems so that when they are used, the negative perceptions can be dispersed as quickly as possible. Indeed, the fact that seven of the 11 skippers did not see cost as a barrier to purchase, and recalling that they were asked this question specifically, is sufficient evidence to give weight to the other reasons and perceived problems which they saw with integrated electronic systems since cost considerations alone were not a prohibiting factor of purchase. All the skippers knew what was meant by electronic integrated systems with few or no points of clarification being needed, thus indicating that they had knowledge of such systems, even without experiencing them on their own vessels. Even so, it must be remembered that from nine of the participants the points made in this article are only perceptions and, as such, may change after using an integrated electronic system.

We have already alluded to the relatively low number of participants in this study. While 11 subjects is enough (Shneiderman, 1998) to indicate trends and possible further investigations, it is insufficient to draw full conclusions which can be considered as binding. It is possible that other fishing skippers may view integrated systems differently and perceive a different set of problems or even none at all. Thus, more interviews are needed with skippers from the same port to see whether the majority of skippers fishing from that port are in agreement with the colleagues interviewed here. This would add numerical weight to this study but would promulgate another limitation, that of location.

In order to give this study focus and completeness, the skippers in this study were deliberately chosen from one port with all but one of the vessels coming from the same registering port which is a few miles along the coast. This aspect of the method was chosen to prevent digression by types of fishing based on species of catch. This is important since it may be that integrated electronic systems are better matched to other types of fishing besides prawn and lobster. For example, it is known that

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sonar systems are not generally used by lobster and crab fishermen since pots are laid and then revisited for lifting and echo-sounders are the best systems for this work (Spence, 1989). It is possible, therefore, that other ports landing different species of catch may have skippers with views which differ significantly from those of this study.

Besides the type of catch, another limitation of this study is that the vessels were all of a smallish LOA. Two vessels were within the 'single ticket' range of LOA but using a different port in which larger vessels (say over 24 metres LOA) landed their catch would give another perspective on these findings especially since larger vessels often carry more screens and so may benefit more from system integration. Indeed, we have already alluded above to the officer from the fish producers' organisation overseeing the landing of the catch who pointed out that there is a problem of information overload with larger vessels which integrated systems may solve. This is an important point and one which further work should address in order to ascertain the perceptions of fishing skippers who may well benefit the most from integrated electronic systems.

Another limitation is that only three areas of questioning were used, safety, cost and need. These are considered satisfactory for a preliminary study of this type but another study is needed which widens the questions to include both more in-depth questions and different aspects of integrated systems. Even so, the interviews allowed the participants to include points beyond the actual questions and these provided useful insights into the perceptions stated.

These limitations lead to the following suggestions for further work: first, the study should be replicated in a port with vessels over 24 metres LOA so that the views of skippers who may benefit more from integrated electronic systems may be gathered. Indeed, some of these skippers may be daily users of such systems and a wider set of questions could be derived in order to ascertain the thoughts of these actual users. Indeed, a larger number of interviewees, based in a port with larger vessels and different types of fishing would eliminate some of the major limitations of this study such as the relatively small number of participants, the predominantly small size of vessels, the focus on one type of fishing and essentially one species of catch (prawns) and the lack of actual experience in using integrated electronic systems by the skippers.

8. CONCLUSION. This small study has indicated that the perceptions of integrated electronic systems among fishing skippers based in one small Scottish port is generally negative. This is due to a belief that such systems lack hardware and software reliability, thus endangering the safety of the vessel and its personnel. Concern was expressed by the skippers about the system choosing which data to display based on its prioritising rather than that selected by the skipper. This led to a perceived feeling of lack of control by the users. Interestingly, cost was not generally a major factor in the decision to purchase and to use an integrated electronic system whereas the reliability and safety aspects of the system were.

Care is needed in reading too much into these findings given the limitations of the study; however, they do indicate concerns for designers of integrated electronic systems as well as a need for further study using vessels of a larger LOA and more varied types of fishing.

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